EFFECT OF LONG TERM FERTILIZATION ON CARBON SEQUESTRATION AND SOIL QUALITY UNDER SORGHUM WHEAT CROPPING SYSTEM

DISSERTATION

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BY

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2015

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I hereby declare that this dissertation or part

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has not beenpreviously submitted by me

to any other university or institution

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I also certify that the dissertation or part thereof has not been previously submitted by her for a degree of any university.

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This is to certify that the dissertation entitled **"EFFECT OF LONG TERM FERTILIZATION ON CARBON SEQUESTRATION AND SOIL QUALITY UNDER SORGHUM WHEAT CROPPING SYSTEM"** submitted by **Ms. GAWANDE RAJANIGANDHA VISHWAMBHAR** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (Agriculture)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** has been approved by the student's advisory committee after viva-voce examination in collaboration with the external examiner.

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(R. V. Gawande)

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ABBREVIATIONS AND SYMBOLS

%	-	Per cent
/	-	Per
@	-	At the rate of
<	-	Less than
>	-	More than
µ	-	Micron
µl	-	Micro litre
^0C	-	Degree centigrade
Actiy	-	Actinomycetes
AICRP	-	All India Coordinated Research Project
AM	-	Ante meridiem
Avai.	-	Available
Bact	-	Bacteria
BD	-	Bulk density
CD	-	Critical difference
CFU	-	Colony forming unit
$CHCL_3$	-	Chloroform
Cm	-	Centimeter
CM	-	Component Matrix[a]
Cmol	-	Centimole
COC	-	Cost of cultivation
dSm^{-1}	-	Deci Siemens per meter
EC	-	Electrical conductivity
et al.	-	et alia and other
etc.	-	etcetera
Fe	-	Iron
Fig.	-	Figure
FYM	-	Farm yard manure
$g\ ha^{-1}$	-	Gram per hectare
GM	-	Green manure
i.e.	-	that is

IR	-	Infiltration rate
J.	-	Journal
K	-	Potassium
kg	-	Kilogram
kg ha^{-1}	-	Kilogram per hectare
LTFE	-	Long Term Fertilizer Experiment
Max	-	Maximum
MDS	-	Minimum Data Set
mg	-	Milligram
Mg	-	Magnesium
mg kg^{-1}	-	Milligram per kilogram
Mg m^{-3}	-	Mega gram per cubic meter
Min	-	Minimum
mm	-	Millimetre
MWHC	-	Maximum water holding capacity
N	-	Nitrogen
No.	-	Number
NS	-	Non- significant
OC	-	Organic carbon
P	-	Phosphorus
p^+	-	Proton
PM	-	Post meridiem
ppm	-	Parts per million
PR	-	Porosity
q	-	Quintals
RBD	-	Randomized Block Design
RDF	-	Recommended dose of fertilizer
Rs.	-	Rupees
SD	-	Standard deviation
SE ($\pm$m)	-	Standard error mean
SE$\pm$	-	Standard error
Sig.	-	Significant
SMBC	-	Soil microbial biomass carbon

SMBN	-	Soil microbial biomass nitrogen
SOM	-	Soil organic matter
T	-	Treatments
t	-	Tonnes
Var.	-	Variety
Viz.	-	Namely
WS	-	Wheat straw
ηm	-	Nanometre

ABSTRACT

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Title : Effect of long term fertilization on carbon sequestration and soil quality under sorghum wheat cropping system

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The present investigation entitled "Effect of long term fertilization on carbon sequestration and soil quality under sorghum wheat cropping system" was under taken during the year 2012-2013 on the old long-term fertilizer experiment started since 1983. The fourteen treatments (Table of treatments) replicated Three times in a RBD comprised of NPK levels with and without FYM, wheat straw, subabul and green leaf manures. The horizon wise soil samples were collected from the excavated soil profile from each treatment. These samples were analyzed for physical, chemical and biological quality parameters and N and P fractions after completion of 30 sorghum-wheat crop cycles. The soil of the experimental site was montmorillonitic type, Hyperthermic haplusterts.. The initial soil was slightly alkaline in reaction, medium in organic carbon, low in available nitrogen, low in available phosphorus and high in available potassium.

The results indicated that the integrated nutrient management practices found to be effective in improving physical, chemical and biological parameter over 30 years of long term manuring and fertilization to kharif sorghum followed by rabi wheat.

The status of N fractions were improved with the application of FYM, green manuring, subabul and wheat straw. All fractions of N evaluated showed appreciable build up under 50% NPK through fertilizer+50% N through FYM in kharif and 100% recommended NPK through fertilizer in rabbi. The relative abundance of N fractions in surface soil followed the order of Acid insoluble N >Total hydrolysable N > Organic ammonium N >Amino acid N > Amino sugar N > Ammonium N > Nitrate N > Nitrite N which contributed 41.67% > 25.00% > 8.99% > 8.56% > 5.30% > 0.61% > 0.37% > 0.15% of total N at 0- 30 cm depth of soil respectively.

The status of P fractions (i.e. saloid-P, Al-P, Fe-P, Ca-P, R-S-P, occluded-P, organic -P) were improved with the application of phosphorus through fertilizers in combination with FYM, GM, WS or subabul leaves. All the fractions of P evaluated showed an appreciable buildup under 50% NPK through fertilizer+50% N through FYM in kharif and 100% recommended NPK through fertilizer in rabbi. The relative abundance of P fractions in soil followed by the order organic-P > Ca-P > R-S-P > Fe-P > Al-P > Saloid-P > Occluded-P which contributed 50.51% > 29.23% > 6.50% > 6.34% > 4.88% > 1.28 > 1.22% of total P at 0-30 cm depth of soil.

The results indicated that application of inorganic in combination with organics increased the availability of nutrients in soil. Hence, it can be concluded that for sorghum-wheat sequence integrated use of organics and inorganics is an essential to obtain maximum productivity on sustainable basis particularly for maintenance of soil fertility.

(Gawande R. V.)	**(Dr. V.D. Patil)**	**(Dr. V.D. Patil)**
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INTRODUCTION

CHAPTER- I

INTRODUCTION

In India, higher demand for food grain on account of alarmingly increasing population has consequently put an extra pressure on per capita availability of cultivated land, which by the turn of century. Adequate food grain could only be produced from this meager area through intensification of cropping both in spacial and temporal dimensions.

Long term manurial experiments conducted in India (1983-2013) showed declining trend in productivity even with application of NPK fertilizers under modern intensive farming. Neither organic sources nor can chemical fertilizers achieve sustainability in crop production under high intensive farming where nutrient turnover in soil plant system is much larger. However, their combined use appeared to be promising. It is well known that among N, P and K, N plays key role in crop production and hence in any nutrient management programme of cropping systems, its consideration is essential.

Most of the native nitrogen in the soil is organically bound, however, only small fraction of it remains in available form. Large proportion of organic nitrogenous substances in soil can be considered as potential reserves of nitrogen from plant nutrients point of view. Under the normal soil condition, inorganic nitrogen appears in soil from the mineralization process of organic sources. In turn, some inorganic nitrogen is transformed to organically bound form by soil microorganisms by the process of microbial immobalization. In this way, there are many possible transformations that can lead to various organic and inorganic products or the formation of soluble and insoluble forms of nitrogen or may be fixed in the lattice structure as native fixed ammonium in soils.

As we know, nitrogen is the key element among the major nutrients in crop production and most of Indian soils are deficient in this nutrient. In most soils, N is mainly organic in nature, hence normally only a small portion of total N is present in inorganic form, except in soils containing much fixed ammonium, available to plants (Stevenson 1986). To supplement N, along with other organic sources, extensive and continuous application of mineral fertilizers stimulates mineralization and immobilization, thereby influencing the biological transformations of the N in soil (Duhan *et al.* 2005). Earlier studies have demonstrated that long-term addition of NPK fertilizers alone or in combination with farmyard manure (FYM) enhanced the contents of both hydrolysable and non-hydrolysable-N in Inceptisol under maize-wheat system (Kamat *et al.* 1982), in Ustochrepts under rice-wheat-jute system (Sammi Reddy *et al.* 2003) and in Mollisol under rice-wheat-cowpea system (Bharadwaj *et al.* 1994). More than 90% of the accumulated N in the surface layer of the most soils occurs in the form of organic compounds, out of which more than half remains to be unidentified (Kelley and Stevenson 1996). Little is known about the bioavailability of the different forms of organic N in soils because these compounds are so complex and their availability depends upon mineralization (Johnson *et al.* 1999).

The contribution of different forms of N to mineralizable N pool must be understood if N fertilizers are to be used efficiently. Unfortunately, little progress has been made in identifying and measuring of easily mineralizable N fraction. Sarawad *et al.* (2001) observed that the rate of N mineralization increased with the conjoint use of organic manures and fertilizer N in an Inceptisol under maize-wheat-cowpea system. However, N mineralization studies have largely been confined to the top soil, although plants also utilize N from the deeper horizons. The top soils have the largest contents of crops residues, easily decomposable organic matter, the greatest microbial biomass and activity, and therefore N mineralization was more in surface soil.(Soudi *et al.* 1990). However, other studies have shown that a significant proportion of N mineralization also occurs in sub soils (Hadas *et al.* 1986 ; Patra *et al.*, 1999).

Continuous application of manures and fertilizers are bound to influence the various fractions of soil N, besides influencing other soil properties. Results from long term experiments in India have clearly demonstrated that the addition of organic manures and inorganic fertilizers for over a long period had favorable effect in increasing the soil N fractions. Studies on N dynamics by Lin *et al* (1973) revealed that the average contribution of non hydrolysable N, total hydrolysable N, amino acid N, hydrolysable NH_4^+-N and unidentified NH_4^+-N to the total N were 24.4, 75.6, 35.7, 25.0 and 10.8 per cent respectively. Studies under All

India Co-ordinate Research Project indicated that the combined use of organic and inorganic indicated saving of fertilizer N as well as better utilization of P and K along with secondary and micronutrients. Long term application of N, P and K fertilizers as well as FYM will alter the fertility status of soil. In respect of nitrogen, there is substantial removal by the crop besides losses through volatilization, denitrification and leaching, where various soluble nitrogenous compounds are translocated in different depths of the soil.

Phosphorus is one of the major essential plant nutrients and without its adequate supply the plant can neither reach its yield potential nor complete a normal reproductive process. Phosphorus deficiency in Indian soils is very serious and in alarming proportions in many situations due to which the use of P fertilizers is increasing at a very rapid rate. But, the use efficiency of fertilizer P by the crop is very low, ranging from 10-20 per cent. The fixation of added P in soils considerably affects the availability of P to the crop, especially in alkaline and calcareous soils. Phosphorus exits in the soil in organic and inorganic forms, of which the P bound to iron, aluminum and calcium and reductant soluble phosphates are known to be present in significant amounts that determine its availability to crops. But, the information on the transformation of added fertilizer P into various insoluble and organic P fractions is meager. Secondly, all forms of P in the soil are known to supply the nutrient to the soil solution, but, the relative proportions of their contribution to the labile pool from which the plant absorbs the nutrients vary (Aulukh, 1990).

The proportion of calcium phosphate increases with soil pH and calcium concentration in soil. Thus in calcareous soils, formation of Ca-phosphate tends to prevail. There is interrelationship between different P fractions in soil and their definite contribution to the available pool of phosphorus. The contribution of different P fractions towards available P was investigated and the Al-P and Fe-P have been found to be major contributors both in acid as well as in neutral to alkaline soils despite the preponderance of Ca-P in the later soil type (Kanwar and Grewal, 1990). Organic phosphorus can hardly be taken up directly by plants. Microorganisms feeding on organic carbon in the rhizosphere are particularly involved in the turnover of organic phosphates. Organic phosphorus which is added into the soil exits in the form of plant, bacterial, fungal and animal residues, ranging from 0.1 to 0.5 per cent, which is not readily available to plants and availability will depend on decomposition of organic matter by micro-organism. The relative quantities of phosphorus compounds in the soil vary in accordance with pH, organic matter, parent material, system of cultivation, fertilizer practices etc.

Schofield (1955) suggested that chemical potential of phosphate in soil might provide a suitable measure of the availability of phosphate to plants. Phosphorus applied through a water soluble fertilizer gets converted into soluble or insoluble forms resulting in low concentration of phosphorus in soil solution. Similarly continuous cropping with chemical fertilizer has shown variable influence on the available and phosphorus in soils (Subbarao and Ghosh, 1981). Mattingly (1965) reported that only 8 to 33 per cent of applied phosphorus is readily utilized by the plants and rest rendered unavailable through different processes of which adsorption remains most important. Quantitative characterization of soil phosphorus is a good measure of capacity of soil to contribute phosphorus to the solution phase as the same is depleted through crop uptake.

Even under best condition not more than 20 to 30 per cent added phosphorus is likely to be taken up by a crop during first growing season. It will depend upon chemical properties of soil, characteristics of added phosphatic material, the methods and rate of application (Eaglestad, 1985). This problematic behavior, availability of phosphorus and increasing cost of phosphatic fertilizers are putting heavy burden on the farmer hence economic use of phosphatic fertilizer is imperative.

The most logical way to manage long term fertility and productivity of soil is the integrated use of both organic and inorganic source of plant nutrients. Long term fertilizer experiments usually provide the best practical test of sustainability of crop management system (Nambiar, 1994). The complex problem of soil fertility management can only be examined by long term field trials as it takes time for the crop rotations, fertilizer and manures to have a reasonable impact on soil fertility.

Intensive cropping which is imperative for achieving higher production to match the growing food requirements, results in heavy removal of nutrients from the soil. It is estimated that different agricultural crops from Maharashtra remove about 179 kg N, P, K from one hectare land as against addition in 119 kg ha^{-1} every year (Patil et al., 2000). Organic wastes and biological sources of nutrients are also best alternative and estimates indicate that their potential source is about 16.9 million tonnes (Livleen and Mathur, 2000).

Sorghum (*Sorghum vulgare*) is one of the important food grain crops in Maharashtra. India has the largest share (32.2%) of world sorghum area and ranks second in production after U.S.A. In Maharashtra, *Kharif* sorghum was cultivated on about 35.98 lakh hectare area with an annual production of 8 million tonnes during the year 2010-2011 (Anonymos, 2011).

Wheat (*Triticum aestivm* L.) is the second important food crops. In India, area under *rabi* wheat during the year 2010-2011 was 265 lakh hectare with an annual production 82 million tonnes. In Maharashtra, area under wheat during 2010-2011 was 7.6 lakh hectares with annual production of 9.8 lakh tonnes (Anonymos, 2011).

The philosophy of sustainable agriculture will become a bitter irony if fertilizer use is reduced or excluded in the name of quality improvement of produce or environmental protection. However, differential merits and demerits of fertilizer application necessitated research for appropriateness of integrated approach to achieve targeted high production besides its effects on the soil productivity.

In a number of long term experiments in our country, major attention has been given in general to the yield performance of crops. However, its effect on soil properties did not receive due attention. Keeping in the view of the problem of the availability of nitrogen and phosphorus and its importance in plant nutrition, it is necessary to study the distribution of various nitrogen and phosphorus fractions and their relative changes under long term fertilization. The studies on different forms of nitrogen and phosphorus in various soils is necessary for better understanding of their capacity to sustain an adequate supply of phosphorus to growing plants. Therefore, the present study was undertaken with the following objectives.

1. To study the organic, inorganic and total carbon behaviour under long term fertilization.
2. To evaluate the impact of long term application of fertilizers and manures on soil quality parameters.
3. To assess the effect of long term fertilization on vertical movement of nutrients.
4. To study the different fractions of N and P as influenced by continuous manuring and fertilization.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

In India, the information on long term effects of continuous of cropping and manuring on soil N and P is voluminous. Extensive research work has been done on distribution of N, P and forms of nitrogen and phosphorus in soil in relation to the availability of nitrogen and phosphorus.

Continuous application of manures and fertilizers is bound to influence the various fractions of soil nitrogen and phosphorus, besides influencing other soil properties. Results from long term experiments in India have clearly demonstrated that the addition of organic manures and inorganic fertilizers over a long period had favorable effect in increasing the soil Nitrogen and Phosphorus fractions.

Estimation of the distribution of added N showed that over 90 per cent of added N in soils was found in the hydrolytic products of soil organic matter, mainly as amino sugar N, and other soluble N.

Adequate attention has been paid in India on the distribution of various inorganic P fractions under different adafic, biotic and climatic conditions. It may be concluded that highly weathered acidic soils of India are generally rich in Fe-P and Al-P, while neutral and alkaline calcareous soils, are abundant in Ca-P.

In this chapter literature regarding the soil nitrogen and phosphorus forms was discussed under the following heads.

1. Effect of long term fertilization on physicochemical properties of soil
2. Effect of long term fertilization on carbon behavior of soil
3. Effect of long term fertilization on vertical movement of nutrients
4. Distribution of forms of nitrogen in soil.
5. Distribution of forms of phosphorus in soil
6. Effect of long term fertilization on biological properties of soil
7. Effect of long term fertilization on residual soil fertility

1. Effect of long term fertilization on physicochemical properties of soil

Ray *et al.* (1986) concluded that Olsen's method was the most promising one for assessing available P in jute growing soils of West Bengal.

Triplett *et al.* (1968) observed that bulk density of vertisol was reduced significantly with crop residue incorporation over fertilizer application. Field capacity was enhanced with crop residues and subabul incorporation as compared to fertilizer application. While, Sadanand (1970) observed the negligible changes in bulk density upto one complete rotation of the crop sequence. Further, it was observed that increase in pore space has closely followed the trend of turnover of organic carbon content of the soil.

Biswas *et al.* (1971) studied the cumulative effect of different manures and fertilizers on the physical properties of sandy loam soil in the permanent experiment. It was reported that bulk density, soil structure, water retention and organic matter status of the soil significantly improved by the treatments with the organics. On the other hand, there was very little change in the soil properties due to application of inorganics.

Three long term manurial and rotational cropping experiments conducted by Maurya and Ghosh (1972) showed that CEC of soil was increased with green manuring. Similarly, Bellakai and Badanur (1997) also reported increase in CEC of vertisol due to continuous application of organics.

Unger *et al.,* (1976) reported the effect of surface residue rates and water application amounts on evaporation from soil and the factors were evaluated for their effects on water accumulation in a clay loam and fine sandy loam soil. Surface residue rates ranged from 0 to 12,000 kg/ha and water was added at 0.25, 0.50, 1.00 or 2.0 cm/addition. He observed that the soils increased as surface residue rates and water applications increased.

Chakravarti (1979) did not notice marked effect on the bulk density and water holding capacity of soil due to increasing application of nitrogenous fertilizers.

Magdoff and Amadon (1980) studied the yield trends and soil chemical changes resulting from nitrogen and manure application and found that calcium and potassium increased greatly with increasing application. They further observed that the organic materials incorporated, plots recorded significantly lower $CaCO_3$. The reason assigned was due to release of organic acids during the decomposition of organic materials and they might have reacted with $CaCO_3$ to release CO_2. Further, Bellakai and Badanur (1997) also reported increase in exchangeable calcium while, decrease in Na and $CaCO_3$ due to continuous application of organic matter.

Yaduvanshi *et al.* (1985) reported noticeable decrease in pH value as a result of continuous manuring over the initial value, the decline being pronounced under 100 per cent N and 150 per cent NPK treatments. The higher pH value in 100 per cent NP over that of 100 per cent N might be due to presence of gypsum in super phosphate which counteracted the acidic effect of nitrogen. A relatively higher soil pH under 100 per cent NPK+FYM in comparison with 100 per cent NPK was observed.

Rabindra *et al* (1985) studied the effect of continuous application of full and half dose of NPK dose and unfertilizer treatments. The beneficial effect of balanced fertilizers on soil structure may be because of the role played by phosphate ions in binding of soil particles due to greater amount of organic residues produced in fertilizer plots.

Notable reduction in soil pH due to long term manuring and fertilization was reported by Lal and Mathur (1988). There was significant decrease in pH and increase in organic matter of the surface soil was noticed by Maurya and Ghosh (1972) in a alluvial calcareous soil. Similarly, decrease in soil reaction with subabul and sunnhemp incorporation over fertilizer application was recorded by Narkhede and Ghugare (1987). Ghuman *et al.* (1997) also reported the significant decrease in soil pH and increase in organic matter of surface soil under dryland condition due to continued manuring of sunnhemp. While, Bharadwaj and Omanwar (1994) studied the long-term effect of rotational cropping fertilization on soil properties and observed that pH and EC of the soil were not affected by any of the treatments.

Lal and Mathur (1988) observed that the available N in soil was significantly increased in fertilizer treated plots as compared to that of FYM alone and the available N was significantly correlated with total N but non-significantly with organic carbon.

Gupta *et al.* (1988) noted that organic carbon increased upto 52 days after application of FYM irrespective of the levels and organic carbon decreased after 52 days at 0-15 and 15-30 cm depth. The available N content of the soil increased up to 20 days after FYM application and decreased thereafter at all the FYM levels.

Ananthanarayana *et al,* (1989) analyzed ninety six acidic soils from Karnataka and showed that Bray's extractant extracted slightly larger quantities of P from the soil as compared with the modified Olsen's reagent. The average content of available P_2O_5 is 16.8 ppm as per Bray's method and 16.1 ppm according to modified Olsen's method.

In black soils of Maharashtra, Palwe and Sonar (1989) indicated that Olsen's method was found to be the most suitable method for estimating available P in soil. The $NaHCO_3$ indicated that Olsen's method was found to be the most suitable method for estimating available P in soil. The $NaHCO_3$ extractant used in Olsen's method suppresses the activity of Ca thereby releasing phosphorus into the extractant. They were reported Morgan's Bray and Soltanpur methods was good in predicting the responses of wheat to applied phosphorus.

Patnaik *et al.*(1989) observed that application of N, P and K in combination with FYM or compost improved the physical properties of soil such as water stable aggregrates, available water content and hydraulic conductivity of soil under rice-maize, rice-wheat cropping system. Further, Ghuman *et al* .(1997) reported that continuous green manuring of sunhemp significantly increased soil water retention and decreased the bulk density. In situ incorporation of Sunhemp reduced the bulk density as compared with fertilizer application. Similarly, improvement in the infiltration rate, water stable aggregrates, porosity, field capacity and maximum water holding capacity under drylands was observed due to application of sunhemp in combination with fertilizers. (Bellaki and Badanur, 1997). Mishra and Sharma (1997) reported that application of balanced fertilizers (N, P and K) did not show any deteriorating effect on physical properties of soil, rather it significantly increased water holding capacity of soil due to increasing application of nitrogenous fertilizers. aggregation and water transformation characteristics and reduced bulk density. Further, they observed the effectiveness of manorial treatment on aggregation, water transmission and hardness of soil.

Badanur *et al.* (1990) reported that in Vertisol, soil N content increased with Subabul, Sunhemp and FYM over fertilizer to application but decreased significantly with crop residues incorporation.

FYM, wheat straw and green manuring (sunhemp) incorporated in combination with inorganic sources invariably resulted increase in available N status of soils thereby marked increase in the uptake pattern by sorghum and wheat (Patil *et al,* 1993). Further they observed that application of 50 per cent recommended dose of

NPK through fertilizer plus 50 per cent through wheat cut straw incorporated in *kharif* registered the uptake of nitrogen (113.35 kg ha^{-1}) in *rabi* followed by 50 per cent recommended dose of NPK through fertilizer plus 50 per cent green manuring in *kharif* recorded 104.6 kg ha^{-1} nitrogen uptake. The substitution of 50 per cent NPK through FYM or green manure (sunhemp) proved to be superior to the other treatment on pooled mean basis, above two treatments significantly increased the grain yield of *rabi* wheat than rest of the treatments indicating residual effect of organic manure.

Malewar and Hasnabade (1995) reported that decrease in the bulk density, improvement of the soil aggregation and organic carbon due to application of 50 % organic + 50 % inorganic fertilizers to sorghum in Vertisol.

Naphade *et al,* (1995) conducted experiment on utilization of nutrients by sorghum-wheat cropping sequence under varying nutrient management on Vertisols of Nagpur. Their results reveals that it is apply balanced amount of NPK to both the crops lowering the doses to suboptimal levels decreased the yield. Whereas, application of 150 per cent dose than optimum dose (100:50:50) and for sorghum (120:60:60). For wheat produced maximum sorghum (43.43 q ha^{-1}) and wheat (22:89 q ha^{-1}) yields. Application of 100 per cent recommended dose of NPK through fertilizer plus FYM @ 10 Mg ha^{-1} was at par with 150 per cent NPK. Application of free fertilizers had a declining effect on yields of both the crops. The total productivity of the sequences, uptake of the nutrients and RPI-index were also highest under 150 per cent NPK application.

Ghosh and Sarkar (1997) also reported in same soils of Bihar, total P content of Dumka and Laxmipur soil series varied from 278 to 1888 mg kg^{-1} and 123 to 557 mg kg^{-1} P respectively.

In acid soils, Prasad and Mathur (1997) reported that total P was increased from 605 to 1020 mg kg^{-1} in soil with the increase in NPK level from 50 to 150 per cent of the recommended dose, but this increase was not in production to the amount of phosphate added, perhaps due to differential uptake of P by crops in these treatments. It was also found that total reserve of P was not affected by liming but organic manuring increased it by 75 mg kg^{-1} P over manured soil at equal phosphate level due to release of P from organic manures and more recycling of organic wastes.

Ravankar *et al,* (2000) studied the long term experiment to introduce right kind of cropping sequence with nutrient management for sustainable management for sustainable crop production and maintenance of soil fertility in sorghum-wheat sequence on Vertisols and reported that increased in levels of fertilizers increased yields of both sorghum and wheat, uptake of nutrients as well as fertility status of soil.Bellaki and Badanur (1997) revealed that application of Sunhemp in combination with fertilizer improved the physical properties of soil under dryland continuous application of organic manure increased the CEC and decreased the $CaCO_3$ in Typic Chromustert at Bijapur.

Marathe (2005) reported that the highest total nitrogen content in soil was observed with the combined application of FYM.

Sujatha *et al.* (2007) reported that all the soil properties such as pH, EC, organic matter, total and available NPK and S etc. were favorably influenced with conjunctive use of organics and inorganics. Highest values were observed in the treatment of 100% NPK + 10 t FYM ha^{-1}. The influence on soil properties ultimately reflected in higher yield of sorghum and wheat and in the same treatment it is also observed that all the soil properties except pH,EC were highly significantly correlated with yield.

Katkar *et al.* (2011) reported that the significantly highest increase in soil organic carbon and total nitrogen were recorded with 100% NPK + FYM @ 10 tonnes/ha. The availability of N,P,K and S soil microbial biomass carbon and nitrogen, dehydrogenase assay and productivity of sorghum and wheat were significantly increased with the integrated application of organic manure (FYM @ 10 tonnes/ha) and mineral fertilizer (100%NPK) over control and other fertilizer treatments.

Padmaja *et al.* (2012) studied *Kharif* sorghum during 2005-06 and noted that highest availability of N and P through out the experimentation was found with application of 50% RD of NPK + 50% N through FYM.

Baljit and Sharma (2012) reported that the soil OC increased by 107% under *shisham* followed by *kikar* (92.4%) over control (3.30 g kg^{-1}) in the surface soil layer, The N content was higher under *subabul* (87.9 mg kg^{-1} in surface layer).

2. Effect of long term fertilization on carbon behaviour.

In the soil of Uttar Pradesh, Bharadwaj and Omanwar (1994) reported continuous cropping without fertilization led to the depletion of organic matter, available nutrients, whereas continuous fertilization had beneficial effect on organic matter and available N, P and K of the soil.

Franzluebber (1994) studied crop management strategies in continuous wheat, continuous wheat/soybean and wheat/soybean-sorghum sequences under conventional tillage (CT) and no tillage (NT) with and without N fertilizers and concluded that increasing cropping intensity increased SOM up to 22 %, SMBC 31 % and minerlizable C up to 27 % under NT.

Santhy *et al.* (2001) studied finger millet-maize-cowpea system at TNAU, Coimbatore (TN) on *Vertic Ustopept* and found that the content of humic and fulvic acid in the soil increased with increasing levels of application of NPK from 50 to 150%. The highest concentration was recorded under 100% NPK+FYM which could be due to conductive environment for the formation of humic acids in this treatments. In 150% treatment addition of root residue consequent to higher yield have produce more amount of humic acid. Whereas. Waikar *et al.* (2004) studied the soils developed under varied agroecological units of Marathwada region in different altitudes and reported that high altitude, high rainfall soils had large accumulation of humin and fulvic acid compared to humic acid. On the other hand, the humus in soils of low rainfall zone showed high humic acid content as compared to the corresponding fulvic acid fraction. Further, the humic acid molecules are more condensed and fractions associated with cultivation condition and a change in vegetation played important role. Humic and fulvic acid ratio ranged from narrow under transitional high rainfall zone to assured rainfall zone and drought-prone zone.

Thakare *et al.* (2005) noted that there are various sources of carbon sequestration like mineralization and significant carbon sequestration was observed in treatment of NPK + FYM.

Banik and Sanyal (2006) reported that humus fractionated from the soil of two tea-estates, Tassetee and Dalgaon of Jalpaiguri district of West Bengal, found that the fulvic acid had more total acidity than did the corresponding humic acid of both the soil types. The naturally occurring humic acid were more complex structure with essentially hydrophobic nature as compare to the corresponding fulvic acids and synthetic analogues of humic acids.

Chander *et al,* (2007) conducted long term fertilizer experiment during 1998-99 on Mollisol to evaluate the effect of continuous cropping system and fertilizer application on potassium fractions and physico-chemical properties of soil and concluded that 100 % NPK + FM treatment showed superiority over all the other nutrient management treatments in improvement of soil organic carbon content and also concluded that for sustaining soil health and crop productivity under such set of conditions, integrated nutrient management coupled with intensive cropping could be a better choice to the farmer.

Similarly, Gathala *et al.* (2007) conducted a long-term fertilizer experiment was initiated in 1997 at the Rajasthan, College of Agriculture, Udaipur with maize-wheat cropping system on *Haplusteps* observed that contents of humin, humic acid and fulvic acid in the soil significantly increased with the application of fertilizer and FYM. The highest amount of their fractions was recorded under FYM@ 20 t ha^{-1} which could be due to the improved soil organic matter and conductive environment for the formation of humic acid. Among the treatments receiving chemical fertilizer alone, humus fractions were highest under 150% NPK. The addition of root residues consequent to higher biomass yield might have produced more amount of humus fraction. Humic acid and fulvic acid ratio was recorded less with the application of FYM alone or along with inorganic fertilizers due to positive association between fulvic acid and total organic matter.

Singh *et al.,* (2009) studied the effect of balanced and imbalanced nutrient use on crop yield and availability of plant nutrients over the years is being studied in a Paleustalf of Ranchi under long term permanent and revealed that the FYM treated plot had a favorable influence on organic carbon content.

Lev *et al.,* (2009) gave the role of plant roots in formation of soil humus. The bulk volume of rhizospherical soil (soil penetrated by plant roots) under individual tree can occupy upto 3-10 m3. However, the bulk volume of a soil in immediate contact with plant roots constitutes only 1-6% of the bulk volume of a soil layer. In a larger bulk volume of rhizospheric soil, the effect of roots on soil properties is neglected. Therefore, such soil characteristics as pH, content of humus and the composition of exchangeable cations do not correlate to the mass of plant roots, including any of their fractions.

Bhoye *et al.,* (2011) in an experiment conducted with sorghum at Nagpur (MS) and the results showed that the addition of well decomposed and undecomposed FYM with or without chemical fertilizers showed significant effect on contents of humic acid and fulvic acid at beginning of winter (1.96 and 13.52%), at end of winter (1.84 and 12.54%) and at mid- summer (1.70 and 11.43%) respectively due to addition of 10 tonnes fully decomposed FYM over all other treatment combination except 10 tonnes partially decomposed FYM with RDF.

Daniele *et al.,* (2011) has been suggested that alteration in the different fractions of SOM are more effective in indicating changes in soil use than total soil organic matter content. The main study was to investigate changes in the content of humic substances in an Ultisol under different land uses, in the northeast region of Brazil. Humic substances were chemically fractionated into fulvic acid, humic acid and humin, based solubility in acid and alkali. Significant loss (47.5%) of soil organic matter was observed in the surface layers of the conventional coconut and citrus orchard, compared to the native forest. However, in the subsurface soil of the integrated coconut orchard, cultivation modified the distribution of the more labile fractions of the soil organic matter, as measured by the ratio between humic and fulvic acids (>1.0), indicating a substantial loss of fulvic acids. The degree of humification was in the range 40-97%. The distributions of the organic matter fractions varied in the ranges 12-32.5% (fulvic acids), 12-34.5% (humic acids) and 40-69.5% (humin).

Pardo *et al.,* (2011) studied the quantitative and qualitative changes in soil organic matter (SOM) due to different land uses. Structural characteristics of the humic acids (Has) were measured by Curie-point pyrolysis-gas chromatography/mass spectrometry. Significant changes in concentration and composition of SOM were observed between land uses. Virgin soils showed large proportions of colloidal humus fractions : humic acid (HAs) and fulvic acid (FAs) but negligible amount of not yet decomposed organic residues. The change in land use produced a contrasting effect on the composition of the HAs.

Diovany *et al.,* (2013) evaluate total carbon and nitrogen and stocks of the humic fractions of soil organic matter under different cropping systems. The replacement of TN one for CT decreased the total organic carbon and C in the stocks of humic substances (fulvic acid, humic acid and humin) in the soil just three years after adoption, especially in the 0-10 cm layer. However, soils, under eucalyptus trees acquired increased carbon stock in the most active fractions. Such as the fractions of largest C and N stocks were measured for the humin fraction, followed by humic acid and fulvic acid. The total N and humic and fulvic acid levels under the conditions of maintenance of TN for 15 years increased when compared with CT, but not in soils under eucalyptus trees.

Meshram (2013) conducted experiment on influence of long term organic manuring and inorganic fertilization under soybean–safflower cropping system on some soil quality indicators in vertisol and recorded the highest organic carbon was observed in treatments receiving chemical fertilizers alongwith with FYM or FYM alone. It was significantly improved from (6.42-6.65 g kg^{-1}) in treatment T_8 treated with 100% NPK + FYM@ 5 Mg ha^{-1} and it was found mostly at par with treatment T_3 receiving 150% NPK and lowest value was observed in absolute control (T_{11}). The conjoint use of chemical fertilizers with FYM, found beneficial in maintaining organic carbon content compared to the use of only chemical fertilizers.

Bonge, C. O. (2014) studied the organic matter fraction under various cropping system i.e., Cotton based cropping system (C1), Green gram based cropping system (C2), Sorghum based cropping system (C3) and Soybean based cropping system (C4) and she found that Green gram based cropping systems and soybean based cropping systems had more build up of organic carbon, available N, Cu, Mn, total N, Total P and Total S whereas more values of available P, K and S were recorded under sorghum based cropping system. Total organic carbon (TOC) and inorganic carbon (IOC) contents were also found significantly more in green gram based cropping system over other systems.

3. Effect of long term fertilization on vertical movement of nutrients

Mahajan and Kanwar (1974) examined the distribution of various forms of nitrogen in typical saline alkali soils of the Punjab and Hariyana and found that the content of total N, nitate N and ammonium N varied from 27 to 291 ppm, 7 to 22.5 and 0.7 ppm respectively. They further observed that total N content declined with the increase in the soil depth. NH_4^+-N did not show any uniform increase or decrease with depth but NO_3^- -N decreased with depth in most of the soil profile studies.

Aulakh and Dev (1976) studied the profile distribution of total and mineral forms of nitrogen in multiple cropping, in all the soils total N content was highest in the surface layers where organic matter content was higher. Both ammonia and nitrate N contents were distributed uniformly thoughout the soil profiles, except in the saline sodic soil where nitrate nitrogen accumulated in the surface layer.

Somani (1985) studied the distribution of nitrogen in humus fraction of some soil of Rajasthan and concluded that the total N content of nine semi arid soil profiles in Rajasthan decreased with increasing profile depth. The distribution of nitrogen in the humus fraction of these profiles indicated that 60 to 86 per cent of the total N was associated with the humic fractions.

Udayasoorian *et al.* (1989) studied the effect of continuous manuring and fertilization on the fractions of soil nitrogen. They reported that continuous addition of organic manures for seven years in an intensive cropping system on an Alfisol significantly increased its total, ammonical, nitrate and organic nitrogen contents. Among the organic manures, FYM at the rate 25 tonne/ha per crop increased all nitrogen fraction in both top and sub soils. Continuous addition of green leaf manure did not influence the nitrogen fractions. The fertilizer combinations also markedly increased the different fractions of nitrogen.

Singh *et al.* (1992) studied the different forms of nitrogen from surface horizon of different soil profiles of Harayana. They reported that most of the nitrogen was in organic form and exchangeable NH_4^+-N . all forms of nitrogen decreases with depth.

Thakur *et al.* (2011) reported that the soil pH was negatively correlated while soil organic carbon and CaCO3 contents registered a positive correlation with content of different micronutrient in the soil profile.

Singh *et al.* (2013) studied the effect of rice husk ash and bagasse aash on inorganic phosphorus fractions and available phosphorus in alkaline soil under rice wheat cropping system and they observed that the subsurface soil samples showed lower content of various P fractions as compared to surface soil

4. Distribution of forms of nitrogen in soil

Nitrogen fractionation in gray wooded soils as influenced by long-term cropping system and fertilizers was studied by Khan (1971). He observed that the percentage of acid hydrolysable N, amino sugar N, amino acid N, hydroxyl amino acid N and unidentified N in acid hydrolysate were greater in the soil under the grain legume rotation than under wheat fallow sequence. Relative amount of total hydrolysable N was significantly lower in treatment involving manures, NPK, NS, lime and P than control. Long term application of mineral fertilizers had no significant effect on the percentage distribution for different forms of hydrolysable N and non exchangeable NH_4^+-N in the soil.

Lin *et al.* (1973) reported that the average contribution of non-hydrolysable N, total hydrolysable N, amino acid N, hydrolysable NH_4^+-N and unidentified NH_4^+-N to soil total N were 24.4, 75.6, 35.7, 25.0 and 10.8 per cent, respectively. They noted the significant correlation between soil properties like organic matter, total N, clay content and CEC and various forms of N. correlation coefficients of soil organic matter with total N, total hydrolysable N and amino acid N were found to be highly significant.

Raju and Mukhopadhyay (1973) studied the forms of N in soils of West Bengal and observed that all soils contained native fixed NH_4^+-N which ranged from 0.61 to 2.28 m.e.100 g^{-1} and contributed 61 to 100 per cent of the mineral N of the soils. As a fraction of total N, it varied from 4.90 to 54.06 per cent. Inorganic N contributed substantially (6.30 to 54.70 per cent) to total N.

Bairathi *et al.* (1974) reported that increase in total nitrogen content (0.012 to 0.031 %) in loamy sand soils with the incorporation of cowpea and moong residue either alone or in combination with inorganic fertilizers over control.

Shrivastava (1975) observed that the alkaline $KMnO_4$ distillable available N was highly significantly correlated with amino sugar N, organic matter, hydrolysable NH_4^+-N + amino sugar N, total N and hydrolysable NH_4^+-N and amino acid –N. However, in the multiple regression analysis, none of the nitrogen fractions, total N and organic matter of the soil could be individually significant but collectively their contribution was highly significant.

Puranik *et al.* (1978) reported that due to continuous use of manures and fertilizers in Vertisols for over 8 years, very small proportion of total N remained in mineralized form, while organic nitrogen fractions predominated in all the treatments. Addition of FYM had markedly influenced total and organic N contents. Green manuring yield and greater amount of readily available N as compared to other treatments.

Ramaswamy *et al.* (1979) observed higher N content in organic manorial treated plots than control. Among the organic manures, FYM and compost treatments were on par with each other and superior to green leaf manure. Soil clay shows negative relationship of exchangeable NH_4^+-N. this may be explained that increasing clay content may decreases KCl extractable NH_4^+-N due to NH_4^+-N fixation with clay. However, they noticed that this relationship does not hold true as continuous mineralization of organic matter and crop residue keeps on adding NH_4^+-N and NO_3^- -N in surface soil.

Oza and Subbiah (1980) conducted a field experiment and reported that about 20 to 30 per cent of the applied nitrogen was utilized by wheat, even though 38 to 43 per cent of the fertilizer N remained in the soil (up to 80 cm depth) after the harvest of wheat.

Singh *et al.* (1980) noted increase in the total and available N content of soil with the application of FYM. Continuous use of FYM with NPK fertilizers over a period of 20 years, helped in maintaining the available N content of soil.

Chaudhary *et al.* (1981) observed that total and available N content in soil was increased significantly with the application of FYM with P but not with K. There was an accumulation of available N in the soil at 150 per cent of recommended NPK application in a multiple cropping system in arid sandy clay laom soil. Available N content increased with application of NPK fertilizer.

Mandal and Roy (1984) reported a decrease in total N content in soil when lower or unbalanced doses of NPK were applied. Maximum decrease was noted in control while highest increase in total N status was obtained at one and half times NPK dose.

Ram *et al.* (1984) studied the NH_4^+-N and NO_3^--N at different depths of Karial, pond and virgin soils of U.P. and noted that the production of NH_4^+-N and NO_3^- -N was always more in the surface layer than in the lower layers because of higher organic matter and more microbial activities.

Yaduvanshi and Tripathi (1985) reported noticeable decrease in pH value as a result of continuous manuring over the initial value, the decline being pronounced under 100 per cent N and 150 per cent NPK treatments. The higher pH value in 100 per cent NP over that of 100 per cent N might be due to presence of gypsum in super phosphate which counteracted the acidic effect of nitrogen. A relatively higher soil pH under 100 per cent NPK was observed.

Prasad *et al.* (1986) conducted a long term experiment on use of fertilizers lime and manures on forms and availability of nitrogen in acid soil under multiple cropping systems. They observed positive and significant correlation between NO_3^- -N, water soluble exchangeable and fixed NH_4^+-N.

Perumal *et al.* (1986) pointed that in the alluvial soil fixed NH4+-N contributed about 6 per cent of total N and significantly correlated with paddy yield. The content of non hydrolysable and unidentified N forms, though quantitatively important are not directly related to the immediate N availability to the rice crop while the different forms of organic N are better related with organic status.

Wilson and Hargrove (1986) reported that the decomposition and release of N from green manure generally proceed very rapidly during the first few weeks followed by much slower phases thereafter under aerobic condition.

Bonde and Rosswall (1987) revealed that the potentially mineralizable nitrogen in four cropping systems and reported that the amount of mineralizable N was decreased during the growing season and increased in autumn as a result of organic matter input this provides evidence for the existence of an active fraction of soil organic matter. Pal *et al.* (1987) studied the influence of cropping and N fertilization on changes in different forms of nitrogen in alluvial soil. They reported that irrespective of cropping and N fertilization, the amount of available N significantly decreased and fixed NH_4^+-N increased with time. A substantial decrease in the amount of total hydrolysable N due to cropping was noted. The magnitude of decrease was less in the fertilized than the unfertilized soil.

Lal and Mathur (1988) observed that the available N in soil was significantly increased in fertilizer treated plots as compared to that of FYM alone and the available N was significantly correlated with total N but non-significantly with organic carbon.

Thakur and Sharma (1988) studied the effect of inoculation with Azotobacter and addition of varying levels of rock phosphate on N and P transformation during composting, and observed that the inoculation with 30 and 60 days of composting increased NH_4^+, NO_3^- and total N content.

Gosh *et al.* (1989) noted that N-saturation increased the amount of the all the inorganic and organic forms of N in soil. Irrespective of N treatment, cropping decreased almost all forms of N under investigation expect non-hydrolysable fraction of organic N in the N-treated system. The decrease in total hydrolysable organic N due to cropping was mainly contributed by hydrolysable NH_4^+-N fraction. Results suggest that the change in fixed NH4+-N must be included in N transformation study.

Udayasoorian *et al.* (1989) studied the effect of continuous manuring and fertilization on the fractions of soil nitrogen. They reported that continuous addition of organic manure for over seven ears in an intensive cropping system on an Alfisol has significantly increased its total, ammonical, nitrate and organic nitrogen contents. Among the organic manures, FYM @ 25 t/ha increased all nitrogen fractions in both top and sub soils. The fertilizer combination also increased the different fractions of nitrogen.

Ghosh *et al.* (1989) reported that N saturations increased the amount of all organic and inorganic forms of nitrogen in an alluvial soil. Irrespective of nitrogen treatment, cropping decreased almost all forms of nitrogen expect non-hydrolysable fraction of organic nitrogen. Decrease in total hydrolysable organic nitrogen due to cropping was mainly contributed by hydrolysable NH_4^+-N fraction.

Badanur *et al.* (1990) reported that in Vertisol, soil N content increased with subabul, sunhemp and farm yard manure over fertilizer to application but decreased significantly with crop residues incorporation.

Chaney (1990) conducted an experiment on effect of nitrogen fertilizer rate on the soil NH_4^+-N content after harvesting of winter wheat and reported that on an average 50 per cent of the total nitrate detected in the 0 to 30 cm soil. Although soil NO_3^- -N increased with amount of nitrogen fertilizer applied, beyond optimum rate of fertilizer application did not significantly increase soil NO_3^- -N after harvest as compared with no fertilizer treatment.

Kaistha *et al.* (1990) found that organic N accounted for major portion of total N concentration of all forms of N expect fixed NH_4^+-N was more in the surface than in subsurface horizons. Fixed NH_4^+-N showed reverse trend. All the forms of N were positively correlated among themselves and with organic matter and exchangeable K^+ and negatively related with pH and base saturation.

The transformation and transport of ammonium nitrogen in a flooded organic soil was observed by Reddy and Rao (1990) from 217 days study and they observed that inorganic nitrogen flux from the soil to overlying water was in the range of 220-230 kg N ha^{-1} per year. About 20-30 per cent of added NH_4^+-N was lost from the soil via, denitrification and NH_3 voltalization.

Field experiment conducted by Yadav and Singh (1991) on calcareous alluvial soil showed that nitrogen application (upto 150 kg N ha-1) as prilled urea, neem and karanj cake blended urea and urea super granules (USG), the efficiency of nitrogen was enhanced upto 50 kg N ha^{-1} . the largest fraction of applied nitrogen was transformed to NH_4^+-N followed by NO_3^--N, hydrolysable N and non hydrolysable N.

Prasad and Rokima (1991) studied the transformation of N added in conjunction with organic manure and blue green algae. It was observed that all fractions of N except NO_3^- - N and hexosamine-N increased with increasing dose of NPK with or without manures. Except hexosamine, nonidentified and non-hydrolysable-N, all other fractions of N were highly correlated with each other and exchangeable, hydrolysable and available N were significantly correlated with yields, N content and N uptake by rice and wheat. Path analysis however indicated that exchangeable NH_4^+ - N was the dominant forms of N that contributed directly or indirectly to nitrogen nutrition of crops.

Kher and Minhas (1992) studied the long-term effect of liming, manuring and cropping on different hydrolysable ammonium N, amino acid N, hexosamine N and unindentified N by 6.0, 13.4, 7.9 and 21.0 per cent, respectively.

Sharma *et al.* (1992) studied the relationship between the inorganic and organic N fractions as affected by application of biogas slurry and fertilizer N in maize-mustard crop sequence. Results revealed that 75.7 per cent of the total soil N was in the hydrolysable N fractions. Among the hydrolysable N fractions amino acid N, unidentified N and hydrolysable NH_4^+ - N constituted 25.8, 25.7 and 18.6 per cent of total N, respectively. Fixed NH_4^+ - N in clay lattice constituted 19.1 per cent of the total. Growing crops decrease the inorganic N fractions. Application of biogas slurry maintained higher status of N in both organic and inorganic N fractions.

Dynamics of N in relation to pH was studied by Shrivastava and Shrivastava (1993). They found that the KCl extractable NH_4^+-N content reduced from 21.7 mg kg^{-1} at pH 7.2 to 8.7 mg kg^{-1} at pH 10.3. Soils with higher pH contained low NH_4^+-N due to slow rate of mineralization. Increasing trends in total hydrolysable N were observed as 124.2, 129.5, 164.5, 185.0 and 215.2 mg kg^{-1} at pH 7.2, 7.6, 8.4, 9.9 and 10.3 respectively. Hexosamine N decreased from 18.0 to 10.5 ppm and amino acid N from 15.7 to 5.2 ppm with rise in soil pH from 7.2 to 10.3. Humin N decreased from 345.4 to87.5 mg kg^{-1} with increase in soil pH from 7.2 to 10.3.

Anilkumar *et al.* (1993) studied the mineralization pattern of urea in rice soils. In a incubation experiment with 3 soils of kerala, under submerged conditions, Hydrolysis of ammonia was influenced by soil reaction and organic matter content. Formation of nitrite and nitrate was low due to lack of oxygen avoiding nitrogen losses through denitrification in water-logged rice soils.

Bhardwaj *et al.* (1994) studied that N fractions consist mostly of amino acid which increase in soil due to addition of organic material and fertilizer nitrogen. The acid insoluble nitrogen fraction increased due to graded application of NPK. Continuous application of fertilizers, particularly NPK increased the amount of acid insoluble nitrogen. Graded doses of 150 per cent NPK application, NH_4^+ - N ranged from 19 to 27 mg kg^{-1}. The average NO_3^- - N content increased with depth, probably due to the leaching of nitrates from surface soil to subsurface soil. Graded doses of NPK also increased the NO_3^- - N in soil.

Further, Bhardwaj *et al.* (1994) reported that the difference in nitrogen fractions were statistically significant. The average distillable acid soluble NH_4^+ - N decreased with depth. As compared with fallow, this fractions decreased in control plot and increased in well fertilized and manured plots (NPK, NPK + FYM), increase in the content of distillable acid soluble NH_4^+ - N due to fertilization and manuring. The non distillable acid soluble nitrogen ranged from 412 to 534 and 432 to 518 mg kg^{-1} for surface and subsurface soil, respectively. This fraction consists mostly of amino acids which increase soil, respectively. This consists mostly of amino acids which increase in soil due to addition of organic material and fertilizer in surface but decreased in subsurface soil. The average NO_3^- - N content increased with depth probably due to the leaching of nitrogen from surface soil to subsurface soil.

Bhardwaj *et al.* (1994) studied that the surface and subsurface soil samples collected from a long-term fertilizer experiment for available N, continuous cropping without fertilization decreased the available N of soil to a considerable extent. However, well fertilized plot showed an increase in available N content of soil.

Liang and Mackenzie (1994) studied the changes of soil nitrate nitrogen fertilizer rates in field conditions. They observed that soil NO_3^- -N levels increased linearly with the increasing nitrogenous fertilizer rates. Denitrification losses varied from 7-24 kg ha^{-1} during the non growing season, increasing with fertilizer rates only on the clay soils. Losses of NO_3^--N due to denirification made up relatively small proportion of total NO_3^- -N losses and significant amounts were probably leached and immobilized.

Singh *et al.* (1996) studied the effect of soil pH on kinetics of nitrification in semi-arid subtropical soils under upland and flooded conditions. Under upland conditions (60 per cent water filled pore space) nitrification rate of added NH_4^+-N was highest in the soils with pH 7.4(7 mg N kg^{-1} d^{-1}), modest in the alkali oils with pH 9.4 (3 mg N kg^{-1} d^{-1}) and lowest in acidic soils with pH 4.8 (1 mg N kg^{-1} d^{-1}) .Applied NH_4^+-N (100 mg N kg^{-1} d^{-1}) was nitrified in 10 days in the near neutral soil were as it took 30 days in the near neutral soil where as it took 30 days for alkali (pH9.4) soil and only 33 per cent is nitrified in acidic soil at 30 days. Under flooded conditions(120 per cent WFPS), rate of nitrification was relatively low, but followed the same trend.

Sarkar *et al.* (1994) studied the fate of N urea applied to a Typic Ustocrept for growing wheat. They observed that there was significant response of wheat yield to increasing rate of N application and yield efficiency varied from 18.8 to 22.2 kg grain per kg N. for two rates N application, fertilizer N recovered by grain plus straw of wheat ranged from 28.0 to 45.1 kg N ha^{-1} and N recovered from the soil ranged from 14.1 to 32.2 kg N ha^{-1} .Ammonia volatilization was the main cause for N loss and varied from 5 to 12 kg N ha^{-1} for the two rates of N application. Leaching, loss of N was not significant.

Tyagi and Venkatesh Bhardwaj (1994) indicated the lowest available nitrogen content in control and the highest in 100 per cent NPK + FYM treated plots. The average nitrogen content of FYM treated plot was higher than control.

Malewar and Hasnabade (1995) reported significant increase in available N with continuous application of organics and inorganic particularly with FYM + NPK.

Mengel (1996) observed that major known fractions of soil nitrogen are amino- nitrogen (proteins and peptides), polymers of amino sugars and NH_4^+-N fixed in inter layers of 2:1 minerals only a small percentage of total soil organic N is easily mineralizable and contributes to the pool of mineral soil N. nitrogen mineralization consists of sequence of enzymatic processes for which living microbial biomass provides the enzymes and dead microbial the substrate.

Bellaki and Badanur (1997) reported that there is increase in available N significantly with organic sources of nutrients either alone or in combination with fertilizer over the fertilizer alone.

Bharigvanshi (1998) reported that significant improvement in organic carbon status of sandy loam and clay loam soils with the application of FYM alone or in combination with the nitrogenous fertilizers.

Basumatary and Talukdar (1998) studied the impact of integrated nutrient supply system on distribution of N fractions in Inceptisol of Assam where content of NH_4^+ - N increased significantly with increase in the level of NPK fertilizer up to 100 per cent of recommended dose. However, a much higher content was observed under integrated treatment where NPK fertilizers were combined with 25 to 50 per cent N through different organic sources like FYM, rice straw and Azolla. Continuous use of integrated treatments resulted in higher accumulation of organic matter and its subsequent decomposition and mineralization might have contributed in accumulating higher NH_4^+ - N over other treatments and hence at the end of seven years of cropping, a buildup of 2-13 mg kg^{-1} of NH_4^+ - N over initial value was observed. Integrated treatments showed a significant increase in organic N over chemical fertilizer treatments.

Bellakki *et al.* (1998) observed that soil available N content increased significantly with combined application of organic and inorganic sources of nutrients to Vertisols.

Patil and Varade (1998) reported that addition of inorganic fertilizers and organic manures increased the total nitrogen content of soil.

Rasmussen *et al.* (1998) observed that soil N mineralization from wheat, wheat-pea and from wheat-wheat crop rotation were 32, 42 and 51% of that mineralized from non-cultivated pasture soil. Nitrogen mineralized, as a fraction of the total N present, increased with increasing N application, reduction in tillage intensity and higher frequency of cropping. Stubble mulch soils mineralized 10-20% more N than did moldboard-plowed soils. The fraction of total N mineralized increased with increasing soil organic N content, indicating that organic N added through recent crop management practices is more labile than N in the native soil matrix.

Ravankar *et al.* (1998) studied the effect of FYM and subabhul on dynamics of N in Vertisols under sorghum-wheat sequence at Akola. Incorporation of subabhul caused higher build p in organic matter, available N and total N of soil. Application of FYM and subabhul in soil increased exchangeable NH_4^+ - N by 8-14 per cent over control. But these organics when applied in conjunction with fertilizer N enhanced NO_3^- - N status of soil by 16-22 per cent over control. Further their application with fertilizer for over 10 years registered an increase in hydrolyzed NH_4^+ - N + amino sugar N to the extent of 9 per cent.

Santhy *et al.* (1998) studied the combined effect of NPK + FYM on forms of N in Vertic Ustropepts at coimbatore. Higher content of NH_4^+ - N under NPK + FYM was observed. Increasing rate of NPK application had a favorable influence on the exchangeable NH_4^+ - N while combined addition of NPK + FYM ensured higher NO_3^--N content due to increased microbial activity and resultant enhanced nitrification process with a concomitant reduction in leaching losses. Various organic N fractions evaluated showed an appreciable build up under NPK + FYM. Among the organic N fractions, amino acid N and hydrolysable NH_4^+ - N formed the dominant fractions considering the favorable effect of green manuring on crop yields.

Yadav and Alok Kumar (1998) reported that the continuous application of NPK fertilizers alone at 100 per cent recommended levels and their combination with organic manures (FYM) increased the level of available N over the initial status. The results indicated that the exchangeable NH_4^+ - N, NO_3^- -N and other organic N forms were increased with either FYM, leucaena loppings or farm waste applied with fertilizer to replace 50 per cent fertilizer N. higher concentration of exchangeable NH_4^+ - N and NO_3^- -N was noted under *kharif* and *rabi* seasons, respectively. Whereas, fixed NH_4^+ - N content did not vary much with cropping systems. Insoluble humin N constituted the major portion of soil total N (Rita Patil, 1999).

Warren and Whitehead (1998) pointed that the organic matter could contribute substantially to the available nitrogen in the soil.

Kolberg *et al.* (1999) studied the effect of cropping intensity and N fertilizer rate on net soil N mineralization as well as their correlation with precipitation, air temperature and soil water content of two no-till cropping systems, wheat-fallow and wheat-corn-fallow and observed that Total net N mineralization in wheat-corn-fallow was half that in wheat-fallow, probable due to greater immobilization as evidenced by nearly three times greater accumulation of crop residue on the soil surface after 6 yr of no-till management. Total mineralized N increased with N rate by~0.2 kg ha^{-1} for each kg ha^{-1} of previously applied N. precipitation in combination with air temperature and their term gave the best prediction of average daily N mineralization at both sites.

Singh *et al.* (1999) noted that conjunctive use of organic manure and urea N increased the total hydrolysable N and its fractions. Decline in all the N pools was observed in control and in the plots receiving low dose of N (i.e. 12.5 kg and 60 kg ha^{-1} for soybean and wheat respectively) and 4 tonnes FYM ha^{-1} alone. However, continuous conjunctive use of organic and urea N not only increased the active pools of N bt also enhanced the most reserve pools like non-hydrolysable and fixed ammonical (non-exchangeable) N in soil. Significant relationship of hydrolysable ammonical N, total hydrolysable N, amino sugar N, non-hydrolysable N and available N with seed yield of soybean was observed. However, hydrolysable ammonical N, amino acid N and amino sugar N were found to be better correlated with yield of wheat and relationship of amino acid N and non exchangeable N were also significant with wheat.

Muneshwar Singh *et al.* (2001) reported that organic matter and total hydrolysable N status declined with application of fertilizer N alone and increased with collective use of fertilizer N and manures and also showed that the combined application of organic and inorganic N sustained productivity at lower level of N application.

Santhy *et al.* (2001) reported considerable build up in all the N fractions viz., exchangeable NH^{+}_{4}-N, NO_3^{-}-N, fixed NH^{+}_{4}-N, hydrolysable NH^{+}_{4}-N , amino acid N, unidentified hydrolysable N and unidentifiend non-hydrolysable N in 100 per cent NPK +FYM @10t ha^{-1} (to finger millet) treatment while the least concentration of these fractions were in the unmanured control. An increase in the rate of applied N was found to be associated with an increase in the build up of total and available N and also the organic matter content of the soil

Sarwad *et al* (2001) studied the effect of nitrogen fractions and their relationship with mineralizable N and its uptake by crop in a long term fertilizers experiment and observed that all the fertilizers treatment significantly increased hydrolsable NH_4^+-N, amino acid N, amino sugar N, exchangeable NH_4^+-N and mineralizable N in soil and revealed that all the fractions of N expect insoluble N and hydrolysable unknown N were highly correlated among themselves and with minearalizable soil N and uptake of N.

Gosh and Dhyani (2005) reported that the soil of the agricultural land showed significantly higher soil pH, moisture and mineral–N. The cultivated soil had significantly higher rate of N-mineralization, nitrification. The change in N transformation rates may be the result of differences in the nitrifier population and their activity and differences in other soil microbial community associated with the type of organic matter substrate present in the grassland and agricultural soil. Land cover change enhanced the rates of N transformation consequently the rate of N loss may also increase especially in absence of adequate plant cover leading to decrease in soil N content. Therefore, measures should be taken to reduce conversion of grasslands.

Guldekar *et al.* (2005) observed that the relative abundance of N fractions in soil followed the order of soluble humin N>fixed NH^+_4-N> NO_3^--N> exchangeable NH^+_4-N which contributed 21.81-27.87 per cent > 15.49-20.84 per cent – 18.05 per cent > 9.73-12.13 per cent > 9.62-11.03 per cent> 8.11-10.72 per cent>8.63-10.66 per cent to total N, respectively.

Gupta *et al.* (2005) studied distribution of mineral-N in the soil profile as influenced by application of nitrogen through urea, farmyard manure and biogas slurry in a rice-wheat sequence and concluded that, the amount of N applied through urea and manure had a direct bearing on accumulation of NO_3 and NH_4-N in the 0-180 cm soil depth. FYM resulted in more accumulation of mineral-N in the soil profile than biogas slurry.

Marathe (2005) reported that the highest total nitrogen content in soil was observed with the combined application of FYM.

Sihag *et al.* (2005) reported that application of chemical fertilizers alone or their combined use with organic manures significantly increased all the forms of nitrogen except unidentified hydrolysable-N over control or their initial status. Among the various N fractions, amino acid-N was the dominant N fraction.

Srinivas *et al.* (2006) reported that, there were considerable variations in the N mineralization patterns of the 20 residues. All the residues caused immobilization of N immediately after addition to soil, but with the progress of time, net mineralization occurred from most of the residues. The proportion of residue N mineralized at the end of 100 days of incubation ranged from -20.67% in sugarcane trash to 81.89% in *Glyricidia sepium.* Correlations between residue quality parameters and % N mineralized at different intervals showed that while N mineralization was strongly influenced by N concentration of the residues and lignin whereas polyphenol concentrations had little or no effect. There were no temporal patterns in the degree of relationship of various residue quality parameters with per cent N mineralized.

Yadav *et al.* (2006) Studied the effect of sub-surface (0.15-0.30 m depth) compaction on utilization efficiency of fertilizer nitrogen by wheat grown on highly permeable loamy sand soil under varying irrigation regimes and nitrogen fertilization. It was observed that grain and straw yield and total N uptake increased due to sub-surface compaction and higher levels of irrigation and nitrogen, whereas, recovery and efficiency of nitrogen were found higher at compaction by 8 passings, higher irrigation frequency and at lower application of fertilizer N. Thus, sub-surface compaction improved yield and nitrogen utilization by wheat under highly permeable soils of semi-arid plain of Rajasthan.

Singh and Room Singh (2007) studied Distribution of forms of nitrogen in mid western U.P. observed that, In all the soil profiles N forms decreased with increase in depth except the fixed NH_4-N increased with increase in depth. Nitrogen forms gave significant positive correlation *i.e.* total-N and organic-N.

Thakre and Gupta (2007) Reported the Effect of irrigated and rainfed cropping systems on carbon and nitrogen mineralization and Maximum C and N mineralization observed under irrigated cropping systems than rainfed. Sorghum-chickpea- groundnut showed highest mineralization under irrigated condition. While monocropping and intercropping with legumes enhances the rate of mineralization under rainfed situation. Mineralization was found to be highest during grand growth period of crops. Application of integrated nutrient supply increased C and N mineralization as compared to their individual application. The FYM+wheat straw+green manuring application augmented the mineralization under soybean wheat crop sequence

Guldekar and Ingle (2009) reported that the status of N fractions were improved with application of N in combination with FYM, zinc and sulphur. Fractions of N evaluated showed an appreciable buildup under 100 per cent NPK + 10 t FYM ha^{-1} , followed by 150 per cent NPK.

Kotangale *et al.*(2009) reported that soil microbial biomass carbon, soil microbial biomass nitrogen, water soluble carbon, water soluble carbohydrate and activity of enzyme such as dehydrogenase activity were found to be highest under the treatment of 100% RDF + 10 t FYM followed by 150% RDF.

Tabassum *et al.* (2010) reported that repeated application of fertilizer N alone, N with FYM or poultry manure or urban compost, FYM alone led to significant increase in organic C, total N, hydrolysable N (*i.e.*, amino acid N, hydrolysable NH_4-N, hexose amine N) and nonhydrolysable N in both surface and subsurface soils as compared to initial status and the status of various organic N fractions was higher in surface than the subsurface soils.

Tamas (2010) reported that the kinetics of incubation of 0.01 M $CaCl_2$ soluble organic N is similar to mineral N;0.01 M $CaCl_2$ soluble N fractions were mainly in inorganic forms in the incubation period but the content of the organic form was significantly too; and the mineralization rate is greater where the microbiological activity of the soil is expressed and the soil properties are more favored as a result of applied treatments.

Singh *et al.* (2012) reported that the Grain yield of wheat with 50% NPK fertilizer + NPK enriched compost was significantly higher than that of 100% NPK fertilizer, it was at par with 50% NPK fertilizer + NP enriched compost. The treatment 50% NPK fertilizer along with NPK enriched compost recorded maximum N uptake (105.0 kg ha-1). Application of fertilizer alone or in combination with compost led to a significant increase in total N, hydrolysable N (amino sugar-N, amino acid-N and hydrolysable NH_3-N) and nonhydrolysable-N in soil as compared to initial status. The correlation studies revealed that amino sugar-N, amino acid-N and hydrolysable NH_3-N fractions in soil were better indices of soil-N mineralization. A better correlation was observed between amino sugar-N with grain yield /N uptake by wheat.

Puli *et al.* (2013) Studied the effect of long term fertilization and manuring on laible carbon and N mineralization. The highest and significant increase in the, liable carbon, and NO_3-N and NH_3-N were recorded in the treatment of 10 t FYM ha^{-1} +100% NPK by 40.1, 18.5 and 29.0 per cent respectively over 100% recommended NPK.

5. Distribution of forms of phosphorus in soil

Bhandari and Saxena (1970) reported that nature of organic phosphorus compounds in soils of Rajasthan. And also found significant correlation between organic P fractions and some soil characteristics.

Guttani *et al.* (1976) observed that available P increased with all the treatments with continuous cropping expect in treatments NK where it is decreased. The highest available P content was in the plot receiving P fertilizer alone. Other treatments which brought about substantial increase in available P content were NPK and NP.

Kalpage and Wang (1977) showed that total P and inorganic P regressed significantly with clay content, pH and organic carbon, while organic P gave significant regression coefficient with clay content and organic carbon only. In this organic and inorganic P, in subsoil varied widely from 49 ppm to 999 ppm with an overall mean of 366 ppm. Different orders were in decreasing amount Oxisols 611 ppm > Entisols 348 > Inceptisols 286 ppm > ultisols 201 ppm.

Talashikar and Patil (1979) indicated that the addition of organic matter in soil treated with SSP increased the amount of added P in the available form over that in the soil treated with SSP alone.

In Rajasthan soils, (Mishra and Verma, 1979) reported that total P and available P were higher in surface level but progressively decreased with depth.

Prasad and Singh (1981) reported that continuous application of phosphatic fertilizers leads to improvement in the available P status.

Gupta *et al.* (1985) studied the effect of $CaCO_3$ on the transformation of monocalcium phosphate (MCP), diammonium phosphate (DAP) and 58 per cent water soluble nitrophosphate (NP) under submerged condition, with increasing period of incubation, Saloid-P and Al-P decreased with Ca-P increased. Increasing levels of $CaCO_3$ tended to enhance the transformation of added P into Ca-P but depressed the formation of Al-P, Fe-P and Saloid-P.

Jeevan Rao and Dakhore (1985) reported that the availability of P increased by 9.5, 16.5 and 14.7 kg P_2O_5 ha^{-1} with the application of 30 kg P_2O^5, 60 kg P_2O_5 ha^{-1} and FYM respectively after 5 years in sorghum-wheat sequence in Vertisols.

Yaduvanshi and Tripathi (1985) reported that Fe-P was progressively increased with the 100 per cent level of fertilizer P. while the significant decline in al-P took place in the absence of P application in control and alone treatment.

Prasad *et al.* (1986b) reported that in Vertisols, total P, organic P and Fe-P ranged from 625 to 875 ppm, 176.0 to 309.9 ppm and 22.5 to 37.5 ppm, respectively, Ca-P was dominant in alluvial Vertisols while Fe-P was dominant in sedentary once. These soils show limited P supplying capacity. But in sedentary Vertisols, response of applied P and uptake by wheat was higher.

Tomar and Sohan Lal (1986) showed that recovery percentage of total IOP into saloid-P, Al-P, Fe-P, Ca-P was only 27 per cent to 53 per cent, the remaining fractions were either in occluded form or fixed in lattice. The neutral alkaline calcareous soils of Indogangetic plains were dominant in Ca-P while acid soils were rich in Fe-P and Al-P. the content of different fractions of inorganic P and their contribution to the total inorganic P in soils are highly variable in different soils.

Agarwal *et al.* (1987) studied the inorganic fractions and available P and reported that graded doe of NPK fertilizers increased the Sal-P, Al-P, Fe-P, R-S-P and available P status of the soil. However, Ca-P remained at original level.

In long term experiment on rice wheat rotation on mollisol after 13 years a continuous application of fertilizers, manures and chemicals increase the saloid – P, Al-P, Fe-P, Reductant soluble P and available-P, however, Ca-P remained at original level (Sudhir *et al.*, 1987).

Kumbhar *et al.* (1988) revealed that in Vertisols of Maharashtra, P fractions were more than 95 per cent of total P which was present in organic forms of which 5 to 12 per cent was present in active form of P fractions (Al-P, Fe-P and Sal-P) while Ca-P was the major form (55 per cent) of inorganic P.

More and Ghonsikar (1988) reported that the availability of P was increased when mixture of superphosphate and organic manure was applied to the soil as compared to superphosphate alone.

Sood and Minhas (1988) reported that organic P and total P varied from 86 to 423 and 498 to 2166 per cent, respectively. The O.P. constituted 11.7 to

31.3 per cent of the total P. Inositol P was the major fraction of O.P. with its range of 20 to 244 ppm and constituted near about 45.6 per cent of total organic-P. Nucleic acid and lipid-P together constituted only pto 5 per cent of the total O.P. Organic P and inositol P showed a positive correlation with total P organic carbon, available N and P, clay, CEC and both citrate lithionite-bicarbonate and ammonium oxalate soluble available P.

Yaduvanshi (1988) reported that available P decreased in absence of P application. But increase when P was applied. A substantial improvement in available P in the soil due to application of FYM, manure, weedicides and marginal depression in it as a result of zinc and lime application. In long term fertilization plots huge amount of P-fertilizer left unutilized in the soil.

Pundarikashudu (1989) reported that over 50 per cent of inorganic P occurred in Ca-P which was the major contributor for labile part of available P in Vertisol.

Rane and Patil (1989) reported that the applied P increased the various P fractions including Olsen's P. the dominant fraction were Ca-P followed by organic P, Fe-P, R-S-P, Al-P and occulded P. the application of NPK had no effect on these fractions.

Badanur *et al.* (1990) reported in vertisols, available P content of soil increased significantly with crop residue and green manures over fertilizer application.

Application of P carriers in any form resulted in the increased formation of Al-P over control in both the soil i.e. laterite and shallow black calcareous soils (Dash *et al.*, 1990).

Jaggi (1991) reported that increase in pH is associated with decrease in Fe bond P and rise in the content of Ca-bound-P. Organic carbon bears significantly negative correlation ($r = 0.60^{**}$) with Fe-P and significantly positive correlation with Ca-P ($r = 0.41^{*}$). CEC of soils is significantly positively correlated with Sal-bound-P and Al-bound-P content. $CaCO_3$ was negatively correlated with Fe-P content, the correlation being significant at 5 per cent levels.

In a study on transformation of applied P in calcareous soil, Rokima and Prasad (1991) found that most of the added P was transformed into org-P and Ca-

P and very little to water soluble-P, Sal-P, Al-P and Fe-P. Addition of FYM and BGA or both in combination enhanced the buildup of all forms of inorganic P.

Sood *et al.* (1991) reported that organic P in soil may be present as inositol P, nucleic acid P and lipid-P. These fractions contribute 9.51, 0.3 to 2.9 and 1.4 to 1.8 per cent of organic P respectively. These fractions did not show any change in their distribution with depth, but these fractions as a whole contribute 42 per cent of organic P, which constituted 3.9 to 35.2 per cent of total P with their amount higher in upper layer and gradually decreasing with depth.

Vishwanath and Doddamani (1991) studied surface samples (0.15 cm) of Vertisols in Malaprabha command area of Karnataka and reported the decrease of saloid-P, organic-P and total P with depth. Distribution of Al-P, Fe-P, R-S-P, occluded P and total Ca-P did not follow a definite pattern, and Ca-P was the dominant form of P i.e. 18.3 per cent of the total P.

Dongale (1993) observed that, total P and organic P contents were maximum in surface horizon showing a decreasing trend with depth. In Maharashtra, clay was not related with any P fractions.

More and Agale (1993) studied the transformation of applied P in irrigated cotton and reported that maximum of applied P as super phosphate was transformed into inorganic P fractions as Al-P, Fe-P, R-S-P and Ca-P. There was continuous increase in P fractions with increasing levels of P, Ca-P was the most dominant fractions in the soil followed by R-S-P at all the growth stages of crop.

Srivastava and Srivastava (1993) studied various forms of P in relation to varying soil pH, availability of P under air-dried and waterlogged condition and response of P-application in saline-sodic soil under rice-wheat crop sequence. They observed that Ca-P was most predominant P fraction followed by P-S-P, Fe-P, Al-P and adsorbed-P in soil pH range of 7.2 to 10.3 showing only a slight increase in availability per unit increase in soil pH due to waterlogged condition. In pot experiment, no response to added P was observed in saline-acidic soil, amended with gypsum at the rate of 100 per cent of GR to rice and succeeding wheat crop due to high initial available P content of soil.

Tekchand and Tomar (1993) studied the effect of different properties of acid soils of Himachal Pradesh, Uttar Pradesh, Assam, hilly areas of Haryana on the distribution of different inorganic-P fractions and observed that except saloid-P none of the inorganic-P fraction was significantly related with any soil property owing to the multicolinearity among soil properties which counteracted the effect of each other, different land usage, variation in agronomic practices and fertilizer use in these agro climatic zones.

Teckchand and Tomar (1993) reported that clay and $CaCO_3$ are the major sinks for phosphate sorption in alkaline calcareous soils of North West India. In many acis soils, the oxides of Fe and Al are the residual products formed during silicate weathering and their amounts increases as weathering proceeds. Therefore, strongly weathered acid soils are rich in Fe and Al-oxides, which are expected to cause decreased availability of P in acid soils.

Dixit *et al.* (1994) reported that after 16 years of long term application of fertilizers, for soybean-wheat-maize (*kharif-rabi-summer*) in Chromustert soil in livestock farm of JNKVV, Jabalpur distribution of inorganic fractions viz., Al-P, Ca-P, Sal-P, R-S-P, available-P, total-P was studied. Out of this Fe-P, Al-P, Sal-P and available-P were increased at the expense of Ca-P and R-S-P. Application of normal 100 per cent NPK dose increased the Sal-P but available-P and R-S-P were maximum in treatment receiving 150 per cent NPK, 100 per cent NPK + Zn gave highest Al-P. While Fe-P was found higher in control and Ca-P was highest in 100 per cent N treatment.

Nagendra Rao and Chakraborty (1994) fractionated the soils of tea growing area in Himachal Pradesh with different extractant viz., Mehlich-1, M-3, Bray-II, Olsen's and evaluated inorganic fractions followed by the order of R-S-P>Fe-P>Ca-P>Al-P>Saloid-P in both depth where RSP content was higher in subsurface soils than surface soils. Al-P and Ca-P were the predominant fractions contributing towards availability of P.

Pritam and Gupta (1994) examined the effect of liming, application of FYM and P fertilization on P-use efficiency and root CEC in Altisols in Western Himalayas using wheat (S-308) as test crop. Liming improved P utilization by 20-26 per cent and FYM 93-99 per cent.

Sharma *et al.* (1995) found that continuous application of 50 per cent and 150 per cent NPK of recommended dose for 20 years resulted 49.5 and 62 per cent increase in total P content of soils over the control (372.5 mg P kg^{-1}) whereas in control total P content decreased by 19 per cent of the initial total P (460 mg kg^{-1}).

Tomar *et al.* (1995) observed that when the soil was incubated with organic matter, the amounts of native. Saloid P and available P were relatively much higher than organic matter untreated soils. Transformation of added P into Sal-P, Al-P and Fe-P increased, whereas Ca-P decreased with increasing water solubility of fertilizer. In the initial stage of incubation, organic matter decreased the transformation of added P into Al-P, Fe-P and Ca-P but at later stage, it enhanced the formation of Al-P and Fe-P.

Tomar *et al.* (1995) studied the influence of clay minerals in major soil groups of India and reported that at low P levels, Kaolinite dominant soils adsorbed highest amount of P followed by illite and 2:1 expanding type mineral dominated soils, acidic soilsad sorbed less than 60 per cent of added P at low pH and greater than 99 per cent at high pH compared to non-acid soils and this peculiar behavior was ascribed to increasing polymerization of exchange Al with increase in pH.

Lyamureme *et al.* (1996) suggested that P rich organic amendments can decrease future P sorption in soils by reacting with sorption sites as compared with inorganic amendments like $CaCO_3$ and $CaSO_4$.

Patangudi *et al.* (1996) studied that the Vertisol profile for distribution pattern of various forms of inorganic phosphorus. Total inorganic P in the soil varied from 137.6 to 292.8 ppm. The abundance of various fractions of inorganic P followed the order Sal-P< Fe-P < Occl-P < Al-P < R-S-P < Ca-P.

Singh *et al.* (1996b) analyzed few Alfisols and soils from arid, semiarid and sub-humid climatic regions of India for phosphorus by using different extractants, out of which P extracted by Soltanpur and Schub's method (r=0.70*) correlated with saloid-bound-P which is important source of available P in soil, ranged from very low 9 mg kg^{-1} in semi arid soil to medium 144 mg kg^{-1} in sub-humid soil.

Sheeba and Chellamuthy (1996) also observed that the continuous application of P fertilizers increased the concentration of total P in the soil. Application of 100 per cent NPK+FYM resulted in buildup of total and available P status of soil.

Tamboli (1996) reported that the fractions of P in soil series of Maharashtra. The Ca-P was the dominant fraction amongst the all inorganic fractions in soil. The fractions are Sal-P (12.96 mg kg^{-1}), Al-P (32.58 mg kg^{-1}), Ca-P (364 mg

kg^{-1}), Fe-P (31 mg kg^{-1}), R-S-P (50.52 mg kg^{-1}), total P (923 mg kg^{-1}) and organic P (432.78 mg kg^{-1})

Bahl *et al.* (1997) suggested that the extractable P was higher in green manured soil samples. The amount of Olsen's extractable P decreased during first 40 days but increased thereafter. Added P in alkaline soil transformed into Sal-P, Ca-P but in acid soil higher amount of Al-P and Sal-P was formed and green manuring increased Sal-P than other fractions.

Prasad and Mathur (1997) reported 28.2, 37.87 and 116.1 per cent increase in total P content of soil after 20 years of continuous fertilization with 50, 100 and 150 per cent NPK of recommended dose, respectively, over control (471 ppm P), application of FYM also increased the content of P in soil.

Bellakki *et al.* (1998) observed that soil available P content increased significantly with combined application of organic and inorganic sources of nutrients to Vertisols.

Bhrigvanshi (1998) reported that the continuous application of phosphatic fertilizer, the inorganic P and fractions like Ca-P, Al-P, Fe-P were increased. The changes in Ca-P were more as compared to Al-P and Fe-P. But overall relative degree of change was more in Al-P than other two fractions.

Tomar and Gautam (1998) reported that the correlation between pH and phosphate retention was not significant for a group of mixed soils, but in a group of pedalogically similar soils, differing mainly in pH.

Santhy *et al.* (1998) revealed that there were buildup of P content and it was maximum with 150 per cent NPK application. N alone application drastically reduced the concentration of available P. the Ca-P was constituted to be the dominant inorganic P form.

Yadav and Alok Kumar (1998) reported that continuous application on NPK fertilizers alone at 100 per cent recommended level, and their combination with FYM increased the available P content of soil over the initial status.

Tomar and Das (1999) found that the amount of P absorbed by CBD-K soils at a given concentration of P in added solution and their clay content were in the same order. The CBD-K soils are devoid of exchangeable P binding cations and free Al_2O_3 and Fe_2O_3. Hence phosphate sorption in these soils occurs only on aluminosilicate clay minerals.

Ravankar *et al.* (1998) reported that the continuous application of 100 per cent NPK along with 10 t FYM ha^{-1} to sorghum wheat sequence had a beneficial effect on available phosphorus content in surface layer of Vertisols.

Pandey *et al.* (2000) reported that the correlation studies revealed that availability of P in all the soil associations in general was significantly and positively influenced by organic matter and clay. Available S content varied from 5.8 to 53.8 mg kg^{-1} in different soil associations. It was observed that about 41 and 59 per cent soil samples showed deficiency and sufficiency, respectively in S-availability. In correlation studies S-availability in all the soil associations was found significantly and positive affected by organic matter, CEC and soil properties (clay).

Yadav *et al.* (2000) formed that total P content in soils of Haryana was not significantly related with any soil property except $CaCO_3$ (r = 0.75) and pH (r = 0.35) and concluded variations were mainly due to fertilizer applied.

Vig *et al.* (2000) studied the forms of P and efficiency of different soil test for P extractability in calcareous soils and revealed that the calcium P was the dominant inorganic P fraction (92.8 %) followed by Al-P (5.4%), Fe-P (1.4 %) and Sal-P (0.4%). They observed that the Olsen's P had a significant negative relationship with $CaCO_3$ and clay content.

The dominance of different P forms among the mineral P fraction was reported by Goroji and Sarangnath (2001) and the fractions are of following order. Sal-P < Fe-P < Al-P < Occl-P < R-S-P < Ca-P. the content of Sal-P, Al-P and Org-P were significantly higher and Ca-P, R-S-P and Occl-P were significantly lower with FYM treated plot irrespective of P sources.

Basawaraj and Manjunathaiah (2002) reported that added P transformed more into Sal-P, Al-P, Fe-P, Ca-P, R-S-P and Occl-P over control in Vertisol of Karnataka.

Mujumdar *et al.* (2004) reported that application of 60 kg P_2O_5 ha^{-1} through SSP alone or with FYM was most efficient dose for forms of P build up followed by 60 kg P_2O_5 ha^{-1} as SSP + RP (1:1) with or without FYM in acid Alfisol of Meghalaya.

Application of FYM in combination with P fertilizers was found to be highly effective in increasing available P. The process of mineralization due to increased biological activities increased the concentration of available P (Marathe, 2005). He further observed also significant increase in available K with the increasing levels of NPK. Highest values of available K was observed with the combined application of FYM.

Setia and Sharma (2007) conducted a field experiment on effect of continuous application of N, P and K to maize wheat annual sequence on the changes in Olsen's-P, inorganic forms of P and total P at tillering, ear initiation and wheat harvést stage and reported that application of P (17.5 and 3.5 kg ha^{-1}) increased all the P forms irrespective of growth stages whereas, N (120 and 180 kg ha^{-1}) and K (0 and 33.2 kg ha^{-1}) application caused decreased in all the P fractions.

Sharma *et al.* (2009) studied the long term lantana addition on soil phosphorus fraction and they observed that continuous addition of lantana also increased available P by about 23-71 % over no lantana addition as well as also increased all fraction of P. they also concluded that among different P fractions $NaHCO_3$-Pi and $NaHCO_3$-Po were the most importance P fractions contributing to nutrition of rice wheat grown in a sequence.

Jatav (2010) conducted field experiment to investigate the role of organic and inorganic sources of P and K on different fractions of P in soil after 3 cycles in a potato radish sequence and fractionation. Studies revealed significant increase in saliod P, Al-P, Ca-P under integrated use of inorganic fertilizers and FYM.

6 Effect of long term fertilization on biological properties of soil

Kukreja *et al.* (1991) in a long term field experiment at Hisar in *Typic Ustochrept* with pearl millet-wheat annual rotation found that the microbial biomass increased with increasing applications of FYM and the biomass was more in treatments

receiving NPK along with FYM. Higher biomass in plots receiving FYM and inorganic N in the present study respects the effect of FYM which serve as a source of carbon and nutrients. Better plant growth also contributes to higher microbial biomass. The viable counts indicated that the soils receiving higher application of FYM had more viable cells. The reduction in CO_2 could therefore, be attributed to the dormancy of a portion of microbial biomass. The substrate induced respiration indicated that the microbial biomass was not dead. Furthermore, Manna and Hazra (1996) noticed the effect of four levels (0, 4, 8 and 16 t ha^{-1}) and farm yard manure on soil microbial biomass carbon and enzyme activities in *Typic Haplustert* with soybean-wheat system and recorded increase in the microbial biomass carbon, with the increase in FYM levels. There was significantly positive correlation between soil organic carbon and microbial biomass carbon.

Patil and Varade (1998) reported that bacteria and actinomycetes proliferated under NPK and FYM. Increasing trend of microbial population was noticed after 30 days of sowing and it declined at harvesting stage. However, Sharma *et al.* (1998) reported that the microbial population was almost doubled with the balanced and integrated use of chemical fertilizers and organics than with imbalanced use of chemical fertilizers and treatments involving the use of 100 per cent NPK.

Malewar *et al.* (1999) reported the observations from a long-term fertilizer experiment with sorghum-wheat cropping sequence and found that the proliferation of bacteria, fungi and actinomycetes decreased in higher proportion in control followed by farmers practice; however highest population of microbes was observed in the treatment receiving 50:50 inorganic + organic combinations. In addition to 50 per cent organics either in the form of FYM, wheat straw, green manure with subabul leaves in combination with fertilizers helped to increase bacteria, actinomycetes, fungi and total microbes and CO_2 evolution.

Sharma *et al.* (2000) also noticed that the microbial population (viz, bacteria and fungi) in soil was high in FYM-treated plots followed by co-incorporation of crop residues while lowest number of these micro-organism were recorded in only chemical fertilizer-treated plots. The increases in microbial population in soil might be due to greater availability of organic carbon and mineralized nutrients for their proliferation and development.

Tiwari *et al.* (2000) conducted a field experiment on *Typic Ustochrept* at Kanpur (UP) with wheat-green gram sequence and observed the CO_2 evolution was maximum with 7.5 t ha^{-1} WSN (Wheat straw nodes)+ BGS(Biogas slurry) along with 100 kg fertilizer N ha^{-1}. Whereas, microbial biomass carbon was higher with application of 7.5 t ha^{-1} WSN application along with 100 kg N ha^{-1} over without WSN application.

Kanchikerimath and Dhyan Singh (2001) observed that, long-term (since 1971) application of manure and fertilizers in maize-wheat–cowpea cropping system in a Cambisol indicated that the soil microbial biomass carbon was increased from 122 mg kg^{-1} in unfertilized treatments to 331 mg kg-1 in soil amended with 100% NPK + manure. The results indicated that soil organic matter content and soil microbial activities are, vital for the nutrient turnover and long-term productivity of the soil.

Patil and Puranik (2001) reported higher biomass C and N under irrigated condition during summer season from planting to flowering in all cropping systems. FYM in combination with mineral fertilizer enhanced the SMBN under sorghum-wheat sequence; however the application of RDF increased their amount over control. FYM, wheat straw and green manuring application increased the SMBC and SMBN content in soil under soybean-wheat in Vertisol.

Selvi *et al.* (2004) recored that uncer long term experiment with millet-maize-fodder cowpea in Inceptisol at TNAU, Coimbatore (TN) and indicated that bacteria, fungi and actinomycetes proliferated well under continuous applications of NPK and FYM treatments. Among the microbes, bacterial population was highest compared to fungi and actinomycetes in the soil. There was gradual increase in biomass C and N content of the soil for graded levels of NPK from 50% to 150%. Application of 100% NPK +FYM was recorded significantly highest biomass C and N followed by 150% NPK application than other treatments.

According to Saini *et al.* (2005) integration of FYM and fertilizer on soybean-maize cropping sequence increased the microbial biomass C, N and P under soybean (*Glycine max* L.) and winter maize (*Zea mays* L.) significantly (r=0.623-0.716, P<0.01) when a combination of *Bradyrhizobium Japonicum* or *Azotobacter chrococcum*, *Bacillus megaterium* and *Colomus fuciculatum* were used and was maximum with 50% RDF (10 kg N ha^{-1} and 20 kg P ha^{-1} for soybean, 75 kg N ha^{-1} and 30 kg P ha^{-1} for maize) along with bio-inoculants. Further, Mandal *et al.* (2007) also conducted a long-term fertilizer experiment (since 1971) on *Typic Haplustept* at IARI, New Delhi .After 34-years, they reported the effect of treatments (Control, N, NP, NPK, NPK + FYM) and three physiological stages of wheat growth on microbial biomass carbon (MBC), dehydrogenase, mineralizable N and phosphatase activities in soil which was considerably increased with applied recommended dose of fertilizers and farmyard manure as compared to rest of treatments. Further, Singh *et al.* (2009) conducted a field experiment at IARI, New Delhi, during 2000-07 on sandy clay loam soil with maize-wheat cropping system and found that for a given N management the

3 different water regimes significantly differed in supporting the microbial activity as reflected by the rate of soil respiration. The highest stimulation of soil respiration activity at supra-optimal level over optimal level (43%) followed by recommended dose of nitrogen with 25% N substituted by biofertilizer (15%) over control. Among the different N management application of 100% recommended dose of nitrogen as organics supported the highest soil microbial biomass carbon and it was 41% higher than recommended dose of nitrogen applied as urea. Substitution of the 25% recommended dose of nitrogen by FYM, biofertilizer and sewage sludge also increased the soil microbial biomass carbon over the recommended dose of nitrogen as urea.

Arbad and Syed Ismail (2011) conducted a long term field experiment with soybean-safflower cropping sequence on Vertisol at Marathwada Agricultural University, Parbhani during 2007-08 and 2008-09 and reported the maximum bacterial and actinomycetes population after harvest of soybean and safflower with 100% NPK+FYM and only FYM @ 10 mg ha^{-1} respectively, whereas fungi population in soil was recorded significantly highest with the only use of FYM and followed by NPK+FYM treatment and these two are significantly superior over rest of the treatments. It might be due to, inorganic treatments showed lower bacterial, fungal and actinomycetes count as compared to plot treated with organic source.

Chesti and Tahir Ali (2012) conducted a field experiment during two consecutive *kharif* seasons of 2004 and 2005 at SKUASTK, Srinagar on Alfisol and the results revealed that application of organic manure significantly increased the rhizospheric microbial population (Bacteria, fungi and actinomycetes) and available NPK. Among organic manures, application of FYM (10 t ha^{-1}) soil inoculation with P-solubilizers recorded significant increase in soil available N, P, bacterial and actinomycetes population. Increasing levels of P up to 30 kg P_2O_5 ha^{-1} was significantly improved microbial population (bacteria, fungi and actinomycetes). Thus, application of 30 kg P_2O_5 ha^{-1} could be designated as the safe limit for maximum microbial build up in the green gram rhizosphere.

Padmavathi *et al.* (2012) conducted the field experiments during 2005-06 to 2007-08 on Vertisol with cropping systems (greengram-safflower, soybean-safflower and maize-safflower) at Hyderabad. The highest values of soil microbial biomass C and N were estimated during the flowering stage of rainy season crops and safflower. During the rainy season, maize-safflower cropping system highly reduced the level of MBC (398 μg C g^{-1} soil) and MBN (53 μg N g^{-1} soil). While, during the post rainy season, soybean-safflower (390 μg C g^{-1} soil and 59.2 μg N g^{-1} soil) and greengram-safflower (388 μg C g^{-1} soil and 58.9 μg N g^{-1} soil) cropping systems of safflower might have resulted in higher level of soil microbial biomass C and N these legume-safflower systems compared to maize-safflower. Among the nutrient management practices, part of substitution of RDF of system with glyricidia (2 t ha^{-1}), safflower residues (3 t ha^{-1} to greengram-safflower and soybean-safflower, 6 t ha^{-1} to maize-safflower) recorded significantly highest soil microbial biomass C and N during rainy season (367 μg C g^{-1} soil and 55.7 μg N g^{-1} soil). During the post rainy season, the microbial biomass C and N with treatment of part substitution of recommended NPK with glyricidia and safflower residues (426 μg C g^{-1} soil and 64.7 μg N g^{-1} soil) was on par with the treatment of part substitution of recommended NPK with glyricidia anf FYM (401μg C g^{-1} soil and 60.9 μg N g^{-1} soil). No application of fertilizer/manure recorded significantly decreased soil microbial biomass C and N.

Singh and Dhar (2012) conducted field experiment during 2003-06 at IARI, New Delhi on sandy clay loam soil with rice-wheat-green gram cropping sequence and indicated that soil microbial population (actinomycetes, bacteria, fungi and BGA) and dehydrogenase enzyme activity were enhanced over the years due to the application of organic inoculants as compared to the total control and recommended fertilizer application. Soil organic carbon content was also found to be significantly enhanced due to organic cultivation over control as well as chemical fertilization.

Suresh *et al.* (2012) in their study with mungbean-safflower system on Vertisol at Hyderabad in 2005 noted highest soil respiration (161 μg C g^{-1} soil per day), microbial biomass carbon (426 μg g^{-1} soil) and microbial biomass nitrogen (62.9 μg g^{-1} soil) after application of full dose of organic nutrients coupled with incorporation of previous crop residues to both the crops in the system. This was closely followed by incorporation of crop residues to safflower only and other treatments consisting part of substitution of RDF with FYM than other treatments. Soil incorporation of mungbean residues (fallen leaf and haulm) might have increased microbial biomass carbon and nitrogen over no residue treatment and no fertilizer treatment.

7 Effect of long term fertilization on residual soil fertility

Padalia (1980) indicated that compost applied with NPK fertilizer not only increase the yield and nutrient uptake but also had a beneficial residual effect on succeeding crop.

Singh *et al.* (1983) revealed that legumes in rotation improved the soil fertility significantly in respect of organic resulting in higher uptake of N and P fertility improvement through *Kharif* legumes was also attained under dryland in respect of including high organic carbon content, total N and available P through better nodulation and microbial colonization.

Kamat *et al.* (1986) observed residual P increase and NPK uptake showed marked increase over a legume crop. Subbarao *et al.* (1995) reported that P applied to soybean showed residual effect in two succeeding crops whereas P applied to wheat contributed to one succeeding crop.

Anand Swarup (2002) shown that imbalance fertilizer use particularly N alone had a deleterious effect on soil productivity and health and the damaging affect in the absence of P and K fertilizers. Integrating organic manures (FYM @ 10-15 mg ha^{-1}) with 100 % recommended NPK fertilizer dose not only sustained high productivity but also maintained fertility in most of the intensive cropping systems and soil types

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

The experimental materials used and the methods followed for the planning and conduct of experiment and laboratory studies during the course of present investigation entitled "Effect of Long Term Fertilization on Carbon Sequestration and Soil Quality Under Sorghum Wheat Cropping System" are described below.

3. 1. Experimental site

The experiments were conducted on deep black soils of (Typic Haplustert) survey No 124 of Parbhani block of central farm, Marathwada Agricultural University, Parbhani since 1983. The initial physico-chemical properties of experimental site are given in table 1.

3.1: Mechanical composition and physico-chemical properties of soil

Soil characteristics	**Unit**	**1984**
A) **Mechanical composition**		
Coarse sand	(%)	5.34
Fine sand	(%)	12.78
Silt	(%)	24.60
Clay	(%)	51.50
Textural class	-	Clay
B) **Chemical composition**		
pH(1: 2.5)	-	7.80
EC	$dS\ m^{-1}$	0.30
Calcium carbonate	$g\ kg^{-1}$	77.9
Organic carbon	$g\ kg^{-1}$	4.5
C) **Fertility analysis**		
Available N	$kg\ ha^{-1}$	110.88
Available P_2O_5	$kg\ ha^{-1}$	8.59
Available K_2O	$kg\ ha^{-1}$	405.20

Soil characteristics	Unit	1984
D) **Different N fractions**		
ammonium nitrogen	mg kg^{-1}	7.00
Nitrate Nitrogen	mg kg^{-1}	11.00
Nitrite Nitrogen	mg kg^{-1}	2.73
Total Hydrolysable Nitrogen	mg kg^{-1}	280.00
Amino Acid Nitrogen	mg kg^{-1}	84.00
Organic Ammonium Nitrogen	mg kg^{-1}	84.00
Amino Sugar Nitrogen	mg kg^{-1}	40.24
Acid Insoluble Nitrogen	mg kg^{-1}	424.00
Total Nitrogen	mg kg^{-1}	704.00
E) **Different P fraction**		
Saloid Phosphorus	mg kg^{-1}	7.18
Aluminum Phosphorus	mg kg^{-1}	23.80
Iron Phosphorus	mg kg^{-1}	35.32
Reductant Phosphorus	mg kg^{-1}	37.98
Occluded Phosphorus	mg kg^{-1}	6.17
Calcium Phosphorus	mg kg^{-1}	152.37
Organic Phosphorus	mg kg^{-1}	282.16
Total P	mg kg^{-1}	551.45
F) **Biological parameters**		
Bacterial count	(CFU x 10^7 g^{-1} soil)	180.34
Fungi count	(CFU x 10^4 g^{-1} soil)	7.65
Actinomycetes count	(CFU x 10^6 g^{-1} soil)	30.52
SMBC	µg g^{-1} soil	138.91
SMBN	µg g^{-1} soil	38.95
CO_2 evolution	mg 100 g^{-1} soil 24 hr^{-1}	37.25

The experimental soil is clayey in texture, calcareous in nature, moderately alkaline in reaction, low in available nitrogen, medium in phosphorous and high in potassium content

3.2 Cropping history

Under present investigation, study of nitrogen and phosphorus fractions under long-term manuring in fixed specific cropping sequence was a major objective. Hence, the experiment where the fixed cropping sequence sorghum-wheat was followed from 1983-84 till to date was selected for the present study.

3.3 Experimental layout

Experiments were laid out on fixed site (permanent plot) where, sorghum (CSH-9) in *kharif* and wheat (HD-2189) in *rabi* season were grown sequentially from 1983-84 till to date. Inorganic NPK fertilizers and four organic sources viz, FYM, wheat straw, green manuring of *glyricidia* and subabul leaves, treatments were fourteen treatment combinations and each treatment was replicated thrice in a Randomized Block Design (Fig.1.).

3.4 Treatment details

Fourteen treatment combinations were to evaluate the direct effect of organic manures on sorghum and its residual effect on succeeding crop wheat and direct inorganic fertilizer effect on sorghum in kharif, and direct and residual fertilizer effect on wheat in rabi. The profiles were excavated in each treatment during the summer season or 2012-13. The horizon wise soil samples collected and stored are utilized for the present project.

3.5 Experiment details:

1) Design of experiment : Randomized Block Design (RBD)
2) Year of start of experiment : 1983
3) Sequence : Sorghum- wheat
4) Crop cycles completed : 33
5) No. Of Treatments : Fourteen
6) No. of replications : Three
7) Plot size
   a) Gross : 10.80 m x 9.00 m
   b) Net : 9.00 m x 7.80 m
8) Spacing row to row
   a) Soghum : 45.00 cm
   b) Wheat : 12.50 cm

Details of Treatments

Treatments	Treatments	
	Kharif	Rabi
T_1	Control	Control
T_2	50 % recommended (40:20:20) NPK kg ha^{-1} through fertilizer	50 % recommended (60:30:30) NPK kg ha^{-1} through fertilizer
T_3	50 % recommended (40:20:20) NPK kg ha^{-1} through fertilizer	100 % recommended (120:60:60) NPK kg ha^{-1} through fertilizer
T_4	75 % recommended (60:30:30) NPK kg ha^{-1} through fertilizer	75 % recommended (90:45:45) NPK kg ha^{-1} through fertilizer
T_5	100 % recommended (80:40:40) NPK kg ha^{-1} through fertilizer	100 % recommended (120:60:60) NPK kg ha^{-1} through fertilizer
T_6	50 % NPK kg ha^{-1} through fertilizer + 50 % N through FYM	100 % recommended NPK kg ha^{-1} through fertilizer
T_7	75 % NPK kg ha^{-1} through fertilizer + 25 % N through FYM	75 % recommended NPK kg ha^{-1} through fertilizer
T_8	50 % NPK kg ha^{-1} through fertilizer + 50 % N through wheat straw	100 % recommended NPK kg ha^{-1} through fertilizer
T_9	75 % NPK kg ha^{-1} through fertilizer + 25 % N through wheat straw	75 % recommended NPK kg ha^{-1} through fertilizer
T_{10}	50 % NPK kg ha^{-1} through fertilizer + 50 % N through green manuring (*Glyricidia*)	100 % recommended NPK kg ha^{-1} through fertilizer
T_{11}	75 % NPK kg ha^{-1} through fertilizer + 25 % N through green manuring (*Glyricidia*)	75 % recommended NPK kg ha^{-1} through fertilizer
T_{12}	Farmers practice (40:20:20) NPK kg ha^{-1} and seed without carbofuron treatment	Farmers practice (60:30:30) NPK kg ha^{-1} and 100 kg seed ha^{-1}
T_{13}	75 % NPK kg ha^{-1} through fertilizer + 25 % N through subabul leaves	75 % recommended NPK kg ha^{-1} through fertilizer
T_{14}	50 % NPK kg ha^{-1} through fertilizer + 50 % N through subabul leaves	100 % recommended NPK kg ha^{-1} through fertilizer

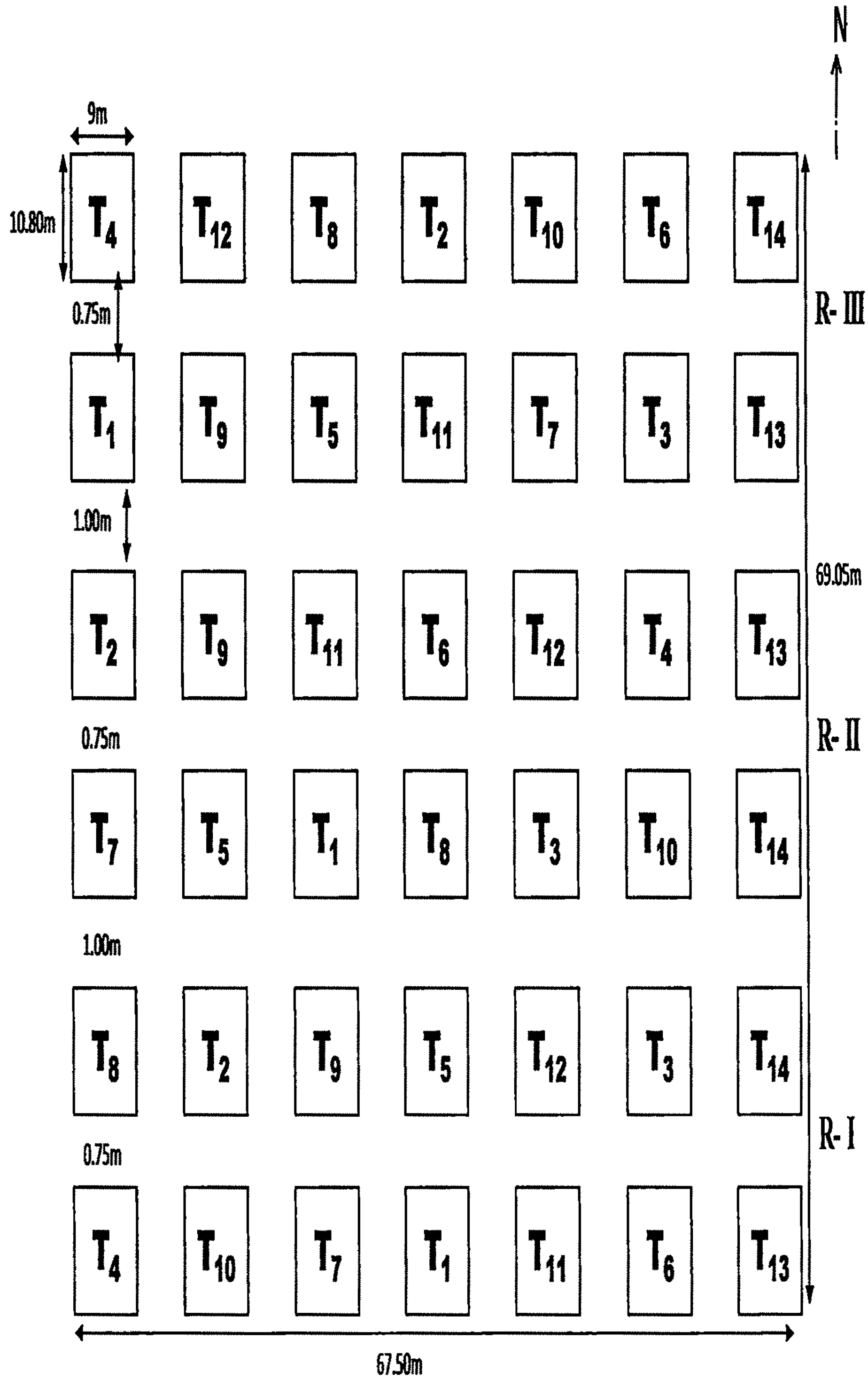


Fig.1. Plan of layout

To work out according to the objective no 3. *i. e.* vertical movement of nutrients, the treatments were grouped as follows

Sr. No.	Treatments No.	Treatment Details
FP	T_{12}	Farmer practice
Inorganic	$(T_2+T_3+T_4+T_5/4)$	Only inorganic fertilization
INM_1	$(T_6+T_8+T_{10}+T_{14}/4)$	Combine application of organic (50%) and inorganic (50%) fertilizer
INM_2	$(T_7+T_9+T_{11}+T_{13}/4)$	Combine application of organic (75%) and inorganic (25%) fertilizer
INM_3	T_6	Best treatment

According to this, the treatments were grouped and calculated results and discussion were discussed in chapter IV

8) Spacing plant to plant
    a) Sorghum : 12.00 cm
    b) Wheat : drilled
9) Crop varieties
    a) Sorghum : CSH-9
    b) Wheat : HD-2189.

Intercultural operations like thinning, fertilizer application and schedule of irrigation and schedule of irrig ation was as per recommendations.

Organic Sources	N(%)	P_2O_5(%)	K_2O(%)	C(%)	C/N Ratio
FYM	0.60	0.21	0.51	36.5	60.83
WS	0.59	0.08	1.10	48.12	80.20
GM	4.54	0.26	2.10	36.40	24.30
SL	2.11	0.21	1.23	41.54	19.66

3.6 Fertilizer application to crops

Organic manures viz; FYM, wheat straw, *Glyricidia* and subabul leaves were incorporated in soil before sowing of kharif crop and chemical fertilizers were applied to sorghum (CSH-9) and wheat (HD-2189) through straight fertilizers (like urea, single super phosphate and murate of potash) and mixed fertilizers, according to treatments described in Table 2 at the time of sowing. The method of application of fertilizer adopted was drilling

3.7 Collection and preparation of soil samples:

Soil samples were collected after completion of wheat harvesting during year 2011-12 for chemical analysis. Soil samples were collected from soil profile dried in shade followed by oven drying and will be ground and sieved. The samples were stored in polythene packets with proper labeling and finally was used for processed soil quality parameters analysis and interpretation of the results.

3.8 Collection of profile samples:

Soil profile of size 1m x 1m x 1.5 m was excavated from each treatment of experiment after harvest of wheat crop. The depth wise, samples i.e., 0-30 cm, 30-60 cm, 60-90 cm and above 90 cm was collected from each profile.

3.9 Soil analysis

Physical indicators, chemical indicators and fractination of nitrogen in soil were determined by the standard method as given in the methodology. The details of procedures adopted and references are given below.

3.9.1 Partical density

It was determined by Pycnometer method (Black, 1965)

3.9.2 Bulk density

It was determined by Core method (Black, 1965)

3.9.3 Porosity

It was determined by (1-(pb/pd)) × 100 (Jackson, 1978)

3.9.4 Soil pH

It was determined in soil water suspension (1:2.5 ratio) using digital pH meter (Jackson, 1978)

3.9.5 Electrical Conductivity

It was estimated in soil water suspension (1:2.5 ratio) using digital pH meter (Jackson, 1978)

3.9.6 Organic carbon

Soil organic carbon was determined by Heated dichromate method for TOC as described by (Technical manual USETA, 2001)

3.9.7 Inorganic carbon

Soil inorganic carbon was determined by heated dichromate method as described by (Technical manual USETA, 2001)

3.9.8 Calcium carbonate

The free calcium carbonate was determined by rapid titration method Jackson (1978)

3.9.9 Infiltration rate

Infiltration rate was determined by double ring infiltrometer. (Black,1965).

3.9.10 Agrregates satability

Aggegate stability was determined by Yoder's apparatus which was given by Jackson (1978).

3.9.11 Water holding capacity

Water holding capacity was determined by method described by Sankaram (1966).

3.9.12 Available Nitrogen

It was determined by using alkaline permanganate method as suggested by Subbiah and Asija (1956)

3.9.13 Fractionation of Nitorgen

3.9.13.1 Total nitrogen

Total nitrogen was estimated by kjeldhal flask, 10 g soil was transferred. To moist the soil 10 ml of distilled water was added, swirled and allowed to settle for 30 minutes. The 35 ml of concentrated sulfuric acid and 1 g salicyclic acid were added and was kept for 5 minutes. After this 5 g sodium thiosulphate was added and heated gently for 5 minutes. Kjeldhal flask was then allowed to cool and 10 g salt mixture was added in the flask. Kjeldhal flasks were kept for digestion of full heat until the mixture becomes colourless. After digestion, flasks were allowed to cool and 50 ml of distilled water was added in each flask and flasks were well stirred. The digested content was transferred by decantification to a 2 litre distillation flask. The content was washed with distilled water to make it acid free and then distilled water was added to make up its volume. Few pieces of zinc were added to prevent back suction of the distillate into distillation flask and few pieces of porcelainor glass beed was added to prevent bumping action. 130 ml of 40 per cent. NaOH solution was added and flask was quickly connected to condenser and distilled receiving ammonia in a known but excess volume of N/10 sulphuric acid (20 ml) with methyl red in a 400 ml beaker. Distillation was started till 150 ml of distillate was get collected. Collected distillate was titrated with N/10 NaOH until the indicator colour change from red to yellow and reading were noted down. In the same manner blank reading was carried out without soil sample. The instrument kjel-plus was used for the digestion and distillation of the samples.

3.9.13.2 Available nitrogen

It was estimated by alkaline permanganate method (Subbiah and Asija, 1956). 10 g of weighted soil sample was added into 1000 ml distillation flask. Then 20 ml of distilled water was added into flask followed by 100 ml each of 0.32 per cent $KMnO_4$ and 2.5 per cent NaOH solutions. About 1 ml liquid paraffin and few pieces of glass beads were added to avoid frothing during boiling and to prevent bumping action, respectively. Flask was immediately connected to the distillation assembly and distillation was carried out. During distillation, the tip of condenser was dipped in the 20 ml of mixed boric acid indicator in the beaker. During distillation, liberated ammonia was collected into boric acid mixed indicator solution due to which original pinkish colour of mixed indicator was turned to green. Near about 100 ml of distillate was get collected in about 30 minutes. That distillate was titrated with 0.02 N H_2SO_4 solutions till the original pinkish shade was developed.

3.9.13.3 Ammonium nitrogen

In a 50 ml Brlenmeyer flask, 5 ml of H_3B0_3- indicator solution was added that was marked to indicate a volume of 30 ml. That flask was kept under the condenser of the steam distillation apparatus so that the end of condenser was about 4 cm above the surface of the H_3BO_3. An aliquot of the soil extract (20 ml) was pipette out into a distillation flask and 0.2 g of MgO was added through a funnel having a long stem that reaches down into the bulb of the flask. Then the flask was attached to the steam distillation apparatus. Distillation was adopted when distillate reached the 30 ml mark on the receiver flask. Then NH^{+}_4 –N was determined by titrating distillate with 0.005 N H_2SO_4

from a micro burette. The colour change at the end point was from green to a permanent faint pink.

3.9.13.4 (Nitrate + Nitrite) Nitrogen

After removal of NH^{+}_{4} –N from the sample as described in the previous section, stopper was removed from the flask and then 0.2 g of Devarda alloy was added rapidly through a funnel that reaches down into the flask and started the steam distillation. Then the amount of NH^{+}_{4} –N liberated was determined by steam distillation as described in section (Ammonium nitrogen).

Preparation of soil hydrolysate

Finely ground (<100 mesh) 50 gm soil was placed in a round-bottom flask. Added 2 drops of octyl alcohol and 20 ml of 6 M HCl, and swirled the flask until the acid is thoroughly mixed with the soil. The flask was kept on an electric heating mantle, fitted with liebig condenser. The soil-acid mixture then heated until it boils gently under reflux for 12 hours.

After completion of hydrolysis, washed the reflux condenser with a small quantity of distilled water, allowed the flask to cool, and removed the flask from the condenser. Filtered the hydrolysis mixture through a Buchner funnel fitted with whatman no. 50 filter paper, using a suction filtration apparatus that permits collection of the filtrate in a 200 ml tall beaker marked to indicate a volume of 60 ml. washed the residue with 5 to 10 ml portions of distilled water until the filtrate reached the 50 ml mark on the beaker. Immersed the lower half of the beaker in crushed ice, and neutralized to pH 6.5 ± 0.1 by cautious addition of NaOH, using a pH meter to follow the course of neutralization. Alternately, hydrolysate was cooled in a freezer, and use cold NaOH for neutralization. Then alkali was slowly added with constant stirring and ensured that the hydrolysate does not become alkaline at any stage of the neutralization process. 5 M NaOH was added to bring the pH to about 5, and completed the neutralization. Neutralized hydrolysate then transferred by means of a small funnel to a 100 ml volumetric flask, and diluted to volume with the washing obtained by rinsing the beaker.

In the methods employed to determine different forms of N, a 5 to 10 ml sample of the hydrolysate was pipette into 100 ml distillation flask, and after appropriate treatment of the sample, the flask was connected to the steam distillation apparatus. The form of N under analysis is determined from the NH_3 liberated by steam distillation for 4 min.

3.9.13.5 Nitrate nitrogen

After following the sample procedure as described in section (preparation of soil hydrolysate) 1 ml of sulfamic acid solution was added to the sample in the distillation flask and then the flask was swirled for a few seconds to destroy NO^{-}_2 in the sample. The NO^{-}_3-N was determined by titrating distillate with 0.005 N H_2SO_4 from a micro-burette. The colour change at the end point was from green to a permanent faint pink.

Nitrite nitrogen

Nitrite nitrogen was determined by subtracting nitrate nitrogen from the sum of nitrate and nitrite nitrogen.

3.9.13.6 Total hydrolysable nitrogen

In a 50 ml distillation flask, 5 ml of the neutralized hydrolysate was placed. 5 g of K_2SO_4 catalyst mixture was added and then 2 ml of concentrated H_2SO_4 was added. That flask was cautiously heated on a micro-kjeldahl digestion unit the water was completely removed and frothing ceases. Then heat was increased until the mixture clears, and digestion was completed by boiling gently for 1 hour.

After digestion, the flask was allowed to cool and 10 ml of water was added (slowly and with shaking). The flask was cooled under a cold water tap and it was placed in a beaker containing crushed ice. In a 50 ml Erlenmeyer flask, 5 ml of H_3BO_3 indicator solution was added that was marked to indicate a volume of 35 ml, and the flask was kept under the condenser of the steam distillation apparatus so that the tip of condenser was about 4 cm above the surface of the H_3BO_3 . Cooled distillation flask was connected to the distillation apparatus, 10 ml of 10 M NaOH was placed in the entry funnel, and alkali was slowly run into the distillation flask by raising the funnel plug.

Steam distillation was started by closing the stopcock and then distillation after 4 minutes was stopped when the distillate was reached the 35 ml marks on the receiver flask. Then the NH^{+}_4 –N in the distillate was determined by titrating it with 0.005 N H_2SO_4 from micro-burette. The colour change at the end point was from green to a faint permanent pink.

3.9.13. 7 Amino acid nitrogen

The neutralized hydrolysate of 5 ml was placed in a 50 ml distillation flask and then 1 ml of 0.5 N NaOH was added. The flask was heated in boiling water until the volume of the sample was reduced to 2 to 3 ml for 20 minutes. The flask was allowed to cool and then 500 mg of citric acid and 100 mg of ninhydrin was added in the flask. The flask was then kept in a vigorously boiling water bath, so that its bulb was completely immersed in boiling water. After 1 minute, the flask was swirled for a few seconds without removing it from the bath and it was allowed to remain in the bath for an additional 9 minutes. Then in the cooled flask, 10 ml of phosphate-borate buffer and 1 ml of 5 N NaOH were added and the flask was then connected to the steam distillation apparatus. After distillation, the NH^{+}_{3}-N liberated by steam distillation were determined by titrating it with 0.005 N H_2SO_4 from micro-burette. The colour change at the end point was from green to a permanent faint pink.

3.9.13.8 Ammonia nitrogen

In a 50 ml distillation flask, 10 ml of the neutral hydrolysate was placed. Then 0.7 g MgO was added in distillation flask and the flask was connected to the steam distillation apparatus. The amount of NH_3 liberated during steam distillation was collected in a 50 ml Erlenmeyer flask that was contain 5 ml of H_3B0_3 indicator solution and marked to indicate a volume of 20 ml. Distillation was stopped within 2 minutes when the distillate reaches to the 20 ml mark. The amount of ammonia liberated during distillation was determined by titrating distillate with 0.005 N H_2SO_4 from micro-burette.

3.9.13.9 (Ammonia + Amino sugar) nitrogen

Ten ml of neutral hydrolysate was placed in a 100 ml distillation flask and then 10 ml of phosphate-borate buffer was added in it. That flask was then connected to the distillation apparatus for distillation about 4 minutes. The amount of NH^{+}_{3}-N liberated during distillation was determined by titrating it with 0.005 N H_2SO_4 from micro-burette. The change in colour at end point was from green to permanent faint pink.

3.9.13.10 amino sugar nitrogen

This form of nitrogen was taken as the differences between the amount of nitrogen recovered during (Ammonia + Amino sugar) nitrogen and ammonia.

3.9.13.11 Acid insoluble nitrogen

Acid insoluble nitrogen was determined by subtracting total hydrolysable nitrogen from total nitrogen.

3.9.14 Fractionation of Phosphorus

3.9.14.1 Saloid Phosphorus

One g of 0.15 mm soil was placed in a 100c.c. polypropylene centrifuge tube, 50 c.c. of 1 M NH_4Cl solution was added, and shaken for 30minutes and centrifuged. Aliquot from the supernatant solution was then taken for spectroscopic measurements.

3.9.14.2 Aluminium bound Phosphorus

The residue left was shaken for an hour with 50 c.c. of 0.5 M NH_4F solution (pH- 8.2) and then centrifuged.

3.9.14.3 Iron bound phosphorus

Further, soil was shaken with 0.1 N NaOH for 17 hrs to extract Fe-P the P in the extract was determined by clorostannous reduced molybdophoric acid blue colour method in a hydrosulphuric acid system.

3.9.14.4 Reducant soluble phosphorus

The soil was suspended in 0.3 N sodium citrate solutions and shaken for 15 minutes with 0.5 g sodium dithionate. The reductant soluble P was estimated by clorostannous reduced molybdophoric acid blue colour method in a sulphuric acid system.

3.9.14.5 Occuluded phosphorus

The soil residue was washed twice with saturated NaCl solution. To the soil, 50 ml of 0.1 N NaOH solutions was added and shaken for 1 hour and centrifuged for 10 minutes at 2000 rpm. 3 ml aliquot was pipette out from the centrifuge tubes into the calorimeter tubes. The blue colour was developed and the absorbance was measured in the same manner as for Al-P was Fe-P.

3.9.14.6 Calcium phosphorus

The residue left was again washed twice with saturated NaCl. Ca-P was extracted by shaking the soil with 0.5 ml of 0.25 M H_2SO_4 for an hour.**3.9.14.7 Organic phosphorus**

This was determined by deducing the sum of all inorganic fraction of P from total phosphorus.

3.9.15 Determination of microbial population

For isolation of fungi, actinomycetes and bacteria from soil three different media were selected. The compositions of these media were given below:

A) Rose Bengal Agar Medium (For fungi)

Glucose	10.00g
Peptone	5.00g
KH_2PO_4	1.00g
$MgSO_4.7H_2O$	0.50g
Streptomycin	30.00mg
Rose Bengal	0.035g
Agar	15.00g
Distilled Water	1000ml

B) Yeast extract mannitol Agar (For bacteria)

Mannitol	10.00g
KH_2PO_4	0.50g
$MgSO_4.7H_2O$	0.20g
NaCl	0.10g
Yeast extract	1.00g
Agar	20.00g
Distilled Water	1000ml

C) Kenknight Medium (For actinomycetes)

Dextrose	1.00g
KH_2PO_4	0.10g
$NaNO_2$	0.10g
KCl	0.10g
$MgSO_4.7H_2O$	0.10g
Agar	10.00g

Distilled Water 1000ml

Preparation of medium

Agar agar shreds were boiled in 500 ml of distilled water in a pan. In another pan about 500 ml distilled water was taken and all chemical ingredients were added and mixed properly. Both these ingredients were mixed together properly, filtered through muslin cloth and made volume to 1000 ml with distilled water. The respective media were distributed in 500 ml conical flasks and plugged with non-absorbent cotton. These plugs were tied with paper by thread and sterilized at 6.82 kg (15 lb) pressure for 15 minutes in an autoclave

Method of inocubation

Dilution plate technique is one of the most popular methods for isolation and enumeration of soil born fungi, antinomycetes and bacteria as described by Dhingra and Sinclair (1993).

1. Transfer 1g of soil sample in 10 ml sterile distilled water in test tube(1:10) and shake properly.
2. Transfer 1 ml of suspension from this tube to another tube containing 9 ml of sterile distilled water (1:100). Again transfer 1 ml of suspension from this tube to another containing 9 ml of sterile distilled water (1:1000).
3. Similarly the dilution process is continued as per requirement.
4. The concerned dilution sample was poured at the rate of 1 ml plate-1.
5. Respective melted medium (Cool at 45 C) was poured at the rate of 20 ml plate-1. Spread the medium by an inclined rotary motion of plate.
6. After solidification of medium, these plates were incubated at 30 $\pm$2 C in an inverted position in an incubator.

3.9.16 Soil microbial biomass carbon (SMBC)

Soil microbial biomass carbon was determined by chloroform fumigation method as described by Vance *et al.* (1987

3.9.17 Soil microbial biomass nitrogen (SMBN)

Soil microbial biomass nitrogen was estimated as par the protocol given by Brooks *et al.* (1985)

3.9.18 Carbon Dioxide Evolution: Alkali Trap Method

CO_2 evolution was determined by alkali trap method as described by Anderson (1982).

3.9.19 Grain yield

The crop was harvested from each net plot and carefully recorded the grain yield and calculated by multiplying net plot size and converted on hectare basis as q ha^{-1}.

3.9.20 Soil organic carbon pool (Mg ha^{-1})

Soil organic pools were calculated a per the following equation:

SOC pool (Mg ha^{-1}) = SOC concentration (%) x Soil depth (m) x bulk density (Mg m^{-3}) x 104 m^2 ha^{-1} x 10^{-2}

Statistical analysis

The results obtained were statistically analyzed and appropriately interpreted as per the methods described in "Statistical Methods for Agricultural Workers" by Panse and Sukhatme, (1985). Appropriate standard error (S.E.) and critical differences (C.D.) at 5% level were worked out as and when necessary.

RESULTS AND DISCUSSION

CHAPTER – IV

RESULTS AND DISSCUSSION

In order to assess "Effect of long term fertilization on carbon sequestration and soil quality under Sorghum wheat cropping system" The experiment were conducted on deep black soils of (Typic haplustert) survey No 124 of Parbhani block of central farm, Vasantrao Naik Marathwada Agricultural University, Parbhani since 1983. The results emerging out of the experimentation were statistically analyzed, organized, appropriately tabulated, interpreted and discussed under the following sub-heads.

4.1 Effect of long term fertilization on organic, inorganic and total carbon behavior of soil.

1. Organic carbon
2. Inorganic carbon
3. Total carbon
4. Soil organic carbon pools

4.2 Effect of long term fertilization on important soil quality parameters

1. Bulk density
2. Porosity
3. Water holding capacity
4. Aggregate stability
5. pH
6. Electrical conductivity
7. Calcium carbonate
8. Available Nitrogen
9. Available phosphorus
10. Available potassium

4.3 Effect of long term fertilization on vertical movement of available nutrients

1. Available N
2. Available P
3. Total N
4. Total P

4.4 Effect of long term fertilization on nitrogen fraction of soil

1. Ammonium nitrogen
2. Nitrate nitrogen
3. Nitrite nitrogen
4. Total hydrolysable nitrogen
5. Amino acid nitrogen
6. Organic ammonium nitrogen
7. Amino sugar nitrogen
8. Acid insoluble nitrogen
9. Total nitrogen

4.5 Effect of long term fertilization on phosphorus fractions of soil

1. Saloid phosphorus
2. Aluminum phosphorus
3. Iron phosphorus
4. Reductant soluble phosphorus
5. Occluded phosphorus
6. Calcium phosphorus
7. Organic phosphorus
8. Total phosphorus

4.6 Effect of long term fertilization on biological parameters

1. Bacterial count
2. Fungi count
3. Actinomycetes count
4. Microbial biomass carbon
5. Microbial biomass nitrogen
6. Microbial decomposition rate

4.7 Effect of long term fertilization on grain and fooder/straw yield of Sorghum and wheat crop

4.1 Effect of long term fertilization on organic, inorganic and total carbon behavior of soil.

4.1.1. Organic carbon

The data recorded on organic carbon on long term fertilizations experiment of sorghum – wheat cropping system shown in Table 1. Organic carbon at depth 0-30 cm varied from 6.5 to 9.6 g kg^{-1}, 30-60 cm varied from 4.6-7.3 g kg^{-1}, 60-90 cm varied 3.3-3.9 g kg^{-1} and more than 90 cm 3.0-3.7 g kg^{-1}. From data it was revealed that organic carbon was significantly affected by various treatments. The lowest organic carbon was recorded in T_1, treatment i.e. control. While the highest organic carbon was recorded in treatment receiving combination of organic and inorganic sources of fertilizers.

There was an increase in organic carbon content over the 30 years of continuous sorghum-wheat cropping sequence. The increase was to the magnitude of 44.4 % (control) to 213 % (T_6). From the data it was also observed that organic carbon decreased with depth and results were matched with the finding of Kumar *et al.* (1998). The higher concentration of organic carbon in the fertilizer + organic manure treated plots was a result of increased root and plant residues coupled with application of organic (FYM, GM, WS) manures. (Singh and Sharma, 2010). Further, Vyas and Khandwe (2012) found that application of FYM@ 5 t ha^{-1} alone and SR 5 t ha^{-1} + FYM@ 5 t ha^{-1} + Zn 5 kg ha^{-1} improved organic carbon content in soil over control under soybean-wheat cropping sequence in Vertisol. Recently, Babar and Dongale (2013) reported that organic carbon content in soil showed significant improvement with the application of organic, inorganic and organic + inorganic sources of nutrients.

4.1.2. Inorganic carbon

The data on effect of long term fertilization on inorganic carbon (g kg^{-1}) of soil under sorghum – wheat cropping sequence presented in table 2. From that table it was revealed that inorganic carbon was significantly affected due to integrated nutrient management practices. The inorganic carbon content found to be decreased with depth. It was ranged from 6.7 – 7.3, 7.0 – 7.6, 7.9 – 8.0 and 7.9 – 8.4 g kg^{-1} at depth 0 to 30, 30 to 60, 60 to 90 and >90 cm depth respectively

Table 1: Effect of long term fertilization on Organic Carbon (g kg^{-1}) of soil under sorghum wheat cropping system

Tr. No.	Treatment Detail		Organic Carbon (g kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	6.5	4.6	3.3	3.0
T_2	50% NPK (F)	50% NPK (F)	6.7	4.8	3.7	3.2
T_3	50 % NPK (F)	100 % NPK (F)	7.2	5.3	3.6	2.7
T_4	75 % NPK (F)	100 % NPK (F)	6.9	5.0	3.7	3.3
T_5	100 % NPK (F)	100 % NPK (F)	7.4	5.5	3.2	3.2
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	9.6	7.3	3.6	3.5
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	7.8	6.0	3.8	3.4
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	9.3	6.9	3.4	3.0
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	8.0	5.9	3.6	3.6
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	8.8	6.5	3.3	3.1
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	7.9	5.8	3.5	3.4
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	7.0	5.2	3.7	3.7
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	7.6	5.6	3.3	3.0
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	8.6	5.9	3.1	2.9
Initial value			4.5	_	_	_
S.E.±			0.05	0.04	0.04	0.03
C.D. at 5 %			0.16	0.13	0.13	0.09
Grand mean			0.78	0.57	0.54	0.51

Table 2: Effect of long term fertilization on inorganic carbon (g kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Inorganic Carbon (g kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	7.0	7.5	8.1	8.1
T_2	50% NPK (F)	50% NPK (F)	7.0	7.3	8.0	8.3
T_3	50 % NPK (F)	100 % NPK (F)	7.1	7.5	8.1	8.2
T_4	75 % NPK (F)	100 % NPK (F)	7.3	7.6	8.1	8.4
T_5	100 % NPK (F)	100 % NPK (F)	7.0	7.5	8.2	7.9
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	7.1	7.5	8.0	8.2
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	7.0	7.4	8.0	8.2
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	6.9	7.5	8.0	8.1
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	7.0	7.0	8.0	8.1
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	6.9	7.5	8.0	8.2
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	7.0	7.3	7.9	8.3
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	6.9	7.5	8.1	8.2
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	6.7	7.4	8.0	8.3
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	6.8	7.5	7.9	8.2
S.E.±			0.011	0.007	0.011	0.007
C.D. at 5 %			0.033	0.021	0.033	0.021
Grand mean			0.747	0.802	0.747	0.802

It was inferred that inorganic carbon content was maximum in plot where treatments containing only inorganic sources of fertilizers. This maximum content might be calcareous nature of soil developed from basaltic alluvium which content ferro-magnesium minerals like calcite, dolomite that are rich in calcium as magnesium carbonates. (Patil *et al,* 1993) also reported that the calcareous nature of vertisols of marathwada are linked with extrusive basaltic rock parent material which is rich in ferromagnesium minerals.

4.1.3. Total carbon

Effect of long term fertilization on total carbon (g kg^{-1}) of soil under sorghum – wheat cropping system presented in table 3. From that table it was revealed that total carbon was significantly affected due to various treatments. Total carbon varied from 13.5 to 16.2, 12.1 to 14.8, 11.4 to 11.8 and 11.1 to 11.9 at 0 to 30, 30 to 60, 60 to 90 and >90 cm depth respectively.

The treatment T_6 to T_8 showed high total carbon content as against T_1 to T_5. The conjoint use of chemical fertilizers with FYM found beneficial for maintaining high total carbon contents compared to the use of only chemical fertilizers.

The increase in total carbon content under integrated use of chemical fertilizers and organic manure treatments might be due to direct incorporation of organic matter, better root growth and more plant residues addition. The subsequent decomposition of these materials might have resulted into enhanced total carbon content in soil (Srikanth *et al.* 2000 and Akbari *et al.* 2011). Further, Arbad and Syed Ismail (2011) in long term fertilizer experiment found the highest total carbon in chemical fertilizers incorporated with FYM or FYM alone applied plots in Vertisol. Moreover, Katkar *et al.* (2011) under long term fertilizer experiment observed significantly more total carbon in soil with the application of 100% NPK + FYM@ 10 t ha^{-1} over control in Vertisol.

4.1.4. Soil organic carbon pools

The data presented in table 4 depicted the effect of long term fertilization on soil organic carbon pool compared to the time of start of the experiment indicated improvement in SOC over control. The application of inorganic NPK increased SOCP content over control although both these treatments did not

Table 3: Effect of long term fertilization on total carbon (g kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Total Carbon (g kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	13.5	12.1	11.4	11.1
T_2	50% NPK (F)	50% NPK (F)	13.7	12.1	11.7	11.5
T_3	50 % NPK (F)	100 % NPK (F)	14.3	12.8	11.7	10.9
T_4	75 % NPK (F)	100 % NPK (F)	14.2	12.6	11.8	11.7
T_5	100 % NPK (F)	100 % NPK (F)	14.4	13	11.4	11.1
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	16.7	14.8	11.6	11.7
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	14.8	13.4	11.8	11.6
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	16.2	14.4	11.4	11.1
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	15	12.9	11.6	11.7
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	15.7	14	11.3	11.3
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	14.9	13.1	11.4	11.7
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	13.9	12.7	11.8	11.9
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	14.3	13	11.3	11.3
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	15.4	13.4	11	11.1
S.E.±			0.061	0.047	0.051	0.037
C.D. at 5 %			0.193	0.151	0.163	0.111
Grand mean			1.527	1.372	1.287	1.312

Table 4: Effect of long term fertilization on soil organic carbon pool (Mg ha^{-1}) of soil under sorghum-wheat cropping system

Treatment	Soil organic carbon (%)	Bulk Density (Mg m^{-3})	Depth (m)	SOCP (Mg ha^{-1})
Control	0.67	1.44	0.30	0.301
Inorganic	0.70	1.39	0.30	0.303
INM	0.84	1.33	0.30	0.348

differ significantly in SOCP. SOCP content in 0-30 cm depth in control plot was 0.301 Mg ha^{-1} , in only inorganic treatment plot was 0.303 Mg ha^{-1} while in INM treatment plot was 0.348 Mg ha^{-1}.

Addition of FYM along with NPK resulted significant increase in carbon pool over control. This might be attributed to greater amount of organic input with higher lignin content (FYM) resulting in a greater accumulation per unit of C input (Stevenson, 1965; Paustian *et al.,* 1992). According to Su *et al.* (2006), integrated use of FYM and fertilizes either maintained or improved SOC.

4.2. Effect of long term fertilization on important soil quality parameters

4.2.1 Bulk density

The data presented in Table 5 showed the vertical distribution of bulk density through soil profile (g cm^{-3}) due to integrated nutrient management under sorghum wheat cropping sequence. It was recorded that integrated nutrient management showed significant impact on bulk density at various soil depth of soil. Bulk density varied from 1.30 – 1.62 g cm^{-3} at different soil layer and it was increased with depth. Further seruting of data revealed that application of 50 % N through FYM, WS, GM with glyricidia and subabul leaves showed lower bulk density than the treatments comprising of 25 % N through there organic manures. Application of NPK through only inorganic fertilizers further increased the bulk density. However in general threr was decrease in BD of soil in all treatments over the 30 years of fertilization expect control treatment.

The decrease in soil BD with organic matter additions is well documented (Sharma *et al.,* 1995) and mainly attributed to higher organic matter content of the soil which results into better aggregation of soil separates and a consequent increase in volume of micro pores in the manure treated plots. Bellakki *et* *al.* (1998) concluded that the addition of different organics *viz.,* cow dung slurry, paddy straw and *Glyricidia* in combination with inorganic fertilizers decreased significantly the bulk density and increased the porosity of soil over control.

4.2.2 Porosity

The data on vertical distribution of porosity was presented in table 6. The vertical distribution on porosity (%) of soil did not differ significantly due to different nutrient management practices. At depth 0-30 it was from 54.32-55.36 % and goes on decreasing with depth of soil. At depth more than 90 cm it was lowest *i.e.* from 44.21 -48.27%.

During this investigation it was observed that porosity decreased with depth and might be due to low pore space at deeper layer of soil. The improvement in porosity of soil was due to addition of organic manure in improving the soil structure and thereby providing better porosity. Porosity plays an important role in retaining water in pure space and aeration. It also responsible for better root development. Similar results were also reported by Lomte *et al.* (1993), Patil (1997) & Dhonde and Bhakare (2008).

4.2.3. Water Holding Capacity

Water holding capacity of soil is mainly governed by soil texture. However, it get influenced by presence of organic manure. The data presented in Table 5 showed the vertical distribution of water holding capacity through soil profile (%) due to integrated nutrient management under sorghum wheat cropping sequence. In the present study various treatments found to have significant impact on water holding capacity of soil. It was ranged between 37.30 – 60.22 % at different soil layer. In 0 to 30, 30 to 60, 60 to 90 and > 90 cm depth it was ranged between 46.47 – 60.22, 42.73 – 59.11, 40.98 – 56.67 and 37.30 – 49.12 % respectively. It was decreased with depth of soil

Amongst all treatments, treatment T6 recorded maximum WHC (60.22 %) followed by T8 (59.40 %), T10 (58.58 %). This shows that addition of more organic manures reflects in to increased WHC. Lowest WHC was recorded in the treatment control and FP. However, there was increase in WHC in all treatment over initial water holding capacity of soil.

Table 5: Effect of long term fertilization on bulk density (g cm^{-3}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Bulk Density (g cm^{-3})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	1.51	1.53	1.55	1.60
T_2	50% NPK (F)	50% NPK (F)	1.39	1.50	1.53	1.56
1T_3	50 % NPK (F)	100 % NPK (F)	1.35	1.49	1.57	1.62
T_4	75 % NPK (F)	100 % NPK (F)	1.34	1.47	1.50	1.58
T_5	100 % NPK (F)	100 % NPK (F)	1.40	1.54	1.57	1.61
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	1.33	1.53	1.56	1.60
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	1.36	1.50	1.53	1.55
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	1.33	1.52	1.54	1.56
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	1.38	1.49	1.52	1.57
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	1.30	1.51	1.55	1.59
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	1.32	1.50	1.59	1.62
T_{12}	FP (40:20:20 NPK & ·seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	1.37	1.49	1.60	1.64
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	1.32	1.48	1.54	1.58
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	1.34	1.56	1.59	1.63
Initial value			1.49	-	-	-
S.E.±			0.028	0.024	0.028	0.030
C.D. at 5 %			0.082	0.071	0.082	0.087
Grand mean C.D. at 5 %			1.465	1.507	1.5528	1.5921

Table 6: Effect of long term fertilization on vertical distribution of Porosity (%) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Porosity (%)			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	54.32	50.60	47.35	44.21
T_2	50% NPK (F)	50% NPK (F)	54.51	51.50	48.44	44.50
T_3	50 % NPK (F)	100 % NPK (F)	54.67	52.21	49.39	45.67
T_4	75 % NPK (F)	100 % NPK (F)	54.78	52.38	49.68	46.39
T_5	100 % NPK (F)	100 % NPK (F)	54.89	52.80	49.92	46.46
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	55.47	53.16	51.83	47.27
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	55.44	54.96	51.62	48.85
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	55.43	54.04	51.53	47.80
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	55.30	53.94	51.34	47.76
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	55.25	53.73	51.57	47.57
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	55.24	53.53	50.93	47.35
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	55.08	51.74	48.75	45.24
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	55.32	53.96	51.69	47.58
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	55.37	53.88	51.53	47.98
Initial value			50.23	–		–
S.E.±			0.013	0.090	0.06	0.14
C.D. at 5 %			0.039	0.262	0.17	0.41
Grand mean			55.02	52.92	55.07	53.03

Tiarks *et al.,* (1974) also observed that due to conjoint use of inorganic and organic fertilizers leads to better aggregation of soil separates and thereby improves the water holding capacity. Decrease in WHC at lower depth was attributed to compaction of lower layers by over bearing weight of above layer and decrease porosity.

4.2.4 Aggregate stability

Effect of long term fertilization on aggregate stability (%) of soil under sorghum-Wheat cropping system was depicted in table 8. It was noticed that the aggregation of soil was affected significantly by nutrient management treatments. There was decreasing trends of aggregate stability with increasing depth which varied from at 0-30 cm, 30-60cm, 60-90 cm and more than 90 cm, depth from 45.71 – 61.21 %, 32.73 – 60.71 %, 44.73 – 60.83 %, and 44.25 – 60.51 % respectively.

The integrated nutrient management treatments by substituting 75 or 25 per cent N fertilization with FYM, wheat straw or glyricidia significantly improved aggregation property. The improvement in aggregate stability of soil was due to the addition of organic components which on decomposition released different organic acids that might have acted on a cementing materials as binded the soil seperates into aggregate. These results are in agreement of Bangar (1991)

4.2.5 pH

The data recorded (Table 9) on pH of soil under long term fertilization experiment of sorghum wheat cropping system reveled an increasing trends of soil pH with continuous fertilization and increasing depth. (87-8.13, 7.90-8.20, 7.93-8.30 and 8.03-8.30 at depth 0.30cm,30-60cm, 60-90cm and more than 90cm respectively.)

Soil pH of sub-surface layer was found to have higher pH value than surface layer in all treatments. Highest pH was recorded in T_1 (control) treatment. While lowest pH value recorded where there was use of both integrated source of organic and inorganic source of fertilizers.

Even though the results were non significant but the application of organic manure or inorganic fertilizers in combination registered the change in pH to a greater extent. In general, the inorganic fertilizer treatments (T_2 to T_5) had relatively higher pH values than the treatment receiving organic + inorganic.

Table 7: Effect of long term fertilization on vertical distribution on WHC (%) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		WHC (%)			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	46.47	42.73	40.98	37.30
T_2	50% NPK (F)	50% NPK (F)	48.77	47.48	45.53	40.49
T_3	50 % NPK (F)	100 % NPK (F)	51.01	49.06	46.49	45.07
T_4	75 % NPK (F)	100 % NPK (F)	52.68	50.72	46.68	44.12
T_5	100 % NPK (F)	100 % NPK (F)	54.19	52.66	50.69	47.80
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	60.22	59.11	56.67	52.48
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	58.89	57.47	54.29	49.12
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	59.40	57.82	54.34	50.55
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	58.06	56.66	53.48	51.56
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	58.58	57.76	55.53	50.62
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	57.49	55.44	52.20	49.01
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	46.65	47.36	44.63	38.97
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	56.94	55.57	51.60	46.36
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	55.32	52.98	50.80	45.06
Initial value			45.29	-	-	-
S.E.±			0.861	0.304	0.521	1.338
C.D. at 5 %			2.504	0.884	1.516	3.889
Grand mean			54.61	53.06	50.27	46.32

Table 8: Effect of long term fertilization on vertical distribution on Aggregate stability (%) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Aggregate Stability (%)			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	45.71	44.15	44.73	44.25
T_2	50% NPK (F)	50% NPK (F)	46.58	32.73	45.56	45.30
T_3	50 % NPK (F)	100 % NPK (F)	50.34	50.05	49.60	49.65
T_4	75 % NPK (F)	100 % NPK (F)	53.27	52.43	52.52	51.57
T_5	100 % NPK (F)	100 % NPK (F)	53.49	53.40	53.12	53.12
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	61.21	60.71	60.83	60.51
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	60.42	60.47	60.09	60.17
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	60.38	60.50	59.40	59.42
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	59.32	59.66	58.79	58.58
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	58.48	58.35	58.98	58.40
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	57.77	56.42	5660	56.29
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	48.53	48.40	48.15	47.47
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	55.77	55.57	55.54	55.62
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	54.51	54.29	54.46	54.41
Initial value			44.20	-	-	-
S.E.±			0.555	3.759	0.516	0.608
C.D. at 5 %			1.613	10.928	1.501	1.768
Grand mean			54.69	53.36	54.17	53.91

Leaching of bases under high rainfall condition might be the primary reason for increase in soil pH with depth of soil and increase in soil pH in deeper layer indicates accumulation of bases. Relatively lower pH values in INM treatments might be due to the fact that the FYM acts as a buffering agent in soil. Similar results were also reported by Jatav *et. al.* (2010).

4.2.6. Electrical conductivity

Electrical conductivity has generally been associated with determining soil salinity. However EC also can serve as a measure of soluble nutrients for both cations and anions and it useful in monitoring the mineralization of organic matter in soil (De Neve *et al.* 2000).

Effect of long term fertilization on EC (dSm^{-1}) of soil under sorghum wheat cropping system was depicted in table 6. EC of 0-30 cm, 30-60 cm, 60-90 cm, and more than 90 cm depth varied from 0.25-0.29 dSm^{-1}, 0.25-0.27 dSm^{-1}, 024-0.27 dSm^{-1} and 0.24-0.26 dSm^{-1} respectively. It was varied with depth and its range of variation is less in treatment receiving both the combination of inorganic and organic sources of fertilizers

4.2.7. Calcium carbonate

The data presented in Table 11 showed the vertical distribution of $CaCO_3$ ($g\ kg^{-1}$) due to nutrient management treatments over 30 crop cycles. From that data it was revealed that integrated nutrient management showed significant impact on $CaCO_3$ ($g\ kg^{-1}$) at various depth of soil. $CaCO_3$ varied from 59.07-67.19 $g\ kg^{-1}$at different soil layer. In 0-30 cm, it varied from 59.07-61.35 $g\ kg^{-1}$, in 30-60 cm it varied from 60.52-62.86 $g\ kg^{-1}$, in 60-90 cm it varied from 61.85-65.19 and in more than 90 cm, it varied from 63.85-67.19 g kg¯1. $CaCO_3$ content also showed increased with depth of soil.

This increase in lime content at deeper layer may be attributed to the movement of $CaCO_3$ content from surface to subsurface. The addition of organic matter further intensified the dissolution lime which was translocated to subsurface horizon.

As observation in present investigation, many researchers were also observed that long-term manuring, fertilization and cropping reduced $CaCO_3$ content of the soil (Magdoff and Amadon, 1980; Bellakai and Badanur, 1997). The results obtained in the present study were also in accordance with them.

Table 9: Effect of long term fertilization on pH of soil under sorghum-wheat cropping system.

Tr. No.	Treatment Detail		pH			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	8.10	8.20	8.30	8.30
T_2	50% NPK (F)	50% NPK (F)	8.07	8.17	8.13	8.17
T_3	50 % NPK (F)	100 % NPK (F)	8.03	8.13	8.13	8.17
T_4	75 % NPK (F)	100 % NPK (F)	8.00	8.13	8.10	8.23
T_5	100 % NPK (F)	100 % NPK (F)	7.90	8.07	8.07	8.17
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	7.93	7.93	7.97	8.13
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	7.90	7.93	7.93	8.13
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	7.90	7.93	7.97	8.07
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	7.87	7.93	8.07	8.10
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	7.90	7.90	7.97	8.03
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	7.87	7.97	8.07	8.07
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	8.13	8.20	8.20	8.20
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	8.03	8.03	8.17	8.17
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	7.90	8.07	8.07	8.07
Initial value			7.80	-	-	-
S.E.±			0.07	0.08	0.09	0.08
C.D. at 5 %			NS	NS	NS	NS
Grand mean			7.96	8.04	8.00	8.14

Table 10: Effect of long term fertilization on EC (dS m^{-1})of soil under sorghum-wheat cropping system.

Tr. No.	Treatment Detail		EC (dS m^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	0.26	0.266	0.261	0.257
T_2	50% NPK (F)	50% NPK (F)	0.27	0.266	0.261	0.255
T_3	50 % NPK (F)	100 % NPK (F)	0.27	0.277	0.273	0.269
T_4	75 % NPK (F)	100 % NPK (F)	0.28	0.271	0.270	0.267
T_5	100 % NPK (F)	100 % NPK (F)	0.29	0.269	0.265	0.257
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	0.29	0.263	0.260	0.253
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	0.28	0.278	0.271	0.269
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	0.29	0.261	0.261	0.255
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	0.27	0.274	0.274	0.267
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	0.27	0.271	0.264	0.259
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	0.27	0.273	0.267	0.267
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	0.27	0.265	0.265	0.259
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	0.27	0.273	0.266	0.265
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	0.25	0.254	0.247	0.247
Initial value			0.30	-	-	-
S.E.±			0.01	0.01	0.01	0.01
C.D. at 5 %			NS	NS	NS	NS
Grand mean			0.27	0.26	0.26	0.26

Table 11: Effect of long term fertilization on $CaCO_3$ (g kg^{-1}) of soil under sorghum wheat cropping system

Tr. No.	Treatment Detail		$CaCO_3$(g kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	61.35	62.35	63.35	64.35
T_2	50% NPK (F)	50% NPK (F)	61.20	61.86	63.53	64.86
T_3	50 % NPK (F)	100 % NPK (F)	60.72	62.05	63.05	64.39
T_4	75 % NPK (F)	100 % NPK (F)	60.24	61.24	63.57	64.57
T_5	100 % NPK (F)	100 % NPK (F)	59.73	61.07	64.07	65.40
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	59.90	62.56	63.90	65.56
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	59.52	61.85	63.85	65.52
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	59.39	61.39	63.39	65.06
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	59.18	61.51	63.18	64.51
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	59.37	61.70	63.37	65.04
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	59.07	60.95	63.62	64.95
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	60.86	62.86	65.19	67.19
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	60.39	61.06	62.72	64.39
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	59.52	60.52	61.85	63.85
Initial value			77.9	_	-	_
S.E.±			0.81	1.08	1.33	1.23
C.D. at 5 %			NS	NS	NS	NS
Grand mean			60.03	61.64	61.47	64.97

4.2.8. Available nitrogen (kg ha^{-1})

The data presented in Table 12 showed the vertical distribution of available N (kg ha^{-1}) from surface to 90 cm depth due to integrated nutrient management under sorghum wheat cropping sequences. It was recorded that integrated nutrient management had significant impact on available N at various depth of soil. Available N varied from 40.20 – 278.25 kg ha^{-1}at different soil layer.

Available N content shows decreases with depth of soil. Maximum content or available N was recorded in T_6 treatment *i.e,* 50 % NPK + 50 % N through FYM and 100 % NPK through inorganic fertilizer followed by T_{10} and T_8 during rabi season. The increase in the available N content was highest in the surface soil layer. The higher content of available N on surface layers was attributed to higher available N in lower soil depths than control might be ascribed to leaching of available N to lower soil depth and release of N from root decay. Because of continuous rainfall in monsoon season in this region, there was possibility of enhanced decomposition,. release and leaching of available N to lower layers with rainfall water. Contractor and Badanur (1996) observed that availability of N was higher on surface layers than subsurface horizons and it decreased gradually with depth.

4.2.9. Available P_2O_5 (kg ha^{-1})

Effect of long term fertilization on vertical distribution of available P_2O_5 (kg ha^{-1}) was presented in Table 13. The available phosphate was significantly varied among the treatment and soil depth. The content varied from 8.12 to 26.32 kg ha^{-1} among various soil depths. Available P_2O_5 content was decreased with soil depth.

Maximum amount of available P_2O_5 was recorded in T_6 *i.e.,* 50 % NPK through inorganic fertilizers + 50 % N through FYM during kharif season and 100 % NPK through inorganic fertilizers during rabi season. While lowest amount of available P_2O_5 was recorded at T_1 *i,e.,* control during both the seasons. The available P_2O_5 content was higher in surface soil as compared to sub surface horizons.

Higher content of available P_2O_5 in soil might be due to the organic acids released through decomposition of litterfall reduce metals one through chelation in soil and they compete for exchange sites, thus releasing P_2O_5 from soil. Mathew *et al.* (1997) observed that availability of P_2O_5 was higher on surface layers than subsurface horizons and it decreased gradually with depth.

Table 12: Effect of long term fertilization on vertical distribution of available nitrogen (kg ha^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Available Nitrogen (kg ha^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	123.32	98.12	70.12	40.20
T_2	50% NPK (F)	50% NPK (F)	126.28	103.29	72.14	43.38
T_3	50 % NPK (F)	100 % NPK (F)	136.18	114.12	74.28	47.29
T_4	75 % NPK (F)	100 % NPK (F)	130.39	107.43	73.22	45.22
T_5	100 % NPK (F)	100 % NPK (F)	226.74	163.45	80.34	56.34
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	278.25	220.37	91.11	60.51
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	219.10	157.16	81.25	59.73
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	145.39	131.34	76.42	53.19
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	141.03	123.22	75.34	53.37
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	239.39	192.23	83.07	58.09
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	183.21	149.30	78.16	53.19
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	130.73	137.40	78.04	54.18
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	239.16	192.20	83.42	61.39
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	252.09	208.48	85.88	58.28
Initial value			110.88	_	_	_
S.E.±			14.74	12.34	3.64	3.75
C.D. at 5 %			42.81	35.84	10.56	10.89
Grand mean			183.66	149.86	78.77	53.30

Table 13 : Effect of long term fertilization on vertical distribution on available P_2O_5 (kg ha^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Available P_2O_5 (kg ha^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	8.69	7.69	7.02	6.69
T_2	50% NPK (F)	50% NPK (F)	10.82	9.15	8.49	8.15
T_3	50 % NPK (F)	100 % NPK (F)	13.80	11.80	10.96	10.63
T_4	75 % NPK (F)	100 % NPK (F)	13.96	12.85	12.18	11.52
T_5	100 % NPK (F)	100 % NPK (F)	16.71	15.71	14.38	13.71
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	27.65	26.99	25.99	25.65
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	25.68	24.34	23.68	23.01
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	24.92	23.59	22.92	22.59
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	22.10	21.43	20.77	20.10
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	22.86	21.86	20.86	20.86
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	18.97	17.97	16.76	16.09
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	10.35	10.02	9.69	8.35
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	17.64	16.98	15.64	14.64
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	18.50	17.84	16.84	16.17
Initial value			8.59	-	-	-
S.E.±			1.73	1.62	1.59	1.65
C.D. at 5 %			5.03	4.72	4.64	4.80
Grand mean			18.05	17.01	16.15	15.58

4.2.10. Available K_2O (kg ha^{-1})

The data presented in Table 14 showed effect of long term fertilization on vertical distribution of available K_2O (kg ha^{-1}) under sorghum wheat cropping sequence. From the data, it was cleared that available K_2O was significantly affected by various treatment of integrated nutrient management. Available K_2O content varied from 404.68 -500.87 kg ha^{-1} at various depth of soil layer. It was also recorded that available K_2O decreased with depth of soil.

Higher content of available K_2O was recorded T_6 treatment *i.e,* 50 % NPK through inorganic fertilizer + 50 % N through FYM to sorghum and 100 % NPK through inorganic fertilizer to wheat while lowest available K_2O recorded at T_1 treatment *i.e,* control. Higher availability of K_2O at surface layers was attributed to solubilization of insoluble forms of K_2O in soil due to organic decomposition products and re;ease of non exchangeable K from exchange sites.

Kumar *et al.* (1998) also found similar results. These INM treatments had a significant residual effect on available K_2O available after the harvest of crop. This was attributed to the conjoint application of organic manures and inorganic fertilizers to sorghum wheat cropping sequence. The results are in conformity to those obtained by Das *et al.* (2003) under cotton wheat Chavan *et al.* (2007) under sorghum wheat cropping sequence.

4.3. Effect of long term fertilization on vertical movement of available nutrients

4.3.1 Available nitrogen (kg ha^{-1})

Effect of long term manuring fertilization on status of available nitrogen from surface horizon to subsurface horizons are presented in table 1 under the group of treatments. From these available nitrogen status values, movement of nitrogen from surface to surface was calculated for each horizon and presented in figure 1.

During study, highest available nitrogen found to be added by treatment INM_3 (278.25 kg ha^{-1}) treated with 50% NPK + 50 % N through FYM in all soil depth respectively, whereas lowest available nitrogen was added by absolute control (40.20 kg ha^{-1}) in all soil depth over the 30 years.

Table 14 : Effect of long term fertilization on vertical distribution on available K_2O (kg ha^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Available K_2O (kg ha^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	405.19	405.28	404.92	404.68
T_2	50% NPK (F)	50% NPK (F)	419.82	419.74	419.56	419.32
T_3	50 % NPK (F)	100 % NPK (F)	436.47	442.38	442.22	441.99
T_4	75 % NPK (F)	100 % NPK (F)	450.14	450.05	449.88	449.61
T_5	100 % NPK (F)	100 % NPK (F)	458.63	458.55	458.36	458.13
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	500.87	500.81	496.98	490.32
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	495.18	495.09	494.88	494.59
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	484.19	484.09	486.65	489.23
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	466.40	466.32	483.55	483.67
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	483.37	479.93	486.65	479.89
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	475.48	475.40	475.22	474.96
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	430.18	430.10	429.94	429.69
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	486.40	462.79	462.79	456.25
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	463.93	463.84	463.56	463.40
Initial value			405.20	-	-	-
S.E.±			8.16	3.51	3.51	63.093
C.D. at 5 %			3.742	10.20	10.20	NS
Grand mean			461.15	461.04	461.04	461.77

The cumulative effect of inorganic fertilization INM_1 (*i.e.* 50% NPK through fertilizer and 50% N through organic manures like FYM, WS, GM and Subabul leaves) added more nitrogen which was to the time of 551.36 kg ha^{-1}. Depth wise addition was 225.52, 184.03, 83.50 and 58.20 kg available N ha^{-1} followed by treatment INM_2 (75% NPK through fertilizer and 25% N through organic manures).

Figure 1 shows that depth wise increase in available N due to various five treatments over control treatment. As reported in above paragraph INM_3 found better (0-30 cm depth) followed by available N over the 30 years of fertilization. Similar trend was also noticed with lower depths.

The various treatments showed impact on treatment of added nitrogen from surface to lower depths. In farmers practice it was lowest (7.41 to 5.98 kg N ha^{-1}) and highest in INM_3 (12.31 to 154.03 kg N ha^{-1}) followed by INM_2 and INM_3 treatments.

Table 15: Effect of long term fertilization on vertical movement of available nitrogen (kg ha^{-1}) of soil under sorghum-wheat cropping system

Treatment	0-30 cm	30-60 cm	60-90 cm	>90 cm	Total
Control	123.32	98.12	70.12	40.20	331.76
Inorganic	154.89	122.07	78.99	48.05	400.00
INM_1	198.5	159.54	80.15	56.62	495.16
INM_2	225.54	184.03	83.50	58.29	551.36
FP	130.73	117.40	78.04	54.18	380.35
Initial value	110.88	-	-	-	-
INM_3	278.25	220.37	91.11	60.51	650.24
SE$\pm$	14.74	12.34	3.64	3.75	-
CD @ 5%	42.81	35.84	10.56	10.89	-

4.3.2 Available P_2O_5 (kg ha^{-1})

The data pertaining to soil available P_2O_5 status influenced by different nutrient management practices is presented in Table 16 and depicted in figure 2.

Highest amount of available P_2O_5 content was recorded in treatment INM_3 (27.65 kg ha^{-1}) at 0-30 cm depth of soil while lowest was recorded at control (6.69 kg ha^{-1}) at >90 cm depth. It was clear that application of 50% NPK through

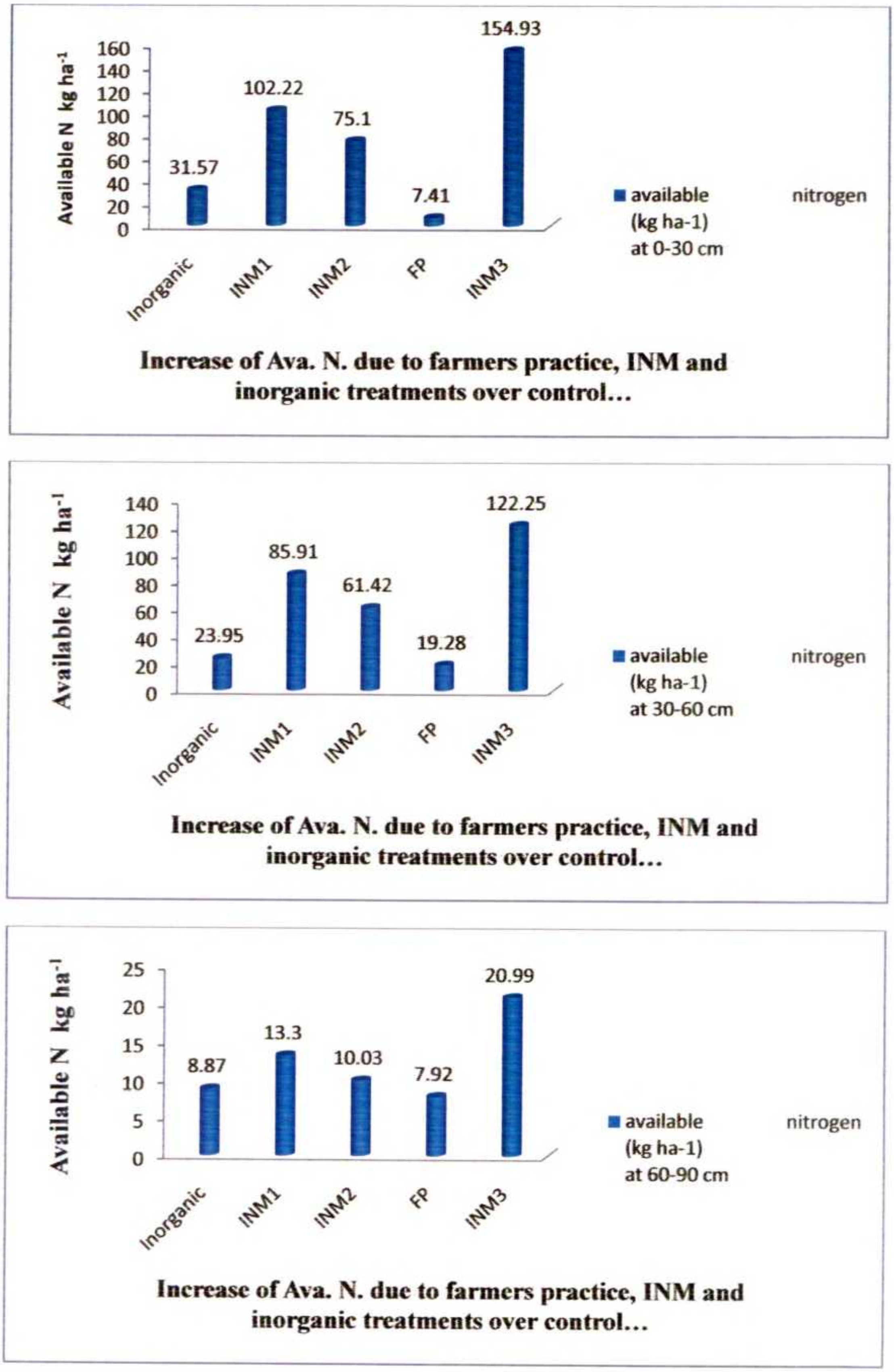
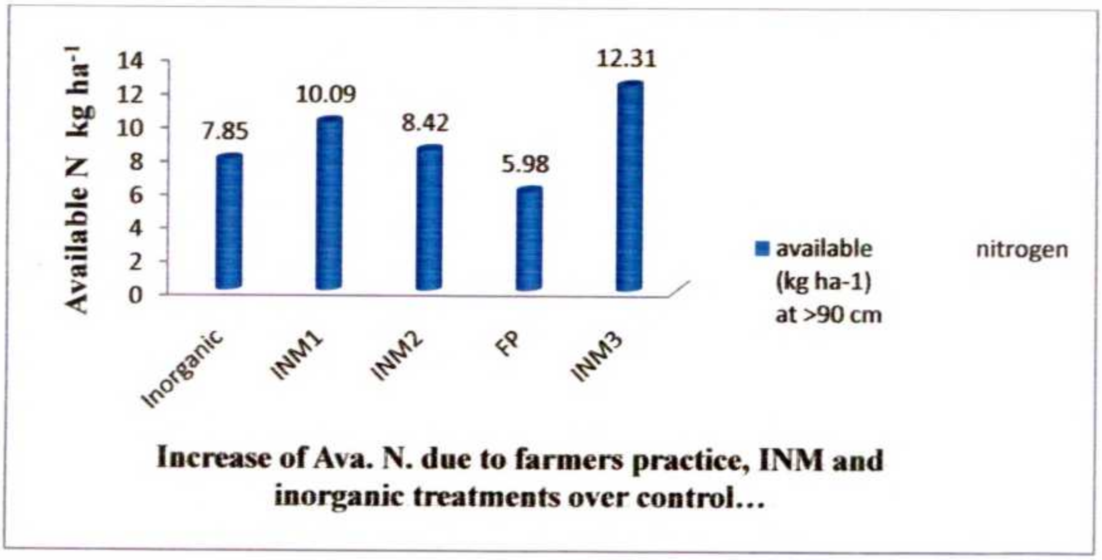


Fig 1. Addition of available nitrogen (kg ha^{-1}) over control due to long term fertilization under sorghum-wheat cropping system



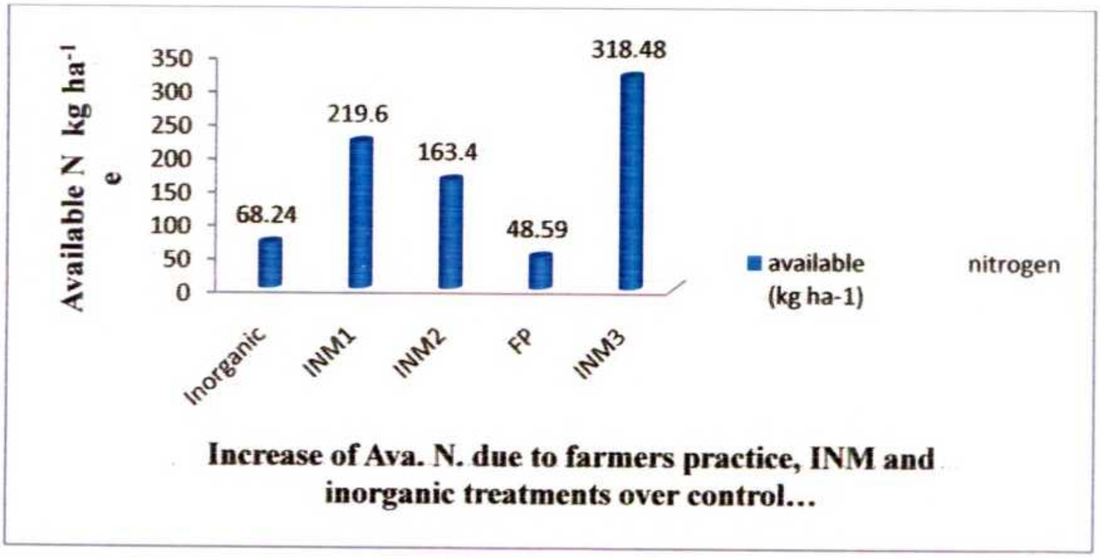


Fig 1. Addition of available nitrogen (kg ha^{-1}) over control due to long term fertilization under sorghum-wheat cropping system

fertilizers and 50% N through organic manures recorded higher addition of available P_2O_5 over farmer practice and control at all depths.

In respect of movement of P_2O_5 from surface to subsurface, it was noticed that treatment INM_3 showed more build up of P_2O_5 at all depth over farmer practice followed by INM_2 and INM_1.

Table 16: Effect of long term fertilization on vertical movement of available P_2O_5 (kg ha^{-1}) of soil under sorghum-wheat cropping system

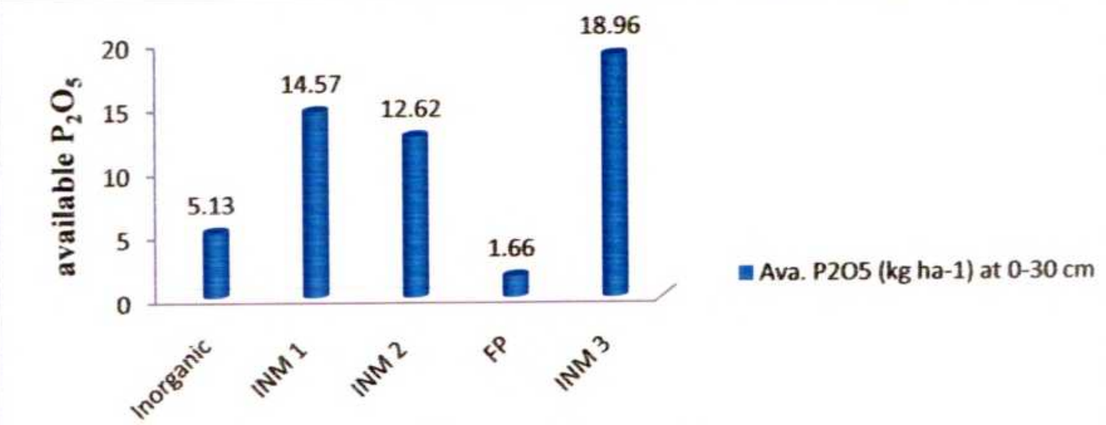
Treatment	0-30 cm	30-60 cm	60-90 cm	>90 cm	Total
Control	8.69	7.69	7.02	6.69	30.09
Inorganic	13.82	12.21	11.50	11.00	48.53
INM_1	23.26	22.35	21.35	20.93	87.89
INM_2	21.31	20.39	19.51	18.84	80.05
FP	10.35	10.02	9.69	8.35	38.41
Initial value	8.59	-	-	-	
INM_3	27.65	26.99	25.99	25.65	106.28
SE$\pm$	1.73	1.62	1.59	1.65	-
CD@5%	5.03	4.72	4.64	4.80	-

The low content of available P_2O_5 at deeper layer might be due to decreasing trend of organic carbon in the soil layer. In all treatment available P_2O_5 was higher in surface layer and same decreased down the depth. These results corroborated with that of Trivedi *et al* (2010) and Dongale (1993).

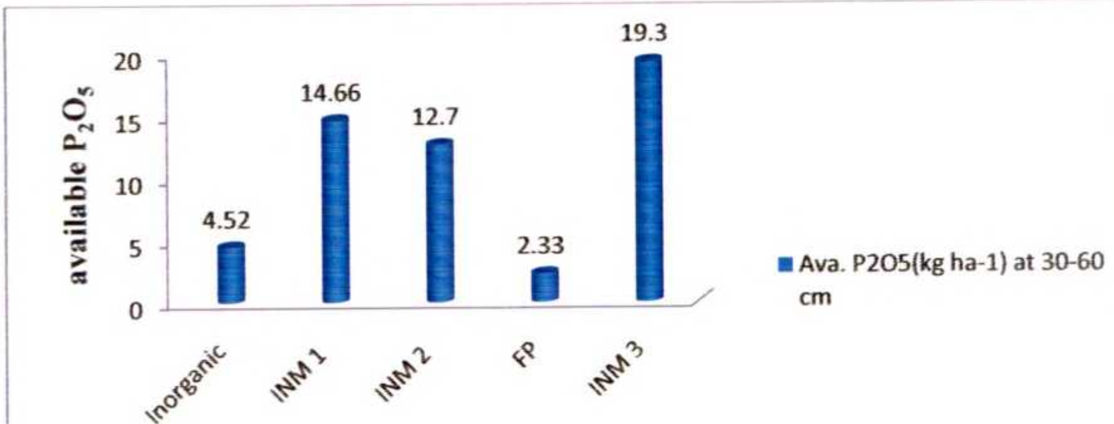
4.3.3. Total nitrogen (mg kg^{-1})

The data presented in Table (17) and Fig. (3) revealed that total nitrogen was found to be significantly influenced by different nutrient management practices.

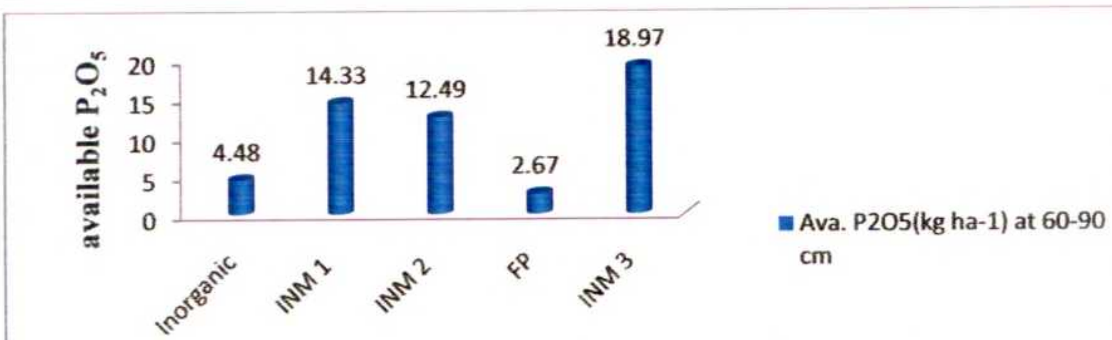
During the study, total nitrogen content of soil was noticed significantly highest in treatment INM_1 (1224.17 mg kg^{-1}) treated with combined application of organic and inorganic fertilizers whereas lowest was noticed in absolute control treatment (173.25 mg kg^{-1}). Total nitrogen content was found to be decreased with depth of soil. This might be due to compaction of soil in deeper layer with leads to restricted growth microbes.



Increase of Ava. P_2O_5 due to farmers practice, INM and inorganic treatments over control

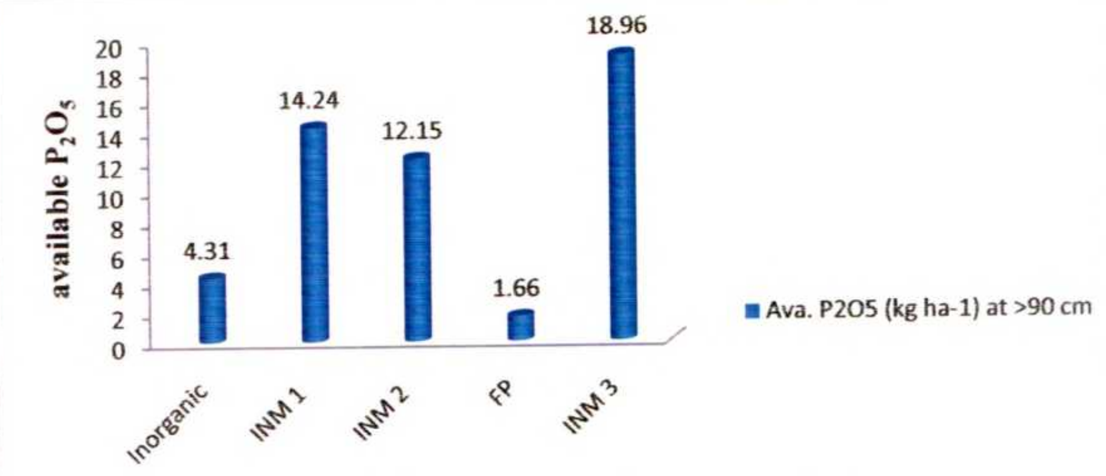


Increase of Ava. P_2O_5 due to farmers practice, INM and inorganic treatments over control

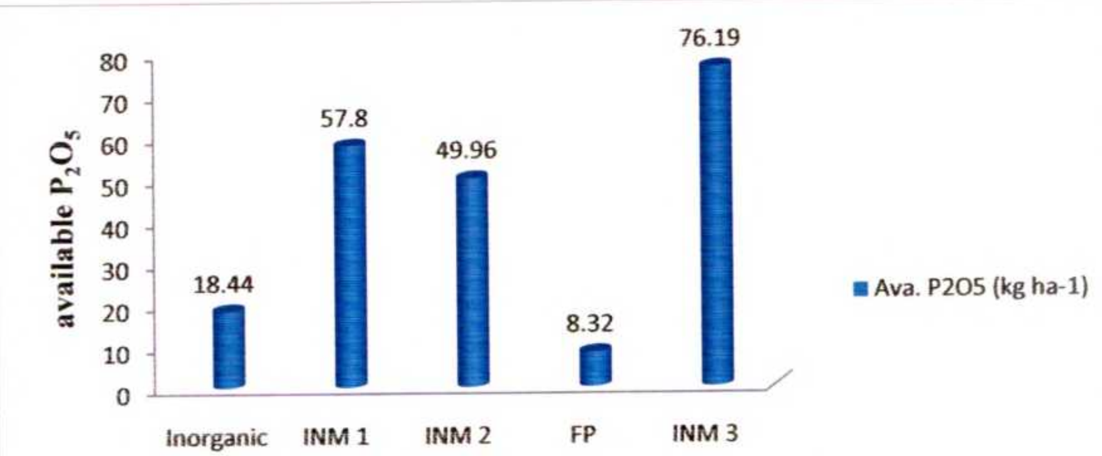


Increase of Ava. P_2O_5 due to farmers practice, INM and inorganic treatments over control

Fig 2. Addition of available P_2O_5 (kg ha^{-1}) over control due to long term fertilization under sorghum-wheat cropping system



Increase of Ava. P_2O_5 due to farmers practice, INM and inorganic treatments over control



Increase of Ava. P_2O_5 due to farmers practice, INM and inorganic treatments over control

Fig 2. Addition of available P_2O_5 (kg ha^{-1}) over control due to long term fertilization under sorghum-wheat cropping system

The movement of total mirror showed that treatment. INM3 showed more build up of total N followed by INM_2 and INM_1. It was lower in control, farmer practice and only inorganic fertilizers.

Table 17: Effect of long term fertilization on vertical movement of total nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

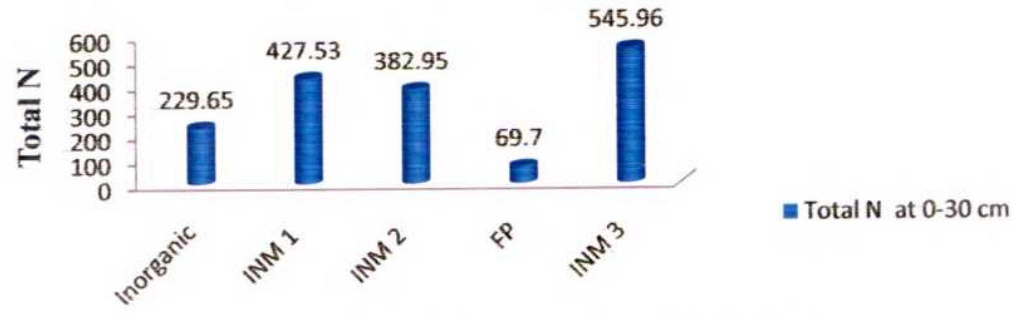
Treatment	0-30 cm	30-60 cm	60-90 cm	>90 cm	Total
Control	796.64	540.26	360.18	113.15	1810.23
Inorganic	1026.29	796.65	594.76	338.75	2756.45
INM_1	1224.17	989.55	785.03	534.24	3532.99
INM_2	1179.59	923.88	730.42	472.96	3306.85
FP	866.34	613.45	423.18	173.25	2076.22
Initial value	704.00	-	-	-	
INM_3	1342.6	1094.2	909.15	649.15	3995.1
SE±	37.21	40.14	29.89	18.01	-
CD@5%	108.04	116.53	86.78	52.28	-

The surface soil had relatively higher total nitrogen content as compared to the sub-surface. Soil profiles showed a declining trend of total nitrogen content with soil depth, which may be attributed to lower intensity of mineralization in the lower horizons. These observations are in accordance with those of Walia *et al.* (1998) and Basumatary and Talukdar (1998) and Singh and Singh (2007).

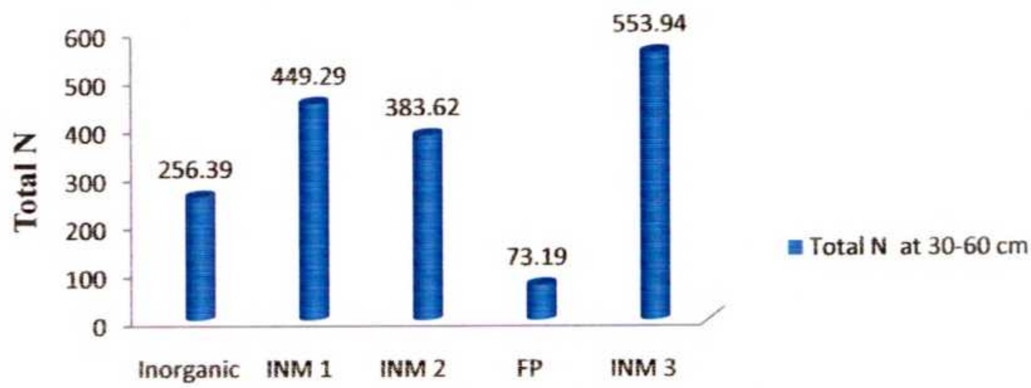
4.3.4. Total phosphorus (mg kg^{-1})

The data given in Table 18 and Fig. 4 revealed that the total phosphorus values of soil ranged from 512.44 to 645.80 mg kg^{-1}. The data narrated on total phosphorus of soil was observed statistically significant by different nutrient management practices.

During the study, total phosphorus of soil was noticed highest in treatment INM_3 (654.80 mg kg^{-1}) treated with 75% NPK + 25 % N through FYM at 0-30 cm depth of soil layer, whereas lowest was noticed in absolute control treatment T_1(512.44 mg kg^{-1}) at > 90 cm depth of soil. From that table total phosphorus content was found to be decreased with depth of soil layer.



Increase of Total N due to farmers practice, INM and inorganic treatments over control...



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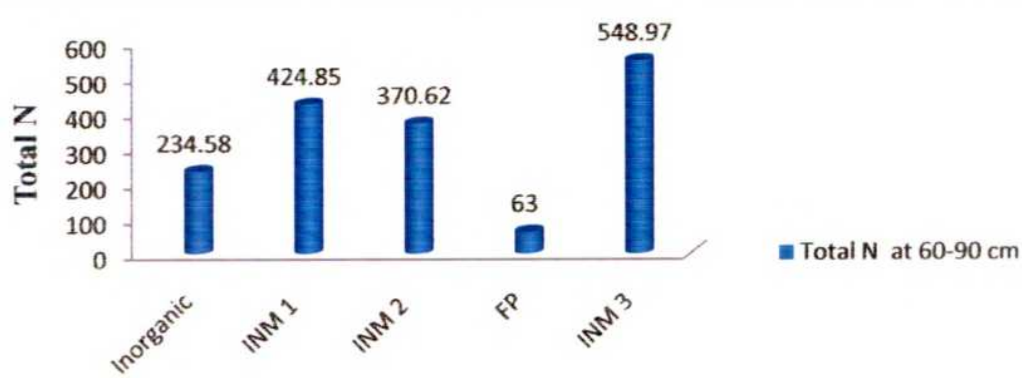

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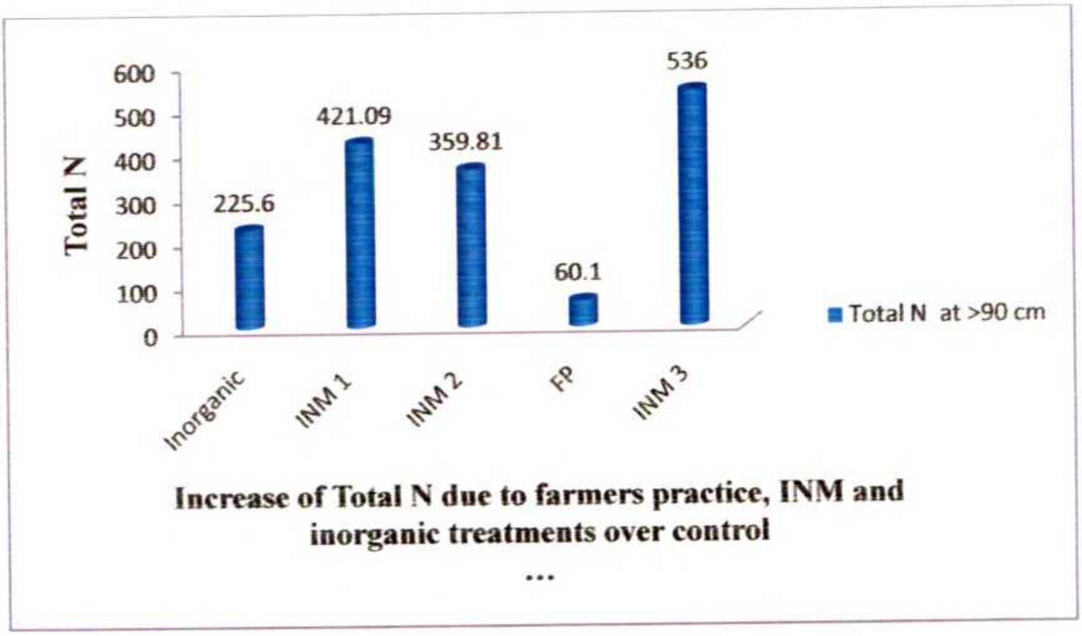
Fig 3. Addition of total nitrogen(mg kg^{-1}) over control due to long term fertilization under sorghum-wheat cropping system



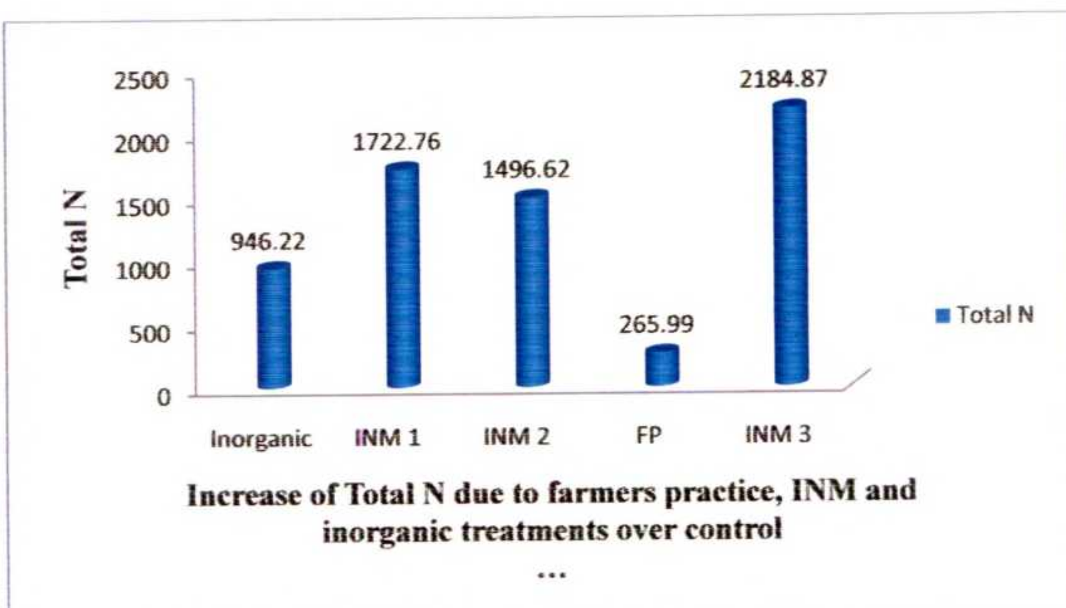


Fig 3. Addition of total nitrogen (mg kg^{-1}) over control due to long term fertilization under sorghum-wheat cropping system

Similar trend was noticed in respect of the content of total phosphorus in subsurface soil due to influence of various treatments and that of total P tended to decrease with depth which may probably be attributed to intense microbial activity and greater mineralization in the surface layer. Mahankar (1978) observed similar trend in vertical distribution of total P in soil subjected to long-term manuring and fertilization.

Table 18: Effect of long term fertilization on vertical movement of total phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Treatment	0-30 cm	30-60 cm	60-90 cm	>90 cm	Total
Control	558.05	548.77	535.16	512.44	2154.42
Inorganic	584.4	577.15	563.01	544.96	2269.52
INM_1	627.78	620.55	610.67	597.99	2456.99
INM_2	621.45	614.22	601.60	587.57	2424.84
FP	578.66	567.41	551.55	535.06	2232.68
Initial value	551.45	-	-	-	
INM_3	645.80	640.41	633.02	623.55	2542.78
SE±	1.07	1.18	1.03	1.57	-
CD@5%	3.11	3.45	2.99	4.57	-

4.4. Effect of long term fertilization on nitrogen fraction of soil.

4.4.1 Ammonium nitrogen (mg kg^{-1})

The results presented in Table 19 and depicted in figure 5 showed that the ammonium N was varied significantly due to long term application of organics and fertilizers. Application of (50% NPK kg ha^{-1} through fertilizers+50% N through FYM in kharif and 50% NPK kg ha^{-1} through fertilizer to rabi) crops found superior in ammonium N content at all depths. Further the said treatment showed 170.30 percent increase over control in 30-60 cm 29.80 percent in 60-90 cm and 33.03 percent in >90 cm depth. Its content at 0-30, 30-60, 60-90 and more than 90 cm depth was 10.79, 4.98, 3.81 and 3.12 mg kg^{-1}. The NH^{4+} -N decreased with depth. It was also found that over a period of 30 years and in all treatments NH^{4+} -N was increased except in control over initial value.

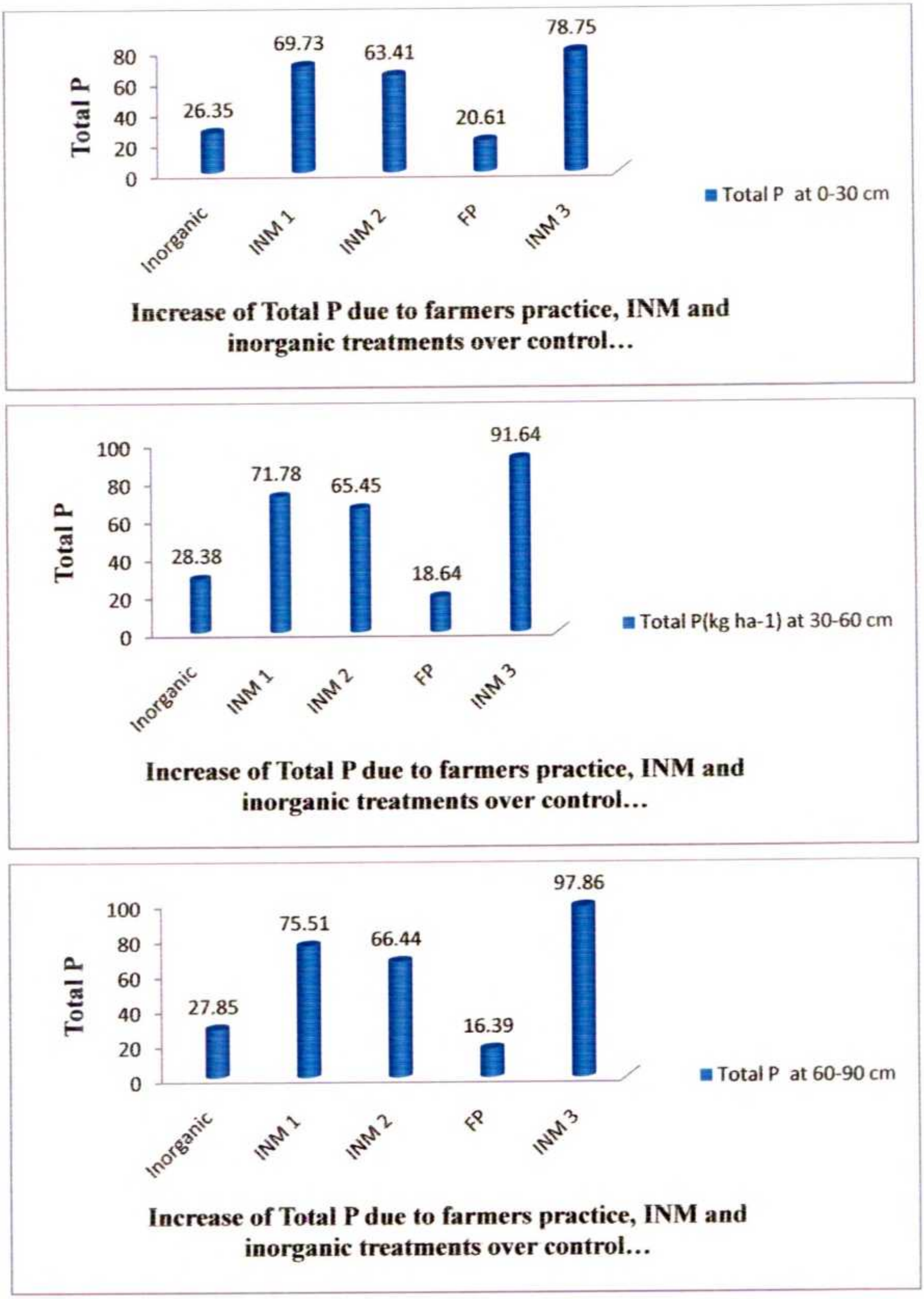
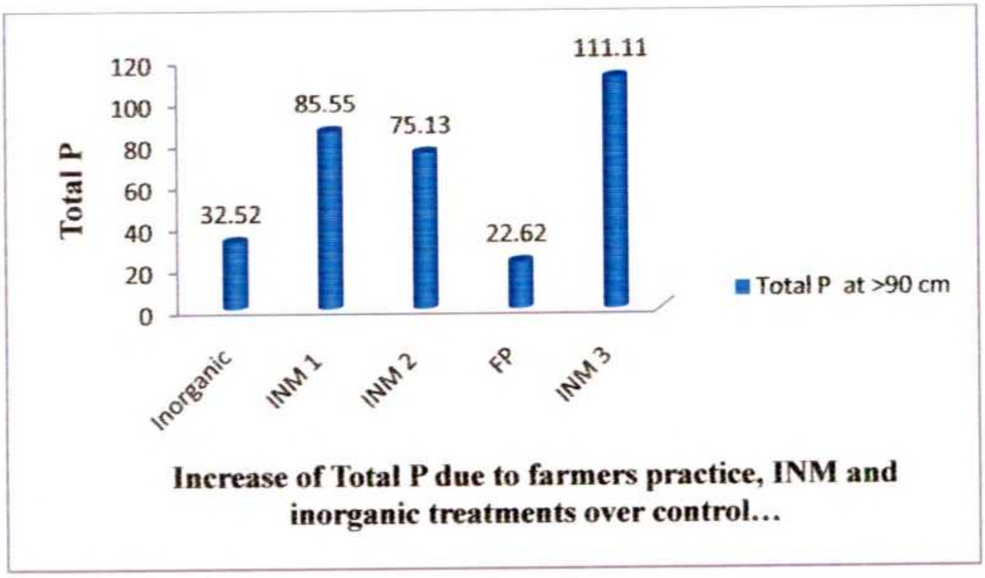


Fig 4. Addition of total phosphorus (mg kg^{-1}) over control due to long term fertilization under sorghum-wheat cropping system



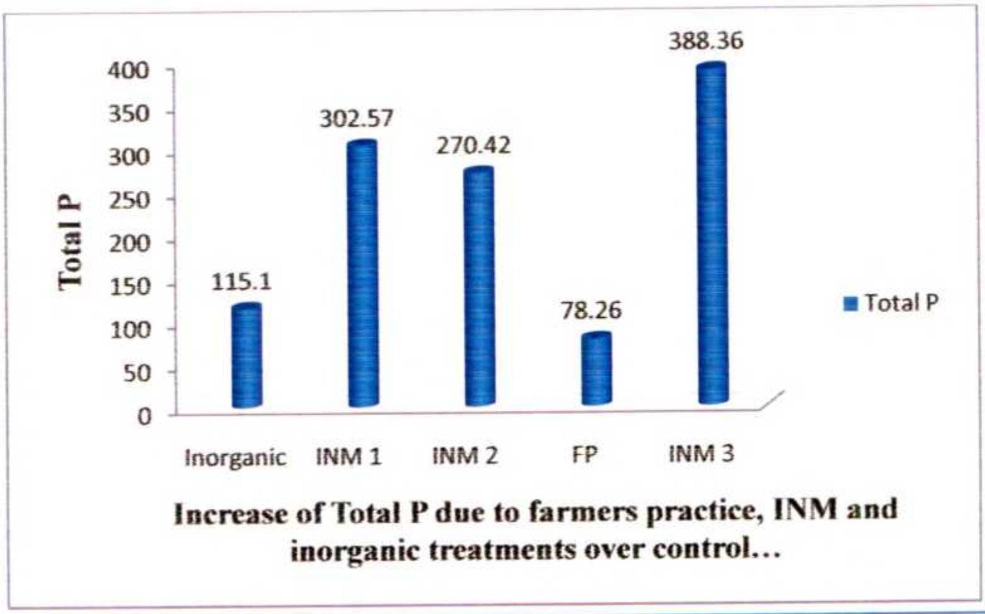


Fig 4. Addition of total phosphorus (mg kg^{-1}) over control due to long term fertilization under sorghum-wheat cropping system

Table 19 : Effect of long term fertilization on vertical distribution of ammonium nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Ammonium Nitrogen (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	6.13	4.53	3.36	2.50
T_2	50% NPK (F)	50% NPK (F)	9.67	4.84	3.66	2.86
T_3	50 % NPK (F)	100 % NPK (F)	10.92	5.09	3.92	3.38
T_4	75 % NPK (F)	100 % NPK (F)	9.67	4.84	3.66	2.86
T_5	100 % NPK (F)	100 % NPK (F)	10.47	4.92	3.74	3.18
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	16.57	5.88	4.47	3.93
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	16.23	5.34	4.33	3.74
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	8.34	4.69	3.58	2.69
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	7.63	4.62	3.46	2.57
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	12.83	5.22	4.07	3.57
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	9.67	4.84	3.66	2.86
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	9.67	4.84	3.66	2.86
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	10.47	4.92	3.74	3.17
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	12.83	5.22	4.07	3.57
Initial value			7.00	_	_	_
S.E.±			0.59	0.20	0.16	0.10
C.D. at 5 %			1.73	0.60	0.48	0.31
Grand mean			10.79	4.98	3.81	3.12

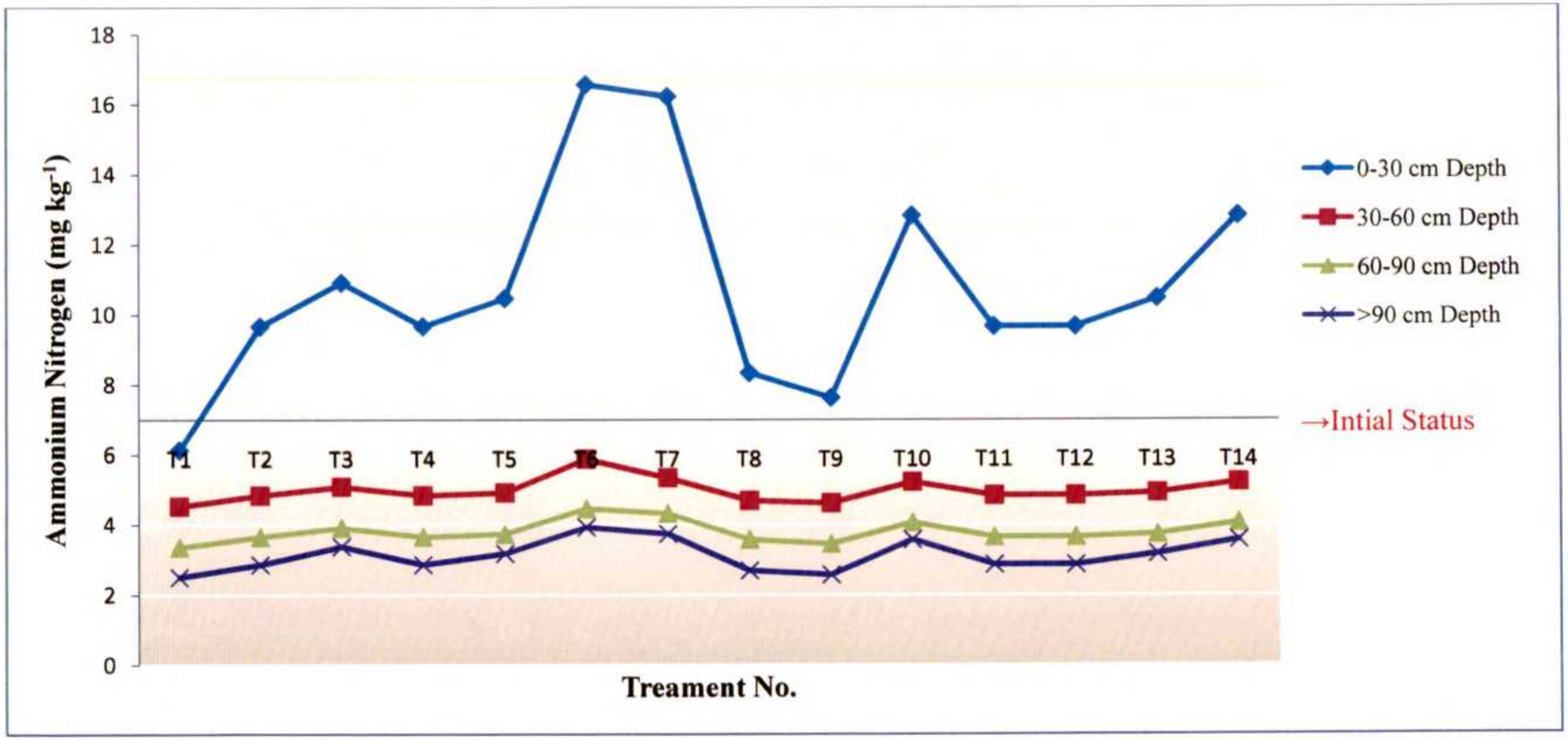


Fig. 5 Effect of long term fertilization on vertical distribution of ammonium nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

The results showed increase in NH^{4+}-N content due to application of nitrogen either through inorganic fertilizers or through organic manures indicating possibility of buildup of ammonical nitrogen (NH^{4+}-N) content of the soil over a period of time was also reported by Puranik *et al.* (1978) and Udyasoorian *et al.* (1989). This buildup of NH^{4+}-N in the fertilized and manured treatments may be attributed to combine use of organic and inorganic fertilizers. (*i.e.* presence of montmorilonite).

Incorporation of manures and fertilizers increased both NH_4^+ -N and NO_3^- -N in soil which may be due to their release during the process of decomposition of added organic materials. Brady and Well (2007) also reported that on decomposition of organic matter, mineralization takes place that releases NH_4^+-N during ammonification and NO_3–N during the process of nitrification. The integrated use of organic and inorganic , recorded higher values of NH_4-N and NO_3-N in comparison to chemical fertilizer treated plots which might be due to the additive effect of manures and fertilizers. It is evident that among different organic sources tried, FYM and green manure mineralized faster resulting in more inorganic N compared to wheat straw.

This is attributed to higher C: N ratio in wheat straw compared to green manure and FYM. Substitution of 50 % N through green manure contributed more towards NH_4-N while FYM contributed much towards NO_3 -N, but overall, N substitution through green manure resulted in higher contribution towards total inorganic forms of N than other two source tried.

4.4.2 Nitrate nitrogen (mg kg^{-1})

Nitrate nitrogen content of the experimental soil varies between 3.60 mg kg^{-1} to 8.29 mg kg^{-1} in surface soil, 2.53 to 6.39 mg kg^{-1} in 30 to 60 cm depth, 1.74 to 4.36 in 60 to 90 cm depth and 0.23 to 1.34 at >90 cm soil depth with an average of 6.45,4.96,3.35 and 0.81. respectively. Among the first five treatments (*i.e.*T_1 to T_5) where nitrogen was supplied only through inorganic fertilizers with varied levels to sorghum and wheat crop. It was recorded that NO_3-N was highest in T_5 treatment followed by T_4, T_3 and T_2 and significantly lower NO_3-N was observed in control. This was far less than the initial NO_3-N content.

Table 20 : Effect of long term fertilization on vertical distribution of nitrate nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Nitrate Nitrogen (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	3.60	2.53	1.74	0.23
T_2	50% NPK (F)	50% NPK (F)	5.82	4.73	3.29	0.76
T_3	50 % NPK (F)	100 % NPK (F)	7.40	5.00	3.27	0.82
T_4	75 % NPK (F)	100 % NPK (F)	7.46	5.66	3.67	0.93
T_5	100 % NPK (F)	100 % NPK (F)	8.09	6.17	4.15	1.18
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	7.46	5.66	3.67	0.93
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	4.73	3.53	2.51	0.43
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	8.29	6.39	4.36	1.34
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	5.82	4.73	3.29	0.76
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	5.82	4.73	3.29	0.76
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	4.73	3.53	2.51	0.43
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	5.83	4.73	3.29	0.76
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	7.46	5.66	3.67	0.93
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	7.84	5.73	3.83	1.07
Initial value			11.00	_	_	_
S.E.±			0.34	0.26	0.23	0.11
C.D. at 5 %			1.00	0.77	0.69	0.34
Grand mean			6.45	4.96	3.35	0.81

In rest of the treatments T_6 to T_4 (except T_{12}) application of 50% N replaced by FYM, wheat straw, Glyricidia green leaves and subabul loppings, respectively showed higher values of NO_3-N than their respective treatments in which 25% was replaced by the above organic material. This indicates that higher organic matter favours NO_3-N formation. However nitrate nitrogen content tended to decrease with depth T_6 treatment in 0-30 cm exhibited 130.27 percent increase over control, 152.56 percent in 30 to 60 cm, 60-90cm depth and 482.60 percent at > 90 cm depth over control.

The surface soil had relatively higher NO_3^-N content as compared to the sub-surface. Soil profiles showed a declining trend of NO_3^- N content with soil depth, which may be attributed to lower intensity of mineralization in the lower horizons. These observations are in accordance with those of Walia *et al.* (1998) and Baumatary and Talukdar (1998) and Singh (2007).

The low bulid up of NO_3^- N may due to easy NO_3^- N immobilization in the presence of more soybean litter, and loss of NO_3^- N due to denitrification and for movement of NO_3^- N from surface to lower layers. These observations are similar to those of Patrick and Reddy (1978). A positive effect of N substitution through compost was observed in terms of improved NH_4^+-N and NO_3^-N of the soil. Adding compost along with inorganic fertilizer had a favourable impact on NO_3^- N and it supports the earlier results obtained by Khankhane and Yadav (2000).

4.4.3. Nitrite nitrogen (mg kg^{-1})

Vertical distribution of nitrite nitrogen due to conjunctive use of inorganic and organic source of fertilizer under sorghum wheat cropping sequence are presented in Table 21. It was observed that nitrite nitrogen content was significantly affected by various treatment combinations including organic and inorganic fertilizers. The data presented in table indicates highest amount of nitrite nitrogen in treatment T_2 *i,e,* control in both the season. While lowest amount of nitrite nitrogen was recorded in treatment T_8 *i.e,* 50% NPK through wheat straw during kharif and 100% NPK through inorganic fertilizers during rabi season.

Table 21: Effect of long term fertilization on vertical distribution of nitrite nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Nitrite Nitrogen (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	3.63	1.92	1.43	0.62
T_2	50% NPK (F)	50% NPK (F)	3.42	1.84	1.25	0.54
T_3	50 % NPK (F)	100 % NPK (F)	2.91	1.63	0.93	0.37
T_4	75 % NPK (F)	100 % NPK (F)	2.91	1.63	0.93	0.37
T_5	100 % NPK (F)	100 % NPK (F)	3.20	1.76	1.16	0.46
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	3.09	1.72	1.11	0.41
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	2.76	1.58	0.82	0.33
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	2.29	1.44	0.64	0.17
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	2.13	1.20	0.69	0.14
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	2.76	1.58	0.69	0.33
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	2.13	1.28	0.64	0.14
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	2.29	1.44	0.82	0.17
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	2.48	1.49	0.69	0.26
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	2.62	1.53	0.73	0.23
Initial value			2.73	_	_	_
S.E.±			0.27	0.11	0.14	0.05
C.D. at 5 %			0.36	0.32	0.42	0.14
Grand mean			2.75	1.58	0.89	0.32

It also observed that nitrite nitrogen decreased with depth of soil. Nitrite nitrogen content varied from 0.17-3.63 mg kg^{-1} of soil at different depth of soil. As nitrite nitrogen content is an inorganic form of nitrogen fraction. So that's why, there might be decrease in nitrite nitrogen content with increase in organic matter content of soil. Hence, nitrite nitrogen content was lowest to those treatments which include integrated use of inorganic and organic source of fertilizers. These results showed that cropping with addition of nitrogen through organic manure tended to decrease the nitrite N content.

4.4.4 Total hydrolysable nitrogen (THN) (mg kg^{-1})

The total hydrolysable nitrogen fraction is most important source of organically bound fractions of nitrogen. The data there of are presented in Table 22 and depicted in figure 6. There was decrease in total hydrolysable nitrogen (THN) with increase in depth of soil. In respect of different treatments, control treatment showed minimum total hydrolysable nitrogen, where as T_6 treatment showed maximum THN. In general there was increase in THN over initial level of THN. Among various organic sources supplying nitrogen FYM found best followed by wheat straw, subabul, green leaf manure and *Glyricidia* green leaf manure in increasing THN fraction over a period of 30 years.

This clearly indicated that organically bound hydrolysable N build up was more than the nitrogen supplied through organic manures that too through other organic FYM. There was also increase in THN under soil media received N through sources but it was at lower magnitude. In general application of fertilizers/manures improved the THN content over 30 years of long cycles.

Most of Nitrogen applied through inorganic sources get immobilized immediately because of microbial transformation and in turn it will become a part of organically bound Nitrogen. Many research workers also reported increase in total hydrolysable nitrogen content of soil due to cropping, fertilization, crop residues recycling and organic manure application (Puranik *et al.* 1978 and Prasad and Rokima 1991).

4.4.5 Amino acid nitrogen (mg kg^{-1})

Effect of chemical fertilizers and organic manures on vertical distribution of amino acid nitrogen fraction under sorghum-wheat cropping sequence were presented in Table 23 and depicted in figure 7.

Table 22: Effect of long term fertilization on vertical distribution of total hydrolysable nitrogen (THN) (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Total Hydrolysable Nitrogen (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	220.04	133.23	60.07	46.26
T_2	50% NPK (F)	50% NPK (F)	458.33	160.30	92.00	62.16
T_3	50 % NPK (F)	100 % NPK (F)	629.36	283.20	147.15	85.35
T_4	75 % NPK (F)	100 % NPK (F)	421.08	160.35	87.25	60.01
T_5	100 % NPK (F)	100 % NPK (F)	515.43	193.39	109.07	71.29
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	655.22	302.70	153.40	93.30
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	562.40	243.41	135.41	82.19
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	543.36	227.39	119.18	74.19
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	482.33	163.23	96.29	65.14
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	325.47	145.22	72.23	53.41
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	293.15	141.28	68.19	51.38
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	268.38	136.22	63.53	48.24
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	349.32	152.45	76.19	54.38
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	385.24	155.43	72.50	56.41
Initial value			280.00	_	_	_
S.E.±			12.58	13.18	12.29	5.66
C.D. at 5 %			36.53	38.28	35.70	16.44
Grand mean			436.36	185.55	97.31	63.12

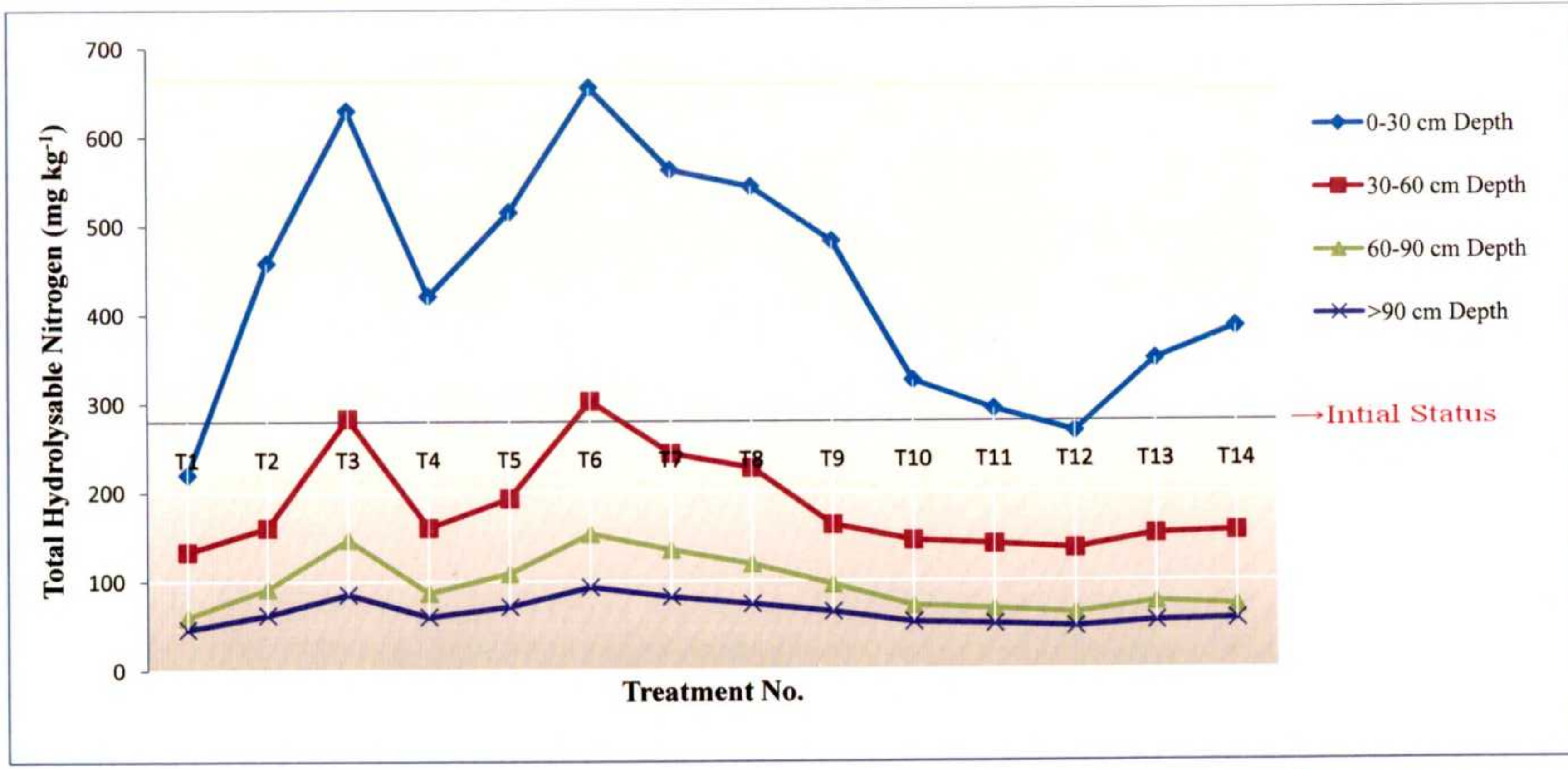


Fig.6 Effect of long term fertilization on vertical distribution of total hydrolysable nitrogen ($mgkg^{-1}$) of soil under sorghum-wheat cropping system

Table 23 : Effect of long term fertilization on vertical distribution of amino acid nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Amino Acid Nitrogen (mg kg^{-1})			
	Kharif	Rabbi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	135.34	91.92	70.96	45.12
T_2	50% NPK (F)	50% NPK (F)	139.13	96.11	73.96	46.21
T_3	50 % NPK (F)	100 % NPK (F)	181.21	113.27	78.46	48.30
T_4	75 % NPK (F)	100 % NPK (F)	158.38	102.36	76.35	46.40
T_5	100 % NPK (F)	100 % NPK (F)	203.10	123.09	86.31	50.30
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	215.21	125.01	90.35	52.28
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	186.17	118.12	82.37	48.19
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	164.12	106.17	76.00	47.23
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	126.35	85.45	68.24	43.22
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	130.39	88.25	68.05	43.17
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	119.36	82.29	66.19	41.15
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	108.24	76.47	65.20	40.13
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	105.17	74.16	65.11	39.22
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	115.16	80.45	65.21	40.19
Initial value			84.00	_	_	_
S.E.±			10.09	10.72	4.59	2.50
C.D. at 5 %			29.31	31.13	13.33	7.26
Grand mean			149.09	97.36	73.76	45.07

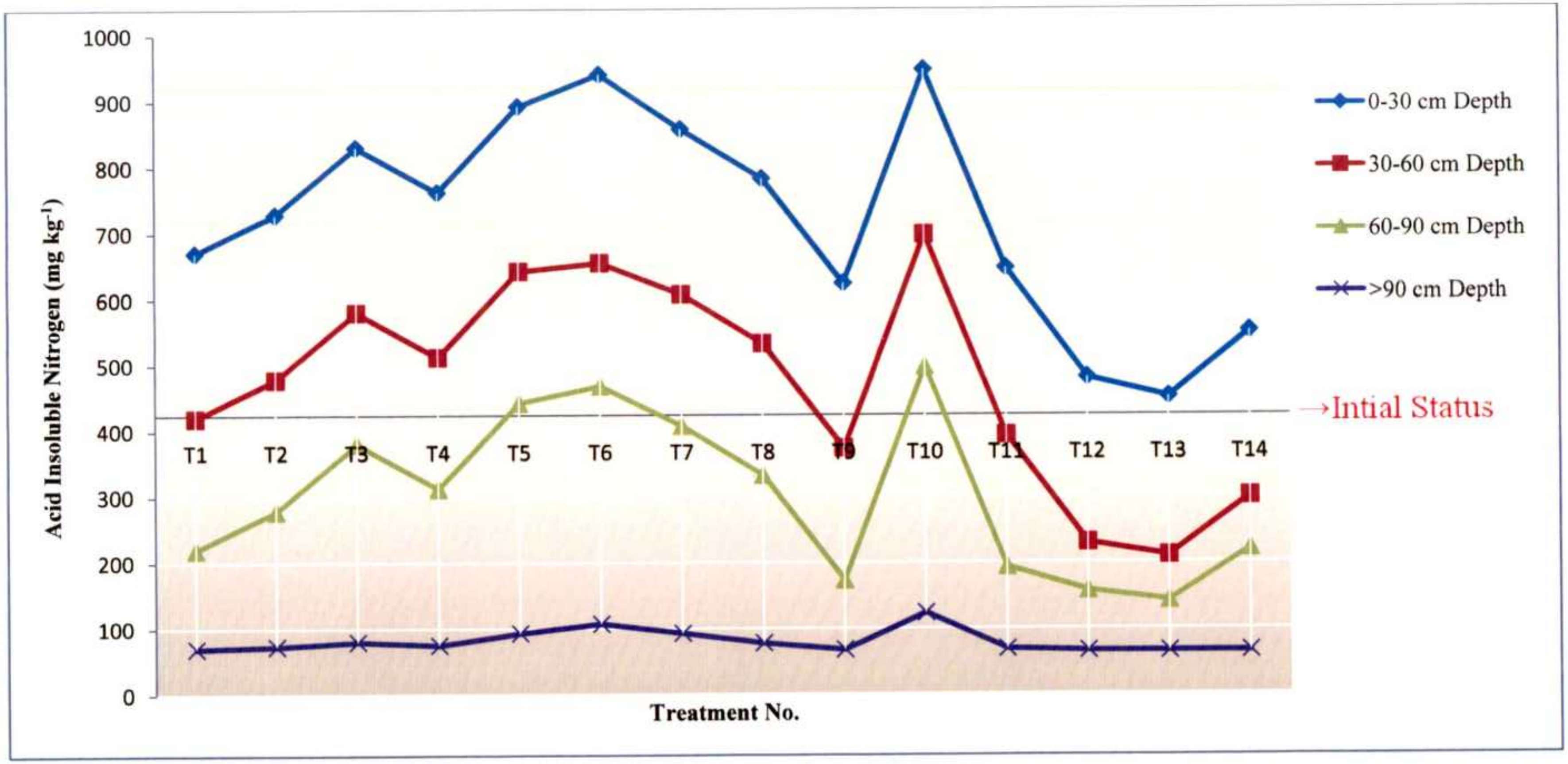


Fig.7. Effect of long term fertilization on vertical distribution of amino acid nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

Amino acid nitrogen content ranged from 39.22 - 215.21 mg kg^{-1}. This content decreased with depth of soil. At 0-30 cm depth it ranged from 105.17 -215.21 mg kg^{-1}, at 30-60 cm depth it ranged 74.16-125.01 mg kg^{-1} at 60-90 cm depth, it ranged from 65.11 – 90.35 mg kg^{-1} while more than 90 cm depth, it ranged from 39.22 -52.28 mg kg^{-1}. Maximum amount of amino acid nitrogen content was found to be at treatment T_6 i.e., 50 % NPK application through inorganic fertilizer + 50 % N through FYM during kharif season and 100% NPK through inorganic fertilizers during rabi season

The rate of increase in the content of amino acid nitrogen with the application of fertilizers and different organic material was highest in all layers of soils. The low content of amino acid nitrogen at deeper layer might be due to decreasing trend of organic carbon content in the soil layer. In all treatment amino acid nitrogen was higher in surface layer and same decreased down the depth. Decrease in amino acid nitrogen content might be due to decrease in organic matter content down to the soil depth. These results corroborated with that of Trivedi *et al* (2010) and Dongale (1993).

4.4.6. Organic ammonium nitrogen (mg kg^{-1})

Vertical distribution of organic ammonium N content due to effect of integrated use of organic and inorganic source of fertilizers under sorghum wheat cropping sequence was presented in table 24 and depicted in figure 8. From that table it was clear that organic ammonium N was significantly affected by various treatment combination including organic and inorganic sources of fertilizers. Organic ammonium N content ranged from 13.37 -210.33 mg kg^{-1} of soil at different soil layers. Organic ammonium N content also seemed that it was decreased with depth. It ranged from 126.25 - 210.33 in 0-30 cm depth, 86.19 - 170.32 in 30-60 cm depth, 36.30 -118.20 in 60-90 cm depth and 13.37 - 88.19 in more than 90 cm depth. Highest amount of organic ammonium N was recorded at T_6 treatment *i.e,* 50% NPK through inorganic fertilizers + 50% N through FYM during kharif season and 100 % NPK through inorganic fertilizer during rabi season. While lowest amount of organic ammonium N content was recorded at T_1 treatment *i.e*, control during both the season.

Table 24 : Effect of long term fertilization on vertical distribution of organic ammonium nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Organic Ammonium Nitrogen (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	151.18	115.90	66.2	30.04
T_2	50% NPK (F)	50% NPK (F)	170.18	135.36	85.25	55.05
T_3	50 % NPK (F)	100 % NPK (F)	190.53	150.11	100.35	70.24
T_4	75 % NPK (F)	100 % NPK (F)	176.44	141.01	91.22	61.15
T_5	100 % NPK (F)	100 % NPK (F)	194.32	154.28	104.53	74.49
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	210.33	170.32	118.20	88.19
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	158.55	118.42	69.18	34.21
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	145.09	107.48	60.18	31.60
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	130.33	92.38	36.30	13.37
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	141.25	101.55	56.33	24.55
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	126.25	86.19	48.13	21.3
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	133.42	93.2	43.18	16.53
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	129.17	89.05	39.28	15.32
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	136.50	96.44	45.28	18.19
Initial value			84.00	_	_	_
S.E.±			14.52	7.51	7.02	4.10
C.D. at 5 %			42.17	21.81	20.38	11.92
Grand mean			156.68	117.97	68.82	39.59

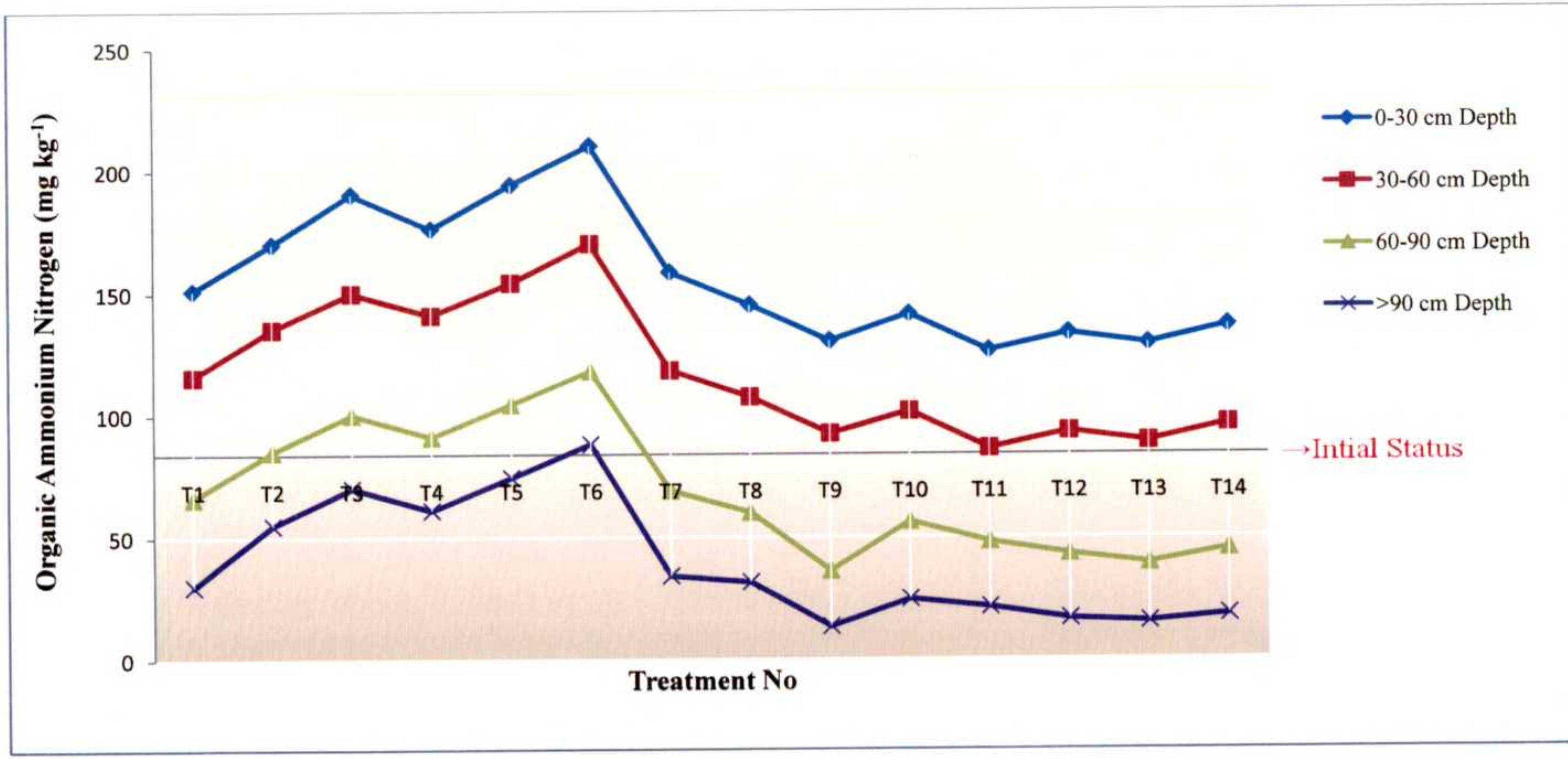


Fig.8. Effect of long term fertilization on vertical distribution of organic ammonium nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

The rate of increase in the organic ammonium N content with application of fertilizers and different organic materials santhy *et.al* (1998) also found positive effect on the buildup of the entire organic ammonium N fraction with the application of FYM along with inorganic fertilizers. Ghosh *et al.* (1989) observed that organic treatment increased the levels of hydrolysable ammonium nitrogen content in soil, continuous integrated nutrient management resulted in higher accumulation of organic matter and its mineralization might have contributed in accumulating higher ammonium nitrogen.

4.4.7 Amino sugar nitrogen (mg kg^{-1})

The data presented in Table 25 showed the effect of long term fertilization on vertical distribution of amino sugar nitrogen under sorghum wheat cropping sequence.

It was observed that amino sugar N was decreased with depth. Maximum amount of amino sugar N was recorded at T_6 treatment *i.e,* 50% NPK through inorganic fertilizers + 50% N through FYM during Kharif season and 100% NPK through inorganic fertilizers during rabi season while lowest amount of amino sugar N was recorded at T_1. Application of inorganic fertilizers along with various sources of organic fertilizers resulted in highest amount of amino sugar N. there was increased in almost two times in amino sugar content years a period of 30 years.

This might be due to carry over effect of continuous use of organic sources and accumulation of organic residue for a period of 30 years which in turn contributed to higher build up in soil. This observation was also corroborated by Basumatry and Talukdar (1998) and Sihag *et.al,* (2005)

4.4.8 Acid insoluble nitrogen (mg kg^{-1})

The acid insoluble nitrogen was determined by subtracting total hydrolysable nitrogen from total nitrogen as the data obtained are presented in Table 26 and depicted in figure 9. Its content was minimum in T_{14} (Farmers practice) and maximum in treatment T_{11} in surface soil. Same trend was reported in lower soil horizons but decreased content.

Table 25 : Effect of long term fertilization on vertical distribution of amino sugar nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Amino Sugar Nitrogen (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	75.42	60.03	51.20	41.25
T_2	50% NPK (F)	50% NPK (F)	76.08	60.98	52.62	41.32
T_3	50 % NPK (F)	100 % NPK (F)	79.20	63.35	53.15	42.11
T_4	75 % NPK (F)	100 % NPK (F)	81.25	63.36	54.09	42.09
T_5	100 % NPK (F)	100 % NPK (F)	113.43	71.16	57.22	48.33
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	116.43	73.39	59.45	50.20
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	102.21	69.89	57.06	48.08
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	96.47	67.55	58.44	46.10
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	84.31	65.25	56.28	44.42
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	102.21	69.22	57.20	48.20
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	89.34	65.28	56.17	46.41
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	102.21	69.22	57.15	46.10
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	83.26	65.32	54.41	44.28
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	92.12	67.22	58.34	46.23
Initial value			40.24	–	–	–
S.E.±			6.27	1.66	1.61	1.81
C.D. at 5 %			18.21	4.84	4.70	5.26
Grand mean			92.42	66.51	55.91	45.36

Table 26 : Effect of long term fertilization on vertical distribution of acid insoluble nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Acid Insoluble Nitrogen (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	670.24	419.92	220.14	70.01
T_2	50% NPK (F)	50% NPK (F)	728.25	478.13	278.24	73.19
T_3	50 % NPK (F)	100 % NPK (F)	830.14	579.99	380.22	79.92
T_4	75 % NPK (F)	100 % NPK (F)	762.17	512.32	312.39	75.01
T_5	100 % NPK (F)	100 % NPK (F)	892.23	642.31	442.44	93.04
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	940.12	655.23	468.11	107.19
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	857.28	607.13	407.44	92.59
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	782.09	532.35	332.26	77.38
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	623.29	373.36	173.27	67.34
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	947.07	697.28	497.23	123.09
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	646.68	393.23	193.10	68.28
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	480.34	230.19	157.31	65.49
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	451.18	210.23	142.17	65.17
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	550.41	300.17	220.45	65.53
Initial value			424.00	_	_	_
S.E.±			44.37	33.32	27.28	6.05
C.D. at 5 %			128.82	96.72	79.20	17.57
Grand mean			725.82	473.06	301.76	1062.81

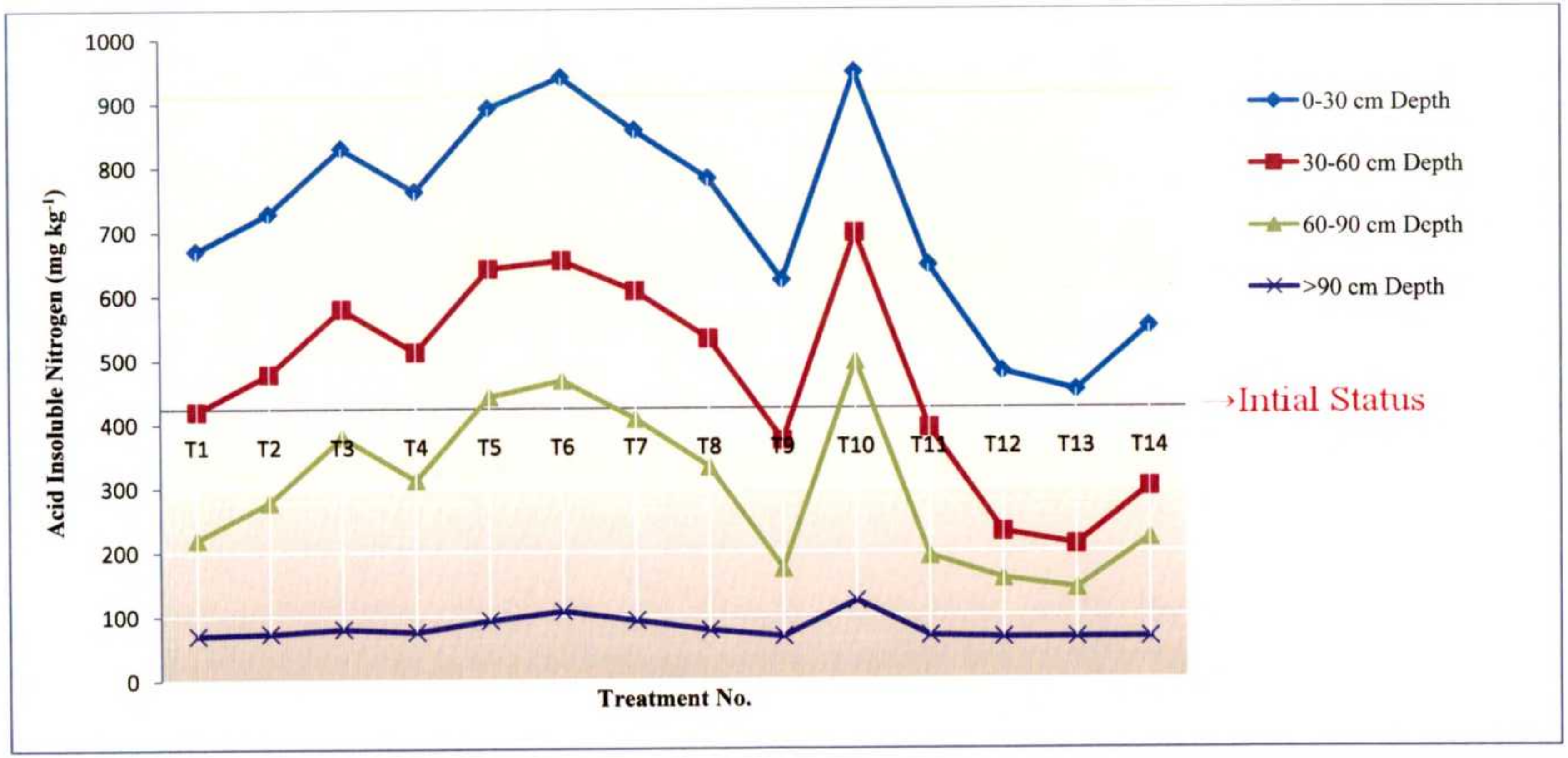


Fig.9. Effect of long term fertilization on vertical distribution of acid insoluble nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

The rate of increase in the content of acid insoluble nitrogen with the application of fertilizers and different organic material was highest in all layers of soils. The low content of acid insoluble nitrogen at deeper layer might be due to decreasing trend of organic carbon in the soil layer. In all treatment amino acid nitrogen was higher in surface layer and same decreased down with the depth. These results are in accordance with that of Trivedi *et. al* (2010) and Dongale (1993).

4.4.9 Total nitrogen (mg kg^{-1})

The results presented in Table 27and depicted in figure 10, reveals that the total N was significantly influenced by long term application of organics and fertilizers under sorghum-wheat cropping system. In 0-30cm and 30-60 cm depth total N was significantly higher in T_{11} treatment, while, In 60-90cm and above 90 cm depth T_6 shows higher total N content. The lowest value of total N was found with treatment T_1 (control). Application of organics enhanced total N status of soil to the tune of 57.72. It was very clear that total N content was improved due to cultivation of sorghum-wheat crops from last 30 years over initial content. In subsurface (30-60cm) it exhibited 83.01 percent over control while in 60-90 cm 114.83 percent. In >90 cm 274.47 percent increase was noticed.

There results indicated in increase in accumulation of total N in lower layers. In all the treatments there was increase in total N over initial content (704.00 kg ha^{-1}). However, lower levels of NPK were not so effective. It is observed from the data that the continuous use of organics in conjunction with NPK fertilizers seems to be more promising in maintaining higher total N status in soil.

Similar trend was noticed in respect of the content of total nitrogen in subsurface soil due to influence of various treatments. However, the contents tended to decrease with depth which may probably be attributed to intense microbial activity and greater mineralization in the surface layer. Mahankar (1978) observed similar trend in vertical distribution of total N in soil subjected to long-term manuring and fertilization.

Amongst the organic sources tried, green leaf manure and FYM proved to be superior in built up of total N status of soil irrespective of depths. The results of the present study are in conformity with those of Puranik *et al.* (1978) and Udaysoorian (1987) who reported increase in total N content of soil due to long-term manuring and fertilization.

Table 27: Effect of long term fertilization on vertical distribution of total nitrogen (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Total Nitrogen (mg kg^{-1})			
	Kharif	Rabbi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	796.64	540.26	360.18	113.15
T_2	50% NPK (F)	50% NPK (F)	1044.1	795.62	558.25	313.28
T_3	50 % NPK (F)	100 % NPK (F)	1056.9	821.32	622.22	359.42
T_4	75 % NPK (F)	100 % NPK (F)	870.77	693.05	503.31	238.32
T_5	100 % NPK (F)	100 % NPK (F)	1133.4	876.62	695.27	444.01
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	971.27	741.50	557.51	320.36
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	927.8	724.07	532.33	272.20
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	1342.6	1094.2	909.15	649.15
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	1317.9	1066.0	854.21	594.28
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	1366.4	1122.7	897.17	646.21
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	1239.3	960.60	786.16	526.30
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	866.34	613.45	423.18	173.25
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	1165.2	916.66	694.04	444.20
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	1284.68	1028.00	831.24	576.14
Initial value			704.00	–	–	–
S.E.±			37.21	40.14	29.89	18.01
C.D. at 5 %			108.04	116.53	86.78	52.28
Grand mean			1098.80	856.71	658.87	405.02

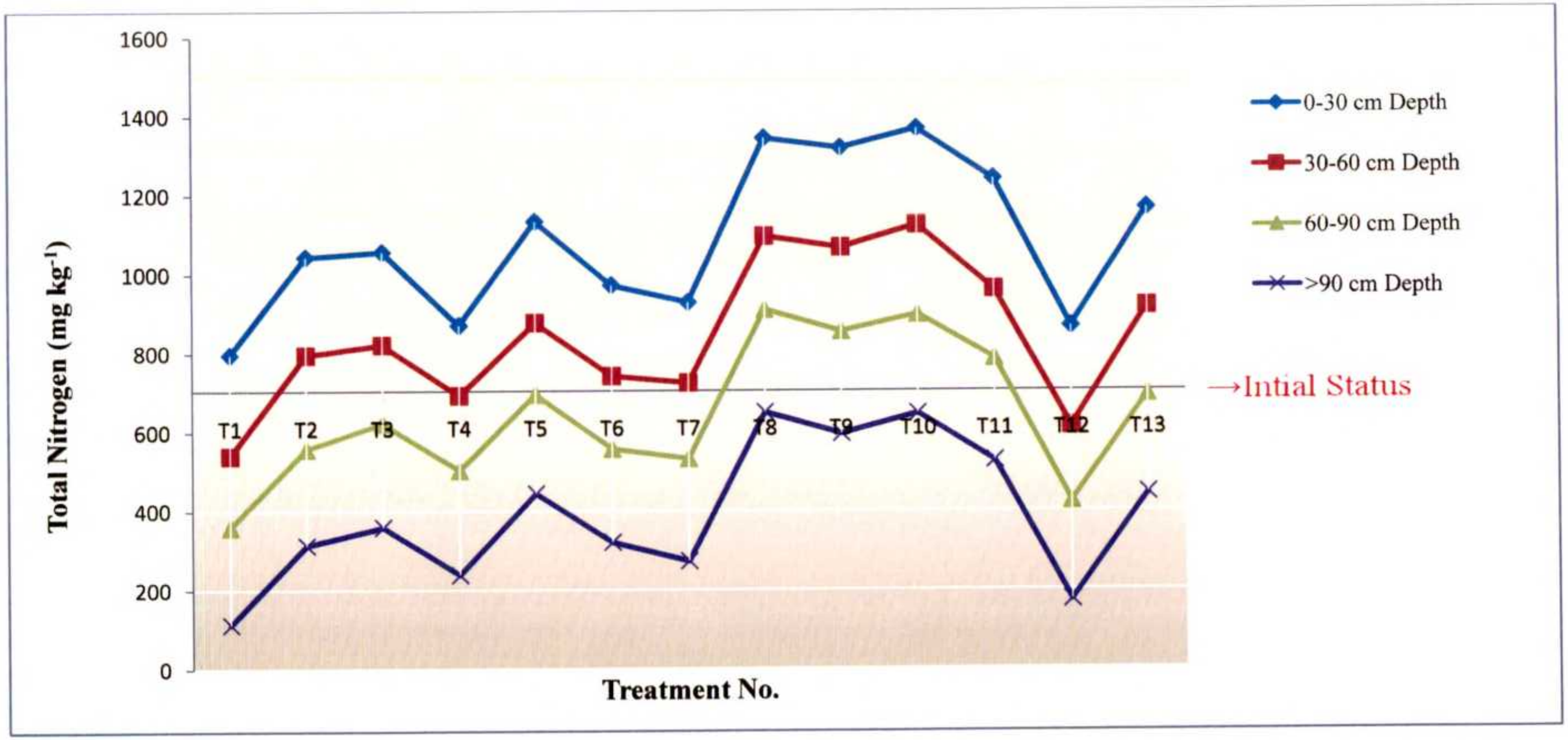


Fig.10. Effect of long term fertilization on vertical distribution of total nitrogen (mgkg^{-1}) of soil under sorghum-wheat cropping system

An increase in the rate of applied N was found to be associated with an increase in the build up of total-N and available-N and also the organic matter content of the soil (Santhy *et al.*, 2001). Similar trend was noticed by Mahankar (1978), Hiwase (1995), Basumatary and Talukdar (1998) and Ravankar *et al.* (1998).

4.4.10. Percent contribution of various fractions of nitrogen to total nitrogen

During the present investigation, mean percentage contribution of different N fractions to total N at 0 – 30 cm depth of soil due to various combinations of organic and inorganic fertilizer under long term fertilization experiment has been studied and depicted in figure 11. It showed that, there was maximum contribution of Acid Insoluble Nitrogen which contribute 41.67% to total N where as minimum contribution was of Nitrite N which constituted 0.15% to total N.

4.5 Effect of long term fertilization on phosphorus fractions

4.5.1 Saloid phosphorus (mg kg^{-1})

Effect of INM practices on vertical distribution of saloid phosphorus (mg kg^{-1}) was depicted in table 28. It was recorded highest at surface *i.e,* 0-30 cm layer while it was recorded lowest at deeper layers. At 0-30 cm depth, it ranges from 8.09 – 7.21, at 30-60 cm depth, it ranges from 8.02 – 7.12, at 60-90 cm depth, it ranges from 7.92-6.98, while at more than 90 cm depth it ranges from 7.82-6.01 mg kg^{-1} of soil. Out of 14 treatments , T_6 treatment *i.e,* 50 % NPK (F) + 50% N(FYM)+100 % NPK (F) recorded highest amount of saloid P content followed by T_8 , T_{10} and T_{14} at all layer of soil.

Significant increase in saloid –P in the present investigation might be as a result of inorganic and organic fertilization could also be attributed to the transformation of applied P into saloid P at the initial stages and later on to insoluble compounds of Al-P and Fe-P (Jain and Sarkar, 1979) similar results have also been reported by Jadhav *et al,* 2010.

4.5.2. Aluminum phosphorus (mg kg^{-1})

Vertical distribution of Al-P due to integrated use of organic and inorganic sources of fertilizers under sorghum – wheat cropping system was presented in table 29 and depicted in figure 12. Table revealed that Al-P was significantly affected by long term fertilization and was significantly decreased with depth of soil. In general Al-P ranged from 34.68 -216.91 mg kg^{-1}.

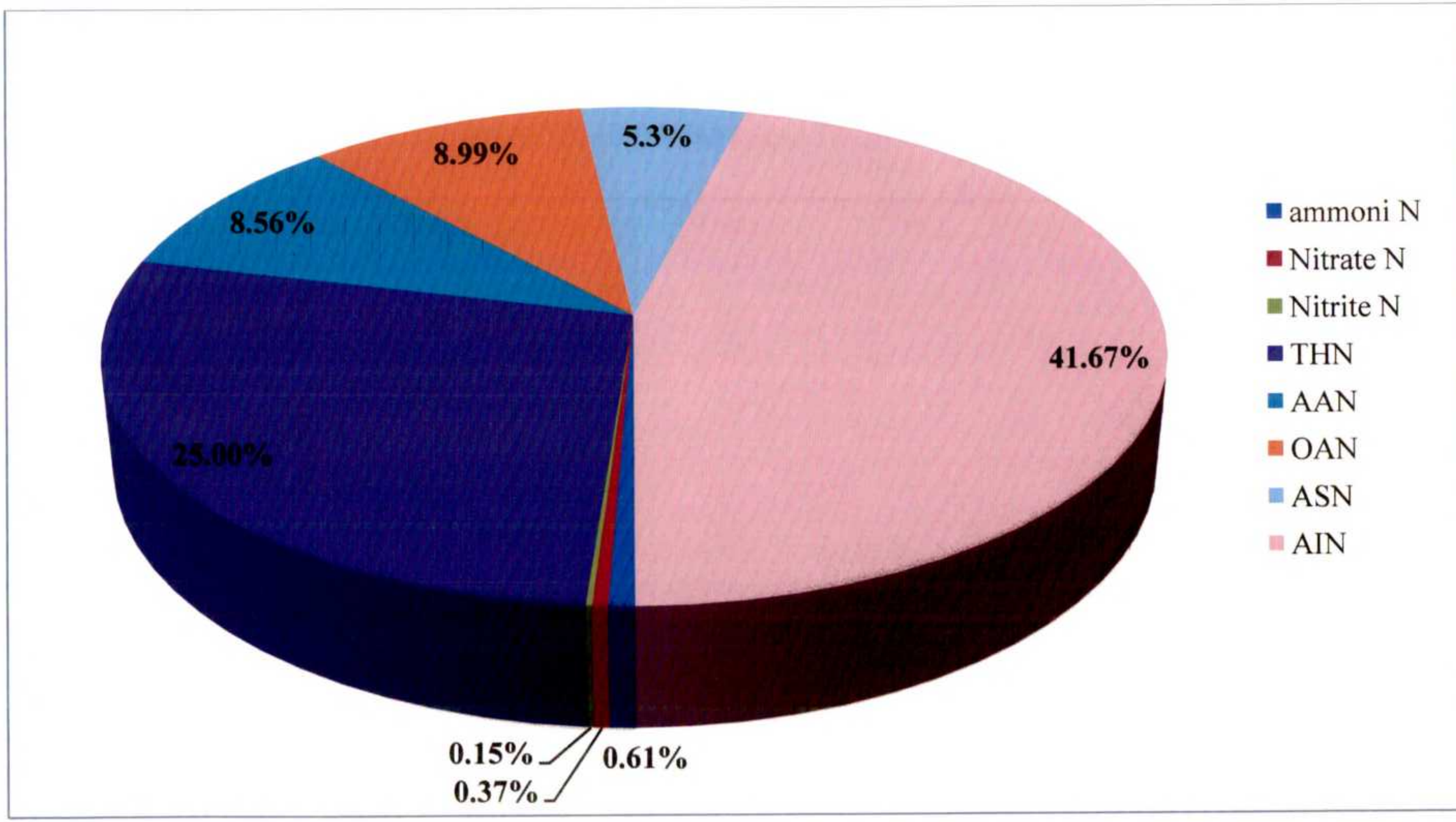


Fig 11. Per cent contribution of different N fractions to Total N at 0-30 cm depth of soil

Table 28: Effect of long term fertilization on vertical distribution of Saloid phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Saloid Phosphorus (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	7.21	7.12	6.98	6.61
T_2	50% NPK (F)	50% NPK (F)	7.34	7.25	7.11	6.96
T_3	50 % NPK (F)	100 % NPK (F)	7.49	7.41	7.30	7.15
T_4	75 % NPK (F)	100 % NPK (F)	7.62	7.51	7.39	7.25
T_5	100 % NPK (F)	100 % NPK (F)	7.73	7.66	7.56	7.43
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	8.09	8.02	7.92	7.82
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	8.05	7.97	7.85	7.76
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	8.04	7.96	7.85	7.76
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	8.03	7.94	7.82	7.71
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	8.02	7.93	7.82	7.73
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	7.99	7.91	7.82	7.70
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	7.42	7.31	7.20	7.02
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	7.71	7.70	7.68	7.55
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	7.91	7.84	7.79	7.65
Initial value			7.18			
S.E.±			0.014	1.099	0.013	0.059
C.D. at 5 %			0.041	NS	0.038	0.172
Grand mean			7.7657	7.6802	7.5788	7.4348

Table 29: Effect of long term fertilization on vertical distribution of Aluminum phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Aluminum Phosphorus (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	25.20	23.81	20.38	23.58
T_2	50% NPK (F)	50% NPK (F)	25.01	24.96	22.23	24.74
T_3	50 % NPK (F)	100 % NPK (F)	27.02	26.63	24.57	26.80
T_4	75 % NPK (F)	100 % NPK (F)	27.62	26.88	24.52	27.36
T_5	100 % NPK (F)	100 % NPK (F)	28.04	26.55	24.84	28.02
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	34.68	31.86	30.47	34.71
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	32.20	29.44	27.40	33.96
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	33.46	32.71	31.95	32.51
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	33.27	30.16	30.09	33.33
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	32.51	31.98	31.93	31.81
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	31.63	30.03	29.30	31.19
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	27.76	25.85	24.48	25.71
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	29.12	28.00	24.92	28.14
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	30.16	28.49	27.10	29.69
Initial value			23.80	-	-	-
S.E.±			12.432	1.69	2.30	0.62
C.D. at 5 %			NS	4.94	6.70	1.81
Grand mean			29.8883	28.38	26.72	29.39

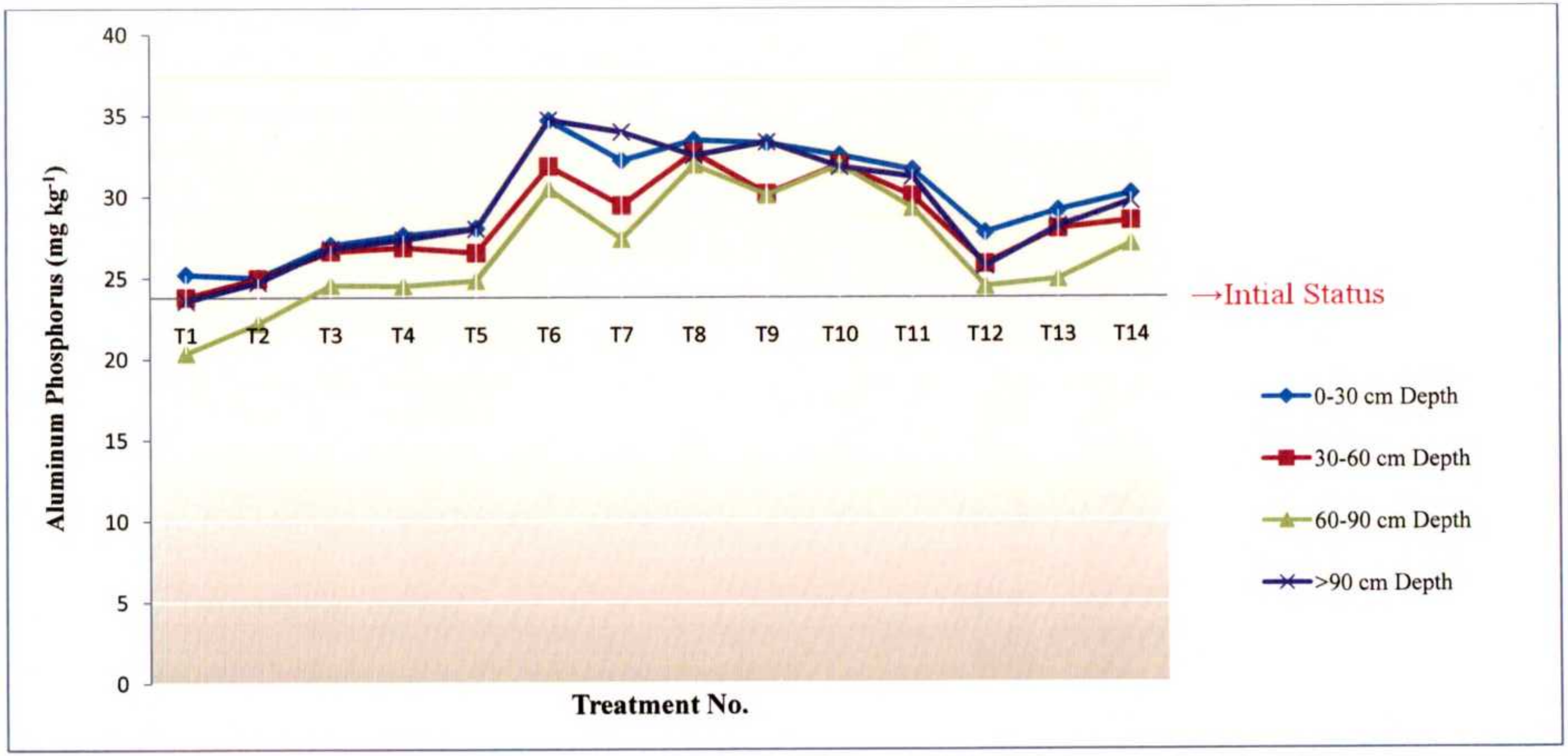


Fig.12. Effect of long term fertilization on vertical distribution of Aluminum phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

In surface soil *i.e.* at 0-30 cm depth, it was ranged from 34.68 – 25.01 mg kg^{-1} and decreased upto 16.91 mg kg^{-1} upto 90 cm depth. It was further observed that Al-P was increased over initial value of Al-P. This might be due to increase in Al-P with the application of organic manures and phosphatic fertilizers to growth media over from last 30 years.

Similar results were reported by Singh *et al,* (1979). The significant increase in Al-P as a result of inorganic fertilizations and organic amendments could be attributed to the transformation of applied P at a faster rate into Al-P in the first instance and then to Fe-P with time (Jain and Sarkar 1979). Sihag *et al,* (2005) reported highest amount of all the forms of P was recorded under farmyard manure followed by green manuring and press mud treatment. These findings are in accordance with the results obtained under this study.

4.5.3 Iron phosphorus (mg kg^{-1})

Effect of long term fertilization on vertical distribution of iron phosphorus of soil under sorghum wheat cropping system was presented in table 30. From that table it was revealed that long term impact of integrated nutrient management practices significantly affected iron phosphorus fraction of soil.

Iron phosphorus content ranged from 40.50 to 35.37 mg kg^{-1} of soil. Highest amount of iron phosphorus content was recorded at surface layer *i.e.,* 40.50 mg Kg^{-1} at T_6 treatment *i. e*, 50 % NPK (F) +50 %N(FYM) during Kharif + 100 % NPK 9(F) during rabi season while lowest amount of iron phosphorus was recorded at depth above 90 cm in T_1 treatment *i.e,* control in both the season. At 0-30 cm depth of soil, it was ranged from 40.50-35.62 mg kg^{-1} at depth 30-60 cm depth of soil, it was ranged from 40.52-35.56 mg kg^{-1} of soil, at depth 60-90 cm depth of soil it was ranged from 39.86 – 35.49 mg kg^{-1} of soil and at depth more than 90 cm, it was ranged from 39.05 -35.37 mg kg^{-1} of soil.

As highest amount of iron phosphorus content was recorded to the treatment receiving the conjunctive use of organic and inorganic fertilizer sources (T_6 to T_{10}). As the different organic materials contained 0.24 to 2.4% P, the increase in contents of different inorganic fractions due to mineralization of P from organic materials was expected and hence these was increase in iron P. Similar results were also reported by Sihag *et al* (2005).

Table 30: Effect of long term fertilization on vertical distribution of Iron phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Iron Phosphorus (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	35.62	35.56	35.49	35.37
T_2	50% NPK (F)	50% NPK (F)	36.07	36.03	35.95	35.83
T_3	50 % NPK (F)	100 % NPK (F)	36.74	36.75	36.66	36.54
T_4	75 % NPK (F)	100 % NPK (F)	37.24	37.22	37.17	37.04
T_5	100 % NPK (F)	100 % NPK (F)	37.59	37.56	37.50	37.38
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	40.50	40.52	39.78	39.05
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	39.44	39.39	39.88	38.80
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	40.04	39.67	39.60	37.22
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	39.44	39.39	39.31	35.85
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	40.27	38.90	38.71	38.71
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	38.79	38.76	38.14	38.62
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	36.29	36.99	36.24	36.19
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	37.97	37.96	37.66	36.89
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	40.11	38.39	37.86	37.77
Initial value			35.32	--	--	--
S.E.±			0.36	5.518	0.43	0.72
C.D. at 5 %			1.06	NS	1.25	2.10
Grand mean			38.33	38.085	37.78	37.23

4.5.4 Reductant phosphorus (mg kg^{-1})

Vertical distribution of reductant phosphorus (mg kg^{-1}) of soil under sorghum – wheat cropping system due conjunctive use of organic and inorganic was prosecuted in table 31. Highest amount of reductant phosphorus recorded at T_6 treatment i.e., 50 %NPK (F) + 50 % N (FYM) during Kharif season + 100 % NPK (F) during rabi season.

The higher content of reductant phosphorus in T_6 treatment was might be due to presence of high content of Fe_2O_3 , Al_2O_3 and clay Mandal (2007), lakshminarayana (2007). The close association of Al-P and F e-P with hydroxides of iron and aluminum might be due to the possible replacement of hydroxide groups from structural Al atoms and linkage of P with on exchange complex forming a clay - Ca –PO_4 or oxide –Ca-PO_4 type linkage (Rokima & Prasad 1991)

4.5.5 Occluded phosphorus (mg kg^{-1})

Occluded phosphorus was found to be decreased with depth of soil(Table 32 and depicted in figure 13). It was ranged from 5.85 – 8.26 mg kg^{-1} of soil. High amount of occluded phosphorus was recorded at treatment T_6 receiving 50% of NPK + 50% N through FYM during Kharif season and 100% NPK through inorganic fertilizers during rabi season.

While lowest amount of occluded Phosphorus was recorded at treatment T_1 receiving no fertilizers during both season. The highest content of occluded phosphorus to T_6 treatment might be attributed due to continuous addition of FYM and fertilizer. Occluded Phosphorus decreased down with depth of soil. Similar results reported by Singh and Omanwar (1987) and Dongale (1993). Dry environment at surface is conductive for its accumulation instead of prolonged moist condition prevailing in deeper layers.

4.5.6 Calcium phosphorus (mg kg^{-1})

Table 33 showed the effect of long term fertilization on vertical distribution of calcium phosphorus of soil under sorghum wheat cropping system and depicted in figure 14. From that table it was observed that calcium phosphorus was significantly affected by various treatment combinations and was ranged from 142-21 to 192.03 mg kg^{-1} of soil.

Table 31: Effect of long term fertilization on vertical distribution of Reductant phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Reductant Phosphorus (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	38.11	38.17	38.10	37.84
T_2	50% NPK (F)	50% NPK (F)	38.42	38.35	38.36	38.28
T_3	50 % NPK (F)	100 % NPK (F)	38.81	38.77	38.72	38.59
T_4	75 % NPK (F)	100 % NPK (F)	39.34	38.99	38.94	38.84
T_5	100 % NPK (F)	100 % NPK (F)	39.22	39.19	39.10	39.05
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	41.06	40.37	40.31	40.25
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	40.04	39.98	39.92	39.85
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	39.88	39.82	39.77	39.67
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	39.77	39.75	39.67	39.56
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	39.67	39.65	39.56	39.48
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	39.62	39.59	39.53	39.45
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	38.63	38.62	38.56	38.50
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	39.41	39.35	39.30	38.21
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	39.54	39.50	39.41	39.34
Initial value			37.98	-	-	-
S.E.±			0.199	0.035	0.029	0.271
C.D. at 5 %			0.579	0.102	0.083	0.788
Grand mean			39.393	39.291	39.2326	39.0650

Table 32: Effect of long term fertilization on vertical distribution of Occluded phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Occluded Phosphorus(mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	6.33	6.24	6.06	5.88
T_2	50% NPK (F)	50% NPK (F)	6.52	6.44	6.29	6.13
T_3	50 % NPK (F)	100 % NPK (F)	6.91	6.83	6.69	6.53
T_4	75 % NPK (F)	100 % NPK (F)	7.08	6.98	6.84	6.68
T_5	100 % NPK (F)	100 % NPK (F)	7.34	7.25	7.16	7.02
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	8.32	8.26	8.19	8.06
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	7.87	7.04	7.92	7.79
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	7.89	7.83	7.79	7.58
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	7.83	7.83	7.71	7.40
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	7.82	7.73	7.58	7.67
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	7.79	7.71	7.56	7.41
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	6.74	6.63	6.50	6.31
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	7.59	7.48	7.49	7.27
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	8.05	7.58	7.46	7.28
Initial value			6.17	–	–	–
S.E.±			0.37	0.26	0.041	0.011
C.D. at 5 %			1.10	0.77	0.120	0.033
Grand mean			7.4376	7.3483	7.2319	7.0726

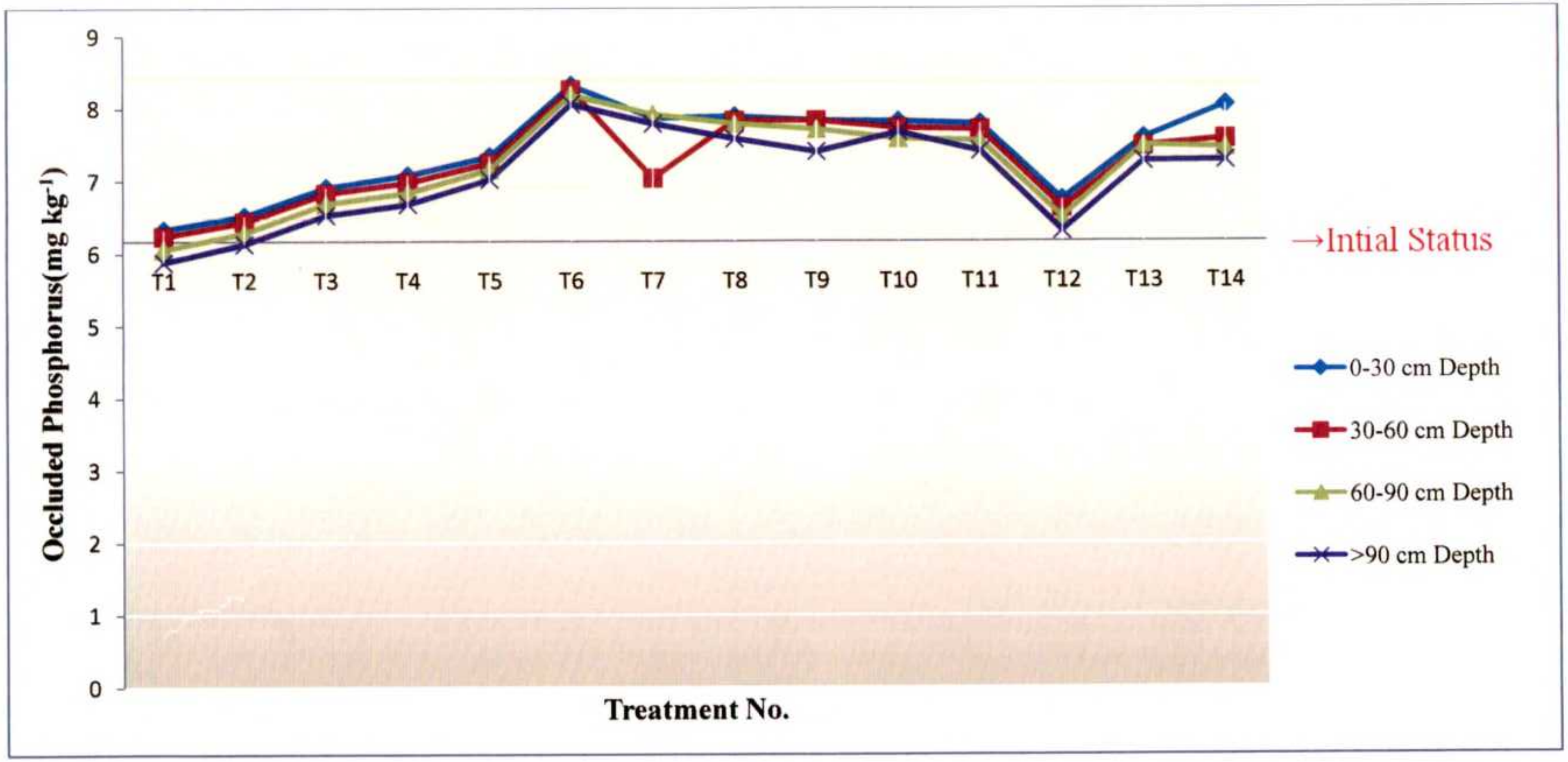


Fig. 13 Effect of long term fertilization on vertical distribution of Occluded phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

It was also seemed that calcium phosphorus increased with depth of soil. It seemed that highest amount of calcium phosphorus fractions was recorded in treatment T_6 *i. e,* treatment receiving 50 % NPK through inorganic fertilizer + 50 % N through FYM during Kharif and 100 % NPK through inorganic fertilizer during rabi season. Lowest amount of calcium phosphorus was noticed in the control plot. The Ca-P fraction was the major inorganic P fraction because calcareous soils are reported to retain larger amount of P as Ca-P, irrespective of nature and kind of added fertilizer due to the more stabilized nature of calcium system under high pH (Jaggi 1991). Similar results on inorganic P fractions in long term experiments in calcareous soil have also been reported by Dhillon and Dev.(1990) and Santhy *et al* (1998).

Ca-P fraction increased with depth of soil. This might be because; there was significant increase in $CaCO_3$ content in soil with depth. There might be positive relation with Ca-P traction which leads to increase in Ca-P fraction with depth. Further with the movement of soluble calcium bicarbonate, applied P might have been transformed to lower layers.

4.5.7 Organic phosphorus (mg kg^{-1})

The data on effect of long term fertilization on vertical distribution of organic phosphorus fraction are presented in Table 34 and depicted in figure 15. From that table, it was observed that organic phosphorus fraction was significantly affected by integrated use of organic and inorganic sources of fertilizers. Organic phosphorus fraction was ranged from 260.95 – 324.46 mg kg^{-1} of soil. It was also observed that organic phosphorus fraction was decreased with depth of soil. At 0-30 cm depth of soil, it ranged from 283.21 -324.46 mg kg^{-1}, 278.47- 321.83 mg kg^{-1} at 30-60 cm depth. At 60-90 cm depth it was range from 271.72 -317.26 mg kg^{-1} while at depth more than 90 cm; it was ranged from 260.95 -310.54 mg kg^{-1} of soil.

Highest amount of organic phosphorus fraction was observed in T_6 treatment *i.e,* 50 % NPK through inorganic fertilizer +50 % N through FYM during Kharif and 100 % NPK through inorganic fertilizers during rabi season while lowest amount recorded at T_1. The maximum value of organic phosphorus fraction might be due to the highest amount of organic matter. Build up of organic P follows the trend of organic matter build up in the soil, which largely depends on the nature of vegetation. Similar results observed by Frost and Edinger (1991), Singh *et al.* (1993), Mujumdar *et al* (2004).

Table 33: Effect of long term fertilization on vertical distribution of Calcium phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Calcium Phosphorus (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	142.21	153.10	159.40	162.38
T_2	50% NPK (F)	50% NPK (F)	144.23	154.45	162.21	165.33
T_3	50 % NPK (F)	100 % NPK (F)	151.80	159.08	166.32	168.68
T_4	75 % NPK (F)	100 % NPK (F)	154.37	160.98	168.05	172.26
T_5	100 % NPK (F)	100 % NPK (F)	156.68	164.78	169.87	173.73
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	181.78	184.09	189.89	192.03
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	174.89	180.39	185.49	188.58
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	180.19	180.30	181.96	191.37
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	166.52	173.29	179.24	186.53
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	175.87	176.80	178.11	184.36
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	162.91	170.54	176.76	180.46
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	147.37	155.66	163.90	167.98
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	157.74	165.31	171.89	175.88
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	161.60	169.09	174.88	179.44
Initial value			152.37	–	–	–
S.E.±			3.03	3.30	0.851	2.59
C.D. at 5 %			8.81	9.59	2.476	7.53
Grand mean			161.10	167.70	173.42	177.782

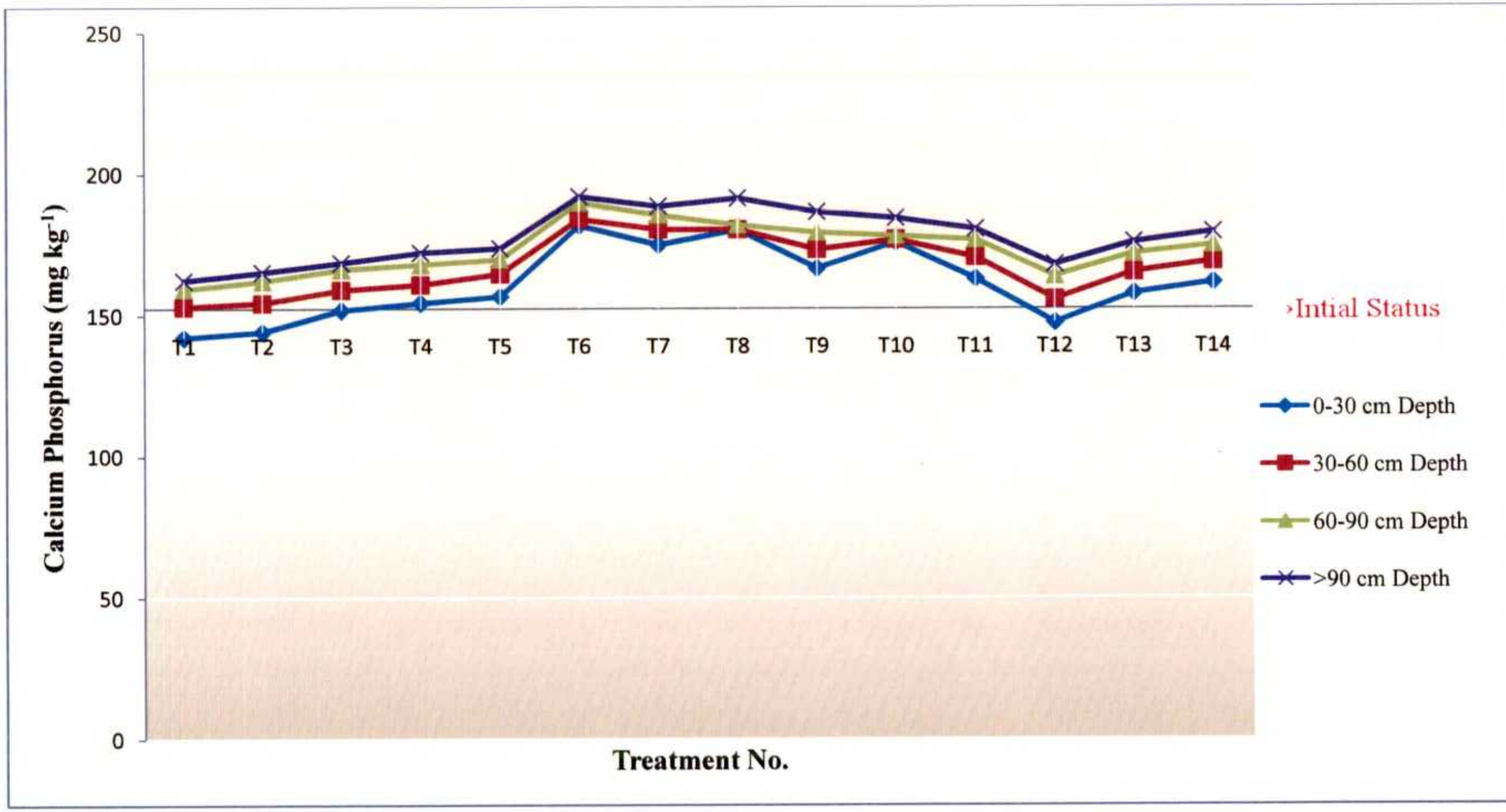


Fig. 14 Effect of long term fertilization on vertical distribution of Calcium phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Table 34: Effect of long term fertilization on vertical distribution of Organic phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Organic Phosphorus (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	283.21	278.47	271.72	260.95
T_2	50% NPK (F)	50% NPK (F)	287.19	282.33	274.83	265.69
T_3	50 % NPK (F)	100 % NPK (F)	297.18	292.30	286.33	276.72
T_4	75 % NPK (F)	100 % NPK (F)	300.12	297.57	291.47	283.98
T_5	100 % NPK (F)	100 % NPK (F)	304.08	302.09	293.89	282.75
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	321.13	318.50	317.26	310.54
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	318.97	314.53	310.02	303.49
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	316.40	313.81	309.06	304.24
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	315.62	313.60	307.62	302.36
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	313.99	310.46	305.62	298.30
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	311.14	307.34	301.59	297.66
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	293.84	288.12	281.57	273.95
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	306.91	301.66	293.23	283.53
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	309.27	304.41	298.73	291.82
Initial value			282.16	--	--	--
S.E.±			0.088	0.921	0.718	1.102
C.D. at 5 %			0.257	2.678	2.088	3.205
Grand mean			305.64	301.79	295.92	288.28

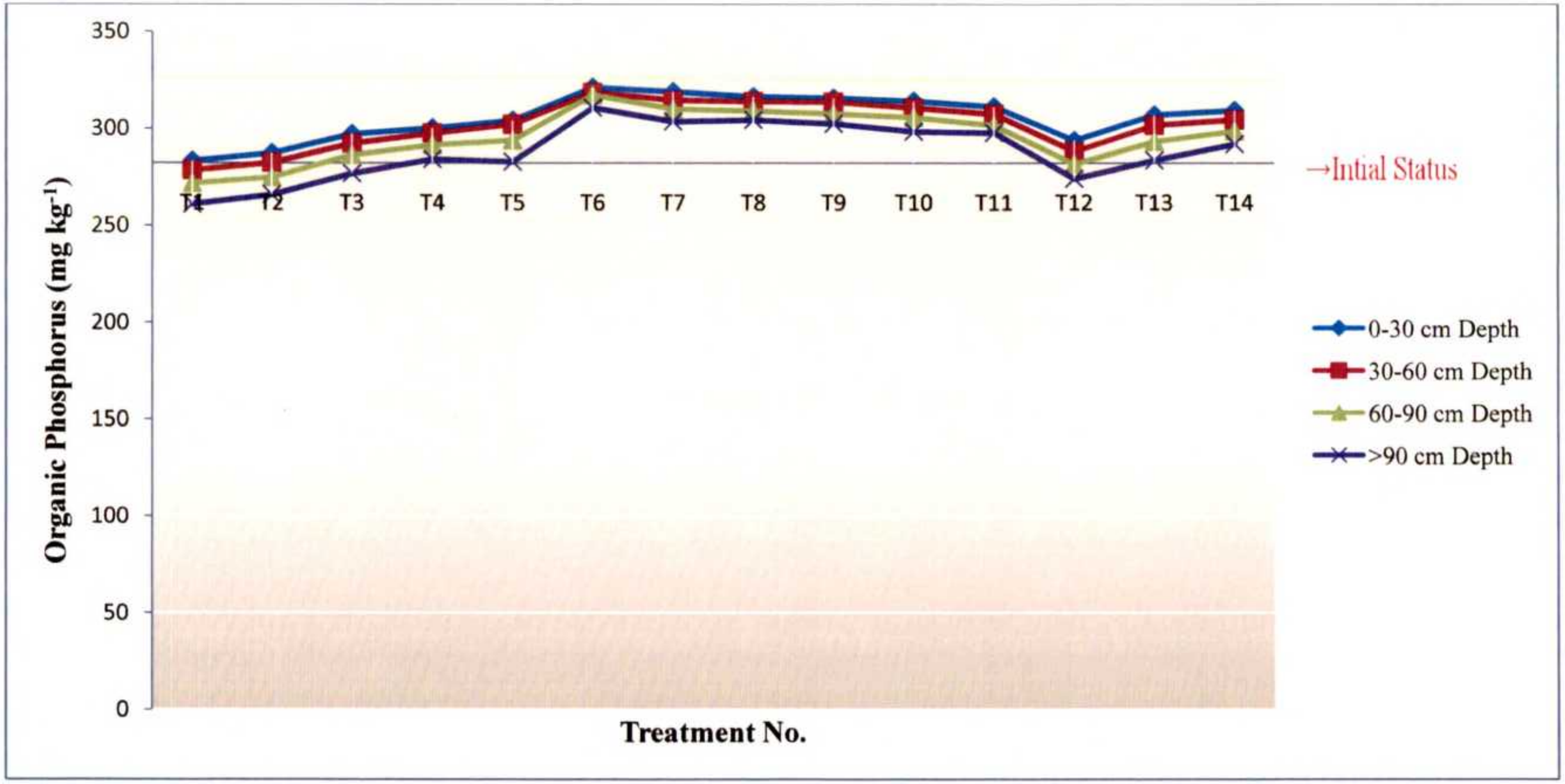


Fig. 15 Effect of long term fertilization on vertical distribution of Organic phosphorus (mg kg^{-1}) of soil under sorghum-wheat cropping system

Table 35: Effect of long term fertilization on vertical distribution on total P(mg kg^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Total P (mg kg^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	558.05	548.77	535.16	512.44
T_2	50% NPK (F)	50% NPK (F)	565.89	557.55	541.88	521.86
T_3	50 % NPK (F)	100 % NPK (F)	582.83	575.34	561.68	544.13
T_4	75 % NPK (F)	100 % NPK (F)	591.16	583.87	570.32	555.53
T_5	100 % NPK (F)	100 % NPK (F)	597.72	591.84	578.17	558.34
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	645.80	640.41	633.02	623.55
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	635.89	630.06	620.05	607.52
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	631.78	624.39	615.12	605.69
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	627.60	620.90	608.05	595.47
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	622.11	614.14	603.16	588.69
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	618.30	610.06	597.67	585.54
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	578.66	567.41	551.55	535.06
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	604.03	595.86	580.63	561.75
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	611.44	603.27	591.41	574.06
Initial value			551.45	-	-	-
S.E.±			1.072	1.188	1.030	1.572
C.D. at 5 %			3.116	3.455	2.994	4.570
Grand mean			605.09	597.41	584.84	569.25

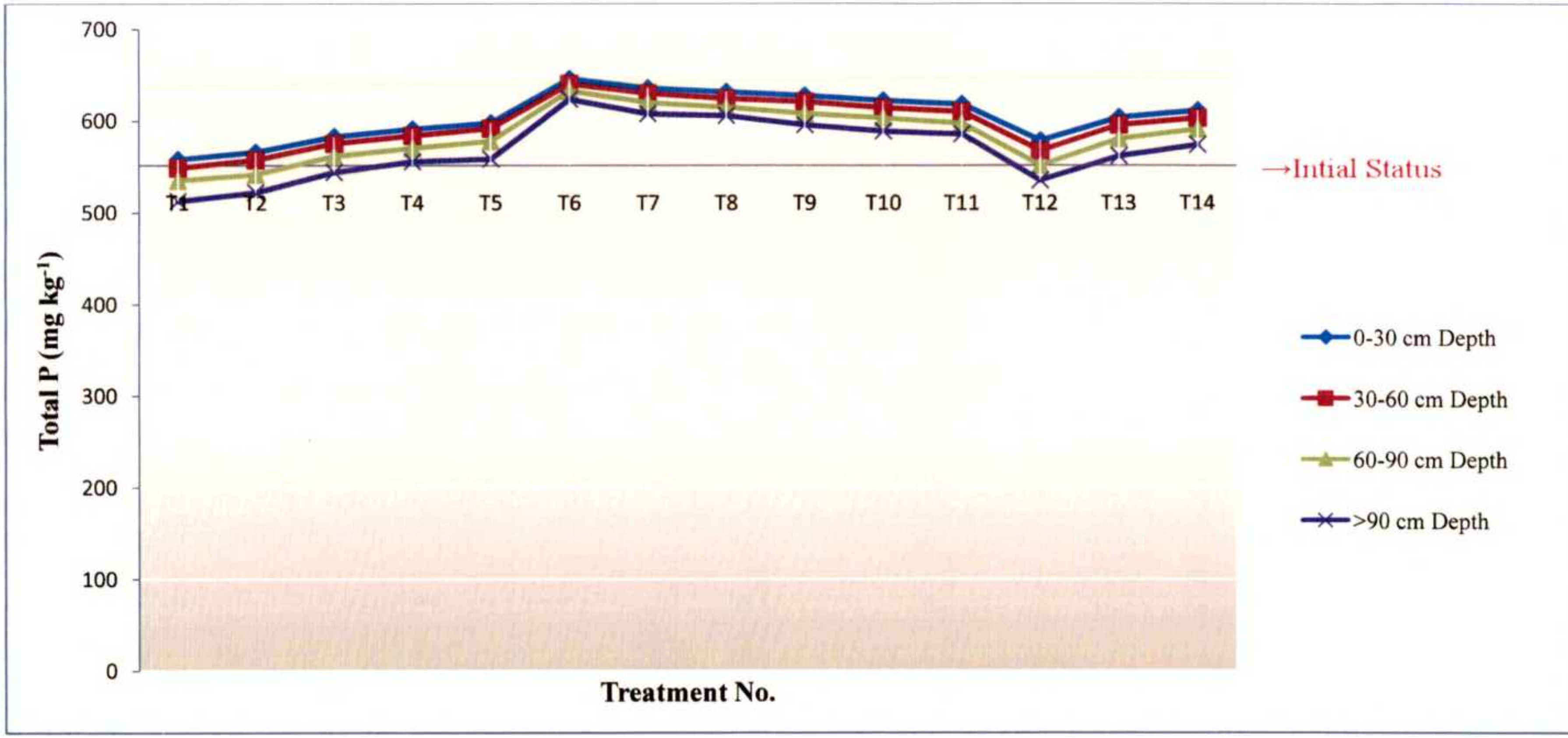


Fig. 16. Effect of long term fertilization on vertical distribution on total P (mg kg^{-1}) of soil under sorghum-wheat cropping system

4.5.8. Total P(mg kg^{-1})

Effect of chemical fertilizers and organic manures on the vertical distribution of total phosphorus fraction under sorghum-wheat cropping sequence was presented in Table 35 and depicted in figure 16. Total phosphorus content ranged from 512.44 – 645.80 mg kg^{-1} of soil. This content decreased with depth of soil.

Maximum amount of total phosphorus fraction was observed in treatment T_6 *i.e.,* 50 % NPK through inorganic fertilizers + 50 % N through FYM during kharif season and 100% NPK through inorganic fertilizer during rabi season while minimum amount of total phosphorus fraction was recorded at T_1 *i. e.,* control. The low content of total phosphorus at deeper layer might be attributed to decreasing trend of organic carbon in the soil layer. In all treatments total phosphorus was higher in surface layer and the same decreased down the depth.

The decreased in total phosphorus content might be due to decreased in organic matter content down the soil depth. Similar results were also reported by Viswanatha and Doddamani (1991) and Dongale (1993). The highest content of total P in T_7 treatment and at surface layers might be attributed to continuous addition of manure and fertilizer in this layer.

4.5.9. Percent contribution of various phosphorus fractions to total phosphorus

During the present investigation, mean percentage contribution of different P fractions to total P at 0 – 30 cm depth of soil due to various combinations of organic and inorganic fertilizer under long term fertilization experiment has been studied and depicted in figure 17. It showed that, there was higher contribution of organic P which contributed 50.51% to total P where and lower contribution was by occluded P which constituted 1.22% to total P.

4.6. Effect of long term fertilization on biological parameters

4.6.1. Bacterial population

The data presented in Table 36 showed that vertical distribution on bacterial count due to effect of long term fertilization under sorghum wheat cropping sequence. From that table, it was clear that, bacterial count was significantly affected by integrated nutrient management treatments. Bacterial count was found to be decreased down with depth. Bacterial count was ranged from 161.31 – 271.67 (CFU x 10^7 g^{-1} soil).

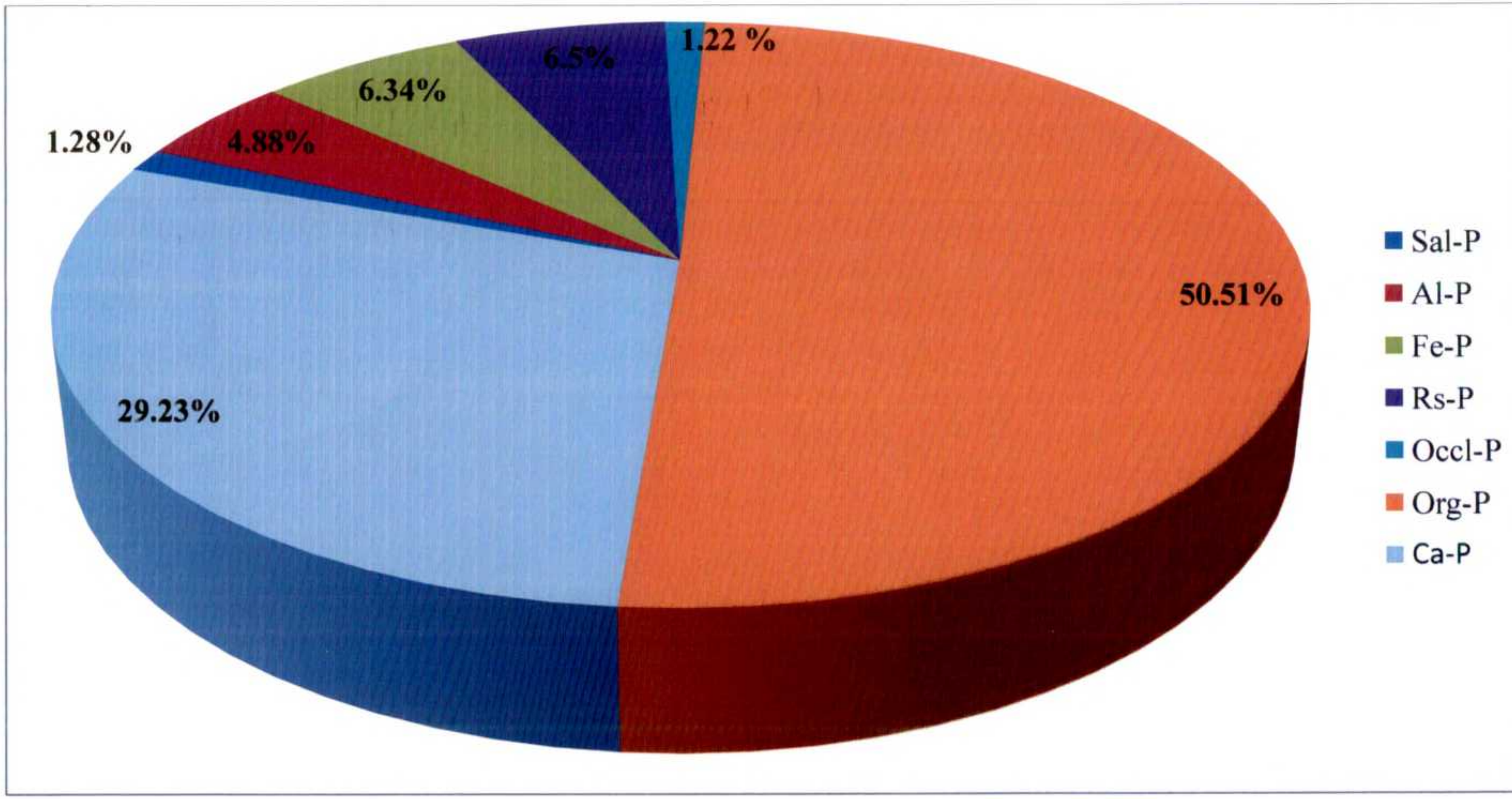


Fig 17. Per cent contribution of different P fractions to Total P at 0-30 cm depth of soil.

Table 36: Effect of long term fertilization on vertical distribution of Bacterial count (CFU x 10^7 g^{-1} soil) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Bacterial count (CFU x 10^7 g^{-1} soil)			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	182.79	177.19	170.29	161.31
T_2	50% NPK (F)	50% NPK (F)	191.68	187.19	180.21	171.82
T_3	50 % NPK (F)	100 % NPK (F)	210.92	204.18	197.19	188.87
T_4	75 % NPK (F)	100 % NPK (F)	218.61	214.17	207.09	198.81
T_5	100 % NPK (F)	100 % NPK (F)	225.63	221.13	215.81	206.17
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	271.67	268.11	265.01	258.71
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	266.47	263.41	258.17	251.81
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	261.17	258.13	252.84	245.19
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	256.31	253.21	247.37	241.82
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	250.83	246.23	240.51	232.14
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	244.92	240.12	234.51	228.01
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	199.39	195.17	188.91	179.13
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	231.44	227.11	220.81	211.18
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	237.96	233.12	226.81	217.14
Initial value			180.34	-	-	-
S.E.±			0.16	0.25	0.26	0.22
C.D. at 5 %			0.47	0.71	0.75	0.63
Grand mean			232.12	227.74	221.82	213.72

Maximum count was recorded at treatment T_6 (50 % NPK through inorganic fertilizer + 50 % N through FYM to sorghum + 100 % NPK through inorganic fertilizer to wheat) in 0-30 cm and 30-60. Due to use of organic manure along with inorganic fertilizers, there might be increase in bacterial count. Soil organic manure introduces a high amount of useful microorganism and phytoharmones into the soil.

There changes improves the water and air relationship in the soil. Thus intensifying mineralization processes and increasing the count and enzymatic activity of soil microorganisms similar results were obtained by Mandal *et al.* (2007) and Zhong *et al.* (2010)

According to Selvi *et al.*(2004) in long-term fertilizer experiment conjoint use of NPK + FYM or FYM alone improved the bacterial population as compared to fungi and actinomycetes in Inceptisol. Recently, Arbad and Syed Ismail (2011) in long term fertilizer experiment recorded significantly maximum bacterial population with 100% NPK + FYM. Inorganic treatments showed lower bacterial count as compared to plot treated with organic sources.

4.6.2 Fungal population

From Table 37 it was clear that fungi count was significantly influenced by various integrated nutrient management treatments and was decreased with depth. It was varied from 2.07 – 24.04 CFU x 10^4 g^{-1} soil at various depth of soil. In 0-30 cm depth, it was ranged from 11.98 -24.04 CFU x 10^4 g^{-1} soil, while at 30-60 cm depth, it was ranged from 7.98 – 22.83 CFU x 10^4 g^{-1} soil, in 60-90 cm depth, it was ranged from 5.01- 20.94 CFU x 10^4 g^{-1} soil and at > 90 cm depth it was varied between 2.07 – 17.83 CFU x 10^4 g^{-1} soil. Maximum count was recorded at treatment T_6 (50 % NPK through inorganic fertilizer + 50 % N through FYM during kharif + 100 % NPK through inorganic·fertilizer during rabi season) while lowest count was recorded at treatment T_1(control). Fungi Count was found to be increased with application inorganic fertilizer with organic one.

This might be due to solid manure showed the highest stimulating effect on soil fungi development as well as opposed to the other groups or microorganisms, soil fungi were also found highly stimulated by the high nitrogen rate and organic manure.

Table 37: Effect of long term fertilization on vertical distribution of Fungi count (CFU x 10^4 g^{-1} soil) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Fungi count (CFU x 10^4 g^{-1} soil)			
	Kharif	Rabbi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	11.98	7.98	5.01	2.07
T_2	50% NPK (F)	50% NPK (F)	12.23	9.03	6.15	3.18
T_3	50 % NPK (F)	100 % NPK (F)	13.39	10.10	8.83	7.95
T_4	75 % NPK (F)	100 % NPK (F)	15.41	12.92	10.84	9.03
T_5	100 % NPK (F)	100 % NPK (F)	16.51	13.86	12.26	9.93
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	24.047	22.83	20.94	17.83
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	23.27	22.04	20.94	17.83
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	22.17	21.85	18.91	14.73
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	20.97	19.63	17.66	13.62
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	20.12	18.03	15.94	12.18
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	19.21	16.98	14.85	11.85
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	12.81	10.83	8.44	5.47
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	17.23	14.93	13.07	10.19
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	18.01	16.02	13.96	10.92
Initial value			7.65	_	_	_
S.E.±			0.275	1.149	0.972	4.052
C.D. at 5 %			0.800	3.340	2.825	11.781
Grand mean			17.67	15.50	13.33	10.31

Similar results were reported by Mandic *et al.* (2011). Sharma *et al.* (2000) also noticed that the microbial population (viz, bacteria and fungi) in soil was high in FYM-treated plots followed by co-incorporation of crop residues while lowest number of these micro-organism were recorded in only chemical fertilizer-treated plots. The increase in microbial population in soil might be due to greater availability of organic carbon and mineralized nutrients for their proliferation and development.

4.6.3 Actinomycetes population

The data presented in table 38 showed fertilization on vertical distribution of actinomycetes count under sorghum wheat cropping sequence. From that table it was seemed that actinomycetes count was beneficially and significantly affected due to integrated nutrient management treatments.

The increased population of actinomycetes was found in the treatment receiving organic + inorganic fertilizer. Which may be attributed to decomposition of organic matter when added to the soil. It indicates that, the judicious use of organic manures and fertilizers is essential to maintain soil flora for sustainable agriculture. The similar findings were reported by Sharma *et al.* (2009), Malewar *et al.* (1999), Chesti and Tahir Ali (2012) and Singh and Dhar (2012).

It was ranged from 29.5 – 33.68 (CFU x 10^6 g^{-1} soil) at various depth of soil. Actinomycetes count also found to be decreased with depth. 30.68 – 33.68 (CFU x 10^6 g^{-1} soil) range observed in 0 - 30 cm depth, 30.45 – 33.32 (CFU x 10^6 g^{-1} soil) range observed in 30-60 cm depth, 29.97 – 33.08 (CFU x 10^6 g^{-1} soil) range observed in 60-90 depth 29.53 – 32.53 (CFU x 10^6 g^{-1} soil) range observed in more than 90 cm depth of soil. Maximum count was observed at T_6 treatment (50 % NPK through inorganic fertilizer + 50 % N through FYM during kharif + 100 % NPK through inorganic fertilizer during rabi season) *i,e,* 33.68 (CFU x 10^6 g^{-1} soil) while minimum count was observed at T_1 treatment (control.) *i.e* 29.53 (CFU x 10^6 g^{-1} soil) in above 90 cm soil depth.

Maximum count in treatment T_6 recorded might be due to beneficial effect of integrated use of N with organic amendments was more pronounced and effective in enhancing the productivity. This could be due to other benefits of organics apart from N supply, such as improvement in microbial activities better supply of macro and micronutrients such as S, Zn Cu and B which are not supplied by mineral fertilizers and less losses of nutrients from the soil (Yadav *et al.* 2000).

Table 38: Effect of long term fertilization on vertical distribution on actinomycetes count (CFU x 10^6 g^{-1} soil) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		Actinomycetes count (CFU x 10^6 g^{-1} soil)			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	30.68	30.45	29.97	29.53
T_2	50% NPK (F)	50% NPK (F)	30.95	30.64	30.41	29.87
T_3	50 % NPK (F)	100 % NPK (F)	31.68	31.47	31.34	30.56
T_4	75 % NPK (F)	100 % NPK (F)	31.95	31.78	31.58	30.88
T_5	100 % NPK (F)	100 % NPK (F)	32.36	32.16	31.35	31.43
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	33.68	33.82	32.80	32.53
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	33.57	33.32	33.08	32.36
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	33.51	33.19	32.94	32.27
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	33.30	33.08	32.60	32.27
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	33.14	32.77	32.17	31.39
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	32.85	32.61	32.10	31.14
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	31.28	31.04	30.04	29.69
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	32.42	32.03	32.07	30.11
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	32.66	32.36	31.67	31.54
Initial value			30.52	-	-	-
S.E.±			0.88	0.41	0.97	1.49
C.D. at 5 %			2.57	1.19	2.83	4.33
Grand mean			32.43	32.15	31.80	31.14

4.6.4 Soil microbial biomass carbon (μg g^{-1} soil)

The results obtained from this study indicated that the microbial biomass carbon content of soil was significantly and beneficially influenced by the treatment of integrated nutrient supply, which involve combined application of inorganic and organic sources as compared to control and recommended dose or fertilizers (Table 39). Soil microbial biomass carbon ranged from 124.17 – 372.43 μg g^{-1} soil of soil at different depth. It was also observed that microbial biomass carbon decreased down with depth of soil. Highest amount of microbial biomass carbon was recorded at treatment T_6 *i.e,* 50 % NPK through inorganic fertilizers + 50 % N through FYM during kharif season and 100 % NPK through inorganic fertilizer during rabi season followed by treatment T_7, T_8 and T_9. While lowest amount was recorded at to treatment T_1 *i.e,* control during both season. Such an increase in microbial population due to integrated nutrient management treatments with both organic and inorganic sources led to the higher SMBC in soil. Increase in microbial biomass carbon might be due to the added effect of organic sources that led to increase in microbial population in soil. Addition of FYM and chemical fertilizers together in balanced form provides favorable C: N ratio for higher activity of microbes in integrated treatments.

These results were in conformity with Mandal *et al.* (2007) and Padmavathi *et al.* (2012). Patil and Puranik (2001) also noticed that the FYM, wheat straw and green manuring application in soybean-wheat increased the soil microbial biomass carbon over control. While, Selvi *et al.*(2004) in long-term fertilizer experiment found gradual increase in biomass C of the soil with the graded levels of NPK from 50% to 150%. Application of 100% NPK +FYM was having significantly highest biomass C followed by 150% NPK application in Inceptisol.

Recently, Suresh *et al.* (2012) noted that application of full dose of organic nutrients coupled with incorporation of previous crop residues to both the crops in the system resulted in highest soil microbial biomass carbon (426 μg g^{-1} soil). This was closely followed by incorporation of crop residues to safflower only and other treatments consisting part of substitution of RDF with FYM in Vertisol.

Table 39: Effect of long term fertilization on vertical distribution of Soil microbial biomass carbon (µg g^{-1} soil) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		SMBC (µg g^{-1} soil)			
	Kharif	Rabbi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	159.04	148.72	134.53	124.17
T_2	50% NPK (F)	50% NPK (F)	173.54	165.32	153.22	139.38
T_3	50 % NPK (F)	100 % NPK (F)	202.27	192.95	183.74	172.22
T_4	75 % NPK (F)	100 % NPK (F)	217.64	212.00	202.98	189.67
T_5	100 % NPK (F)	100 % NPK (F)	232.79	227.58	217.88	209.13
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	372.43	365.37	359.07	348.06
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	367.83	360.57	355.64	345.41
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	352.17	344.80	332.18	320.63
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	339.89	332.45	322.60	313.08
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	307.07	301.97	287.95	276.45
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	270.20	265.08	257.45	242.90
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	189.83	181.68	179.76	164.80
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	243.19	236.09	226.58	213.72
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	255.84	248.70	239.09	227.00
Initial value			138.91	_	_	_
S.E.±			0.977	1.081	1.013	0.990
C.D. at 5 %			2.841	3.144	2.945	2.878
Grand mean			263.12	255.94	246.62	234.75

4.6.5 Soil microbial biomass nitrogen (µg g^{-1} soil)

The distribution of soil microbial biomass nitrogen µg g^{-1} in soil profile under integrated nutrient management was presented in table 40. The SMBN varied from 28.82 – 70.48 µg g^{-1} and showed that SMBN decrease with depth of soil.

The maximum amount of SMBN was recorded at T_6 treatment *i, e.* 50 % NPK through inorganic fertilizers + 50 % N through RYM during kharif season and 100 % NPK through inorganic fertilizers during rabi season followed by T_7. While lowest amount of SMBN recorded at treatment T_1 *i.e,* control during both season.

The highest value of SMBN was obtained due to use of organic source of fertilizers. This might be attributed to stimulated suitable conditions for microbial growth where development had acted as a good substratum for microbial activity. Thakare and Ravakar (2005) also observed high values of SMBC, SMBN in NPK+GYM treated plot followed by NPK, PN, N and control in vertisol. This might be due to improvement of water soluble fraction in this treatment. The increase in microbial population due to integrated treatments with both organic and inorganic sources led to the higher SMBN in soil. Similar results obtained Gogoi *et al.* (2010) and Padmavathi *et al.* (2012).

4.6.6 Releasable CO_2 (mg 100 g^{-1} soil 24 hr^{-1})

Releasable CO_2 measurements found to be a good measure to study the decomposition rate of organic matter. In this study CO_2 evolution under various treatments were studied and reported in Table 41. Maximum CO_2 evolution was observed at T_7 treatment (50 % NPK through inorganic fertilizer + 50 % N through FYM during kharif + 100 % NPK through inorganic fertilizer during rabi season) *i, e,* 372.43 while minimum CO_2 evolution was observed at T_1 treatment (control.) *i.e,* 124.17 in more than 90 cm soil depth.

It is also indicative of the nutrient turn over at higher carbon expenses met through added organic carbon. Thus, the increased microbial biomass metabolically active could have resulted in increased soil respiration rate. Similar findings were also reported by Tiwari *et al.* (2000).

Table 40: Effect of long term fertilization on vertical distribution of SMBN (μg g^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		SMBN (μg g^{-1} of soil)			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	39.44	37.53	33.41	28.82
T_2	50% NPK (F)	50% NPK (F)	26.87	38.14	35.53	29.13
T_3	50 % NPK (F)	100 % NPK (F)	43.88	42.15	38.67	29.99
T_4	75 % NPK (F)	100 % NPK (F)	44.85	42.88	40.39	33.48
T_5	100 % NPK (F)	100 % NPK (F)	46.27	44.60	40.72	32.55
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	70.48	68.32	66.00	58.91
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	68.40	65.86	61.91	50.54
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	65.02	64.43	60.05	51.87
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	62.33	60.66	57.81	52.28
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	59.46	57.00	53.26	41.37
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	55.35	53.51	50.34	40.61
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	41.60	39.31	36.34	23.58
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	48.41	46.25	43.86	32.36
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	51.48	51.32	48.64	38.43
Initial value			38.95	-	-	-
S.E.±			3.483	0.761	0.816	1.120
C.D. at 5 %			10.126	2.213	2.372	3.255
Grand mean			51.70	50.85	47.63	38.85

Table 41: Effect of long term fertilization on vertical distribution of CO_2 releasable (mg 100 g^{-1} soil 24 hr^{-1}) of soil under sorghum-wheat cropping system

Tr. No.	Treatment Detail		CO_2 evolution (mg 100 g^{-1} soil 24 hr^{-1})			
	Kharif	Rabi	0-30 cm Depth	30-60 cm Depth	60-90 cm Depth	>90 cm Depth
T_1	Control	Control	39.67	38.38	36.26	33.56
T_2	50% NPK (F)	50% NPK (F)	44.79	43.30	41.13	38.80
T_3	50 % NPK (F)	100 % NPK (F)	53.28	51.99	50.09	47.67
T_4	75 % NPK (F)	100 % NPK (F)	56.92	55.72	53.45	50.14
T_5	100 % NPK (F)	100 % NPK (F)	59.37	58.18	56.63	54.26
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	77.91	76.19	73.92	70.57
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	77.47	74.13	72.76	70.78
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	74.11	73.29	71.96	70.42
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	69.81	68.83	67.51	65.71
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	68.36	66.80	64.82	62.79
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	65.99	64.68	63.19	61.68
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	63.07	48.26	45.90	43.44
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	61.38	59.46	57.23	54.79
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	64.33	63.10	61.79	59.29
Initial value			37.25	_	_	_
S.E.±			17.81	0.82	0.68	0.73
C.D. at 5 %			51.80	2.53	1.98	2.14
Grand mean			62.46	60.16	58.3	55.99

Malewar *et al.* (1999) also recorded that 50 per cent organics either in the form of FYM, wheat straw, green manure with subabul leaves in combination with fertilizers helped to increase releasable CO_2 under long-term fertilizer experiment in Vertisols. Suresh *et al.* (2012) noted maximum CO_2 evolution with the application of full dose of organic nutrients coupled with incorporation of previous crop residues and was closely followed by incorporation of crop residues to safflower only and other treatments consisting part of substitution of RDF with FYM over no residue treatment and no fertilizer treatment in Vertisol.

4.8 Effect of long term fertilization on grain and fooder/straw yield of sorghum, wheat

The data related to sorghum wheat grain and straw yield as influenced by different treatments are presented in Table 42 for the year 2011-12. Grain yield of sorghum was significantly highest in treatment T_6 (25.36 q ha^{-1}) receiving 50% NPK (F) + 50% N (FYM) closely followed by the treatment T_5 (24.83 q ha^{-1}) and these treatments were found to be at par with each other, whereas lowest values were recorded in treatment T_1 (2.52 q ha^{-1}) absolute control. The grain yield of wheat followed same trend.

In other set of treatment combinations of inorganic fertilizers with FYM, GM, WS and subabul leaves as a source of organic material further added to grain and straw yield of sorghum and wheat. Among organic sources, FYM followed by wheat straw have proved the superiority over other organic material and increasing the grain and straw yield by complementary effect on increased the availability and efficiency of inorganic fertilizers as well as release of inorganic forms of nutrients on its decomposition.

The higher yield by NPK with FYM application could be attributed to enhanced soil quality parameters particularly in the treatments receiving organic manures in combination with inorganic fertilization. Many researcher reported positive impact of INM over only organic or inorganic fertilization on soil quality and productivity. Billore and Joshi (2005) found that integrated nutrient management produce more yields as compare to recommended dose of fertilizers alone. Bayu *et al* (2006) also found that combined application of FYM and RDF increased the grain and straw yield of sorghum by 36% and 21% respectively

Table 42: Effect of long term fertilization on grain and fooder/straw yield of sorghum, wheat

Tr. No.	Treatment Detail		Yield (q/ha)			
			Sorghum		Wheat	
	Kharif	Rabi	Grain	Fodder	Grain	Fooder
T_1	Control	Control	2.52	4.53	2.87	4.35
T_2	50% NPK (F)	50% NPK (F)	17.2	36.30	16.86	25.62
T_3	50 % NPK (F)	100 % NPK (F)	18.04	38.79	18.61	29.58
T_4	75 % NPK (F)	100 % NPK (F)	20.47	46.05	20.56	31.87
T_5	100 % NPK (F)	100 % NPK (F)	24.83	55.13	24.69	39.62
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	25.36	54.71	25.12	38.93
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	21.79	48.38	22.36	35.09
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	20.94	46.49	20.94	33.79
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	18.28	40.58	18.80	30.27
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	23.79	52.81	24.07	38.04
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	16.62	36.89	17.14	27.58
T_{12}	FP (40:20:20 NPK & seed without seed treatments)	FP(60:30:30 NPK & 100 kg seed ha^{-1}	14.72	32.68	15.53	24.35
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	20.61	45.75	21.60	32.82
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	23.50	52.81	23.98	37.88
S.E.±			0.77	1.68	0.70	1.11
C.D. at 5 %			2.26	4.90	2.04	3.24
Grand mean			19.20	6.93	6.21	7.25

SUMMARY AND CONCLUSION

CHAPTER-V

SUMMARY AND CONCLUSION

The present investigation was carried out to study the "Effect of long term fertilization on carbon sequestration and soil quality under sorghum wheat cropping system". The long-term fertilizer experiment was initiated during 1983 on deep black soils of (Typic haplustert) survey No 124 of Parbhani block of central farm, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (MS). The soil of the experimental site was Vertisol, particularly montmorillonitic, hyperthermic family of *Typic Haplustert*. The experiment was laid out in randomized block design with fourteen treatments and three replications in sorghum wheat cropping system. The soil samples were collected after the harvest of wheat crop during 2012-2013 at 0-30 cm, 30-60 cm, 60 – 90 cm and more than 90 cm depth after excavating the soil profile in each treatment plot. These samples were analyzed for soil quality parameters *viz.* physical, chemical and biological properties. In addition to have in depth study of behavior of two important nutrients viz. N and P and their fractionation were results are presented in chapter IV. Further movement of N and P under the influence of set of treatments was also seen and interpreted in previous chapter.

The major findings emerged out of this study interpreted and discussed in previous chapter are summarized below.

Soil quality parameters : Physical

Physical properties of soil *viz.* bulk density, porosity, aggregate stability and maximum water holding capacity found to be significantly were influenced by the various treatments. Bulk density of soil was found to be significantly lowest in the plots receiving 50% NPK + 50 % N through FYM at 0-30 cm layer, while it showed the highest value in fallow treatment. However, the bulk density was higher under the treatments receiving only chemical fertilizers.

The porosity of soil showed considerable improvement under treatments of 50 % NPK + 50 % N through FYM (T_6) over the control at each soil layer. The significantly highest porosity of soil was recorded in the treatment where conjunctive use of chemical fertilizers with FYM was used.

Maximum water holding capacity of soil was noticed significantly highest in treatment T_6 receiving 50 % NPK + 50 % N through FYM in 0 -30 cm, 30 – 60 cm, 60 – 90 cm and more than 90 cm soil layer which was most nearly followed by treatments T_8 (50% NPK through inorganic + 50% N through WS to sorghum and 100% NPK through fertilizers to wheat) and T_{10} (50% NPK through inorganic + 50% N through GM to sorghum and 100% NPK through fertilizers to wheat) which were found to be at par with each other and lowest value was obtained in control treatment.

Aggregate stability of soil was higher in treatment T_6 receiving 50 % NPK + 50 % N through FYM followed by treatment T_7 which received 75% NPK + 25% N through FYM found to be at par with each other. Lowest value of aggregate stability was observed in control treatment.

Thus, it is inferred that soil quality parameters viz. bulk density, porosity, aggregate stability and water holding capacity were improved significantly due to combine use of organic and inorganic fertilization. Amongst all application of 50% NPK through inorganic fertilizers and 50% N through FYM to kharif sorghum and 100% NPK through fertilizers to Rabi wheat recorded significant improvement in soil quality in particular.

Soil chemical parameters : Chemical

Among the chemical properties soil pH was high in control and recorded increase when only chemical fertilizers were applied; soil pH was at lower magnitude under the treatment of NPK + Organic manures. EC was low in control and treatments receiving only chemical fertilizers. It was higher was in treatment receiving both sources of nutrients.

Significant increase in organic carbon and inorganic carbon was noticed over initial content. Treatments receiving chemical fertilizers along with organic sources had more organic carbon whereas low values were observed in absolute control (T_1). The highest inorganic carbon was observed in 100 % NPK (T_5) The conjoint use of chemical fertilizers with organic manures, found beneficial in maintaining organic carbon content compared to the use of only chemical fertilizers. Soil organic carbon pool also found to be improved. Soil organic carbon pool content was increased in plot receiving INM practices.

Calcium carbonate in soil was not affected significantly due to different nutrient management practices. Minimum $CaCO_3$ in soil was observed in NPK + Organic Manures and maximum was recorded in absolute control at each soil layers.

Available soil N was higher in treatment integration of NPK with organic sources. It was superior over chemical fertilizers applied plots. The balanced use of NPK fertilizers along with organics was found essential for augmenting N status in Vertisol under sorghum wheat cropping system.

There was progressive buildup of available P_2O_5 as compared to the initial value. Available P_2O_5 of soil was noticed significantly high in treatment T_6 receiving 50% NPK + 50% N through FYM and followed by T_8, T_{10} and T_{13} in all soil layers. These treatments were found to be at par with each other

There was increase in available K_2O as compared to the initial value of the experimental soil but not significantly. There was slight increase in availability of K_2O treatments in T_6

Soil Quality Parameters: Biological

Application of 50 % NPK through fertilizers and 50% N through FYM and other sources of organic manures proved better than only chemical fertilizers in increasing the population of bacteria, fungi and actinomycetes in all soil layers. The continuous use of only chemical fertilizers recorded lower microbial count as compared to the integrated use of organics with chemical fertilizers.

The soil microbial biomass carbon (SMBC) and nitrogen (SMBN) was significantly increased under integrated use of organic and inorganic sources of fertilizers. All the sources of organics were found equally beneficial in improving soil microbial biomass carbon and nitrogen. In respect of soil respiration for evaluation of soil biological activity and extent of organic matter decomposition. Profound influence of long-term fertilizer management treatment was found on soil respiration over chemical fertilizer treatments during both the years.

Nitrogen and Phosphorus fractions

Ammonium nitrogen, nitrate nitrogen, nitrite nitrogen, total hydrolysable nitrogen, amino acid nitrogen, organic ammonium nitrogen, amino sugar nitrogen and acid insoluble nitrogen in soil were significantly influenced and were maximum under T_6 treated with 50 % NPK+50 % N through FYM mostly followed by treatment T_8, T_{10} and T_{14} which were at par with each other.

Saloid phosphorus, aluminium phosphorus, iron phosphorus, reductant soluble phosphorus, occluded phosphorus, calcium phosphorus, organic phosphorus tends to be higher in integrated nutrient management treatments as compared to other treatments.

Movement and buildup of nitrogen and phosphorus

The 30 years cumulative effect of inorganic fertilization + organic manuring (50% NPK through fertilizers and 50% N either through FYM, WS, GM and subabul leaves) added more nitrogen to the tune of 551.36 kg ha^{-1}.

The lowest amount of available nitrogen moved downward by treatments under farmers practice. Highest available N was moved from surface to subsurface (12.31 to 154.03 kg ha^{-1}) layers when soil receiving 50% NPK through fertilizers + 50% N through organic manures for kharif sorghum crop and 100% N through fertilizer for rabi wheat crop. Similar trend was recorded with respect to buildup and movement of available P_2O_5, total P and total N.

Crop yield

The application of 50% N through FYM along with 50% NPK through fertilizer was found to be superior among all the treatments. The higher yields of sorghum and wheat crop were recorded under integrated nutrient management as compared to only chemical fertilizers. The significantly low sorghum and wheat yields were produced by unfertilized treatment (T_1) as compared to NPK through only inorganic. Application of 50% NPK through organic manures and 50% N through FYM or other manures indicated the soil fertility buildup. The declined soil quality parameters in control, farmers practice was due to exhaustive sorghum wheat cropping system.

CONCLUSIONS

From the summarized results following conclusions drawn are;

1) Build up of soil organic carbon pool was found due to application of either 50% N or 75% N through fertilizers and remaining through organic manure.
2) Application of 50% N through farm yard manure along with 50% NPK through chemical fertilizers over a long term period found to be beneficial in

improving the physical, chemical and biological properties of soil resulting into enhancement in soil quality as well as increased nutrient content, under sorghum wheat cropping system in Vertisol.

3) Available N, Available P_2O_5, total N and total P buildup and even movement of there nutrients was more in soil over 30 years of application of nutrients through organic manures in combination with inorganic fertilizers.
4) Long term manuring and fertilization registered significant increase in total N and all the fractions of N i.e. ammonium nitrogen, nitrate nitrogen, nitrite nitrogen, total hydrolysable nitrogen, amino acid nitrogen, organic ammonium nitrogen, amino sugar nitrogen and acid insoluble nitrogen of soil.
5) Total P and all the fractions of P *viz.* Saloid phosphorus, aluminium phosphorus, iron phosphorus, reductant soluble phosphorus, occluded phosphorus, calcium phosphorus, organic phosphorus evaluated showed an appreciable build up under recommended dose of fertilizer along with organic fertilizers.

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ANNEXURE

All India Coordinated Research Project
On
Long -Term Fertilizer Experiments To Study Changes In Soil Quality, Crop Productivity And Sustainability

MISSION

Soil Fertility Management through Integrated Plant Nutrient Supply for Enhancing and Sustaining Crop Production and Maintaining Soil Quality

MANDATE

_ To conduct coordinated long term fertilizer experiments in different soil types under diversified cropping systems

_ To collate information on long term soil fertility trials.

OBJECTIVES

1. To study the effect of continuous application of plant nutrients, singly an in combination, in organic and inorganic forms including secondary and micronutrient elements (as per the need) on crop yield, nutrient composition and uptake in multiple cropping systems

2. To work out the amount of nutrient removal by the crops

3. To monitor the changes in soil properties as a result of continuous manuring and cropping with respect to the physical, chemical and microbiological characteristics of the soil in relation to its productivity

4. To investigate the effect of intensive use of biocidal chemicals (weedicides and pesticides) on the build up of residues and soil productivity

5. To make an assessment of the incidence of soil borne diseases and changes in pests and pathogens under the proposed manuring and cropping programme.

10 TREATMENTS IN EACH EXPERIMENT

T_1 50% optimal NPK dose

T_2 100% optimal NPK dose

T_3 150% optimal NPK dose

T_4 100% optimal NPK dose + hand weeding

T_5 100% optimal NPK dose + Zinc or lime

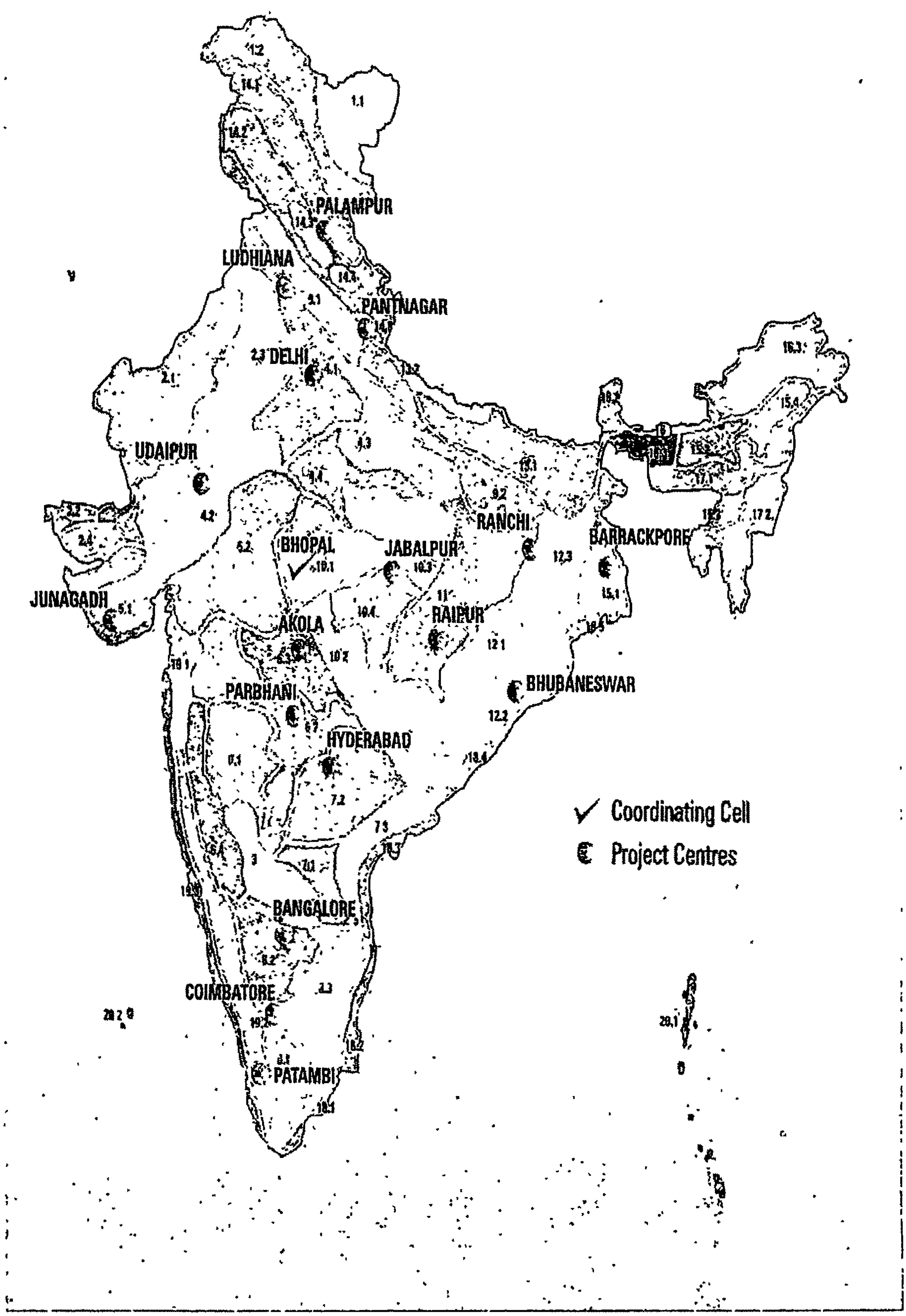
T_6 100% optimal NP

T_7 100% optimal N

T_8 100% optimal NPK + FYM

T_9 100% optimal NPK (Sulphur free source)

T_{10} Unmanured (Control)



The map showing location of different cooperating centers of AICRP -LTFE

LIST OF COORDINATING CENTRE/STATIONS:

Details of Centres of AICRP on LTFE

S. No.	Location (State)	Year of start	Taxonomic Class	Cropping system
1	CRIAF Barrackpore (W.B.)	1971	Typic Eutrochrept	Rice-wheat-jute fibre
2	PAU Ludhiana (Punjab)	1971	Typic Ustochrept	Maize-wheat
3	IARI New Delhi (Delhi)	1971	Typic Ustochrept	Maize-wheat
4	TNAU Coimbtore (T.N.)	1971	Vertic Ustochrept	Fingermillet-maize
5	JNKVV Jabalpur (M.P.)	1972	Typic Chromustert	Soybean-wheat
6	GKVK Bangalore (Karnataka)	1972	Kandic Paleustalf	Fingermillet-maize
7	ANGRAU RRS Jagtial (A.P.)	2000	Typic Tropaquept	Rice-rice
8	OUAT Bhubaneswar (Orissa)	2002	Aeric Haplustalf	Rice-rice
9	BAU Ranchi (Jharkhand)	1972	Typic Haplustalf	Soybean-wheat
10	CSKHPKV Palampur (H.P.)	1971	Typic Hapludalf	Maize-wheat
11	GBPUA&T Pantnagar (Uttaranchal)	1996	Typic Hapludoll	Rice-wheat
12	JAU Junagadh (Gujarat)	1996	Vertic Ustochrept	Groundnut-wheat
13	Dr. PDKV Akola (M.S.)	1996	Typic Haplustert	Soybean-wheat
14	KAU Pattambi (Kerala)	1996	Typic Haplustalf	Rice-rice
15	IGKV Raipur (Chhatisgarh)	1996	Typic Haplusterts	Rice-wheat
16	MPUA&T Udaipur (Rajasthan)	1996	Typic Ustochrept	Maize-wheat
17	MPKV Parbhani (M.S.)	1996	Typic Chromustert	Soybean-safflower
B	Voluntary Centre			
18	IASRI New Delhi	1972	-	-

SALIENT ACHIEVEMENTS

• Continuous application of N alone in Alfisol resulted drastic reduction in yield under upland situation. The application on N through ammonium sulphate had more adverse effect on crop yield. However, under submerged conditions the adverse effect of application of N alone was not so harmful as was recorded in upland situation. Except finger millet at Bangalore and rice at Pattambi all crops responded to lime. Incorporation of FYM either alone or with lime irrespective of crop and soil condition resulted in further increase in crop yields.

• The data generated under LTFE at different centre disproved the notion that application of fertilizer and cultivation of soil reduced the SOC. The conjunctive use of chemical fertilizer and FYM always maintained relatively larger amount of SOC compared to chemical nutrients use. This particular treatment even maintained SOC at Pantnagar also. Thus the use of chemical fertilizer should not be blamed for decline in SOC. Decline in SOC was noticed only on application of chemical nutrients in either imbalanced form i.e. N or NP or in less quantity which did not return enough amount of crop residue to soil.

• The data on dynamics of available N clearly indicated that balanced application of nutrient invariably resulted increase in available status of N in soil irrespective of cropping system and soil. However, legume cropping system facilitated the built up in available N in soil. Whereas high rainfall and porosity of soil adversely affected the available status of N in soil.

• Soil analysis indicated that the amount of P applied is always larger than the uptake of P by the crop. The fertilizer P applied in excess to crop uptake resulted in built up in soil available P. The built up in soil P was again dependent on the amount of P applied and the productivity of the crop. Application of organic manure facilitated build up in available soil P.

• The result of K status in soil recorded at various centres indicated that absence of K in fertilizer schedule resulted decline in available K status irrespective soil type and cropping system. Application of NPK+FYM resulted in improvement in available K status in soil at almost all the places. The decline in magnitude however, was dependent on productivity of crop and the K renewal capacity of the soil. Probably Pattambi and Bhubaneswar are the exceptions where in spite of absence of K in nutrient supply schedule resulted in increase in soil K status. The increase in magnitude of K was of 5-7 kg ha_{-1} at Pattambi and 20-25 kg ha_{-1} at Bhubaneswar.

• Micronutrient analyses of soil revealed hidden hunger of Zn in Mollisol of Pantnagar and Inceptisol of Ludhiana. At these places Zn availability is growth limiting factor. The Other micronutrient cations are available in sufficient quantity in soil.

• The results of demonstrations trials conducted at farmers' field clearly indicated that the P dose can be reduced to half safely without any reduction in yield. But to enhance the productivity, K is needed in more quantity and part of that could be supplemented through FYM. To harness greater nutrient utilization efficiency integrated use of chemical fertilizer with FYM is a better option.

• The results of yield experiment clearly indicated that application of P and Zn is essential to harness the potential productivity of crops. But to sustain the productivity at higher level conjunctive use of chemical fertilizer and FYM is the only option. This supports the strategies developed out of LTFE results.

• The analysis of soil for physical conditions clearly demonstrated that continuous growing of crop with fertilizer resulted decline in bulk density and cone penetration resistance. However, reverse was found true on hydraulic conductivity and mean weight diameter. The conjunctive use of fertilizer and organic manaure resulted in maximum effect on all the soil physical properties.

• The studies carried out on microbial population at Palampur indicated decline in populations of actinomycetes, bacteria and azotobacter with increase in fertilizer nutrient application. But increase in the population of these microorganisms was recorded on incorporation of FYM even in presence of fertilizer. Whereas the reverse was observed on population of fungi.

• The yield data of rice-rice at Jagtial, Bhubaneswar and Pattambi clearly demonstrated that to sustain the productivity of rice-rice system application of all three major nutrients are essential. Of course application of FYM would help in sustaining the productivity at higher level.

• The results of superimposition of treatment indicated that in Alfisols reduction in P dose did not have any adverse effect on yield of finger millet and maize. Addition of K in 100% NP and superimposition of P and K in 100% N treatment resulted in very large increase in yield of both finger millet and maize. Farm yard manure (FYM) was found better off amendment i.e. lime.

• The results at Ludhiana clearly showed that curtailment of P dose to half from optimal and super optimal doses did not have any adverse effect on yields of both maize and wheat. However, to get potential yield of both maize and wheat Zn application is essential. The farmer must keep an eye on P status in soil to get sustainable yield.

• The results confirmed that Zn and S are yield limiting nutrients at Pantnagar. To sustain the yield of rice-wheat system at higher level over a period of time, application of Zn and S are essential in addition to NPK. In Alfisol K is the major growth limiting nutrient.

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LONG TERM IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON GRAIN AND FODDER/STRAW YIELD OF SORGHUM AND WHEAT CROP UNDER SORGHUM-WHEAT CROPPING SEQUENCE

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Abstract

The field experiment was under taken during the year 2012-2013 on the old long-term fertilizer experiment started since 1983. The fourteen treatments replicated Three times in a RBD comprised of NPK levels with and without FYM, wheat straw , subabul and green leaf manures. After excavating the soil samples in each treatment plot, these samples were analyzed for soil quality parameters viz. physical, chemical and biological properties. The application of FYM along with NPK found superior among all the treatments. The higher yield of sorghum and wheat crop was recorded under integrated nutrient management as compared to only chemical fertilizers.

Key words-Impact, nutrient, management, FYM , NPK.

Introduction

Long term manurial experiments conducted in India (1983-2005) showed declining trend in productivity even with application of NPK fertilizers under modern intensive farming. Neither organic sources alone nor can chemical fertilizers alone achieve sustainability in crop production under high intensive farming where nutrient turnover in soil plant system is much larger. However, their combined use appeared to be promising. It is well known that among N, P and K, N plays key role in crop production and hence in any nutrient management programme of cropping systems its consideration is essential.

The most logical way to manage long term fertility and productivity of soil is the integrated use of both organic and inorganic source of plant nutrients. Long term fertilizer experiments usually provide the best practical test of sustainability of crop management system (Nambiar, 1994).

Sorghum (*Sorghum vulgare*) is one of the important food grain crop in Maharashtra. India has the largest share (32.2%) of world sorghum area and ranks second in production after U.S.A. In Maharashtra, *Kharif* sorghum was cultivated on about 35.98 lakh hectare area with an annual production of 8 million tonnes during the year 2010-2011 (Anonyymos, 2011).

Wheat (*Triticum aestivm* L.) is a second important food crop. In India, area under *rabi* wheat during the year 2010-2011 was 265 lakh hectare with an annual production 82 million tonnes. In Maharashtra, area under wheat during 2010-2011 was 7.6 lakh hectares with annual production of 9.8 lakh tonnes (Anonyymos, 2011).

Materials And Methods

The study was framed to investigate the long term impact of integrated nutrient management on vertical movement of organic and inorganic carbon behavior of soil, in V.N.M.K.V, Parbhani during 2012-2013. The experiments were conducted on deep black soils of (Typic haplustert) survey No 124 of parbhani block of central farm, Marathwada Agricultural University, Parbhani since 1983. Marathwada lies in the South Eastern part of Indian Union.

The major soils of Parbhani district are derived from "deccan trap" (Basalt) which is rich in iron, lime and magnesium (Gajbe *et al.,* 1976). On the basis of morphology, soil depth and texture, these soils are considered to be identical to that of Parbhani series (Typic Haplusterts) as classified by Malewar (1976). The topography of experimental plot was fairly leveled. The soil was medium, deep, well, drained and calcareous in nature ehich was developed from weathered basalt.

The experiment was laid in RBD with fourteen treatments involving NPK fertilizers alone and in combination with FYM, glyricidia, wheat straw and subabul leaves. Treatment details are given in Table 1.

Results And Discussion

The data related to sorghum wheat grain and straw yield as influenced by different treatments are presented in Table 2 for the year 2012-13. Grain yield of sorghum was significantly highest in treatment T_6 (25.36 q ha^{-1}) receiving 50% NPK (F) + 50% N (FYM) closely followed by the treatment T_5 (24.83 q ha^{-1}) and these treatments were found to be at par with each other, whereas lowest values were recorded in treatment T_1 (2.52 q ha^{-1}) absolute control. The grain yield of wheat followed same trend.

In other set of treatment combinations of inorganic fertilizers with FYM, GM, WS and subabul leaves as a source of organic material further added to grain and straw yield of sorghum and wheat. Among organic sources, FYM followed by wheat straw have proved the superiority over other organic material and increasing the grain and straw yield by complementary effect on increased the availability and efficiency of inorganic fertilizers as well as release of inorganic forms of nutrients on its decomposition.

The higher yield by NPK with FYM application could be attributed to enhanced soil quality parameters particularly in the treatments receiving organic manures in combination with inorganic fertilization. Many researcher reported positive impact of INM over only organic or inorganic fertilization on soil quality and productivity. Billore and Joshi (2005) found that integrated nutrient management produce more yields as compare to recommended dose of fertilizers alone. Bayu *et al* (2006) also found that combined application of FYM and RDF increased the grain and straw yield of sorghum by 36% and 21% respectively

Summary And Conclusion

The higher yield of sorghum and wheat crop was recorded under integrated nutrient management as compared to only chemical fertilizers. The significantly lower yields under unfertilized treatment (T_1) as compared with NPK, NPK + organic manures indicated the soil fertility depletion, which may be due to exhaustive sorghum wheat cropping system.

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Table 1: Details of Treatments

Treatments	Treatments	
	Kharif	Rabi
T_1	Control	Control
T_2	50 % recommended (40:20:20) NPK kg ha⁻¹ through fertilizer	50 % recommended (60:30:30) NPK kg ha⁻¹ through fertilizer
T_3	50 % recommended (40:20:20) NPK kg ha^{-1} through fertilizer	100 % recommended (120:60:60) NPK kg ha^{-1} through fertilizer
T_4	75 % recommended (60:30:30) NPK kg ha^{-1} through fertilizer	75 % recommended (90:45:45) NPK kg ha^{-1} through fertilizer
T_5	100 % recommended (80:40:40) NPK kg ha^{-1} through fertilizer	100 % recommended (120:60:60) NPK kg ha^{-1} through fertilizer

T_6	50 % NPK kg ha^{-1} through fertilizer + 50 % N through FYM	100 % recommended NPK kg ha^{-1} through fertilizer
T_7	75 % NPK kg ha^{-1} through fertilizer + 25 % N through FYM	75 % recommended NPK kg ha^{-1} through fertilizer
T_8	50 % NPK kg ha^{-1} through fertilizer + 50 % N through wheat straw	100 % recommended NPK kg ha^{-1} through fertilizer
T_9	75 % NPK kg ha^{-1} through fertilizer + 25 % N through wheat straw	75 % recommended NPK kg ha^{-1} through fertilizer
T_{10}	50 % NPK kg ha^{-1} through fertilizer + 50 % N through green manuring (*Glyricidia*)	100 % recommended NPK kg ha^{-1} through fertilizer
T_{11}	75 % NPK kg ha^{-1} through fertilizer + 25 % N through green manuring (*Glyricidia*)	75 % recommended NPK kg ha^{-1} through fertilizer
T_{12}	Farmers practice (40:20:20) NPK kg ha^{-1} and seed without carbofuron treatment	Farmers practice (60:30:30) NPK kg ha^{-1} and 100 kg seed ha^{-1}
T_{13}	75 % NPK kg ha^{-1} through fertilizer + 25 % N through subabul leaves	75 % recommended NPK kg ha^{-1} through fertilizer
T_{14}	50 % NPK kg ha^{-1} through fertilizer + 50 % N through subabul leaves	100 % recommended NPK kg ha^{-1} through fertilizer

Table 2: Effect of long term fertilization on grain and fooder/straw yield of sorghum, wheat

Tr. No.	Treatment Detail		Yield (q/ha)			
			Sorghum		Wheat	
	Kharif	Rabi	Grain	Fodder	Grain	Fooder
T_1	Control	Control	2.52	4.53	2.87	4.35
T_2	50% NPK (F)	50% NPK (F)	17.24	36.30	16.86	25.62
T_3	50 % NPK (F)	100 % NPK (F)	18.04	38.79	18.61	29.58
T_4	75% NPK (F)	100 % NPK (F)	20.47	46.05	20.56	31.87
T_5	100 % NPK (F)	100 % NPK (F)	24.83	55.13	24.69	39.62
T_6	50% NPK (F) + 50% N (FYM)	100% NPK (F)	25.36	54.71	25.12	38.93
T_7	75% NPK(F) + 25% N (FYM)	75% NPK (F)	21.79	48.38	22.36	35.09
T_8	50% NPK(F) + 50% N(WS)	100% NPK(F)	20.94	46.49	20.94	33.79
T_9	75% NPK(F) + 25% N(WS)	75% NPK(F)	18.28	40.58	18.80	30.27
T_{10}	50% NPK(F) + 50% N(GM)	100% NPK(F)	23.79	52.81	24.07	38.04
T_{11}	75% NPK(F) + 25% N(GM)	75% NPK(F)	16.62	36.89	17.14	27.58

[illegible]	FP (40:20:20 NPK & seed without seed treatments)	FP (60:30:30 NPK & 100 [illegible] seed [illegible])	14.72	32.68	15.53	24.35
T_{13}	75% NPK(F) + 25% N(SL)	75% NPK(F)	20.61	45.75	21.60	32.82
T_{14}	50% NPK(F) + 50% N(SL)	100% NPK(F)	23.50	52.81	23.98	37.88
S.E.±			0.77	1.68	0.70	1.11
C.D. at 5 %			2.26	4.90	2.04	3.24
Grand mean			19.20	6.93	6.21	7.25

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