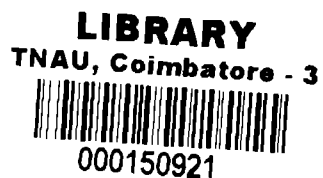


**EFFECT OF TILLAGE, ORGANICS AND NITROGEN ON PHYSICAL
PROPERTIES AND NITROGEN AVAILABILITY IN SOILS WITH
SUBSOIL HARDPAN AT SHALLOW DEPTH**

BY

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Thesis submitted in part fulfilment of the requirements for the degree of
Doctor of Philosophy (Agriculture) in Soil Science and Agricultural Chemistry to the
Tamil Nadu Agricultural University, Coimbatore.



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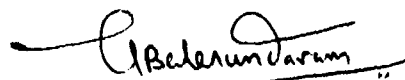
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CERTIFICATE

This is to certify that the thesis entitled "EFFECT OF TILLAGE, ORGANICS AND NITROGEN ON PHYSICAL PROPERTIES AND NITROGEN AVAILABILITY IN SOILS WITH SUBSOIL HARDPAN AT SHALLOW DEPTH" submitted in part fulfilment for the requirement for the degree of DOCTOR OF PHILOSOPHY (Agriculture) in Soil Science and Agricultural Chemistry to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Mr. B. RAJKANNAN** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, following or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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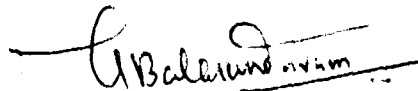


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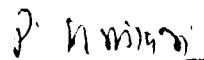
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ABSTRACT

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EFFECT OF TILLAGE, ORGANICS AND NITROGEN ON PHYSICAL PROPERTIES AND NITROGEN AVAILABILITY IN SOILS WITH SUBSOIL HARDPAN AT SHALLOW DEPTH

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A field experiment was carried out with sorghum (Co 26) - groundnut (Co 2) cropping sequence during the year 1993-94 in an Alfisol having hardpan at shallow depth (Typic Haplustalf - Pichanur series) at Nachipalayam of Madukkarai block, Coimbatore district, Tamil Nadu to study the interaction effect of tillage practices viz., country ploughing twice (T1), mouldboard ploughing (T2) and chiseling once followed by country ploughing twice (T3), organics viz., control (M1), farm yard manure at 12.5 t ha⁻¹ (M2) and composted coir pith at 12.5 t ha⁻¹ (M3), levels of nitrogen viz., control (N1), 75 per cent recommended dose (N2) and 100 per cent recommended dose

(N3) in improving the soil physical condition and yield of crops, transformation and mobility of N and residual effect of tillage and organics on the subsequent crop.

Twenty seven treatments were imposed over the recommended dose of P and K (45 : 45 kg ha⁻¹ for sorghum and 36 : 54 kg ha⁻¹ for groundnut) and were replicated thrice by following split plot design. The salient features of the investigation are presented below :

The stupendous effect of chiseling followed by two country ploughing (T3) in improving the physical properties *viz.*, bulk density, hydraulic conductivity and poresize distribution particularly by shattering the subsurface layers, thereby providing a conducive physical environment for better movement of water, nutrients, better foraging of roots to deeper layers facilitating for effective mining of nutrients from deeper layers thus culminating in higher N uptake and grain yield.

Application of organic manures *viz.*, farm yard manure and composted coir pith at 12.5 t ha⁻¹ had a marked influence on the physical properties only in the surface layer but its effect was negligible in the subsurface layers. Addition of organics helped in significantly enhancing the grain yield of sorghum and pod yield of groundnut.

Remarkable influence of chiseling on the root length and root volume of the sorghum crop is well evidenced from the better proliferation of roots into the deeper layers. Root length increased with increasing levels of N, while organics had no effect. In general, NH₄-N content increased with N levels and the increase was gradual upto 15 DAS and a gradual decline thereafter. The NO₃-N content was comparatively low upto 15 DAS, but later recorded a gradual increase indicating the transformation of ammoniacal form to nitrate form. Higher NH₄-N and NO₃-N contents present in the second depth under chiseling gave evidence for the movement of these ions to the deeper layers.

Chiseling accomplished for the perceptible depletion of available N. Increased available N status with concomitant increasing levels of N was found upto 90 DAS in sorghum. Higher available N content in the organic manure added treatment of the residual crop of groundnut was observed due to slow mineralisation of N.

A concomitant increase in organic carbon content was observed due to application of organic manures, while tillage treatments and nitrogen levels had no effect.

The present investigation revealed clearly the overwhelming effect of chiseling in effectively shattering hardpan at shallow depth thereby providing a conducive physical environment for better nutrient and water availability, foraging of roots for mining the nutrient from the subsurface layers also thus favouring for higher nutrient uptake and productivity. However, the effect of chiseling lasts only for two seasons thus warranting the need for repeating it once in a year at the start of the season. Chiseling along with 75 per cent of the recommended N registered the grain yield on par with the treatment receiving 100 per cent recommended N with mouldboard or country ploughing. Adoption of this technology can help in the saving of 25 per cent fertiliser N. The organic manures also had a positive influence with physical properties which reflected on the grain and kernel yield.

The study has emphatically brought out the adoption of chiseling along with organics and 75 per cent recommended fertiliser N for realising higher grain and kernel yield of sorghum and groundnut crops.

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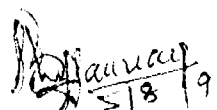
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(RAJKANNAN)

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ABBREVIATIONS USED

N	:	Nitrogen
NH ₄ -N	:	Ammoniacal nitrogen
NO ₃ -N	:	Nitrate nitrogen
KMnO ₄ -N	:	Potassium permanganate nitrogen or available nitrogen
Olsen-P	:	Available phosphorus
NH ₄ OAc-K	:	Ammonium acetate potassium or available potassium
*	:	Significant at 5 per cent level
**	:	Significant at 1 per cent level
NS	:	Not significant
kg	:	Kilogram
ha	:	Hectare
t	:	Tonnes
ppm	:	parts per million
Mg m ⁻³	:	Mega gram per cubic metre
dS m ⁻¹	:	Desi Siemens per metre
CD	:	Critical difference
%	:	Per cent
c.mole (p+) kg ⁻¹	:	Centimole proton per kilogram

INTRODUCTION

CHAPTER I

INTRODUCTION

Burgeoning population predisposes heavy demand on soils for higher food production. It is estimated that India's human population (currently 927 million) would cross one billion mark by the turn of this century and would stabilise around 1.5 billion by about 2025 AD. This implies that per capita cultivable land holding has been declining from 0.5 ha (in 1951-52) to 0.14 ha (by 2000 AD). The food production, no doubt increased from 52 million (M) tonnes (in 1950's) to almost 190 M tonnes (in 1990's). It is anticipated that by 2025 AD, the country will need 310 M tonnes of food grain to feed 1500 million mouths (Seghal, 1995). Hence, there is an imminent need for increasing the production and productivity, so as to produce 2.7 t ha^{-1} in order to meet the required food demand from the present 1.35 t ha^{-1} . Shrinking water resources and decreasing land area for agricultural uses are the major constraints for increasing the production of agricultural commodities.

The gross cropped area of the state is around 68.08 lakh ha. Further, in Tamil Nadu, 73.0 per cent of the holdings are below 1 ha. It will be very difficult to bring in further area under crops. Under this context, it is necessary to devote attention on three categories of land viz., cultivable waste (3.03 lakh ha), current fallow (18.6 lakh ha) and other fallow lands (6.89 lakh ha). The significant growth of agriculture has been at the cost of decline in soil quality and risk of soil degradation. According to an estimate, about 57 per cent of soils are under different kinds and degrees of degradation and these are getting further deteriorated with the risk of jeopardizing our food security system.

At this crucial juncture, the only option is to increase the productivity through the adoption of proven scientific technologies. The constraints confronted are of physical,

chemical and biological nature and out of these the chemical constraints such as salinity, sodicity and acidity received greater attention while the others received less emphasis.

Soil physical constraints affecting the retention and movement of soil moisture, soil aeration, soil nutrient movement, soil temperature, seed germination, seedling establishment, root penetration and proliferation have been well documented (Savithiri, 1971; Ramanathan *et al.*, 1983; Glinski and Stepniewski, 1985; Stypa *et al.*, 1987; Ghildyal and Gupta, 1991). Even judicious application of all the required plant nutrients at times fails to yield good results due to the poor soil physical environment.

Among the various physical constraints, subsoil hardpan at shallow depth is one which limits the crop growth to a greater extent. The hardpan is characterised by high bulk density ($> 1.8 \text{ Mg m}^{-3}$). Normally this problem occurs in red soil area due to illuviation of clay in the subsoil horizon coupled with cementing action of oxides of iron and aluminium and calcium carbonate. Since red soil occupies sixty two per cent of the total geographical area of Tamil Nadu, the problem is found to occur over a larger extent. Survey conducted in seven districts, viz., Coimbatore, Periyar, Salem, Dharmapuri, Trichy, Madurai and North Arcot by the All India Coordinated Research Project on Soil Physical Conditions Improvement in Problematic Areas to Increase the Agricultural Production revealed that totally 5,218 sq.km is affected by this problem in Coimbatore, Madurai and North Arcot districts alone and the area is likely to go up when the survey is completed (Basker *et al.*, 1995).

The subsoil hardpan lowers the infiltration and percolation rates, nutrient movement and free air transport within the soil profile. It prevents root proliferation and limits the volume of soil available for nutrient uptake resulting in depleted, less fertile surface soil. The contribution of subsoil fertility to crop growth is hampered.

To overcome this problem, the chisel ploughing to a depth of 45 cm at 50 cm interval criss cross was found to be effective. However, the effect of chiseling was found to last for only 2 seasons. There are stray reports stating on the sustained effect for a longer time when organics used in combination with chisel ploughing. In addition, organics provide a favourable physical environment to the crop growth which results in higher productivity.

Usually red soils are low in fertility particularly nitrogen due to low organic matter content which leads to low productivity of the crops grown in these soils. When subsoil hardpan occurs in these type of soils at shallow depth, due to root restriction, nutrients in the surface soil are exhausted exorbitantly thus leading to further deterioration of the soil fertility.

Keeping the above facts in mind, the present study was carried out in the farmer's holding at Nachipalayam village of Madukkarai block of Coimbatore district, where such a problem exists, adopting sorghum-groundnut sequence with the following objectives:

- * To study the effect of chiseling and organics on the physical properties of the soil with subsoil hardpan at shallow depth.
- * To quantify the transformation and movement of nitrogen due to different tillage practices.
- * To quantify the transformation and movement of nitrogen due to organics and levels of nitrogen application.
- * To study the comparative effect of organics on the improvement of physical properties and their residual effect.
- * To investigate the interaction effect of tillage, organics and nitrogen on yield of crops and physical properties of soil.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The plant nutrient availability in soil is a measure of soil fertility, while the soil physical environment is the kingpin which regulates the retention and movement of the soil moisture, soil aeration, soil nutrient movement, soil temperature, seed germination, seedling establishment, root penetration and proliferation etc. Hence, soil physical environment directly or indirectly controls all the other factors that influence the plant growth and in turn the production potential of the crop (Basker *et al.*, 1995).

Among the various physical constraints, subsoil hardpan at shallow depth is the major constraint in red soils of Tamil Nadu. In literature, various terminologies like the subsoil hardpan, soil compaction, mechanical impedance, hard soils etc. are being used synonymously. The earlier work done in various aspects of the subsoil hardpan is reviewed in this chapter.

2.1. Subsoil hardpan

2.1.1. Extent

In Tamil Nadu red soils occupies 8 million hectares which constitutes 62 per cent of the total geographical area. Subsoil hardpan is commonly encountered in red soils due to various causes as described in 2.1.2. A survey conducted by the All India Coordinated Research Project on Soil Physics indicated that about 1320 sq.km in Coimbatore district, 2450 sq.km in Madurai district and 1448 sq.km in North Arcot district of Tamil Nadu are found to have subsoil hardpan (Basker *et al.*, 1995). The delineation work is being continued which may reveal more areas under this problem.

The subsoil hardpan in red soil is due to illuviation of clay to the subsoil horizon coupled with cementing action of oxides of iron and aluminium and calcium carbonates, which increases the soil bulk density to more than 1.8 Mg m^{-3} . The hardpan can also develop due to continuous and constant use of heavy implements for cultivation.

Soane *et al.* (1994) stated that draft animals were observed to cause compaction during cultivation. Further, they stated that soil compaction is now considered to be a multi disciplinary problem in which machine, soil, crop and weather interactions play an important role.

Ramanathan *et al.* (1983) reported that hardpan in arid climates are associated with sufficiently long period of weathering. The authors also opined that age and proportion of mobile silica in the solution are responsible for the cementing action in the subsurface soil.

Subsurface mechanical impedance is developed due to formation of plough sole as in the case of rice fields on medium textured soils, accumulation of clay in B horizon under sub humid conditions or presence of Kankar layers (Ghildyal and Gupta, 1991).

Ferrero (1994) observed that the perennial pastures subjected to rotational grazing or hay making plus grazing and trampling resulted in compaction.

2.2. Soil properties and plant growth in subsoil hardpan soils

The subsoil hardpan is characterized by the high bulk density ($> 1.8 \text{ Mg m}^{-3}$) which lowers the infiltration rate, water holding capacity, available water and movement of air and nutrients with concomitant adverse effect on the yield of crops (Basker *et al.*, 1995).

2.2.1. Soil properties

Soil compaction affects the soil aeration, alters soil water relations and thermal conductivity of the soil (Savithiri, 1971). It poses agronomic problems due to inherent physical properties such as high bulk density and penetration resistance (Ramanathan *et al.*, 1983).

Effect of soil compaction on reduced infiltration rate, reduced internal drainage and reduced effectiveness of underground drainage systems was reported by Larson *et al.* (1994).

The effect of compaction on transport, absorption and transformation of nutrients is particularly influenced by alteration of soil aeration status (Glinski and Stepniewski, 1985), hydraulic properties (Wolkowski, 1990) and diffusive transport of nutrients from the soil to the plant roots (Barracclough and Tinker, 1981; Bhadoria *et al.*, 1991). Alteration of strength properties and closer packing of soil particles in compacted soil restrict the nutrient uptake indirectly by affecting the root configuration (Glinski and Lipiec, 1990) and root soil contact (Veen *et al.*, 1992).

The effect of soil compaction on transport of nutrients to the roots depends on the amount of soil compaction and on water and nutrient supply. Under high fertility conditions, moderate soil compaction may have a beneficial effect. This can be due to greater water retention and hydraulic conductivity in the case of mass flow transport (Kemper *et al.*, 1971), increased diffusion coefficient of ions (Warneke and Barber, 1972; Bhadoria *et al.*, 1991) or due to increased ion concentration of the soil. Further increase of bulk density above a certain value may lead to a decrease of the diffusion co-efficient, as a result of increased tortuosity of pores and restriction of root penetration (Lipiec and Stepniewski, 1995).

Reduced N uptake caused by physical impedance and stress on plant roots (Castillo *et al.*, 1982; Garcia *et al.*, 1988) and alteration of soil N transformation processes (Bakken *et al.*, 1987) have also been attributed to soil compaction.

Soil compaction alters the soil pore space which was found to promote soil microsite anaerobiosis resulting in increased denitrification (Torbert and Wood, 1992). Soil compaction leads to a three to four fold increase in N losses via denitrification (Bakken *et al.*, 1987).

2.2.2. Plant growth and yield

Soils with subsoil hardpan reduce the growth and yield of crops by restricting the root growth, movement of water and nutrients, aeration status, drainage etc. The reduction in the yield levels varies depending upon the depth of hardpan occurrence which determines the volume of soil available for root exhaustion. Wittsell and Hobbs (1965) have observed reduced wheat grain yield when the bulk density of the surface and sub-surface soils increased to 1.6 Mg m^{-3} .

Varade and Ghildyal (1967) observed that upto a bulk density of 1.5 Mg m^{-3} the rice yield increased significantly with increasing levels of compaction but decreased at higher levels.

The change in the mechanical impedance of the soil as compared to the normal soil is the main reason for the reduced plant growth (Savithiri, 1971). The poor growth of crops are due to limited use of the subsoil by the roots (Ramanathan *et al.*, 1983). Further, the authors reported reduction in sorghum yield in red sandy loam soils where the subsoil hardpan exists. Yield reduction has also been reported in maize grain (Gupta *et al.*, 1984; Gupta and Satyendra Kumar, 1994), groundnut pod and tapioca tuber at Coimbatore,

wheat grain at Ludhiana and sugarbeet at Hyderabad (Gupta and Satyendra Kumar, 1994). They have also reported the reduction in dry matter yield of maize and wheat crops.

Larson *et al.* (1994) opined that the detrimental effect of compaction is perceptible in the form of uneven plant growth and restricted root growth.

Experiments conducted in Pichanur soil series of Coimbatore district, Tamil Nadu, where the actual problem of subsoil hardpan exists resulted in yield reduction in sorghum, tapioca, groundnut, cotton, maize, blackgram and tomato crops. The dry matter yield also exhibited a similar trend (Basker *et al.*, 1995).

2.2.3. Root growth

Soil compaction results not only in the decrease of total pore space but also reduces the size of pores and therefore offers increased resistance to the penetration of roots (Bodman and Constantin, 1965).

Taylor *et al.* (1966) reported that cotton tap root penetration was greatly reduced as soil strength increased to 25 bars. A sharp decline in root penetration occurred as soil strength increased from 3 to 15 bars. Soil strength was found to increase with increase in bulk density and soil moisture tension.

The elongation rate of roots is highly correlated with the penetrometer resistance (Greacen *et al.*, 1968). The penetrometer resistance is strongly affected by both the bulk density and the water content of the soil (Williams and Shaykewich, 1970). Taylor and Ratliff (1969) who worked with peanut and cotton found that the correlation between elongation rate and penetration resistance remained strong, no matter whether the resistance varied by changing water content or bulk density.

In a lateritic sandy clay loam soil, Varade and Mahajan (1970) found that beyond a bulk density of 1.8 Mg m^{-3} , rice root growth was considerably reduced due to the mechanical resistance offered by soil.

Greacen and Oh (1972) proposed a simple physical model on the mechanism by which the elongation rate of roots is reduced by hard soils in which the elongation was controlled by the difference between the turgor pressure within the expanding cells and the penetration resistance of the soil.

Root diameter generally increased when roots encounter a mechanical resistance as reported by Russel and Goss (1974).

Normally roots grow in macro pores (Russel, 1977; Hatano *et al.*, 1988). These macro pores might have been formed by worms or by the roots of previous plants (biopores) or by the gross movement of the soil to form slickensides and similar fissures (Hamblin, 1985). Roots that gain access to them are able to penetrate the soil much more deeply, although their ability to extract water and nutrients is restricted.

Russel (1977) opined that roots of plants grown in highly compacted soils are likely to be impeded by the smallest pores.

Experiments conducted in a sandy loam soil with subsoil hardpan revealed that the highest percentage of roots were found on the top layer, whereas deep ploughing of such soils showed the highest quantity of roots in the 15-30 cm layer (Sundara Sarma *et al.*, 1978).

Veen (1982) observed that the plant hormone ethylene may be responsible for the changed shape of impeded roots. Soil characteristics such as water content, mechanical

impedance, aeration, temperature and nutrient content may markedly alter root growth and distribution (Russel, 1981; Miller, 1983).

Stunted root growth was observed in subsoil hardpan soil in sorghum and tapioca crops (Ramanathan *et al.*, 1983; Gopalasamy, 1984).

Stypa *et al.* (1987) stated that roots did not penetrate the Ck horizon (0.6 m depth) in the soil having bulk density 1.8 Mg m^{-3} .

A root growing in hardsoil is morphologically different from the one growing in friable soil. It will be shorter and thicker and much more closely oppressed to the soil particles (Baligar *et al.*, 1975; Atwell, 1990).

The ability of roots to penetrate compacted soil depends on the number of factors and penetration is generally restricted to pressure above 2500 K Pa (Simmons, 1992). At deeper soil zones penetration resistance in various tillage treatments was great enough that it could have restricted root growth forcing the roots to grow in areas of lesser resistance such as macro pores (Henderson, 1991; Martino, 1991).

Ghildyal and Gupta (1991) stated that the impervious layer at shallow depth does not allow the roots of cotton and sugarcane to penetrate.

Compaction increased the bulk density and penetration resistance in Entisols and Alfisols. Increased bulk density and reduced penetration resistance reduced the number of roots, mean and total root lengths, rates of root elongation and fresh and dry root mass. Panayiotopoulos *et al.* (1994) reported on the significant linear and curvilinear relationships established between bulk density or penetration resistance and most root growth parameters.

Adequate root growth is dependent on soil physical and chemical environments such as soil compaction, soil strength, amount of water and nutrient supply, soil temperature and depth of water table (Das *et al.*, 1995).

2.3 MANAGEMENT OF SUBSOIL HARDPAN SOILS

To overcome the problems of subsoil impervious layer in red soils, chisel ploughing was found to be very effective than any other implements in successfully breaking open of the hardpan to facilitate better root growth and nutrient and water movement with concomitant increased productivity (Basker *et al.*, 1995). Chisel plough is a tractor drawn heavy iron plough which goes upto 45 cm depth and shatters the hardpan in the subsoil. The various implements *viz.*, subsoilers, scarifiers and cultivators with weights are also used for breaking the subsoil hardness (Pignedoli, 1993).

Grevers and Jong (1993) found that subsoiling reduced the bulk density in most of the solonetzic soils. Under irrigated condition, it reduced soil salinity and sodicity. Under dry condition, salinity and sodicity remained unchanged. Increased crop production resulted from increase in soil water depletion with depth and from greater crop water efficiency.

Soil and water management plays a major role in managing the compacted soils. Further, agronomic practices like crop rotation, crops that produce organic materials for the maintenance of soil organic matter, crops with penetration and fibrous root system, liming and animal management systems also help in alleviating the soil compaction (Larson *et al.*, 1994).

2.4. TILLAGE EFFECTS ON SOIL PROPERTIES AND YIELD

2.4.1 Soil properties

2.4.1.1. Physical properties

Chambers *et al.* (1990) reported that subsoiling reduced the cone resistance and bulk density in compacted and non compacted soils. The reduction in bulk density due to subsoiling was also reported by Grevers and Jong (1993).

Nicou *et al.* (1993) observed that total porosity of the ploughed layer drastically increased. Porosity ranges from 37-48 per cent in unploughed soil which increased to 44-50 per cent after ploughing.

Sfeyn *et al.* (1995) compared minimum tillage and chisel ploughing and found that chisel ploughing resulted in lowering the bulk density of subsoil upto 40 cm. The same was also reported by Gupta and Abrol (1993). The authors also observed increased hydraulic conductivity, non capillary porosity, infiltration rate etc. due to chisel ploughing.

2.4.1.2. Other properties

Thoma (1991) studied four tillage systems with varying tillage intensity and run off soil loss was measured. Most soil loss was observed in conventional tillage and the losses gradually decreased with increased tillage intensity.

Organic matter decomposition was 2 per cent for zero tillage, 36 per cent for wing share cultivator with rotary harrow and 45 per cent for chisel plough with rotary harrow as reported by Tebrugge (1992).

Deep ploughing can reduce erosion since water penetrates more deeply and thus improves drainage. In the dry season, the soil moisture in the subsoil is conserved (Subagio and Mumwandono, 1992).

Nicou *et al.* (1993) reported that repeated ploughing often accelerates oxidation and humus mineralisation and modifies microbial activity and biochemical processes. Further, they reported the significant effect of ploughing on symbiotic activity of rhizobium. The effect of ploughing on effective weed control was also observed.

Studies of Shipitalo and Edwards (1993) showed that tillage has a greater effect on movement of NH_4 -N than of NO_3 -N.

Nitrogen concentrations in the soil profile were lower in no tillage system compared to conventional tillage (Angle *et al.*, 1993).

Basker *et al.* (1995) observed movement of nitrogen and potassium to deeper layers due to chiseling in subsoil hardpan soil.

2.4.2. Growth and yield

Experiments conducted under rainfed conditions of sandy loam soils recorded higher grain yield and root growth in chiseled plots (Mallick and Nagarajao, 1972). Similar result was reported by Srivastava *et al.* (1994) for wheat crop in Rice-wheat rotation.

The highest quantity of maize roots were observed in 15 to 30 cm layer due to chisel ploughing upto a depth of 40 cm, while more roots were concentrated on top layer in shallow tillage treatments (Sundara Sarma *et al.*, 1978).

Ramanathan *et al.* (1983) recorded higher grain yield of sorghum due to chiseling in red sandy loam soils having subsoil hardpan.

Gopalasamy (1984) recorded 38, 40 and 23 per cent yield increase respectively for groundnut, tapioca and sorghum crops due to chiseling to a depth of 45 cm in subsoil hardpan soil, besides increasing the dry matter yields.

Gupta *et al* (1984) observed two fold increase in maize grain yield by chiseling over the control yield of 13.4 q/ha. Chiseling the soil having mechanical impedance at shallow depth increased the yield of groundnut pods, sorghum grain and tapioca tubers in red sandy loam soils of Coimbatore, maize grain and wheat grain in Ludhiana and sugarbeet in Hyderabad (Gupta and Satyendra Kumar, 1994). Similar trend of results were also observed in crops like tomato, cotton and blackgram (Basker *et al.*, 1995).

2.5. ORGANICS ON PHYSICAL PROPERTIES AND YIELD

Organic manures improve the physical characteristics of the soil by way of better aggregation, higher cation exchange capacity, available water content besides reducing soil erosion. The use of organics in crop production has declined drastically owing to easy availability of chemical fertilisers and dearth of organics. In recent times, an awakening on the importance of organics in order to preserve environmental sanitation and sustainability is being keenly felt.

2.5.1. Physical properties

2.5.1.1. Bulk density

Gupta *et al.* (1984) noticed an inverse relationship between bulk density and organic matter content in a sandy soil and a significant inverse relationship between the organic matter content and the particle densities of all the other soils.

Lowering of bulk density by the continuous application of farm yard manure has been reported by Havangai and Mann (1970), Suresh Lal and Mathur (1989) and Anderson *et al.* (1990). Mahimairaja *et al.* (1986) reported that combined application of

organics and inorganics improved the physical condition of the soil by reducing the bulk density. Similar trend was reported by Parameswar *et al.* (1989) and Bharadwaj and Omanwar (1992).

Experiments conducted in red sandy loam soils of Coimbatore district revealed that application of poultry manure at 5 t ha^{-1} has lowered the bulk density from 1.30 to 1.11 Mg m^{-3} (Basker *et al.*, 1995). The authors further observed that composted coir pith when applied to groundnut crop as amendment improved the soil physical conditions through desirable changes in bulk density. Similar results have been reported by Nagarajan *et al.* (1985).

2.5.1.2. Hydraulic conductivity

An increase in the hydraulic conductivity by the addition of organic manures was observed by Becher and Kainz (1983) who stated that the increase in hydraulic conductivity of soils of the plough pan was associated with the build up of organic matter. Anderson *et al.* (1990) observed that the saturated hydraulic conductivity was increased by about nine times after 100 years of continuous soil and crop management with annual addition of 13.5 t ha^{-1} of organic manures.

Basker *et al.* (1995) reported that application of pigmanure at the rate of 10 t ha^{-1} has improved the hydraulic conductivity from 5.95 to 10.06 cm h^{-1} . The improvement in hydraulic conductivity by the addition of coir pith at 12.5 t ha^{-1} was also reported by the authors. Similar result has also been reported by Nagarajan *et al.* (1985).

2.5.1.3. Pore space

Soils fertilised with organic materials were characterised by greater porosity and this trend was found in the whole of pF range tested (Kahle *et al.*, 1992).

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Improvement of pore space especially non-capillary porespace due to application of various organics was reported by Gopalasamy (1984), Gupta *et al.* (1984), Nagarajan *et al.* (1985) and Gupta and Satyendra Kumar (1994).

2.5.1.4. Soil structure

Manickam and Venkataramanan (1972) observed significant increase in aggregation due to the application of cattle manure along with NPK. Similar results were reported by Kanwar and Prihar (1962), Biswas *et al.* (1969) and Muthuvel *et al.* (1982).

2.5.1.5. Moisture retention

The positive influence of organic manures especially farm yard manure on water holding capacity of soil was reported by Grewal *et al.* (1985), Parameswar *et al.* (1989) and Suresh Lal and Mathur (1989).

Suresh Lal and Mathur (1989) noticed significantly higher water holding capacity in soils receiving organics than inorganics. Bharadwaj and Omanwar (1992) reported that application of farm yard manure on long term basis increased the water holding capacity when compared to the control and inorganic fertiliser treated plots. Similar results were earlier reported by Chen (1981) and Prasad *et al.* (1983).

Water retention found to be high in the whole of pF ranges tested due to application of organic materials was reported by Kahle *et al.* (1992).

Addition of coir pith either raw or composted at 12.5 t ha^{-1} was found to increase the water retention characteristics of the red sandy loam soils as reported by Basker *et al.* (1995). Similar result was reported earlier by Nagarajan *et al.* (1985).

2.5.2. YIELD

Field experiments conducted under irrigated condition on the alluvial sandy loam soil (Typic Ustrochrept) showed that farm yard manure had improved the wheat grain yield mainly due to availability of more nutrients (Mallick and Nagarajao, 1972).

Increased grain yield of sorghum was observed due to addition of groundnut husk and rice husk (Ramanathan *et al.*, 1983), while Clarson *et al.* (1983) recorded increased yield of rice grain by the application of coir pith at 10 t ha^{-1} .

Gupta and Satyendra Kumar (1994) stated that in red sandy loam soil, incorporation of pressmud at 100 q ha^{-1} increased the groundnut pod yield significantly by 14 per cent over the control yield of 14.9 q ha^{-1} . They further stated that incorporation of FYM at 50 q ha^{-1} in clay soil at Jabalpur has increased the rice grain and straw yields significantly by 30 and 39 per cent over the yield of 17.2 q ha^{-1} and 27.2 q ha^{-1} for control respectively.

Application of pig manure at 10 t ha^{-1} resulted in 29 per cent yield increase in ragi and the same manure when applied at 20 t ha^{-1} increased the grain yield from 3100 kg ha^{-1} to 4250 kg ha^{-1} as reported by Basker *et al.* (1995). Increased yield of sorghum grain from 3520 to 4540 kg ha^{-1} due to addition of 5 t ha^{-1} of groundnut husk was also reported by the same authors.

Composted coir pith when applied at the rate of 12.5 t ha^{-1} was found to increase the grain yield of sorghum and groundnut in red sandy loam soils of Pichanur soil series which is having subsoil hardpan at shallow depth (Anonymous, 1992).

2.6. TRANSFORMATION AND MOBILITY OF NITROGEN

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2.6.1. Transformation

A knowledge on the transformation of nitrogen in soil is a prerequisite for better appreciation and manipulation of the various processes for making efficient use of soil and fertiliser nitrogen (Yadav and Singh, 1991).

2.6.1.1. Forms of Nitrogen

Only about 2 per cent of the total nitrogen content in soil is of inorganic nature and the rest is organic. The inorganic nitrogen present in most of the soils is in the form of exchangeable and fixed $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$. These forms constitute an extremely dynamic system in the soil which is influenced by physical and chemical processes (Savant and De Datta, 1982).

Nitrite is sometimes present in traces and except under specified situation, it is wholly considered that the quantity present in the soil is negligible enough to ignore its determination. In addition to this, several other forms of inorganic N such as hydroxylamine, hyponitrous acid and nitramide may occur during the transformation process leading to nitrification, denitrification and nitrogen fixation in soil. These compounds are chemically unstable and are not detected in significant amounts during analysis.

2.6.1.2. Reaction of fertilizer N

Applied N formed different pools of nitrogen in the soil but $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ play dominant role and maximum amount of ammoniacal nitrogen at early stage may be due to the formation from hydrolysis of urea in the soil.

Nitrification of urea does not proceed indefinitely because nitric acid formed as a result of nitrification makes the soil acid and thereby retards nitrification. Nitrification of

urea is completed within 2-4 weeks (Broadbent *et al.*, 1958). Nitrate-N was found to increase with increasing time of incubation and increasing rates of urea-N was also observed (Bhuiya *et al.*, 1974).

The $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ increased significantly with increasing levels of nitrogen in all the stages of crop growth. There is a steady decline in $\text{NH}_4\text{-N}$ with time which may be due to its conversion to $\text{NO}_3\text{-N}$ (Subbiah and Kothandaraman, 1980).

Weier and MacRae (1993) observed high amount of $\text{NH}_4\text{-N}$ within first two weeks in the soil after fertiliser urea application in upper three depths of soil and in beneath was entirely nitrate-N indicating active nitrification.

2.6.1.3. Temperature effect

The optimal temperature of oxidation of $\text{NH}_4\text{-N}$ to $\text{NO}_2\text{-N}$ and of $\text{NO}_2\text{-N}$ to $\text{NO}_3\text{-N}$ is between 25 and 35°C. However, nitrification can take place over a wide range of temperatures (2 to 35°C) but rarely above 40°C (Frederick, 1956).

Hydrolysis of urea to NH_4^+ with subsequent conversion to NO_3^- was greatly affected by temperature. Only a small portion of the urea applied was transformed to NH_4^+ and NO_3^- at 15°C, the transformation accelerated with increasing temperature, reaching virtual completion at 30°C after 28 days (Jian Luo *et al.*, 1993).

2.6.1.4. Mineralisation

Harper (1984) reported that urea applied to the soil can be rapidly hydrolysed to NH_4^+ by soil urease, with subsequent conversion of NH_4^+ to NO_3^- . Hence, urea is utilised by plants mainly as inorganic nitrogen although it can be taken up as intact molecule to some extent.

Production of $\text{NO}_3\text{-N}$ often been used as the indicator of mineralisation in soil as reported by Hadas *et al.* (1989). The $\text{NH}_4\text{-N}$ concentration in aerated soils have been found to be small and constant during crop growth (Harmsen and Van Schreven, 1995).

2.6.2. Mobility of nitrogen in hardpan soils

The effects of soil compaction on transport of nutrients to the roots depend on the amount of soil compaction and on water and nutrient supply. Under well watered and high fertility conditions, moderate soil compaction may have a beneficial effect. This can be due to the greater water retention and hydraulic conductivity in the case of mass flow transport (Kemper *et al.*, 1971) increased diffusion coefficient of ions (Warneke and Barber, 1972) or due to increased ion concentration in the soil. Further increase in bulk density above a certain value, however may decrease the diffusion coefficient, as a result of increased tortuosity of pores and restriction of root penetration.

Mass flow is an important mechanism in the transport of N, Ca, Mg, S, B, Cu, Zn, Fe and Cl while it is diffusion for the transport of P and K. Soil aeration, being dependent on water status and the degree of compaction of the soil (Stepniewski *et al.*, 1995), is another important factor influencing nutrient transformation and uptake. The soil aeration status directly affects redox transformations of N, Mn and Fe.

Modification of the soil nitrogen balance due to compaction takes place as a result of (1) alteration of the soil aeration status, which contributes directly to denitrification and gaseous nitrogen losses, decreased nitrogen mineralisation rate and reduction of nodulation and symbiotic nitrogen fixation by leguminous plants (2) alteration of the soil water properties, which induce changes in N transport and leaching (3) alteration of the arrangement of soil particles, resulting in changes in root configuration, root-soil contact and ion diffusivity (Lipiec and Stepniewski, 1995).

Nitrate ions are characterised by relatively high diffusivity i.e. greater than $10^{-7} \text{ cm}^2 \text{ s}^{-1}$ in uncompacted soil (Fitter, 1991). It has been shown that denitrification is related to air filled porosity of the soil (Sextone *et al.*, 1988) and to the soil aggregation status (Bakken *et al.*, 1987; Horn, *et al.*, 1994).

Laboratory studies of Wollersheim *et al.* (1987) showed that on a loess soil, denitrification almost doubled when bulk density increased from 1.3 Mg m^{-3} to 1.6 Mg m^{-3} and matric potentials of both -20 and -5 K Pa. At bulk density 1.6 Mg m^{-3} and matric potential -20 K Pa, denitrification was almost the same as at bulk density 1.3 Mg m^{-3} and matric potential -5 K Pa. In both cases air filled porosity was similar (about 12 per cent), which indicates that denitrification is dependent on soil aeration.

Compaction of sandy soils, which are highly conducive to leaching, resulted in a considerably greater nitrate retention in the top soil (Agarwal and Jhorar, 1989). Agarwal (1991) reported that in a surface compacted sandy soil, the $\text{NO}_3\text{-N}$ content was several times greater than the uncompacted soil. The effect of subsurface compared to surface compaction on the reduction of leaching was considerably less.

Studies of Shipitalo and Edwards (1993) showed that tillage has a greater effect on the movement of $\text{NH}_4\text{-N}$ than of $\text{NO}_3\text{-N}$. Much of the $\text{NH}_4\text{-N}$ transport occurred early in the maize growing season. When the effects on the crop and water movement were assumed to have been minimal and the concentration of NH_4^+ in the percolate was high.

Nitrogen concentration in the soil profile was lower in no tillage system compared to conventional tillage (Angle *et al.*, 1993). The differences among the tillage systems were greater when high rates of N were applied.

Slower release of nitrate from organic matter in no tillage may result in a reduced crop yield (Thomson, 1992; Braim *et al.*, 1992).

In moderately compacted soil, the nutrient uptake efficiency increased when fertilisers were uniformly distributed in the entire ploughed layer (Nosko *et al.*, 1979). However, higher N application may also cause increased leaching losses (Angle *et al.*, 1993).

Soil compaction has a marked effect on both the development and nitrogen fixing capacity of leguminous plants (Voorhees *et al.*, 1976; Lindemann *et al.*, 1982; Tricot *et al.*, 1990; Grath and Hakansson, 1992). Studies by Tricot *et al.* (1990) showed that average total numbers of nodules per unit plant were 137 and 188 for uncompacted and compacted soils respectively. This lower nodule activity in compacted soil was attributed mainly to greater surface concentration and greater sensitivity to water stress.

Increasing the bulk density of clay loam soil from 1.1 to 1.8 Mg m⁻³ resulted in significantly higher root cation exchange capacity of several plant species (Kulkarni and Savant, 1977). This is apparently due to the increase in the N content of the roots and in the number of carboxyl groups on the root surface.

EXPERIMENTAL DETAILS

CHAPTER III

EXPERIMENTAL DETAILS

The details of the field experiments conducted and the methods followed for plant and soil analyses are presented in this chapter.

3.1. Field experiment

Field experiments were conducted for two seasons in succession during 1993-94 to study the effect of chiseling, organics and levels of nitrogen on the yield of crops, improvement of physical properties and on transformation and movement of nitrogen in a soil having subsoil hardpan at shallow depth in sorghum-groundnut sequence at Nachipalayam village of Madukkarai block, Coimbatore district, Tamil Nadu.

3.2. Location and soil type

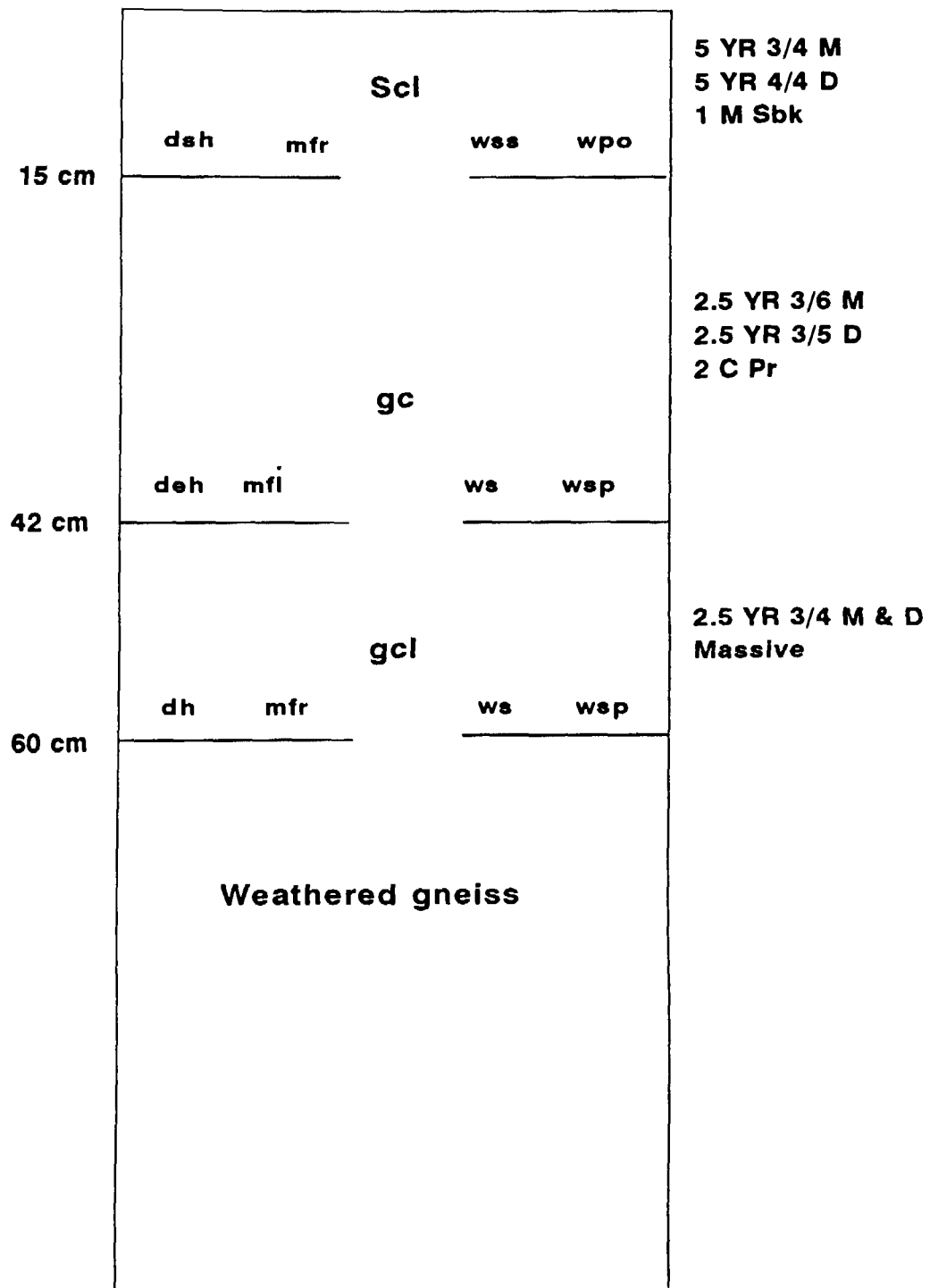
The experiments were conducted on sandy clayloam (Pichanur series- Typic Haplustalf), reddish brown soil having subsoil hardpan at shallow depth (at 15 cm) in farmer's field at Nachipalayam village. The experimental site is situated at an altitude of 427 m above Mean Sea Level. 11°N latitude and 78.58°E longitude.

A profile was excavated open in the experimental site and described systematically and the details are furnished in Table 1 and the profile diagram is depicted in Fig 1.

Table 1. Profile description of the experimental site

Soil Order	:	Alfisol
Soil Series	:	Pichanur (Pch)
Location	:	Nachipalayam, Madukkarai Block, Coimbatore District, Tamil Nadu.

Fig 1 PROFILE DIAGRAM OF PICHANUR SERIES



Horizon	Depth	Description
Ap	0-15	Dark reddish brown (5YR 3/4) moist; reddish brown (5YR 4/4) dry; sandy clay loam; weak; medium, sub angular blocky breaking to granular; dry slightly sticky and non plastic, many very fine to fine roots; abrupt smooth boundary.
B ₂	15-42	Dark red (2.5YR 3/6) moist and (2.5 YR 3/5) dry gravelly clay; moderate, coarse, prismatic; dry extremely hard, moist firm wet sticky and slightly plastic; very few to none number of fine roots abrupt smooth boundary.
B ₃	42-60	Dark red (2.5YR 3/6) moist and dry; gravelly clay loam; massive; dry hard moist friable, wet sticky and slightly plastic clear smooth boundary.
C	60-80	Weathered gneiss

The initial soil characteristics presented in chapter IV is in confirmation with the profile description showing the presence of dense sub soil layer just below 15 cm depth.

3.3. Crops and varieties

The test crops viz., sorghum Co 26 and groundnut Co 2 in the sequence were grown during August-December and January-April respectively during the year 1993-94.

3.4. Field layout

The sorghum experiment was laid out in a split plot design (2 factors in main plot) with twenty seven treatment combinations comprising of nine main plots and three sub plot treatments replicated thrice by following a plot size of 5m x 4m. The lay out plan is given in Fig 2.

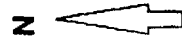


Fig 2 Field layout plan

T3			T2			T1			T3			T2			T1			T2			T3		
N2	N1		N3	N2		N1	N3		N2	N3		N2	N2		N1	N2		N2	N2		N1	N3	
N1	N2		N3	N1		N3	N2		N1	N2		N3	N1		N3	N2		N2	N2		N3	N2	
N3	N3		N2	N1		N2	N1		N3	N1		N1	N3		N2	N1		N1	N3		N2	N1	
M2 M1 M3			M3 M2 M1			M2 M3 M1			M3 M1 M2			M1 M2 M3			M2 M1 M3			M3 M2 M1			M1 M2 M3		
R1			R1			R2			R2			R3			R3			R3			R3		

The residual crop of groundnut was raised in the same field after the harvest of the sorghum crop to study the residual effect of tillage and organic on the succeeding crop. The layout plan of the experimental site is given in Fig. 2.

3.5. Treatment details

3.5.1. Treatments

The following treatments were imposed to meet the objectives of this study as detailed in chapter I.

Main plot treatments

Type of tillage

T1 - Country ploughing twice

T2 - Mouldboard ploughing twice

T3 - Chisel ploughing once + country ploughing twice

Source of organics

M1 - No organics

M2 - Farm yard manure @ 12.5 t ha⁻¹

M3 - Composted coir pith @ 12.5 t ha⁻¹

Sub plot treatments

Levels of nitrogen

N1 - No nitrogen

N2 - 75 per cent recommended N level

N3 - 100 per cent recommended N level

3.4.2. Treatment combinations

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T1 - T1M1N1	T10 - T2M1N1	T19 - T3M1N1
T2 - T1M1N2	T11 - T2M1N2	T20 - T3M1N2
T3 - T1M1N3	T12 - T2M1N3	T21 - T3M1N3
T4 - T1M2N1	T13 - T2M2N1	T22 - T3M2N1
T5 - T1M2N2	T14 - T2M2N2	T23 - T3M2N2
T6 - T1M2N3	T15 - T2M2N3	T24 - T3M2N3
T7 - T1M3N1	T16 - T2M3N1	T25 - T3M3N1
T8 - T1M3N2	T17 - T2M3N2	T26 - T3M3N2
T9 - T1M3N3	T18 - T2M3N3	T27 - T3M3N3

The above treatments were tried for sorghum crop and after the harvest of sorghum crop, country ploughing alone was given to the entire field without altering the lay out plan and groundnut crop was raised. Neither the tillage treatments nor the organics applied to the groundnut crop since it was planned to study the residual effect of tillage treatments as well as organics.

3.5. Application of fertilisers

The calculated dose of fertiliser N applied in the form of urea for sorghum and groundnut crops, half the dose as basal and the remaining half the dose as top dressing on 45 days after sowing for sorghum and 30 days after sowing for the groundnut crop. Phosphorus and potassium at recommended levels were applied basally in the form of single super phosphate and muriate of potash respectively.

The organics viz., farm yard manure and composted coir pith were applied basally and incorporated thoroughly in the top soil as per the treatment schedule 15 days before sowing.

3.6. Sowing and after cultivation practices

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The sowing of sorghum crop was done by adopting the normal spacing of 45 X 15 cm. Two weedings were done during the crop growth period. Necessary plant protection measures were taken up. Irrigation was restored to as and when necessary. The main effect of tillage and organics were studied in this crop. Subsequently in the same layout just after giving two country ploughings, groundnut crop was raised to study the residual effect of tillage and organic treatments. The groundnut was sown adopting the spacing of 30 x 15 cm. Gypsum was applied @ 400 kg ha⁻¹ on 30th day after sowing.

3.7. Yield

3.7.1. Dry Matter Production

Five plants were removed at 15 days interval from each plot, shade dried initially and then dried in a hot air oven at 60°C for constant weight, based on which the dry matter production was calculated.

3.7.2. Grain and Straw yield

All the plants of the test crops from the net plot were harvested and the treatment wise yield of grain and straw in sorghum / kernel and haulm in groundnut were recorded.

3.8. Collection of samples

3.8.1. Soil samples

3.8.1.1. Disturbed soil samples

Soil samples were collected at periodical intervals to monitor the changes that occur in the physical and chemical properties of the soil. For determining the physical properties, core samples were collected as described in 3.8.1.2. For nitrogen fractions determination (Ammoniacal nitrogen and nitrate nitrogen) samples were collected at 3,5,7,10,15,30,45,60,75,90 and 105 days after sowing and at harvest stage in 3 depths viz., 0-15, 15-30 and 30-45 cm in the case of sorghum crop. With respect to the

groundnut crop, the samples were restricted to 15,30,45 and 60 days after sowing and at harvest stage at the same depths as in the case of sorghum crop. For other chemical properties, samples were collected at 45 and 90 days after sowing and at harvest were used.

3.8.1.2. Collection of core samples

The undisturbed core samples were collected at 45 and 90 days after sowing and at harvest in 3 depths viz., 0-15, 15-30 and 30-45 cm to monitor the changes in the physical properties of soil.

The core samples were collected by placing the core cutter in position along with the collar and driving it with the help of hammer into the soil until the edge of the collar rests on the surface. With the help of the kurpi, the soil around the core cutter was dug and the soil core sampler was removed. The collar was then removed and opened. The sectional cylinder that retains the soil column was then removed gently along with the guard rings which were covered on both sides with wet cotton cloth. Proper labelling was done indicating the treatment and depth of sample collected. Then it was preserved in polythene covers air tight before bringing to the laboratory.

3.8.2. Plant samples

Plant samples were collected at 15 days interval upto harvest and analysed for nitrogen content.

3.8.3. Root samples

For the collection of root samples (15 days interval), the soil around the selected plants were removed using spade to the required depth, then the plants with the mass of soil were put in a drum of water to remove the soil. After washing, the root samples were dried under shade and used for measuring its length and volume.

3.8.4. Determination of root volume

The volume of the root was measured by the method of displacement, when the root bunches were immersed in water contained in a measuring cylinder (Jena *et al.*, 1980).

3.9. Analytical techniques

The methods and procedures employed for the determination of various physico-chemical properties of the soil and the nutrient concentration of plant samples are furnished in Table 2.

3.9.1. Fractionation of soil nitrogen

The fractionation of soil nitrogen was carried out by an adapted version of the procedure given by Cheng and Kurtz (1963) and Keeney and Bremner (1964). The individual fractions were estimated according to the procedure given by Bremner (1965).

3.9.1.1. Preparation of equilibrium extract

A quantity of 10 g of soil (< 0.2 mm) treated with 100 mL of 2M KCl solution was shaken for one hour and filtered through Whatman No.1 filter paper. The filtrate was used for the determination of $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$.

3.9.1.1.1. Ammoniacal-N

An aliquot of 20 mL of the filtrate was distilled with freshly ignited MgO in Bremner's distillation apparatus and the distillate collected in 2 per cent boric acid containing mixed indicator was titrated with standard H_2SO_4 .

3.9.1.1.2. Nitrate-N

On removal of exchangeable NH_4 from the samples, a pinch of Devarda's alloy was added and continued the steam distillation. The amount of $\text{NO}_3\text{-N}$ was determined as described for ammoniacal nitrogen.

3.9.2. Plant nitrogen content

Nitrogen in the plant samples were estimated in diacid extract (sulphuric : perchloric acid 5:1) (Piper, 1966).

3.10. Statistical analysis

The experimental data collected in the present investigations were subjected to statistical scrutiny as per the standard procedures given by Panse and Sukhatme (1978).

Table 2. Details of the analytical method employed in the study

Soil characteristics		Reference	Methodology
A. PHYSICAL PROPERTIES			
1.	Textural fractions	Piper (1966)	International Pipette method
2.	Bulk density	Gupta and Dakshinamoorthy (1980)	Core sample
3.	Hydraulic conductivity	Gupta and Dakshinamoorthy (1980)	Core sample
4.	Pore size distribution	Gupta and Dakshinamoorthy (1980)	Core sample
5.	Infiltration rate	Gupta and Dakshinamoorthy (1980)	Double ring infiltrometer
6.	Available soil moisture	Gupta and Dakshinamoorthy (1980)	Pressure plate
B. PHYSICO CHEMICAL PROPERTIES			
1.	Soil reaction	Jackson (1973)	Potentiometry (1:2.5 soil water suspension)
2.	Electrical conductivity	Jackson (1973)	Conductometry (1:2.5 soil water suspension)
3.	Cation exchange capacity	Piper (1966)	Using neutral (CEC) normal ammonium acetate

C. CHEMICAL PROPERTIES

1.	Organic carbon	Walkley and Black (1934)	Wet oxidation
2.	Total nitrogen	Piper (1966)	Macro Kjeldahl digestion
3.	Total phosphorus	Pemberton (1945)	Volumetry
4.	Total potassium	Toth and Prince (1949)	Flame photometry
5.	Total calcium	Jackson (1973)	Titrimetry
6.	Total magnesium	Jackson (1973)	Titrimetry
7.	Total sesquioxides	Piper (1966)	Gravimetry
8.	Iron oxide	Piper (1966)	Volumetry
9.	Aluminium oxide	Piper (1966)	By difference between Sesqui oxides and iron oxide
10.	Available nitrogen	Subbiah and Asija (1956)	Alkaline permanganate distillation
11.	Available phosphorus	Olsen <i>et al.</i> (1954)	Colorimetry
12.	Available potassium	Stanford and English (1949)	Flame photometry Neutral normal ammonium acetate
13.	Exchangeable calcium	Jackson (1973)	Versenate titration
14.	Exchangeable magnesium	Jackson (1973)	Versenate titration
15.	Exchangeable potassium	Pratt (1965)	Flame photometry
16.	Exchangeable sodium	Pratt (1965)	Flame photometry
17.	Inorganic N fraction		
	a. ammoniacal-N		2M KCl
	b. Nitrate-N	Bremner (1965)	extraction and distillation

RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

Field experiments were carried out on red soils (Pichanur series) where the actual problem of subsoil hardpan occurs, at Nachipalayam village, Madukarai block, Coimbatore district, Tamil Nadu to study the direct and residual effect of different tillage practices, organic sources and levels of N application on sorghum-groundnut cropping sequence. Soil samples were collected in various stages starting from 3rd day upto harvest for sorghum crop and from 15th day upto harvest stage for groundnut crop and analysed for ammoniacal nitrogen ($\text{NH}_4\text{-N}$) and nitrate nitrogen ($\text{NO}_3\text{-N}$). Undisturbed soil samples were collected in 3 stages viz., 45 and 90 days after sowing (DAS) and at harvest for sorghum and groundnut crops and analysed for various physical parameters. Plant samples were collected starting from 15th day upto harvest stage at 15 days interval for estimating N uptake and dry matter production. Root samples were also collected in the above stages to determine the root length and volume. The yield data of the test crops were recorded. The results of soil analyses, yield and response of crops to the treatments in the sequence, uptake of nutrients and their relationships are detailed in this chapter.

4.1. Characteristics of initial soil (Table 3)

The initial representative soil samples collected from each horizon of the profile in the experimental site were assessed for the physico-chemical properties. Mechanical analysis of the soil showed that the texture was sandy clay with 35.70 per cent finer fractions (clay + silt) and 62.46 per cent of coarser fractions (fine sand + coarse sand). The apparent specific gravity was found to be 1.45 Mg m^{-3} in the top layer (0-15cm) and it was 1.82 and 1.84 mg m^{-3} in the second and third depths respectively. The hydraulic conductivity was very low in sub soil ($0.30\text{-}0.38 \text{ cm h}^{-1}$) compared to surface soil (2.42 cm h^{-1}). The soil was tested to be of neutral in reaction (pH 7.1).

Table 3 Horizonwise physical and chemical characteristics of soils of the experimental site

No.	Properties	0 - 15 cm	15 - 42 cm	42 - 60 cm
1.	Bulk density (Mg m^{-3})	1.45	1.82	1.84
2.	Hydraulic conductivity (cm h^{-1})	2.42	0.36	0.38
3.	Capillary porosity (%)	34.45	32.28	32.76
4.	Non-capillary porosity (%)	11.31	7.80	7.62
5.	Total porosity (%)	45.76	40.08	39.38
6.	Water holding capacity (%)	28.44	35.32	34.96
7.	Field capacity moisture - 1/3 bar (%)	25.64	27.44	28.48
8.	Permanent wilting point moisture - 15 bar (%)	10.96	13.28	12.96
9.	Available soil moisture (%)	10.68	14.16	15.52
10.	Infiltration rate (cm h^{-1})	0.64	--	--
11.	Soil pH	7.10	7.20	7.40
12.	Electrical conductivity (dS m^{-1})	0.42	0.51	0.48
13.	Available nitrogen (kg ha^{-1})	142.00	196.00	118.00
14.	Available phosphorus ($\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$)	7.30	13.60	5.60
15.	Available potassium ($\text{kg K}_2\text{O ha}^{-1}$)	112.00	154.00	107.00
16.	Cation exchange capacity (c.mole (p+) kg^{-1})	11.20	13.80	12.20
17.	Exchangeable calcium (c.mole (p+) kg^{-1})	6.80	7.20	5.90
18.	Exchangeable magnesium (c.mole (p+) kg^{-1})	2.00	2.20	1.80
19.	Exchangeable potassium (c.mole (p+) kg^{-1})	0.16	0.20	0.14
20.	Organic carbon (%)	0.21	0.18	0.16
21.	Total nitrogen (%)	0.08	0.08	0.07
22.	Total phosphorus (%)	0.02	0.02	0.02
23.	Total potassium (%)	0.45	0.43	0.40
24.	Total calcium (%)	0.86	1.02	0.94
25.	Total magnesium (%)	0.36	0.42	0.44
26.	Iron oxide (%)	5.86	9.24	10.68
27.	Aluminium oxide (%)	6.98	8.68	9.76
28.	Clay (%)	23.42	42.27	43.86
29.	Silt (%)	12.28	29.63	12.24
30.	Fine sand (%)	9.78	14.68	28.94
31.	Coarse sand (%)	52.68	12.24	13.62
32.	Texture	Scl	Cl	Cl

The KMnO_4 oxidisable-N, Olsen-P and NH_4OAc -K status of the soil were 142, 7.3 and 112 kg ha^{-1} respectively. The iron and aluminium oxides were found to be high in subsoil compared to surface soil.

Based on the morphological and physico chemical characteristics, the soil has been grouped under Pichanur series and classified as Typic Haplustalf.

4.2. Physical properties of soil prior to tillage (Table 4)

The undisturbed soil samples collected from three depths viz., 0-15, 15-30 and 30-45 cm were subjected to various physical estimations. The results showed that the bulk density was 1.45 Mg m^{-3} in surface layer, whereas the bulk density was much higher in second (1.81 Mg m^{-3}) and third layers (1.84 Mg m^{-3}). Contrary to this, the hydraulic conductivity was very high in surface layer (2.38 cm h^{-1}) compared to second and third depths (0.30 and 0.34 cm h^{-1}). The pore space was found to be higher in top layer compared to subsoil layers. The infiltration rate was found to be 0.62 cm h^{-1} .

4.2.1. Physical properties of soil immediately after tillage (Table 5; Fig 3)

The undisturbed soil samples were collected from each tillage treatment at three depths and subjected to physical estimations as mentioned earlier. The results indicated that in the surface layer (0-15 cm), perceptible variation was not found in the physical properties due to different tillage operations. However, in the second (15-30 cm) and third (30-45 cm) layers, chiseling followed by country ploughing twice (T3) resulted in reduced bulk density (from 1.81 to 1.58 Mg m^{-3} and from 1.84 to 1.66 Mg m^{-3} respectively). The hydraulic conductivity and pore size distribution were found to be increased due to chiseling, only in second layer. The other tillage treatments namely country ploughing twice (T1) and mouldboard ploughing twice (T2) did not influence the physical properties of the second and third layers.

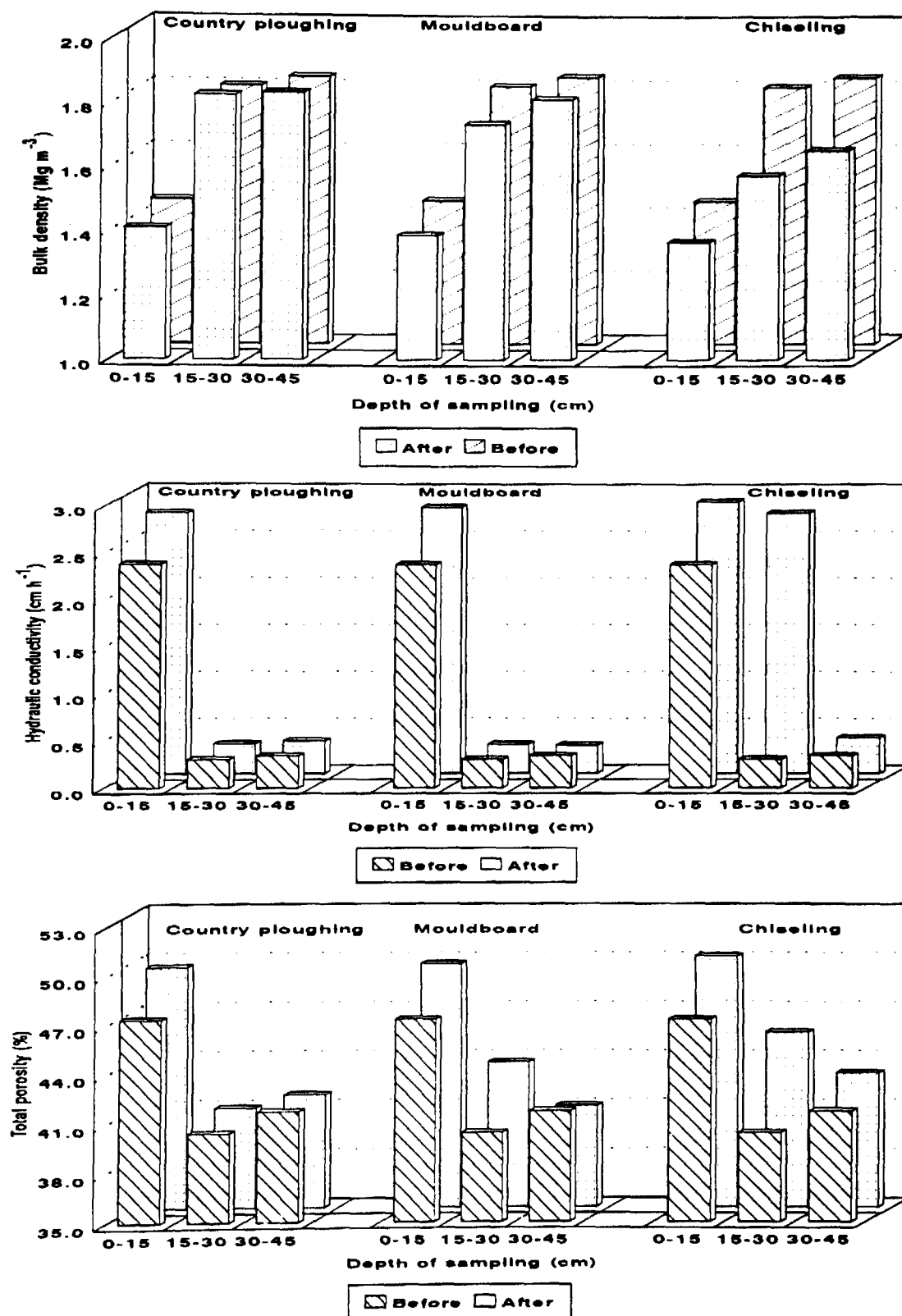
Table 4 Physical properties of initial soil samples at different depths

Depth (cm)	Bulk density (Mg m ⁻³)	Hydraulic conductivity (cm h ⁻¹)	Capillary porosity (%)	Non-capillary porosity (%)	Total porosity (%)	Infiltration rate (cm h ⁻¹)
0 - 15	1.45	2.38	35.26	12.08	47.34	0.62
15 - 30	1.81	0.30	32.44	7.96	40.40	--
30 - 45	1.84	0.34	33.68	8.04	41.72	--

Table 5 Physical properties of soil at different depths immediately after imposing tillage treatments

Property	T1			T2			T3		
	0 - 15 cm	15 - 30 cm	30 - 45 cm	0 - 15 cm	15 - 30 cm	30 - 45 cm	0 - 15 cm	15 - 30 cm	30 - 45 cm
Bulk density (Mg m ⁻³)	1.41	1.83	1.84	1.38	1.74	1.82	1.37	1.58	1.66
Hydraulic conductivity (cm h ⁻¹)	2.78	0.32	0.35	2.84	0.31	0.30	2.90	2.78	0.38
Capillary porosity (%)	36.44	32.94	33.49	36.88	34.12	32.98	37.12	34.98	33.49
Non-capillary porosity (%)	13.22	8.12	8.36	12.96	9.68	8.16	13.19	10.69	9.68
Total porosity (%)	49.66	41.06	41.85	49.84	43.80	41.14	50.31	45.67	43.17
Infiltration rate (cm h ⁻¹)	0.68	--	--	0.72	--	--	1.48	--	--

Fig 3 Changes in physical properties due to tillage



4.3. Effect of treatments on physical properties

4.3.1. Bulk density

4.3.1.1. Sorghum crop (Tables 6, 7 and 8)

The bulk density values of the core samples collected on 45 Days After Sowing (DAS) revealed that the lowest bulk density of 1.54 Mg m^{-3} was registered in the chiseled plots which was significantly lower value than other tillage treatments. The highest bulk density (1.67 Mg m^{-3}) was observed in country ploughing treatment. Among depths, significantly higher bulk densities were recorded in subsoil layers than in surface soil. The interaction effect of T x D showed that chiseled plots registered lesser bulk density values in second and third depths compared to other tillage treatments. As for as the surface soil is concerned, the values were comparable.

The correlation studies showed that the bulk density at 45 DAS had significant negative relationship with grain yield ($r = -0.847^{**}$), root length ($r = -0.984^{**}$), root volume ($r = -0.970^{**}$), total N uptake ($r = -0.726^{*}$) and grain N uptake ($r = -0.864^{*}$). It also had significant negative correlation with other physical parameters like hydraulic conductivity and pore size distribution of soil samples collected on 45 and 90 DAS and at harvest stage (Appendix I).

The results of bulk density on 90 DAS revealed the same trend as that of the bulk density values of 45 DAS. The bulk density values were significantly lower in second and third depths under chiseled plots, whereas the bulk densities were on par in these depths in other tillage treatments. However, in surface layer all the tillage treatments behaved similarly.

The correlation studies of bulk density on 90 DAS indicated the significant inverse relationship with grain yield ($r = -0.863^{**}$), root length ($r = -0.978^{**}$), root volume ($r = -0.970^{**}$), total N uptake ($r = -0.762^{**}$) and grain N uptake ($r = -0.862^{**}$).

Table 6 Effect of tillage and organics on the bulk density of soil in different depths (Mg m⁻³) at 45 DAS (sorghum)

Treatments	T1			T2			T3			D Mean		
	M1	Tx D Mean		M1	Tx D Mean		M1	Tx D Mean				
		M2	M3		M2	M3		M2	M3			
0 - 15	1.440	1.395	1.410	1.415	1.430	1.370	1.390	1.405	1.360	1.380	1.382	1.396
15 - 30	1.855	1.835	1.850	1.547	1.755	1.780	1.740	1.580	1.535	1.530	1.548	1.718
30 - 45	1.740	1.775	1.750	1.755	1.745	1.750	1.750	1.685	1.695	1.680	1.687	1.730
TxM Mean T Mean	1.678	1.668	1.670	1.672	1.643	1.633	1.620	1.557	1.530	1.530	1.539	
SE _b	0.014			-			0.012		0.022		0.020	
CD (0.05)	0.033			NS			0.024		0.048		0.042	

Table 7 Effect of tillage and organics on the bulk density of soil in different depths (Mg m⁻³) at 90 DAS (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	T x D Mean	M1	M2	M3	T x D Mean	M1		M2	M3	T x D Mean
0 - 15	1.415	1.360	1.360	1.378	1.435	1.360	1.350	1.382	1.430	1.355	1.365	1.383	1.381
15 - 30	1.870	1.860	1.865	1.865	1.790	1.775	1.810	1.792	1.605	1.585	1.645	1.602	1.753
30 - 45	1.745	1.730	1.705	1.727	1.715	1.745	1.745	1.735	1.655	1.665	1.675	1.665	1.709
T x M Mean T Mean	1.677	1.650	1.643	1.647	1.647	1.627	1.635	1.636	1.563	1.535	1.552	1.550	
SE _b	0.018	-			0.016			0.029			0.027		
CD (0.05)	0.041	NS			0.033			0.062			0.057		

Table 8 Effect of tillage and organics on the bulk density of soil in different depths (Mg m⁻³) at harvest (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2		M1	M2		M1	M2			TxD Mean		
		M3	TxD Mean		M3	TxD Mean		M3	TxD Mean				
0 - 15	1.455	1.395	1.375	1.408	1.455	1.425	1.395	1.425	1.435	1.390	1.385	1.403	1.412
15 - 30	1.865	1.845	1.875	1.862	1.840	1.845	1.845	1.843	1.670	1.660	1.685	1.672	1.792
30 - 45	1.750	1.760	1.765	1.758	1.785	1.760	1.775	1.773	1.735	1.720	1.725	1.727	1.753
T x M Mean T Mean	1.690	1.667	1.672	1.676	1.693	1.677	1.672	1.681	1.613	1.590	1.598	1.601	
SE _D	0.009			-			0.018			T on D 0.026			D on T 0.030
CD (0.05)	0.021			NS			0.037			0.056			0.064

Table 9 Effect of tillage and organics on the bulk density of soil in different depths (Mg m⁻³) at 45 DAS (groundnut)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	1.410	1.390	1.405	1.402	1.395	1.385	1.405	1.395	1.405	1.380	1.390	1.392	1.396
15 - 30	1.825	1.845	1.800	1.823	1.855	1.845	1.850	1.850	1.740	1.740	1.760	1.747	1.807
30 - 45	1.765	1.735	1.755	1.752	1.780	1.800	1.775	1.785	1.755	1.760	1.795	1.770	1.769
TxM Mean T Mean	1.667	1.657	1.653	1.659	1.677	1.677	1.677	1.677	1.633	1.627	1.648	1.636	
SE _b	-			-			-			0.015			4
CD (0.05)	NS			NS			NS			0.032			

Besides, it also had significant inverse relationship with other physical properties of the soil samples collected on 45 and 90 DAS and at harvest (Appendix I).

The results of the bulk density at post harvest stage also revealed the same trend as that of the earlier stages, as far as tillage treatments and depths are concerned. The interaction effect of T x D indicated that chiseled plots alone registered comparable bulk density values in both the subsurface layers, whereas in other tillage treatments, the second depth registered significantly higher values followed by third depth. Irrespective of tillage treatments, the surface layer registered significantly lower bulk density values. In second depth, the bulk density values were significantly lower due to chiseling, whereas the other two tillage treatments did not alter the bulk density in subsurface layers.

The correlation studies indicated the significant negative relationship of bulk density at post harvest stage with grain yield ($r = -0.897^{**}$), root length ($r = -0.947^{**}$), root volume ($r = -0.947^{**}$), total N uptake ($r = -0.754^*$) and grain N uptake ($r = -0.853^{**}$). With other physical properties the same negative trend was observed as mentioned in the earlier stages (Appendix I).

4.3.1.2. Groundnut crop (Tables 9, 10 and 11)

The bulk density values of 45 DAS revealed that the values were significantly lower in surface layer (0-15 cm) compared to subsurface layers (15-30 and 30-40 cm). At this stage, the tillage treatments did not influence the bulk density values.

The correlation studies of bulk density values at 45 DAS indicated significant negative relationship with hydraulic conductivity on 45 DAS ($r = -0.785^*$) and 90 DAS ($r = -0.754^*$). It also revealed that, this property did not influence yield and uptake (Appendix II).

The bulk density values of the 90 DAS revealed the same trend as that of the 45 DAS sampling.

At harvest stage also a similar trend of bulk density values as that of 45 DAS sampling was noticed. The effect of tillage treatments was absent. Only the depth showed significant difference.

The correlation studies of bulk density values at post harvest stage indicated no relationship with yield, uptake and with other physical parameters (Appendix II).

4.3.2. Hydraulic conductivity

4.3.2.1. Sorghum crop (Table 12, 13 and 14)

The hydraulic conductivity values of the core samples collected on 45 DAS indicated that chiseling increased the hydraulic conductivity value to 2.189 cm h^{-1} which is significantly superior over other two tillage treatments. The organics viz., composted coir pith and farm yard manure at 12.5 t ha^{-1} also significantly improved the hydraulic conductivity compared to control.

In second depth, the chiseled plots recorded significantly higher values than other two tillage treatments.

The correlation studies of hydraulic conductivity showed significant positive relationship with grain yield ($r = 0.948^{**}$), root length ($r = 0.930^{**}$), root volume ($r = 0.922^{**}$), total N uptake ($r = 0.842^{**}$) and grain N uptake ($r = 0.921^{**}$). It also had significant positive correlation with other physical parameters except bulk density on 45 and 90 DAS and at harvest stage. It had significant negative correlation with bulk density at all stages of sampling (Appendix I).

Table 12 Effect of tillage and organics on the hydraulic conductivity of soil in different depths (cm h⁻¹) at 45 DAS (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	2.600	3.510	3.505	3.205	2.800	3.540	3.680	3.340	2.890	3.535	3.600	3.342	3.296
15 - 30	0.390	0.380	0.385	0.385	0.370	0.330	0.350	0.350	2.440	2.940	2.850	2.743	1.159
30 - 45	0.510	0.495	0.510	0.505	0.505	0.470	0.505	0.493	0.505	0.485	0.455	0.482	0.493
TxM Mean T Mean	1.167	1.462	1.467	1.365	1.225	1.447	1.512	1.394	1.945	2.320	2.302	2.189	
SE _b	0.085		0.085		0.074		0.135		0.129		0.135		0.129
CD (0.05)	0.178		0.178		0.158		0.295		0.270		0.295		0.270

Table 13 Effect of tillage and organics on the hydraulic conductivity of soil in different depths (cm h⁻¹) at 90 DAS (sorghum)

Treatments	T1			T2			T3			D			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	Mean
0 - 15	2.220	3.320	3.345	2.962	2.310	3.280	3.390	2.993	2.260	3.530	3.520	3.103	3.019
15 - 30	0.320	0.335	0.340	0.332	0.340	0.320	0.340	0.333	2.000	2.080	2.135	2.072	0.912
30 - 45	0.405	0.390	0.370	0.388	0.380	0.390	0.400	0.390	0.365	0.380	0.395	0.380	0.386
TxM Mean T Mean	0.982	1.348	1.352	1.227	1.010	1.330	1.337	1.239	1.542	1.997	2.017	1.852	
SE _b	0.064		0.064		0.054		0.094		0.091		0.094		0.091
CD (0.05)	0.142		0.142		0.112		0.208		0.181		0.208		0.181

Table 14 Effect of tillage and organics on the hydraulic conductivity of soil in different depths (cm h⁻¹) at harvest (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	1.950	3.150	3.100	2.733	2.060	3.220	3.250	2.843	2.085	3.425	3.315	2.942	2.839
15 - 30	0.350	0.355	0.335	0.347	0.335	0.385	0.325	0.348	1.720	2.000	1.970	1.897	0.864
30 - 45	0.410	0.380	0.380	0.390	0.355	0.385	0.360	0.367	0.365	0.350	0.370	0.362	0.373
TxM Mean T Mean	0.903	1.295	1.272	1.157	0.917	1.330	1.312	1.186	1.390	1.925	1.885	1.733	
SE _D	0.044		0.044		0.041		0.074		0.064		0.074		0.064
CD (0.05)	0.102		0.102		0.083		0.152		0.131		0.152		0.131

Table 15 Effect of tillage and organics on the hydraulic conductivity of soil in different depths (cm h⁻¹) at 45 DAS (groundnut)

Treatments	T1			T2			T3			D Mean		
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3
0 - 15	2.355	2.940	2.955	2.750	2.460	3.060	3.030	2.850	2.440	3.040	2.880	2.787
15 - 30	0.400	0.410	0.395	0.402	0.400	0.375	0.375	0.383	1.445	1.420	1.475	1.447
30 - 45	0.495	0.510	0.500	0.502	0.455	0.430	0.465	0.450	0.470	0.450	0.430	0.450
TxM Mean T Mean	1.083	1.287	1.283	1.218	1.105	1.288	1.290	1.228	1.452	1.637	1.595	1.561
SE _D	0.044		0.044		0.048		0.084		0.082		0.084	0.082
CD (0.05)	0.102		0.102		0.101		0.171		0.168		0.171	0.168

The results of hydraulic conductivity of soil samples on 90 DAS revealed a similar trend as that of the results of hydraulic conductivity on 45 DAS.

The correlation studies with yield, root length, root volume, total N uptake and grain N uptake also indicated significant positive correlation as in the case of 45 DAS samples. It also had positive correlation with other physical properties at all stages except bulk density wherein it had significant negative relationship (Appendix I).

The hydraulic conductivity values of post harvest soil revealed the same trend as that of the results of 45 DAS samples with respect to main treatments and interaction of M x D. The interaction of T x D indicated that irrespective of tillage treatments, the surface layer registered the highest values. In chiseled plots, the hydraulic conductivity was significantly higher in second depth (15-30 cm) than third depth, whereas in other two tillage treatments, the subsurface depths were comparable. At first depth the hydraulic conductivity values of chiseling were comparable with mouldboard ploughing treatment which in turn comparable with country ploughing treatment. In second depth (15-30 cm), chiseling recorded markedly higher values than other two treatments. In third depth, the tillage treatments did not influence the hydraulic conductivity.

The correlation studies of hydraulic conductivity of post harvest soil indicated a similar trend as that of the results of the hydraulic conductivity on 45 DAS.

4.3.2.2. Groundnut crop (Tables 15, 16 and 17)

The hydraulic conductivity values of the soil samples collected on 45 DAS revealed that among tillage treatments, chiseling was found to increase the hydraulic conductivity significantly as compared to other two tillage treatments. Organic manures had marked influence in increasing the hydraulic conductivity compared to control. The values were significantly higher in surface layer followed by second depth. The lowest value of

Table 16 Effect of tillage and organics on the hydraulic conductivity of soil in different depths (cm h⁻¹) at 90 DAS (groundnut)

Treatments	T1			T2			T3			D Mean		
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3
0 - 15	2.270	2.705	2.785	2.587	2.330	2.755	2.675	2.587	2.370	2.960	2.630	2.653
15 - 30	0.320	0.475	0.465	0.420	0.400	0.385	0.485	0.423	1.045	1.000	1.005	1.017
30 - 45	0.510	0.500	0.520	0.510	0.465	0.540	0.505	0.503	0.440	0.435	0.420	0.432
TxM Mean T Mean	1.033	1.227	1.257	1.172	1.065	1.227	1.222	1.171	1.285	1.465	1.352	1.367

T	M	D	T on D	D on T
SE _D	0.074	-	0.094	0.164
CD (0.05)	0.162	NS	0.192	0.342

Table 17 Effect of tillage and organics on the hydraulic conductivity of soil in different depths (cm h⁻¹) at harvest (groundnut)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	2.230	2.670	2.535	2.478	2.200	2.490	2.590	2.427	2.235	2.790	2.710	2.578	2.494
15 - 30	0.340	0.440	0.400	0.393	0.360	0.430	0.445	0.422	0.410	0.395	0.495	0.433	0.416
30 - 45	0.490	0.515	0.560	0.522	0.445	0.450	0.510	0.468	0.475	0.530	0.530	0.512	0.501
TxM Mean T Mean	1.020	1.208	1.165	1.131	1.002	1.133	1.182	1.106	1.040	1.238	1.245	1.174	

T	M	D
SE _D	-	0.114
CD (0.05)	NS	0.241

0.47 cm h⁻¹ was registered in third depth. The interaction effect of T x D indicated that irrespective of tillage treatments, the hydraulic conductivity values were higher in the surface layer. In subsurface layers, chiseling alone recorded higher values especially in second depth. The other two tillage treatments did not influence the hydraulic conductivity in both the subsurface layers. In top layer and also in third layer the different tillage treatments had no significant influence. However, in second layer (15-30 cm), chiseled plot registered higher values. The M x D interaction showed that in first layer both the organics had registered markedly higher values than control and comparable among themselves. But, the treatments did not influence the hydraulic conductivity in subsurface layers (15-30 and 30-45 cm). Under each manure and control treatments, the values were significantly superior in top soil followed by second depth. The lowest values were recorded in the third layer.

The correlation studies of hydraulic conductivity on 45 DAS showed significant positive correlation with pod yield ($r = 0.848^{**}$), total dry matter production ($r = 0.886^{**}$), total N uptake ($r = 0.870^{**}$) and kernel N uptake ($r = 0.852^{**}$). The studies also indicated the significant positive correlation with other physical parameters like non capillary porosity and total porosity in all stages and hydraulic conductivity on 90 DAS and at harvest stage. It had significant negative relationship with bulk density on 45 DAS. (Appendix II).

The results pertaining to hydraulic conductivity on 90 DAS indicated a similar trend as that of the results of hydraulic conductivity on 45 DAS as far as tillage, depth and T x D interaction were concerned. At this stage, neither organic manures nor its interaction with depth influenced the hydraulic conductivity.

The correlation studies also indicated the same trend as that of the results of hydraulic conductivity on 45 DAS (Appendix II).

The results of hydraulic conductivity at harvest stage revealed that neither the different tillage treatments nor the organics influenced the hydraulic conductivity of soil. The depth alone influenced the parameter. The surface layer registered significantly higher value than the subsurface layers. All the interaction effects were found to be not significant.

The correlation studies indicated a similar trend as that of the results of hydraulic conductivity values on 45 DAS (Appendix II).

4.3.3. Capillary porosity

4.3.3.1. Sorghum crop (Tables 18, 19 and 20)

The statistical analysis of the data pertaining to capillary porosity of core soil samples collected on 45 DAS indicated that chiseling the field markedly increased the capillary porosity. Among the different depths, the top layer (0-15 cm) found to register significantly higher value than other two depths. The interaction effect of T x D revealed that irrespective of tillage treatments, the first layer recorded higher values which were significantly superior over other depths. In other two depths the capillary porosity values were on par with each other in mouldboard ploughing and chiseling, whereas under country ploughing the capillary porosity is markedly higher in third layer and the lowest value was registered in second layer. In second layer, chiseling had markedly influenced the capillary porosity followed by mouldboard ploughing treatment. Country ploughing registered the lowest value. In third depth, chiseling alone significantly influenced the capillary porosity than the other two tillage treatments. The interaction effect of M x D revealed that at each organic sources and at control significantly superior values were



Table 18 Effect of tillage and organics on the capillary porosity of soil in different depths (%) at 45 DAS (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	35.29	37.08	37.61	36.66	35.82	37.60	38.03	37.15	35.26	37.35	37.96	36.86	36.88
15 - 30	31.26	31.01	31.41	31.23	32.62	32.65	32.66	32.64	34.29	35.40	35.13	34.94	32.94
30 - 45	32.84	32.61	32.97	32.81	32.57	31.80	32.23	32.20	35.04	34.69	34.49	34.74	33.25
TxM Mean T Mean	33.13	33.57	34.00	33.56	33.67	34.02	34.31	34.00	34.86	35.81	35.86	35.51	
SE _D	0.33		-		0.25		0.48		0.43		0.48		0.43
CD (0.05)	0.76		NS		0.52		1.06		0.90		1.06		0.90

Table 19 Effect of tillage and organics on the capillary porosity of soil in different depths (%) at 90 DAS (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	34.74	37.28	37.91	36.64	35.27	37.69	37.09	36.68	34.02	37.17	37.62	36.27	36.53
15 - 30	30.98	31.89	31.19	31.35	32.53	32.40	32.92	32.62	34.31	34.69	35.11	34.70	32.89
30 - 45	32.28	31.76	32.19	32.08	32.08	32.03	31.88	32.00	33.87	34.31	34.50	34.22	32.76
TxM Mean T Mean	32.67	33.64	33.76	33.36	33.29	34.04	33.96	33.77	34.07	35.39	35.74	35.07	
SE _n	0.39		0.39		0.27		0.54		0.47		0.54		0.47
CD (0.05)	0.90		0.90		0.57		1.20		0.98		1.20		0.98

Table 20 Effect of tillage and organics on the capillary porosity of soil in different depths (%) at harvest (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2		M3	TxD Mean	M1	M2		M3		TxD Mean		
0 - 15	33.96	36.11	36.84	35.64	34.22	36.77	37.14	36.04	35.68	36.93	36.06	36.22	35.97
15 - 30	31.55	31.29	31.08	31.31	31.93	31.21	32.17	31.77	33.93	33.17	33.24	33.45	32.17
30 - 45	32.32	31.52	32.01	31.95	31.94	32.00	31.90	31.95	32.63	33.06	33.47	33.05	32.32
TxM Mean T Mean	32.61	32.97	33.31	32.96	32.70	33.33	33.74	33.25	34.08	34.39	34.26	34.24	
SE _D	0.30	-			0.26			0.47			0.45		
CD (0.05)	0.69	NS			0.54			1.03			0.94		

Table 21 Effect of tillage and organics on the capillary porosity of soil in different depths (%) at 45 DAS (groundnut)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	35.45	37.84	36.11	36.47	35.97	35.57	35.61	35.72	36.89	36.18	36.28	36.45	36.21
15 - 30	30.06	30.12	31.12	30.43	30.42	32.23	30.13	30.93	33.08	33.39	32.73	33.07	31.48
30 - 45	32.07	31.87	30.88	31.61	31.60	30.97	31.27	31.28	31.28	32.37	31.73	31.79	31.56
TxM Mean T Mean	32.53	33.28	32.70	32.84	32.66	32.92	32.34	31.79	33.75	33.98	33.58	33.77	
	T			M			D						
SE _D	-			-			-			0.70			
CD (0.05)	NS			NS			NS			1.48			

registered in the first layer. The second and third layers were comparable in all the three organic treatments.

The correlation studies of capillary porosity on 45 DAS indicated the significant positive relationship with grain yield ($r = 0.957^{**}$), root length ($r = 0.882^{**}$), root volume ($r = 0.906^{**}$) total N uptake ($r = 0.882^{**}$) and grain N uptake ($r = 0.957^{**}$). Besides it had significant correlation with other physical properties except bulk density at all stages. It had significant negative correlation with bulk density at all stages (Appendix I).

The results pertaining to the data on capillary porosity at 90 DAS indicated a similar trend as that of the results of capillary porosity on 45 DAS.

The correlation studies of capillary porosity on 90 DAS indicated a significant positive correlation with grain yield ($r = 0.964^{**}$), root length ($r = 0.819^{**}$), root volume ($r = 0.794^{*}$), total N uptake ($r = 0.950^{**}$) and grain N uptake ($r = 0.968^{**}$). It also had significant correlation with other physical properties similar to the results of capillary porosity on 45 DAS (Appendix I)

The results of capillary porosity at post harvest stage indicated that chiseling had significantly influenced the capillary porosity than other two tillage treatments. The organics did not influence the parameter. The top layer registered the highest value which is significantly superior over subsurface layers. The M x D interaction was found to be statistically significant. All the manurial treatments recorded higher values in top layer than the bottom layers.

The correlation studies revealed a similar trend as that of the results of capillary porosity on 90 DAS (Appendix I).

4.3.3.2. Groundnut crop (Tables 21, 22 and 23)

The results of the capillary porosity of soil samples collected on 45 DAS indicated that different tillage and organic treatments did not influence the capillary porosity. Depth alone significantly influenced the parameter. Among the different depths, top layer registered the highest capillary porosity of 36.21 per cent compared to other depths. All the interaction effects were found to be not significant.

The correlation studies of capillary porosity on 45 DAS indicated the significant positive relationship with total porosity on 45 DAS ($r = 0.944^{**}$), 90 DAS ($r = 0.792^*$), hydraulic conductivity on 45 DAS ($r = 0.838^{**}$) and 90 DAS ($r = 0.799^*$). But, it had significant negative correlation with bulk density on 45 DAS ($r = -0.878^{**}$). It had no significant correlation with pod yield, total dry matter production, total N uptake and kernel N uptake (Appendix II).

The statistical analysis of the data pertaining to capillary porosity on 90 DAS revealed a similar trend as that of the results of the capillary porosity at 45 DAS.

The correlation studies indicated the significant positive correlation with pod yield ($r = 0.823^{**}$), total dry matter production ($r = 0.802^{**}$), total N uptake ($r = 0.817^{**}$) and kernel N uptake ($r = 0.822^{**}$). As for as physical parameters are concerned, a similar trend was noticed as in the case of the results of capillary porosity on 45 DAS (Appendix II).

The results of the capillary porosity at post harvest stage revealed a similar trend as that of the results of capillary porosity on 45 DAS.

The correlation studies of capillary porosity at post harvest stage indicated no significant relationship with pod yield, N uptake and physical properties. (Appendix II).

Table 22 Effect of tillage and organics on the capillary porosity of soil in different depths (%) at 90 DAS (groundnut)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	34.97	36.52	35.74	35.74	32.99	35.96	36.58	35.18	32.97	35.92	35.36	34.75	35.22
15 - 30	30.96	30.95	30.94	30.95	30.78	30.57	30.95	30.77	33.22	33.10	32.82	33.05	31.59
30 - 45	31.69	32.68	30.82	31.73	31.19	31.12	30.64	30.98	31.00	31.72	31.95	31.56	31.46
TxM Mean T Mean	32.54	33.38	32.50	32.81	31.65	32.55	32.72	32.31	32.40	33.58	33.38	33.12	

T

M

D

SE_D

-

-

0.57

CD (0.05)

NS

NS

1.20

Table 23 Effect of tillage and organics on the capillary porosity of soil in different depths (%) at harvest (groundnut)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	35.72	37.20	37.46	36.79	36.73	36.57	36.37	36.56	37.33	36.97	37.78	37.36	36.90
15 - 30	31.31	30.86	30.02	30.73	30.21	31.66	30.42	30.76	30.93	30.82	30.62	30.79	30.76
30 - 45	32.12	31.42	30.40	31.31	30.82	31.91	31.04	31.26	30.93	30.01	30.47	30.47	31.01
TxM Mean T Mean	33.05	33.16	32.63	32.95	32.59	33.38	32.61	32.86	33.06	32.60	32.96	32.87	

T

M

D

SE_D

-

-

0.60

CD (0.05)

NS

NS

1.26

51
51

4.3.4. Non capillary porosity

4.3.4.1. Sorghum crop (Tables 24, 25 and 26)

The statistical analysis of the data on non capillary porosity on 45 DAS indicated that chiseling significantly influenced the parameter. The non capillary porosity values were found to be markedly high in organic manures than in control. However, the values were comparable among composted coir pith and farm yard manure treatments. As the depth increases, the non capillary porosity decreased significantly. The interaction effect of T x D revealed that irrespective of tillage treatments, the first depth showed significantly higher values than other two depths. In chiseled plots, the non capillary porosity was significantly higher in first two depths than third layer, whereas in other two tillage treatments the second and third depths were on par with each other. The M x D interaction showed that irrespective of manurial sources, the top layer registered significantly higher values and the rest of the two layers were comparable among themselves. In the first depth, the organic manures found to influence the non capillary porosity significantly than control. However, the effect was on par among the organics treatment.

The correlation studies of non capillary porosity on 45 DAS indicated the significant positive correlation with grain yield ($r = 0.942^{**}$), root length ($r = 0.93^{**}$), root volume ($r = 0.923^{**}$), total N uptake ($r = 0.840^{**}$) and grain N uptake ($r = 0.932^{**}$). It also had significant positive correlation with other physical properties except bulk density at all stages of sampling. With bulk density, it had significant negative correlation (Appendix I).

The results of the non capillary porosity at 90 DAS showed a similar trend as that of the results of non capillary porosity at 45 DAS.

Table 24 Effect of tillage and organics on the non-capillary porosity of soil in different depths (%) at 45 DAS (sorghum)

Treatments	T1			T2			T3			D Mean		
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3
0 - 15	12.77	14.00	14.08	13.62	12.80	13.87	14.38	13.68	12.70	14.43	14.35	13.83
15 - 30	8.35	8.34	8.01	8.23	8.83	8.89	9.10	8.94	11.23	11.26	11.36	11.28
30 - 45	8.86	8.77	8.83	8.82	8.67	8.92	8.35	8.65	9.61	9.92	9.90	9.81
TxM Mean T Mean	9.99	10.37	10.31	10.22	10.10	10.56	10.61	10.42	11.18	11.87	11.87	11.64

T	M	D	M on D	D on M	T on D	D on T
0.10	0.10	0.18	0.27	0.31	0.27	0.31
0.23	0.23	0.38	0.58	0.65	0.58	0.65

Table 25 Effect of tillage and organics on the non-capillary porosity of soil in different depths (%) at 90 DAS (sorghum)

Treatments	T1			T2			T3			D Mean		
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3
0 - 15	12.08	12.97	12.99	12.68	11.87	13.48	13.56	12.97	11.38	13.41	13.92	12.90
15 - 30	8.17	8.17	7.75	8.03	8.40	8.76	8.68	8.61	10.63	11.11	10.97	10.90
30 - 45	8.53	8.60	8.53	8.55	8.44	8.80	8.24	8.49	9.11	9.32	9.30	9.24
TxM Mean T Mean	9.59	9.91	9.76	9.75	9.57	10.35	10.16	10.03	10.37	11.28	11.40	11.27

T	M	D	T on D	D on T	M on D	D on M
0.15	0.15	0.16	0.27	0.28	0.27	0.28
0.33	0.33	0.34	0.58	0.58	0.58	0.58

Table 26 Effect of tillage and organics on the non-capillary porosity of soil in different depths (%) at harvest (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
D1	11.10	12.17	12.83	12.03	10.98	12.85	12.67	12.17	11.22	12.63	12.60	12.15	12.12
D2	8.05	8.38	8.03	8.15	7.96	8.05	8.01	8.01	10.09	10.00	9.99	10.03	8.73
D3	8.69	8.46	8.62	8.59	8.42	8.57	8.69	8.56	8.95	8.94	8.73	8.87	8.67
TxM Mean T Mean	9.28	9.67	9.83	9.59	9.12	9.82	9.79	9.58	10.09	10.52	10.44	10.35	

T **M** **D** **T on D** **D on T** **M on D** **D on M**

Table 27 Effect of tillage and organics on the non-capillary porosity of soil in different depths (%) at 45 DAS (groundnut)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
D1	12.32	12.46	11.65	12.14	12.25	11.94	12.92	12.37	12.59	11.83	12.69	12.37	12.29
D2	9.31	8.85	8.86	9.01	8.41	9.03	8.49	8.64	9.74	10.23	10.19	10.05	9.23
D3	8.96	8.98	9.60	9.18	8.70	8.96	9.15	8.94	9.81	8.39	8.71	8.97	9.03
TxM Mean T Mean	10.20	10.10	10.04	10.11	9.79	9.98	10.19	9.98	10.71	10.15	10.53	10.46	

T **M** **D**

The correlation studies of non capillary porosity on 90 DAS indicated a significant positive relationship with yield, N uptake and other physical properties at all sampling stages except bulk density which had significant negative relationship (Appendix I).

The results of non capillary porosity at post harvest stage indicated a similar trend as that of the results of non capillary porosity on 45 DAS except in depths, wherein the non capillary porosity was found to be significantly higher in surface layer than other two depths. The second and third depths were on par with each other.

The correlation studies of the non capillary porosity at harvest stage indicated a similar trend as that of the correlation studies of non capillary porosity on 45 DAS (Appendix I).

4.3.4.2. Groundnut crop (Tables 27,28 and 29)

The statistical scrutiny of the data pertaining to non capillary porosity on 45 DAS revealed that neither the tillage treatments nor the organic manures had significant influence on this parameter. The different depths *viz.*, 0-15, 15-30 and 30-45 cm alone had marked effect on non capillary porosity. Among the depths, the first depth (0-15 cm) was found to register a higher value of 12.29 per cent which was significantly superior over other two depths. The second and third depths were comparable among themselves. All the interaction effects were found to be not significant.

The correlation studies of the non capillary porosity at 45 DAS with total porosity at the same stage of sampling revealed a significant positive correlation ($r = 0.727^*$) and had a significant negative correlation with bulk density at the same stage ($r = -0.701^*$). It had no correlation with pod yield, N uptake and other physical properties (Appendix II).

The results of the non capillary porosity on 90 DAS showed a similar trend as that of the results of non capillary porosity on 45 DAS.

The correlation studies revealed a significant positive correlation with pod yield ($r = 0.823^{**}$), total dry matter production ($r = 0.802^{**}$), total N uptake ($r = 0.822^{**}$). Besides, it also had significant positive correlation with other physical properties like capillary porosity, total porosity and hydraulic conductivity at 45 and 90 DAS. However, it had a significant negative correlation with bulk density at 45 and 90 DAS. At post harvest stage, no significant correlation was observed with other physical properties (Appendix II).

The results of the non capillary porosity at post harvest stage revealed that none of the treatments had influenced this property. The different depths had shown a marked difference in non capillary porosity at this stage. The non capillary porosity decreased along with the depth significantly.

The correlation studies revealed no relationship with yield, uptake and other physical properties at all stages of sampling (Appendix II).

4.3.5. Total porosity

4.3.5.1. Sorghum crop (Tables 30, 31 and 32)

The statistical scrutiny of the data on total porosity revealed that chiseling increased the total porosity markedly than other two tillage treatments. Organic manuring at the rate of 12.5 t ha^{-1} found to increase the total porosity compared to control. The effect was comparable among composted coir pith and farm yard manure treatments. The top layer was found to have significantly higher total porosity than the subsurface layers. The interaction effect was also found to be significant with respect to T x D and M x D. The T x D interaction showed that irrespective of the tillage treatments, the total porosity was found to be significantly higher in first layer followed by second depth. The lowest values were observed in the third depth. In the top layer, all the tillage treatments behaved similarly. The values were not markedly different from each other. In the second depth,

Table 30 Effect of tillage and organics on the total porosity of soil in different depths (%) at 45 DAS (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
D1	48.06	51.08	51.69	50.28	48.62	51.47	52.41	50.83	47.93	51.78	52.31	50.67	50.59
D2	39.61	39.44	39.42	39.49	41.45	41.54	41.76	41.58	45.52	46.66	46.49	46.22	42.43
D3	41.70	41.42	41.80	41.64	41.24	40.72	40.58	40.85	44.65	44.61	44.39	44.55	42.34
TxM Mean T Mean	43.12	43.98	44.30	43.80	43.77	44.58	44.92	44.42	46.03	47.68	47.73	47.15	
SE _D	0.30		0.30		0.32		0.55		0.56		0.55		0.56
CD (0.05)	0.70		0.70		0.68		1.19		1.18		1.19		1.18

Table 31 Effect of tillage and organics on the total porosity of soil in different depths (%) at 90 DAS (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2		TxD Mean	M1	M2		TxD Mean	M1		M2		TxD Mean
		M3	M3			M3	M3				M3	M3	
D1	46.82	50.25	50.90	49.32	47.14	51.17	50.65	49.65	45.40	50.58	51.47	49.15	49.37
D2	39.15	40.06	38.94	39.38	40.93	41.16	41.60	41.23	44.94	45.80	46.08	45.61	42.07
D3	40.81	40.36	40.72	40.63	40.52	40.83	40.12	40.49	42.98	42.63	42.80	43.47	41.52
TxM Mean T Mean	42.26	42.56	43.52	43.11	42.86	44.39	44.12	43.79	44.44	46.67	47.12	46.07	
T				M	D	T on D			D on T		M on D		DonM
SE _p				0.40	0.30	0.58			0.51		0.58		0.51
CD (0.05)				0.92	0.62	1.27			1.08		1.27		1.08

the chiseling treatment had significantly increased the total porosity followed by mouldboard ploughing and the lowest value of 39.49 per cent was registered under country ploughing treatment. In the third layer, chiseling had influenced the total porosity which was significantly superior over other two tillage practices which were on par with each other.

The correlation studies revealed a significant positive correlation with grain yield ($r = 0.955^{**}$), root length ($r = 0.931^{**}$), root volume ($r = 0.916^{**}$), total N uptake ($r = 0.868^{**}$) and grain N uptake ($r = 0.952^{**}$). It also had significant positive correlation with other physical properties like capillary porosity, non capillary porosity and hydraulic conductivity at all stages of sampling. A significant negative correlation was observed between total porosity on 45 DAS with bulk density at all stages (Appendix I).

The statistical scrutiny of the data pertaining to total porosity at 90 DAS indicated a same trend as that of the results of the total porosity at 45 DAS.

The correlation studies also indicated a similar trend as that of the results of the total porosity at 45 DAS (Appendix I).

The results of the total porosity of the post harvest soil showed a similar trend as that of the results of total porosity at 45 DAS.

The correlation studies also indicated a significant positive relationship with grain yield, N uptake, root length, root volume and physical properties other than bulk density as in the case of 45 DAS (Appendix I).

4.3.5.2. Groundnut (Tables 33, 34 and 35)

The statistical analysis of the data with respect to total porosity of core samples collected at 45 DAS indicated that neither the different tillage practices nor the sources of

Table 32 Effect of tillage and organics on the total porosity of soil in different depths (%) at harvest (sorghum)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	45.06	48.28	49.67	47.67	45.20	49.62	49.81	48.21	46.90	49.56	48.37	48.37	48.08
15 - 30	39.60	39.67	39.11	39.46	39.88	39.26	40.20	39.78	44.01	43.17	43.64	43.64	40.96
30 - 45	41.01	39.98	40.63	40.54	40.36	40.57	40.59	40.50	41.58	42.00	41.93	41.93	40.99
TxM Mean T Mean	41.89	42.64	43.14	42.56	41.81	43.15	43.53	42.83	44.16	44.91	44.86	44.65	

T **M** **D** **T on D** **D on T** **M on D** **D on M**

SE_D 0.32 0.32 0.27 0.49 0.46 0.49 0.46

CD (0.05) 0.73 0.73 0.56 1.08 0.97 1.08 0.97

Table 33 Effect of tillage and organics on the total porosity of soil in different depths (%) at 45 DAS (groundnut)

Treatments	T1			T2			T3			D Mean		
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3
0 - 15	47.77	50.30	47.76	48.61	48.22	49.01	49.53	48.59	49.48	48.01	48.92	48.80
15 - 30	39.27	38.97	39.98	39.44	38.83	41.26	38.62	39.57	42.82	43.62	42.92	43.12
30 - 45	41.03	40.85	40.52	40.80	40.30	39.93	40.42	40.22	41.09	40.67	40.44	40.73
TxM Mean T Mean	42.72	43.37	42.75	42.95	42.45	43.40	42.52	42.79	44.46	44.10	44.09	44.22

T

M

D

SE_D

-

-

0.81

CD (0.05)

NS

NS

1.70

Table 34 Effect of tillage and organics on the total porosity of soil in different depths (%) at 90 DAS (groundnut)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0-15	44.09	44.09	48.19	47.11	43.67	48.27	49.21	47.05	44.15	48.24	47.45	46.61	46.92
15-30	38.73	39.11	39.35	39.06	39.42	39.10	38.69	39.07	42.99	43.29	42.77	42.02	40.38
30-45	40.52	41.65	39.71	40.63	39.56	40.79	38.62	39.66	40.10	40.36	40.62	40.36	40.21
TxM Mean T Mean	41.11	43.27	42.42	42.26	40.88	42.72	42.17	41.92	42.41	43.96	43.61	43.33	

	T	M	D	Ton D	Don T	Mon D	D on M
SE _b	-	0.60	0.67	1.11	1.15	1.11	1.15
CD (0.05)	NS	1.37	1.40	2.41	2.42	2.41	2.42

Table 35 Effect of tillage and organics on the total porosity of soil in different depths (%) at harvest (groundnut)

Treatments	T1			T2			T3			D Mean			
	M1	M2	M3	TxD Mean	M1	M2	M3	TxD Mean	M1		M2	M3	TxD Mean
0 - 15	49.20	50.82	51.00	50.41	50.97	50.33	49.85	50.38	51.15	50.09	51.14	50.79	50.23
15 - 30	39.43	38.98	38.12	38.84	39.66	40.11	48.76	39.51	39.17	38.60	39.13	38.97	39.11
30 - 45	41.61	40.49	39.32	40.73	39.74	40.25	40.23	40.07	39.43	39.13	39.54	39.36	39.97
TxM Mean T Mean	43.49	43.43	42.81	43.24	43.46	43.56	42.95	43.32	43.25	42.61	43.27	43.04	

	T	M	D
SE _b	-	-	0.72
CD (0.05)	NS	NS	1.52

CV

The correlation studies of the total porosity showed a significant positive correlation with pod yield ($r = 0.938^{**}$), total dry matter production ($r = 0.925^{**}$), total N uptake ($r = 0.934^{**}$) and kernel N uptake ($r = 0.936^{**}$). It also had significant positive relationship with other physical properties except bulk density at the same stage of sampling (Appendix II).

The results of the total porosity on post harvest stage revealed a similar trend as that of the results of total porosity on 45 DAS.

The correlation studies made also indicated a similar trend. It had no significant correlation with yield, N uptake and other physical properties (Appendix II).

4.3.6. Root length

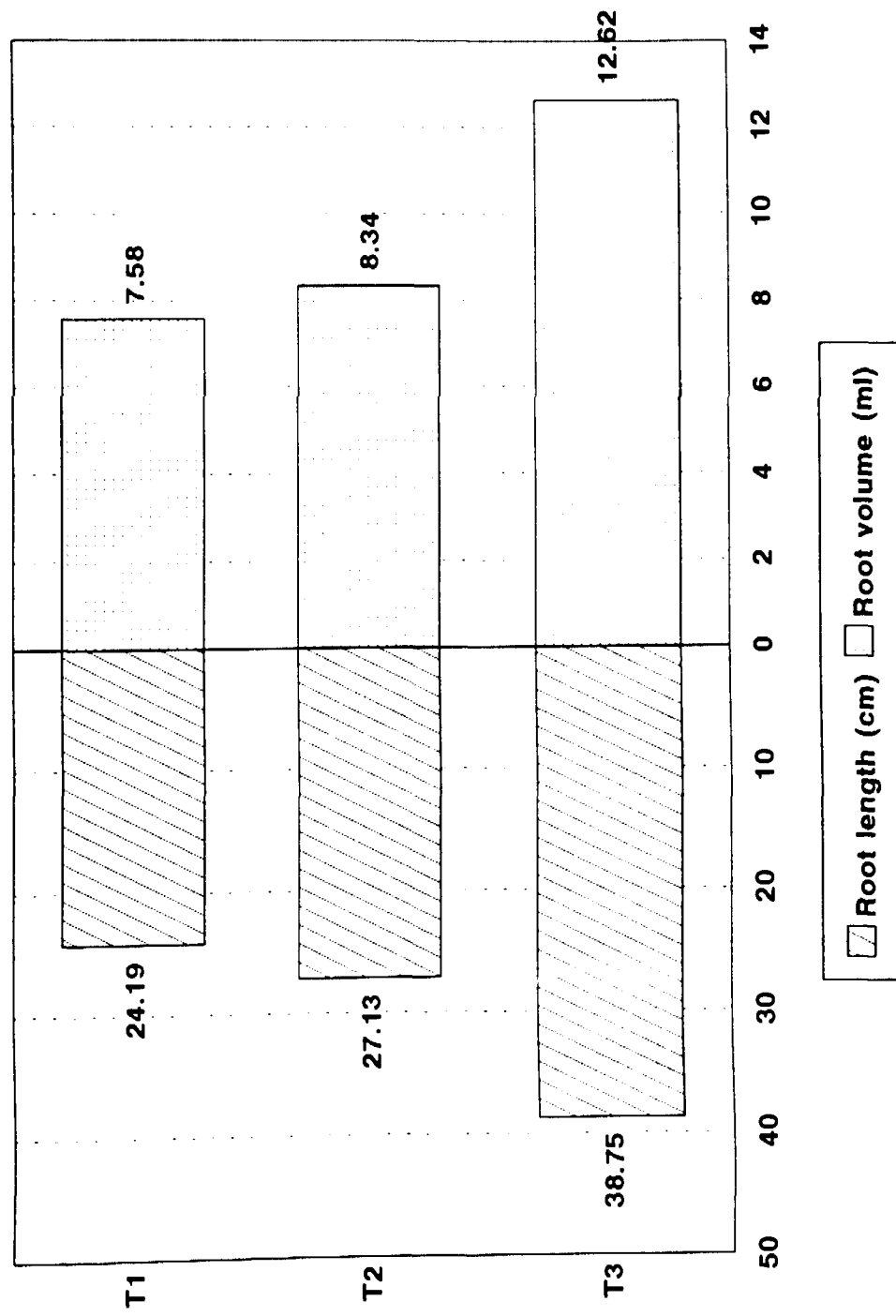
4.3.6.1. Sorghum crop (Table 36; Fig 4)

The statistical analysis of the data on root length measured at different stages indicated that chiseling the field had a significant positive influence on root length. It registered the highest value of 38.75 cm followed by mouldboard ploughing treatment (27.13 cm) and the lowest root length of 24.19 cm was registered under country ploughing treatment. Among the levels of N, application of 100 per cent recommended dose (N3) registered the highest value but comparable with 75 per cent recommended dose (N2). The N2 level was in turn comparable with control (N1). The last stage (S8) found to record the highest value but on par with the preceding stage (S7). The root length in all stages are significantly different from each other. The root length increased along with the stages. The manurial treatment did not influence the length of the roots. The interaction effect of T x S indicated that irrespective of tillage treatments, the last stage registered the highest value. However, in chiseling, upto seventh stage the root lengths were significantly superior over the preceding stage. The S7 and S8 were comparable, whereas in other two tillage treatments, the root lengths were significantly

Table 36 Effect of tillage, organics and levels of N on root length (cm) at different stages (sorghum)

Treatment	M1			TxSxM	M2			TxSxM	M3			TxSxM	TxS
				TxM				TxM				TxM	T
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	Mean
S1	8.35	9.10	9.30	8.92	8.60	9.25	8.35	8.73	8.65	8.70	8.30	8.55	8.73
S2	15.20	15.90	15.95	15.68	16.35	15.65	16.95	16.32	16.95	16.30	16.10	16.45	16.15
S3	20.90	21.80	21.40	21.37	20.55	23.00	23.70	22.42	21.30	22.75	23.35	22.47	22.08
S4	26.75	27.30	28.25	27.43	26.75	27.35	28.35	27.48	25.95	27.30	22.60	25.28	26.73
S5	28.85	28.65	29.00	28.83	28.60	28.80	29.15	28.85	27.30	28.85	28.90	28.35	28.68
S6	29.45	30.05	30.00	29.83	30.65	29.70	30.20	30.18	30.20	29.95	29.20	29.78	29.93
S7	29.85	30.35	30.20	30.13	31.55	29.95	30.85	30.78	31.35	30.35	31.05	30.97	30.62
S8	30.05	30.05	30.10	30.07	30.55	30.75	30.35	30.55	31.35	30.95	31.55	31.28	30.63
NxM Mean	23.67	24.15	24.27	24.03	24.20	24.31	24.74	24.41	24.13	24.39	23.88	24.17	24.19
S1	8.65	8.50	8.95	8.70	8.15	8.40	8.05	8.20	8.30	8.20	8.45	8.32	8.40
S2	18.10	19.10	18.05	18.42	18.75	19.30	19.25	19.10	18.45	18.80	23.10	20.12	19.21
S3	24.70	25.05	25.60	25.12	23.35	24.20	24.45	24.00	23.30	24.45	24.35	24.03	24.38
S4	31.20	31.00	32.05	31.42	31.40	31.60	32.80	31.93	31.10	30.95	32.05	31.37	31.57
S5	32.00	32.00	32.40	32.13	33.55	32.40	34.10	33.35	33.20	32.80	31.90	32.63	32.70
S6	32.15	32.70	32.30	32.38	33.90	33.20	34.40	33.83	33.65	33.15	33.90	33.57	33.26
S7	32.35	33.20	33.60	33.05	34.25	33.45	33.95	33.88	34.65	33.40	34.25	34.10	33.67
S8	31.25	33.15	34.25	32.88	34.95	33.50	33.80	34.08	34.25	34.55	34.60	34.47	33.81
NxM Mean	26.3	26.84	27.09	26.76	27.28	27.00	27.60	27.30	27.11	27.04	27.82	27.33	27.13
S1	8.40	8.45	8.25	8.37	8.90	8.55	8.80	8.75	9.20	8.95	9.00	9.05	8.72
S2	22.75	23.90	24.15	23.60	22.90	22.95	23.15	23.00	23.80	23.80	23.45	23.68	23.43
S3	32.90	34.55	33.20	33.55	31.75	33.70	33.95	33.13	31.90	32.35	33.35	32.53	33.07
S4	42.45	42.20	43.70	42.78	41.90	41.40	42.00	41.77	41.80	42.70	41.40	41.97	42.17
S5	47.20	47.80	47.65	47.55	48.30	49.10	49.45	48.95	49.05	48.70	48.40	48.72	48.41
S6	44.10	50.80	51.00	50.30	50.20	50.95	50.90	50.68	49.85	51.65	51.10	50.87	50.62
S7	49.90	52.10	50.65	50.88	51.30	51.20	53.70	52.07	53.10	52.05	52.05	52.40	51.78
S8	51.00	52.05	51.25	51.43	50.9	51.45	51.30	51.22	53.30	52.25	52.55	52.70	51.78
NxM Mean	37.96	38.98	38.73	38.55	38.26	38.66	39.16	38.70	39.0	39.06	38.20	38.99	38.75
MxN Mean	29.31	29.99	30.03	29.78	29.92	29.99	30.50	30.14	30.08	30.16	29.97	30.15	
	T			M	N			S	T on S			S on T	
F _D	0.21			-	0.17			0.27	0.47			0.47	
D (0.05)	0.48			NS	0.33			0.54	0.93			0.93	

Fig 4 Effect of tillage on root length and volume on sorghum



higher upto 5 stages than the preceding stage and thereafter they were on par with each other. In first stage (S1), the different tillage treatments did not influence the root length. Aftermath, the chiseling found to influence the root length significantly upto last stage followed by mouldboard ploughing. The lowest values were registered under country ploughing treatment in all stages.

The correlation studies of root length indicated a significant positive relationship with grain yield ($r = 0.796^*$), root volume ($r = 0.99^{**}$), grain N uptake ($r = 791^*$) and other physical properties at all stages except bulk density. It had a significant negative correlation with bulk density at all stages of sampling. No significant correlation was observed between root length and dry matter (Appendix I).

4.3.7 Root volume

4.3.7.1. Sorghum crop (Table 37)

The results pertaining to the root volume of sorghum crop indicated a similar trend as that of the results of root length with regard to main effects and also the interaction effect of T x S. The T x N interaction revealed that irrespective of tillage treatments, N3 level increased the root volume. In chiseled plots, the N3 level was significantly superior over other levels, whereas in mouldboard ploughing and country ploughing treatments, N3 and N2 levels were on par with each other but significantly higher than control (N1). In all the three N levels, chiseling was found to be significantly superior followed by mouldboard ploughing which in turn superior to country ploughing. The S x N interaction revealed that irrespective of the N levels, the root volume increased with advancement in stages. In almost all the stages, 100 per cent recommended N (N3) registered numerically higher values followed by N2 and N1 levels. All the three levels were comparable among themselves. The correlation studies of the root volume indicated a similar trend as that of the root length (Appendix-I).

Table 37 Effect of tillage, organics and levels of N on root volume (cm³) at different stages (sorghum)

Treat ments	M1			TxSxM	M2			TxSxM	M3			TxSxM	TxS
				TxM				TxM				TxM	T
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	Mean
T1S1	1.81	1.81	1.90	1.84	1.85	1.93	2.04	1.94	1.78	1.86	1.87	1.84	1.87
T1S2	2.59	2.54	2.61	2.58	2.53	2.58	2.58	2.56	2.52	2.64	2.54	2.57	2.57
T1S3	6.20	6.16	6.02	6.13	6.69	5.95	6.22	6.29	5.95	6.24	6.03	6.07	6.16
T1S4	11.15	10.78	12.07	11.33	10.15	11.07	11.74	10.99	10.91	12.47	12.57	11.98	11.43
T1S5	11.18	11.66	12.13	11.65	11.16	11.11	11.67	11.31	10.75	12.64	12.59	11.99	11.65
T1S6	9.85	9.40	9.74	9.66	9.39	9.62	9.46	9.49	9.24	9.13	9.41	9.26	9.47
T1S7	9.45	9.03	9.37	9.28	8.82	9.19	9.24	9.08	9.17	8.14	8.74	8.68	9.01
T1S8	8.48	8.57	8.65	8.87	8.64	8.57	8.29	8.50	8.19	8.02	8.97	8.39	8.48
TxNxM Mean	7.59	7.49	7.81	7.63	7.40	7.18	7.65	7.52	7.31	7.14	6.27	7.59	7.58
T2S1	1.88	1.90	2.05	1.94	1.95	1.92	2.04	1.97	1.98	1.89	1.99	1.95	1.95
T2S2	2.91	2.90	3.01	2.94	2.93	2.86	2.87	2.89	2.91	2.85	2.95	2.90	2.91
T2S3	7.11	7.13	7.10	7.11	7.09	7.20	7.03	7.11	7.21	7.17	7.15	7.18	7.13
T2S4	11.75	12.46	14.08	12.76	11.55	12.66	13.33	12.51	11.42	12.28	12.87	12.19	12.49
T2S5	13.06	13.55	12.62	13.08	12.78	13.24	13.42	13.15	11.59	12.60	13.50	12.56	12.93
T2S6	10.19	10.44	10.05	10.23	10.12	11.22	11.13	10.82	9.87	10.54	10.12	10.18	10.41
T2S7	9.83	9.96	9.73	9.84	9.44	10.19	10.18	9.94	9.13	9.55	9.11	9.26	9.68
T2S8	9.12	9.78	9.17	9.36	9.50	9.19	9.03	9.24	9.09	9.20	9.12	9.14	9.25
TxNxM1 Mean	8.23	8.52	8.48	8.41	8.17	8.56	8.63	8.45	7.90	8.26	8.35	8.17	8.34
T3S1	1.92	1.97	1.92	1.94	1.82	1.98	1.93	1.91	1.83	1.81	1.96	1.87	1.91
T3S2	4.01	4.06	4.07	4.04	3.96	4.15	4.12	4.08	3.99	4.11	4.03	4.04	4.07
T3S3	9.70	9.94	10.29	9.98	9.87	10.15	11.12	10.38	10.12	11.35	11.47	10.98	10.45
T3S4	18.10	18.45	19.60	18.72	17.30	19.90	20.85	19.35	16.25	19.80	20.80	18.95	19.00
T3S5	19.46	21.62	20.48	20.52	18.16	20.29	21.12	19.86	17.91	21.48	21.72	20.37	20.25
T3S6	15.71	16.10	16.97	16.26	16.25	16.97	17.12	16.78	15.12	14.95	17.09	15.85	16.29
T3S7	14.71	15.65	15.67	15.34	14.70	15.72	15.47	15.30	13.96	14.23	15.59	14.59	15.08
T3S8	14.06	13.80	14.74	14.20	13.05	14.09	14.41	13.85	12.66	13.81	14.65	13.71	13.92
TxNxM Mean	12.20	12.69	12.96	12.63	11.89	12.91	13.26	12.68	11.48	12.69	13.41	12.54	12.62

4.3.7. Dry matter, grain yield and straw yield (Sorghum crop)

4.3.7.1. Dry Matter (Table 38; Fig 5)

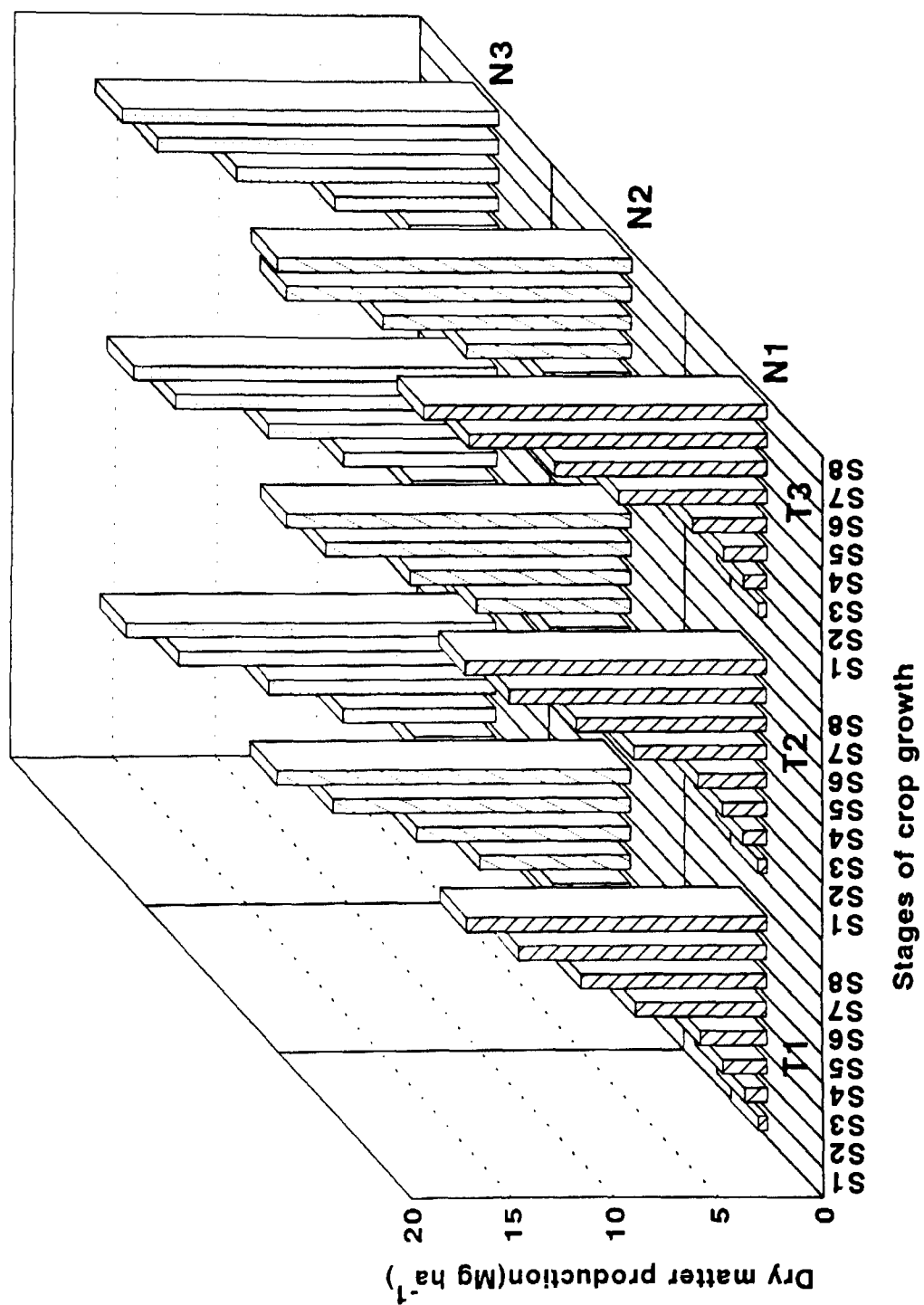
The statistical scrutiny of the dry matter production at different stages revealed that chiseling was found to register the significantly higher dry matter production followed by mouldboard ploughing treatment. The lowest value was registered under country ploughing treatment. Among the sources of organic manures, the composted coir pith treatment (M3) had recorded the highest value followed by farm yard manure (M2) and control (M1). The differences were found to be statistically superior. The N application had a positive influence with dry matter production. The dry matter production paralleled the increasing N levels. Among the different stages, the final stage (S8) registered the highest value. The dry matter production increased along with the stages. The values of each stage were significantly superior over the preceding stage. The interaction effect of T x S revealed that irrespective of tillage treatments, dry matter production was found to increase along with crop growth stages. The dry matter production was found to be comparable among different tillage treatments upto third stage (45 DAS). From fourth stage onwards, chiseling recorded significantly higher values upto eighth stage as compared to other two tillage practices. The mouldboard ploughing and country ploughing treatments were on par with each other at fourth, fifth and sixth stages, whereas in seventh and eighth stages, the mouldboard ploughing treatment registered significantly higher production than country ploughing treatment. The interaction effect of M x S indicated that irrespective of sources of organic manure, the dry matter production increased with advancement in stages. The different manures had no significant influence upto third stage (45 DAS). Thereafter the organic manures had significant increase compared to control but comparable among themselves. The interaction effect of N x S revealed that irrespective of N levels, the dry matter production was found to increase with advancement of stages. No difference was observed upto third stage (45 DAS). The fourth and fifth stages showed significantly lower dry matter yield in control (N1)

Table 38 Effect of tillage, organics and levels of N on dry matter production (t ha⁻¹) at different stages (sorghum)

Treat ments	M1			TxSxM	M2			TxSxM	M3			TxSxM	TxS T
				TxM				TxM				TxM	T
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	Mean
T1S1	0.42	0.43	0.45	0.44	0.41	0.41	0.41	0.41	0.45	0.45	0.47	0.46	0.44
T1S2	1.13	1.11	1.19	1.14	1.10	1.18	1.02	1.10	1.02	1.13	1.05	1.06	1.10
T1S3	2.06	2.11	2.14	2.10	2.15	2.06	2.14	2.12	2.13	2.13	2.15	2.14	2.12
T1S4	3.08	3.51	3.84	3.48	3.20	3.81	4.00	3.67	3.43	4.05	4.31	3.93	3.69
T1S5	6.10	7.10	7.48	6.89	6.23	7.59	7.74	7.18	6.48	7.47	7.85	7.27	7.11
T1S6	8.84	9.90	10.63	9.80	9.01	10.43	11.52	10.32	8.97	11.31	11.79	10.69	10.27
T1S7	11.55	14.41	15.51	13.82	12.12	14.74	16.04	14.30	12.40	15.08	15.73	14.40	14.17
T1S8	13.91	17.17	18.04	16.37	14.76	17.69	18.34	16.93	15.26	17.70	18.68	17.21	16.83
TxNxM Mean	5.89	6.97	7.47	6.76	6.12	7.24	7.65	7.00	6.27	7.42	7.75	6.02	6.59
T2S1	0.42	0.40	0.41	0.41	0.43	0.45	0.44	0.44	0.44	0.43	0.42	0.43	0.43
T2S2	1.13	1.11	1.09	1.11	1.15	1.16	1.09	1.13	1.13	1.11	1.10	1.11	1.12
T2S3	2.14	2.11	2.09	2.11	2.17	2.15	2.16	2.16	2.13	2.14	2.14	2.13	2.13
T2S4	3.16	3.69	4.00	3.62	3.27	3.90	4.26	3.81	3.47	4.17	4.48	4.04	3.82
T2S5	6.21	7.37	7.51	7.03	6.41	7.55	7.66	7.20	6.63	7.78	7.94	7.45	7.22
T2S6	8.93	10.38	11.21	10.17	9.38	11.04	11.41	10.61	9.37	11.29	11.67	10.77	10.51
T2S7	11.71	15.01	15.81	14.18	13.09	15.53	16.49	15.04	12.79	14.95	15.80	14.51	14.58
T2S8	14.69	17.09	17.92	16.57	14.81	17.06	18.50	16.79	14.65	17.49	17.78	16.64	16.66
TxNxM Mean	6.05	7.15	7.51	6.90	6.34	7.36	7.75	7.15	6.33	7.42	7.67	7.14	7.06
T3S1	0.41	0.41	0.42	0.41	0.41	0.40	0.41	0.42	0.41	0.41	0.43	0.42	0.41
T3S2	1.06	1.11	1.12	1.10	1.15	1.14	1.10	1.13	1.12	1.12	1.11	1.12	1.12
T3S3	2.17	2.11	2.09	2.12	2.12	2.14	2.18	2.15	2.00	2.16	2.18	2.11	2.13
T3S4	3.47	4.18	4.32	3.99	3.60	4.27	4.49	4.19	3.66	4.39	4.63	4.22	4.13
T3S5	6.84	8.04	8.02	7.63	7.06	8.00	8.21	7.76	7.71	8.17	8.41	8.10	7.83
T3S6	10.19	12.00	12.68	11.62	10.33	12.29	13.25	11.96	10.48	12.66	13.40	12.18	11.92
T3S7	14.03	16.49	16.45	15.66	14.64	17.34	18.04	16.67	15.14	17.74	16.47	16.45	16.76
T3S8	15.10	16.82	18.12	16.68	16.21	17.98	18.64	17.61	16.31	18.18	19.37	17.95	17.41
TxNxM Mean	6.66	7.64	7.90	7.40	6.94	7.95	8.29	7.74	7.10	8.11	8.25	7.82	7.65
MxN N' Mean	6.20	7.25	7.61	7.02	6.46	7.52	7.89	7.29	6.57	7.65	7.89	6.99	

	T	M	N	S	M on S	S on M	T on S	S on T	N x S
SED	0.02	0.02	0.06	0.09	0.15	0.16	0.15	0.16	0.16
CD(0.05)	0.05	0.05	0.11	0.18	0.29	0.31	0.29	0.31	0.31

Fig 5 Effect of tillage and N on the dry matter production during different stages of sorghum crop



compared to other N levels. The N2 and N3 levels were found to be on par from sixth and eighth stage, the 100 per cent recommended dose of N (N3) significantly increased the dry matter production followed by 75 per cent recommended dose of N (N2). The lowest values were observed under control (N1).

The correlation studies of dry matter production revealed a significant positive correlation with grain yield ($r = 0.696^*$), total N uptake ($r = 0.733^*$) and capillary porosity ($r = 0.671^*$) at 90 DAS (Appendix-I).

4.3.7.2. Grain yield (Table 39; Fig 6)

The statistical analysis of the grain yield data revealed that among the tillage treatments, chiseling registered significantly higher grain yield of 3948 kg ha^{-1} followed by mouldboard ploughing (3562 kg ha^{-1}) while the lowest yield of 3506 kg ha^{-1} was recorded under country ploughing treatment. Among the different manures tried, composted coir pith registered the highest yield of 3860 kg ha^{-1} which was significantly superior over the other two treatments. The control registered the significantly lower yield of 3452 kg ha^{-1} as compared to farm yard manure treatment (3527 kg ha^{-1}). The perceptible influence of increasing N levels on the grain yield has been clearly found with increasing yield. The N3 level registered the highest grain yield of 4068 kg ha^{-1} followed by N2 level (3870 kg ha^{-1}). The lowest yield of 3077 kg ha^{-1} was registered in control treatment (N1). The interaction effect of T x M showed that irrespective of tillage treatments, composted coir pith recorded significantly superior yield followed by farm yard manure. Control recorded the lowest grain yield. In all the organic manure treatments, chiseling registered markedly higher grain yield compared to other tillage treatments. Mouldboard ploughing and country ploughing treatments were found to be on par with each other. The interaction effect of T x N indicated that irrespective of tillage treatments, N application had a significant positive influence. The N3 treatment recorded

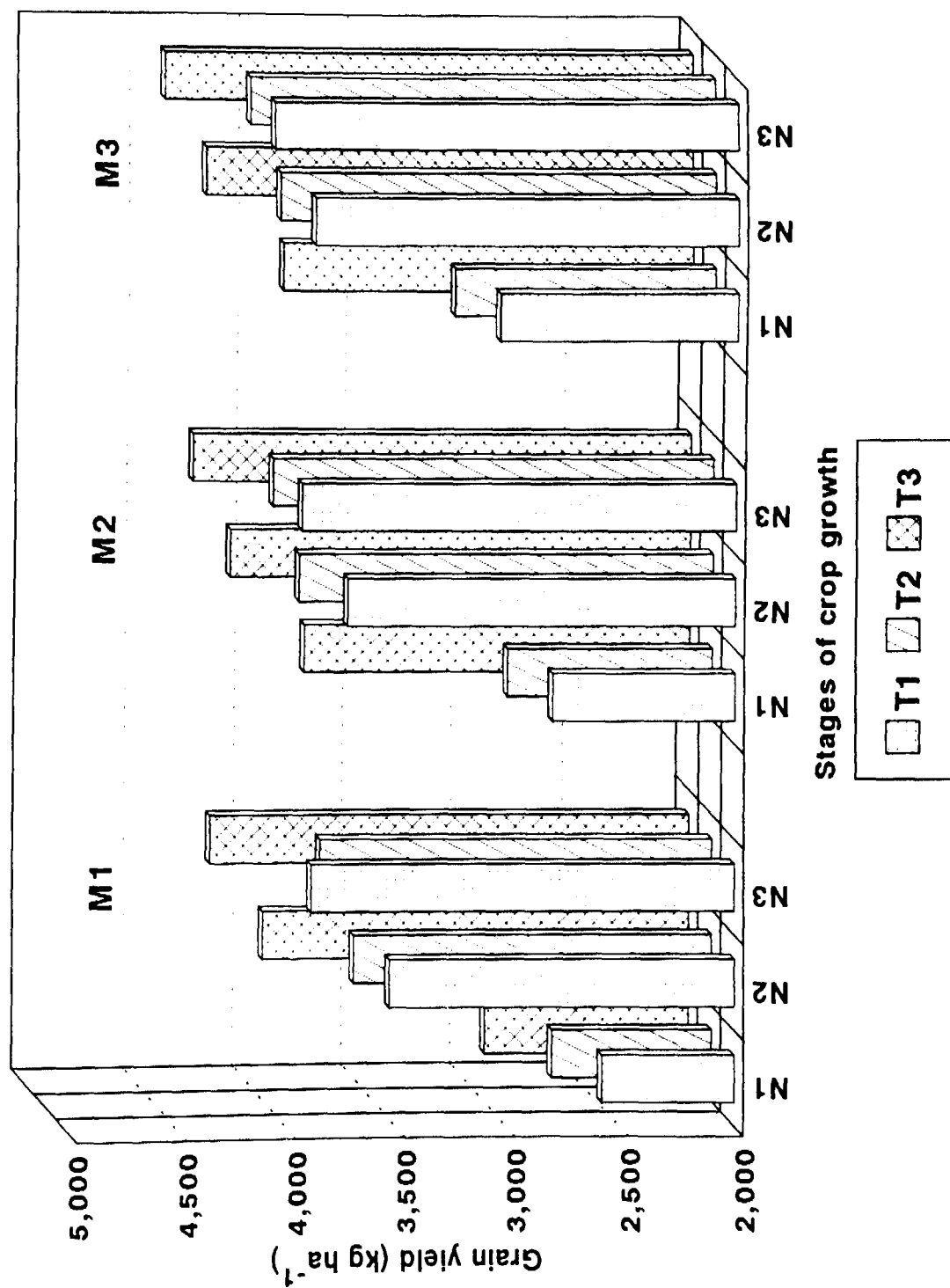
Table 39 Effect of tillage, organics and levels of N on grain yield of sorghum (kg ha⁻¹)

Treatments	T1			T2			T3			N Mean
	M1	M2	M3	M1	M2	M3	M1	M2	M3	
N1	2578	2803	3053	2811	2700	3160	2903	3738	3853	3077
N2	3538	3738	3903	3726	3603	3968	3925	4085	4210	3870
N3	3898	3953	4093	3981	3758	4105	4165	4258	4398	4068
TxM Mean T Mean	3338	3498	3683	3506	3354	3654	3664	4117	4154	3948
SE _n	18	18	18	19	31	32	33	33	32	33
CD (0.05)	41	41	41	40	71	68	69	69	68	69

Table 40 Effect of tillage, organics and levels of N on straw yield of sorghum (kg ha⁻¹)

Treatments	T1			T2			T3			N Mean
	M1	M2	M3	M1	M2	M3	M1	M2	M3	
N1	11335	11960	12205	11833	11990	11515	11803	12195	12475	12004
N2	13630	13955	13795	13793	13490	13595	13412	12710	13890	13576
N3	14140	14385	14585	14370	14030	13675	14072	13955	14389	14293
TxM Mean T Mean	13035	13433	13528	13332	13170	12928	13096	12953	13583	13446
SE _n	-	-	-	-	-	83	244	145	304	
CD (0.05)	NS	NS	NS	NS	175	551	551	551	551	

Fig 6 Effect of tillage, organics and N on the grain yield of sorghum



markedly higher yield followed by N2 and N1 treatments. Irrespective of N levels, chisel ploughing influenced the grain yield significantly than other two tillage treatments. The M x N interaction revealed that irrespective of organic manures N application at higher dose recorded significantly higher grain yield than the lower levels. Irrespective of N levels, composted coir pith increased the sorghum grain yield significantly followed by farm yard manure. The lowest yield of grain was registered under control treatment.

The correlation studies of grain yield revealed a significant positive relationship with total dry matter production ($r = 0.690^*$), root length ($r = 0.796^*$), root volume ($r = 0.780^*$), total N uptake ($r = 0.949^{**}$) and grain N uptake ($r = 0.977^{**}$). It also had a significant positive correlation with physical properties like hydraulic conductivity, capillary porosity, non-capillary porosity and total porosity at all stages of sampling. However, it had a significant negative correlation with bulk density at all stages of sampling (Appendix-I).

4.3.7.3. Straw yield (Table 40)

The results of the straw yield of sorghum showed that neither the various tillage treatments nor the organics treatments influenced the straw yield. However, the N levels had a significant effect. Among the N levels, 100 per cent recommended dose (N3) registered the highest straw yield of 14.29 t ha^{-1} followed by N2 treatment (13.58 t ha^{-1}). The lowest straw yield of 12.01 t ha^{-1} was recorded in control treatment (N1). The interaction effect of T x N showed that irrespective of tillage treatments, higher level of N application (N3) registered significantly higher straw yield followed by lower levels (N2 and N1). The N1 recorded the significantly lowest value than N2 level. Under each level of N application, all the tillage treatments behaved similarly. They were not statistically different from one another.

4.3.8 Dry matter, Pod yield, Kernel yield and haulm yield (Groundnut crop) 79

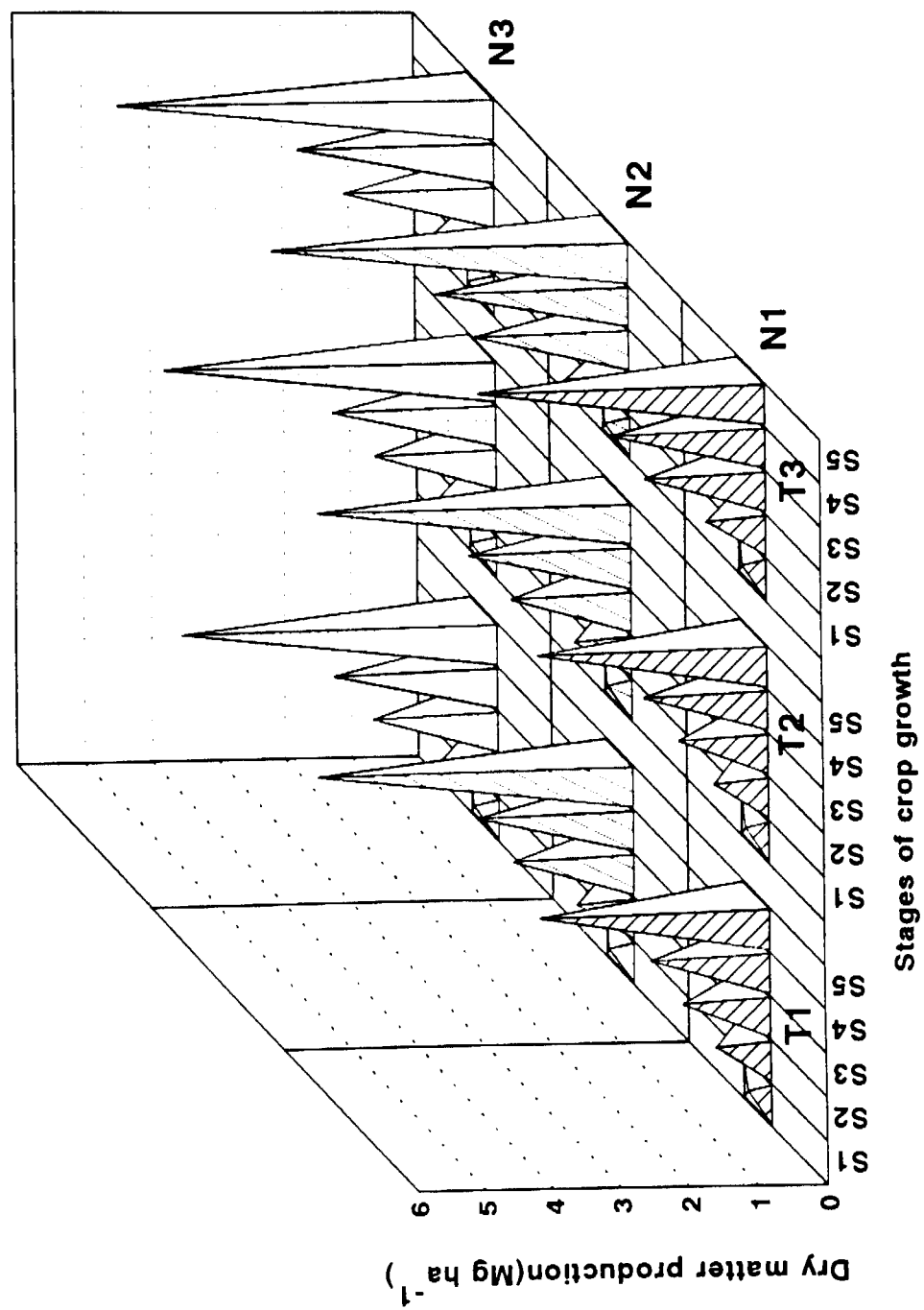
4.3.8.1. Dry matter (Table 41; Fig 7)

The results pertaining to the dry matter production of groundnut crop indicated that among the different tillage practices imposed, chiseling was found to be significantly superior followed by mouldboard ploughing and country ploughing. Application of organics significantly influenced the dry matter production than the control. Nitrogen application at higher levels registered the highest dry matter production which were significantly different from lower levels. At each stage, the dry matter production values were significantly higher than the preceding stage. The interaction effect of T x S revealed that irrespective of tillage treatments, the last stage (S5) registered the highest dry matter production followed by S4, S3, S2 and S1 stages. At first stage (15 DAS) all the tillage treatments behaved similarly. At second and third stages (30 and 45 DAS), chiseling influenced the dry matter production significantly than other two tillage practices, which were on par with each other. At fourth and final stage (60 DAS and post harvest) chiseling registered significantly higher yield followed by mouldboard ploughing. The lowest yield was registered under country ploughing treatment. The M x S interaction showed that irrespective of the source of manure, final stage recorded significantly higher yield followed by S4, S3, S2 and S1 stages. The effect at each stage was significantly different from other stages. At first stage application of manures and control treatment behaved similarly, whereas in rest of the four stages (S2, S3, S4 and S5), application of composted coir pith and farm yard manure treatments registered comparable dry matter production and significantly higher than control treatment. The M x N interaction indicated that irrespective of manures, N3 level influenced the dry matter significantly followed by N2 and N1 levels. They were significantly different from each other. Among these two, N2 level registered markedly higher dry matter yield. At all N levels, application of composted coir pith and farm yard manure at 12.5 t ha⁻¹ recorded significantly superior dry matter yield compared to non application of organics (control).

Table 41 Effect of tillage, organics and levels of N on dry matter production (t ha⁻¹) at different stages (groundnut)

Treat ments	M1			TxSxM		M2			TxSxM		M3			TxSxM		TxS	
				TxM					TxM					TxM		T	
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	Mean
T1S1	0.12	0.14	0.16	0.14	0.15	0.18	0.18	0.17	0.16	0.18	0.16	0.17					0.16
T1S2	0.50	0.55	0.64	0.57	0.61	0.66	0.70	0.66	0.65	0.67	0.68	0.67					0.63
T1S3	0.71	1.37	1.51	1.20	1.23	1.68	1.72	1.54	1.28	1.68	1.78	1.58					1.44
T1S4	1.08	1.79	2.08	1.65	1.84	2.35	2.30	2.16	1.69	2.20	2.37	2.09					1.97
T1S5	2.23	3.79	4.12	3.38	3.65	4.71	5.05	4.47	3.63	4.98	4.46	4.36					4.05
TxNxM Mean	0.93	1.53	1.70	1.39	1.50	1.91	1.99	1.80	1.48	1.94	1.89	1.77					1.65
T2S1	0.13	0.14	0.16	0.14	0.15	0.18	0.18	0.17	0.14	0.17	0.20	0.17					0.16
T2S2	0.52	0.55	0.62	0.56	0.61	0.66	0.70	0.66	0.64	0.67	0.71	0.67					0.63
T2S3	0.79	1.39	1.45	1.21	1.23	1.68	1.72	1.54	1.32	1.68	1.74	1.58					1.44
T2S4	1.09	1.86	2.05	1.67	1.84	2.35	2.30	2.16	1.91	2.42	2.42	2.25					2.02
T2S5	2.27	3.90	4.19	3.46	3.65	4.71	5.05	4.47	3.61	4.86	5.13	4.53					4.15
TxNxM Mean	0.96	1.56	1.69	1.40	1.50	1.80	1.99	1.80	1.52	1.96	2.04	1.84					1.68
T3S1	0.13	0.16	0.18	0.16	0.16	0.19	0.21	0.19	0.16	0.17	0.20	0.18					0.18
T3S2	0.64	0.71	0.74	0.69	0.69	0.75	0.77	0.74	0.69	0.76	0.76	0.73					0.72
T3S3	1.12	1.81	1.78	1.57	1.78	2.22	2.26	2.09	1.82	2.21	2.18	2.07					1.91
T3S4	1.50	2.35	2.36	2.07	2.37	2.82	2.96	2.72	2.33	2.80	2.95	2.70					2.50
T3S5	3.03	4.41	4.90	4.11	4.37	5.41	5.71	5.16	4.68	5.60	5.76	5.34					4.87
TxNxM Mean	1.28	1.89	1.99	1.72	1.87	2.28	2.38	2.18	1.34	2.30	2.37	2.20					2.03
MxN N Mean	1.06	1.66	1.79	1.50	1.62	2.00	2.12	1.93	1.47	2.07	2.10	1.94					
	T	M	N	S	Mon N	Non M	Mon S	Non M	Mon S	Non M	Non S						
SE _D	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.03						
CD(0.05)	0.02	0.02	0.02	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.06						

Fig 7 Effect of tillage and N on the dry matter production during different stages of groundnut crop



However, among the organics the effect was comparable. The N x S interaction showed that irrespective of N levels, stage S5 (Harvest stage) registered the highest yield followed by S4, S3, S2 and S1 stages. Each stage influenced the dry matter yield significantly from the preceding stage. Upto the stage S3 (45 DAS), N3 and N2 levels were found to be on par with each other but significantly superior over N1 levels. At S4 and S5 stages, 100 per cent N (N3) registered the highest dry matter production. A significantly lower yield was recorded by N1 than N2.

The correlation studies of the total dry matter production revealed a significant positive correlation with pod yield ($r = 0.988^{**}$), total N uptake ($r = 0.991^{**}$) and kernel N uptake ($r = 0.996^{**}$). Besides, it also had a significant positive correlation with hydraulic conductivity at all the three stages of sampling and pore size distribution characteristics on 90 DAS (Appendix-II).

4.3.8.2. Pod yield (Table 42)

The statistical scrutiny of the pod yield data revealed that chiseled plots registered significantly superior pod yield than other two tillage treatments viz., mouldboard ploughing and country ploughing. Among the sources of manures, both the organics viz., composted coir pith and farm yard manure at the rate of 12.5 t ha^{-1} had markedly influenced the pod yield than non application of organics treatment (control) and were comparable among themselves. As far as N levels are concerned, N3 registered significantly higher yield followed by N2 level which in turn showed significantly higher pod yield than control (N1). The interaction effect of M x N indicated that, irrespective of manurial sources, higher levels of N registered statistically higher yield than the preceding levels of N. At all the N levels, composted coir pith and farm yard manure behaved similarly. The pod yields under these treatments were significantly superior over non application of organic manure (M1).

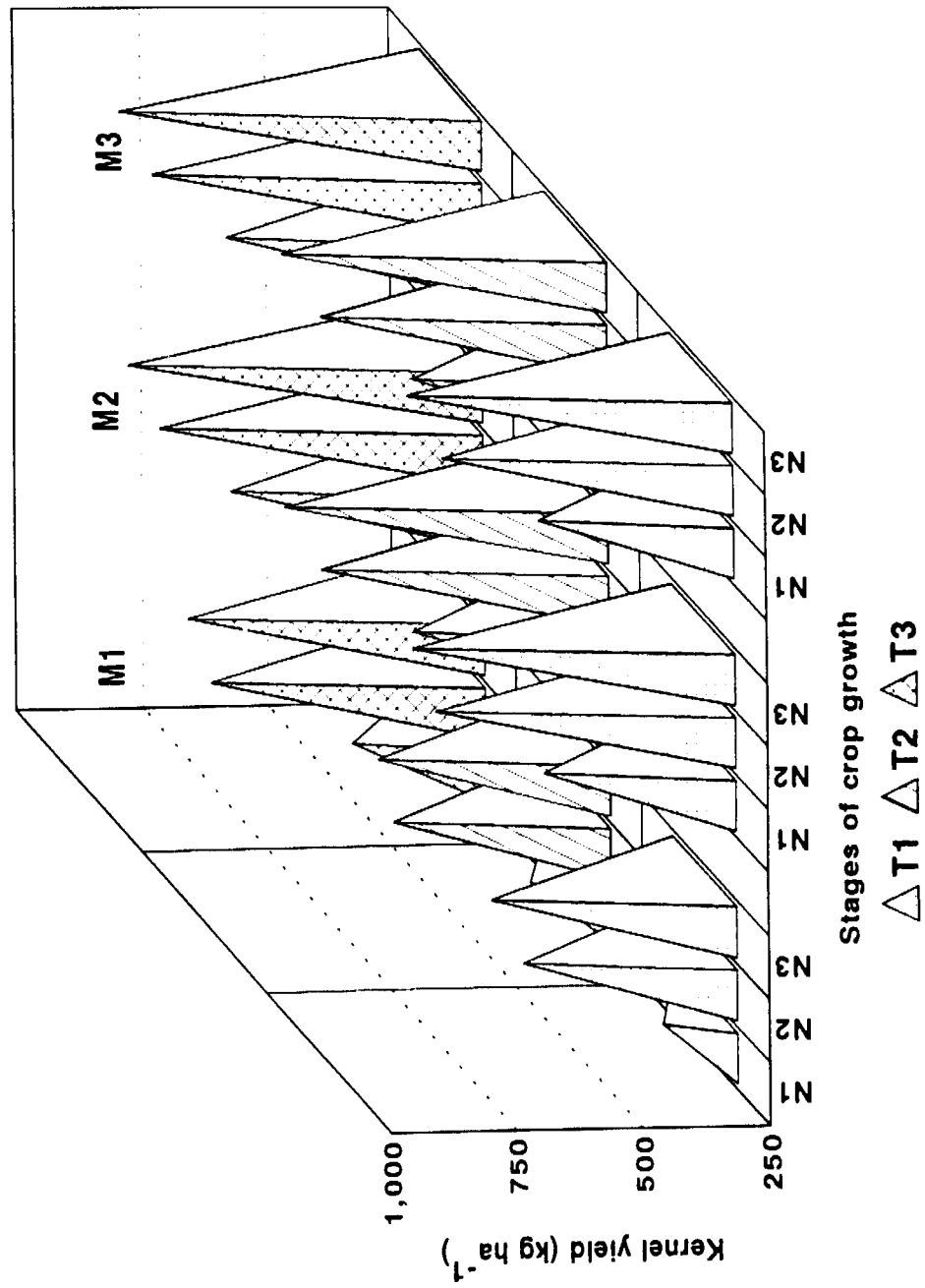
Table 42 Effect of tillage, organics and levels of N on pod yield of ground nut (kg ha⁻¹)

Treatments	T1			T2			T3			N Mean			
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3	TxN Mean
N1	558	943	957	819	578	963	961	834	760	1162	1175	1032	967
N2	1020	1303	1276	1200	1035	1271	1271	1192	1231	1396	1418	1348	1257
N3	1121	1377	1395	1298	1088	1395	1404	1296	1310	1503	1528	1447	1264
TxM Mean T Mean	900	1208	1209	1036	900	1210	1212	1112	1100	1354	1374	1276	
SE _D	T	M			N			M on N			Non M		
CD (0.05)	12	12			12			21			21		
	28	28			25			45			44		

Table 43 Effect of tillage, organics and levels of N on kernel yield of groundnut (kg ha⁻¹)

Treatments	T1			T2			T3			N Mean			
	M1	M2		TxN Mean	M1	M2		TxN Mean	M1		M2		
		M3	M3			M3	M3				M3	M3	
N1	334	567	574	492	347	578	577	500	456	698	705	619	537
N2	612	783	766	720	621	763	763	715	739	838	851	809	748
N3	673	827	836	778	653	837	843	777	786	902	917	868	808
TxM Mean T Mean	540	726	725	663	540	726	728	664	660	813	824	765	
	T	M			N			M on N			Non M		
SE _D	7	7			7			13			13		
CD (0.05)	17	17			15			27			27		

Fig 8 Effect of tillage, organics and N on the kernel yield of groundnut



The correlation studies of pod yield indicated a significant positive relationship with total dry matter ($r = 0.988^{**}$), total N uptake ($r = 0.991^{**}$) and kernel N uptake ($r = 0.996^{**}$). It also had significant positive correlation with physical properties similar to the results of the dry matter production of groundnut crop (Appendix-II).

4.3.8.3. Kernel yield (Table 43; Fig 8)

The results of the kernel yield of groundnut crop indicated a similar result as that of the results of pod yield.

4.3.8.4. Haulm yield (Table 44)

The statistical analysis of the haulm yield data indicated that among the different tillage practices, chiseling registered the highest haulm yield which was significantly superior than other two tillage practices. Though application of composted coir pith and farm yard manures were on par with each other, they registered significantly higher haulm yield than no organic manures (M1) applied plot. Application of N at 100 and 75 per cent recommended dose influenced the haulm yield significantly. The yields were statically superior over non application of N (N1). However, the organics were on par with each other. The M x N interaction revealed that, irrespective of manurial sources, application of N though comparable among themselves registered significantly higher haulm yields than the plots receiving no N application (N1). The composted coir pith and farm yard manure treatments were comparable in all the N levels but significantly superior over plots not receiving the treatment of organic manure (M1).

4.3.9 Ammoniacal nitrogen

4.3.9.1. Sorghum crop (Table 45-56)

The results of the ammoniacal N ($\text{NH}_4\text{-N}$) content at 3 DAS (Table 45) indicated that the different tillage practices and various sources of organics did not influence the $\text{NH}_4\text{-N}$. Among N levels, 100 and 75 per cent recommended dose (N3 and N2)

Table 44 Effect of tillage, organics and levels of N on haulm yield of groundnut (kg ha⁻¹)

Treatments	T1			T2			T3			N Mean			
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3	TxN Mean
N1	1673	2803	2675	2383	1695	2685	2650	2343	2268	3205	3505	2993	2573
N2	3268	3495	3603	3455	2868	3690	3588	3382	3183	4105	4180	3823	3553
N3	2998	3630	3570	3399	3103	3655	3723	3493	3590	4208	4318	4038	3644
TxM Mean T Mean	2646	3309	3283	3079	2555	3343	3320	3073	3014	3839	4001	3618	
Non Af													
SE _D	41			41			48			92		101	
CD (0.05)	85			85			122			196		211	

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registered significantly superior values than control (N1) and were comparable among themselves. Among depths, the second depth (15-30 cm) registered markedly higher value than surface layer (D1) and third depth (D3). The surface layer registered significantly higher value than third depth (30-45 cm). The T x D interaction revealed that, irrespective of tillage treatments, second depth (15-30 cm) registered significantly higher values followed by surface layer (0-15 cm) and the lowest values were recorded in third layer (30-45 cm). In all the three depths, the different tillage treatments behaved similarly and comparable among themselves. The N x D interaction indicated that at all N levels, second depth registered the highest $\text{NH}_4\text{-N}$ compared to other levels followed by D1 and D3 layers except in N1 level wherein, D1 and D3 layers were on par with each other. The rest of the interaction effects were found to be not significant.

The correlation studies of $\text{NH}_4\text{-N}$ on 3 DAS showed a significant positive correlation with sorghum grain yield ($r = 0.720^{**}$). It also had significant positive correlation with $\text{NH}_4\text{-N}$ at various stages of sampling and also with nitrate N ($\text{NO}_3\text{-N}$) from 10 DAS to post harvest stage (Appendix-III).

The results of $\text{NH}_4\text{-N}$ at 5 DAS indicated that tillage practices and application of organics had no effect on $\text{NH}_4\text{-N}$ on 5 DAS. Among N levels, N3 registered significantly superior value followed by N2 and N1 levels. As for as depths are concerned, the second depth registered the highest value which was significantly superior over surface layer (D1), which in turn registered statistically superior value than the third depth (D3). The N x D interaction showed that at N1 level, except second depth (15-30 cm) the remaining depths were on par with each other and significantly lower than D2. At N2 level, second depth registered the highest value followed by D1 which in turn registered significantly higher value than third depth (D3). The first two depths were comparable but significantly higher than third depth as for as N3 level was concerned. In first depth N3 registered

Table 45 Effect of tillage, organics and levels of N on the NH₄-N content of soil in different depths (ppm) at 3 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	6.10	11.35	5.20	7.55	7.40	10.20	4.85	7.48	8.15	10.00	4.55	7.57	7.53
T1M2	5.45	10.60	4.35	6.80	7.60	10.15	4.55	7.43	8.25	10.90	3.85	7.67	7.30
T1M3	4.80	10.00	6.50	7.10	6.95	11.85	4.90	7.90	8.35	11.05	5.05	8.15	7.72
TxNx D Mean	5.45	10.65	5.35	7.15	7.32	10.73	4.77	7.60	8.25	10.65	4.48	7.80	7.52
T2M1	5.15	10.20	5.60	6.98	7.15	11.75	5.05	7.98	8.45	12.15	4.94	8.52	7.83
T2M2	5.20	11.20	4.50	6.97	7.35	11.40	5.00	7.92	8.11	12.10	5.00	8.42	7.77
T2M3	4.95	11.85	4.00	6.93	7.55	12.10	5.00	8.22	8.50	11.95	4.80	8.42	7.86
TxNx D Mean	5.10	11.08	4.70	6.96	7.35	11.75	5.02	8.04	8.37	12.07	4.92	8.45	7.82
T3M1	5.05	10.65	4.90	6.87	7.55	11.25	4.35	7.72	8.50	12.45	4.45	8.47	7.69
T3M2	4.00	11.50	4.00	6.50	7.95	12.40	4.20	8.18	8.30	12.65	5.60	8.85	7.84
T3M3	4.90	11.00	5.10	7.00	7.35	12.80	4.95	8.37	8.20	11.95	4.25	8.13	7.83
TxNx D Mean	4.65	11.05	4.67	6.79	7.62	12.15	4.50	8.09	8.33	12.35	4.77	8.48	7.79
NxD Mean N Mean	4.65	11.05	4.67	6.79	7.62	12.15	4.50	8.09	8.33	12.35	4.77	8.48	

T	-	M	N	D	T on D	D on T	N x D
SE _e	-	-	0.19	0.19	0.32	0.32	0.32
CD (0.05)	NS	NS	0.37	0.37	0.67	0.64	0.64

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Table 46 Effect of tillage, organics and levels of N on the $\text{NH}_4\text{-N}$ content of soil in different depths (ppm) at 5 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	5.45	10.90	5.90	7.42	10.00	9.70	4.60	8.10	11.60	10.90	4.80	9.10	8.20
T1M2	5.55	11.90	4.35	7.27	10.30	10.40	5.15	8.62	11.40	11.50	4.45	9.12	8.33
T1M3	5.05	10.95	4.10	6.70	10.50	11.40	5.45	9.12	10.90	11.95	4.35	9.07	8.29
TxNx D Mean	5.35	11.25	4.78	7.13	10.27	10.50	5.07	8.61	11.30	11.45	4.53	9.10	8.28
T2M1	5.45	10.20	4.70	6.78	11.00	12.70	4.35	9.35	11.60	11.45	4.10	9.05	8.39
T2M2	5.35	11.10	4.35	6.98	10.40	12.05	5.35	9.27	11.45	12.10	5.00	9.52	8.59
T2M3	4.70	10.10	4.75	6.5	10.10	12.15	5.60	9.28	11.50	12.50	4.55	9.52	8.44
TxNx D Mean	5.17	10.47	4.60	6.74	10.50	12.30	5.10	9.30	11.52	12.02	4.55	9.36	8.46
T3M1	5.70	10.70	5.30	7.23	10.10	11.55	4.95	8.87	11.50	11.60	3.90	9.00	8.36
T3M2	5.20	11.95	4.15	7.10	9.80	12.40	4.15	8.78	11.10	12.50	6.00	9.87	8.58
T3M3	5.00	11.15	3.65	6.60	10.80	12.00	5.05	9.28	11.70	11.60	4.35	9.22	8.36
TxNx D Mean	5.30	11.27	4.37	6.98	10.23	11.98	4.72	8.98	11.43	11.90	4.75	9.36	8.44
NxD Mean N Mean	5.27	10.99	4.58	6.95	10.33	11.59	4.96	8.96	11.41	11.41	4.61	9.27	-

SE_e T M N D N x D
 - - 0.23 0.23 0.40
 CD (0.05) NS NS 0.46 0.46 0.80

significantly superior value of $\text{NH}_4\text{-N}$ followed by N_2 level which in turn registered significantly higher $\text{NH}_4\text{-N}$ than N_1 level. In other two depths *viz.*, 15-30 cm (D2) and 30-45 cm (D3) all the N levels behaved similarly and comparable among themselves.

The correlation studies of $\text{NH}_4\text{-N}$ at 5 DAS revealed a similar trend as that of the results of $\text{NH}_4\text{-N}$ at 3 DAS (Appendix-III & V).

The statistical scrutiny of the data pertaining to $\text{NH}_4\text{-N}$ content on 7 DAS revealed a similar trend as that of the results of $\text{NH}_4\text{-N}$ on 5 DAS with respect to N levels and depths. The interaction effect of N x D indicated that at N_1 level, second depth registered significantly higher value followed by first depth (D1) and the lowest value was registered in third depth (D3) while in N_2 and N_3 levels, the top layer recorded the highest values followed by D2 and D3 depths. Each depth recorded significantly higher value than the subsequent lower depth. At first depth, N_3 level registered the highest value followed by N_2 and N_1 levels. Each level influenced significantly over other levels. At second depth, N application plots (N_3 and N_2) registered significantly higher values than plots not applied with N and were comparable among themselves. At third depth, all the N levels were comparable with each other.

The correlation studies revealed the same trend as that of the results of $\text{NH}_4\text{-N}$ on 3 DAS (Appendix - III and V).

The results of the $\text{NH}_4\text{-N}$ on 10 DAS (Table 48) indicated that the different tillage practices and various organic manurial treatments had no significant effect on this parameter. As the N level increased, the $\text{NH}_4\text{-N}$ content was found to increase significantly over the lower level. Regarding depth, the same trend as that of the results of $\text{NH}_4\text{-N}$ on 7 DAS was observed. The N x D interaction revealed that at first depth (0-15 cm) 100 per cent recommended N (N_3) registered the highest value followed by 75 per

Table 47 Effect of tillage, organics and levels of N on the $\text{NH}_4\text{-N}$ content of soil in different depths (ppm) at 7 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	5.35	10.15	5.00	6.83	14.50	11.15	5.10	10.25	17.20	12.10	4.90	11.40	9.49
T1M2	4.25	10.05	4.55	6.28	14.25	12.05	4.30	10.20	16.50	11.80	5.00	11.10	9.19
T1M3	6.00	12.00	4.90	7.63	14.85	12.05	4.45	10.45	17.85	11.70	4.50	11.35	9.81
TxNx D Mean	5.20	10.73	4.82	6.91	14.53	11.75	4.62	10.30	17.18	11.87	4.80	11.28	9.49
T2M1	4.85	9.35	4.15	6.12	15.10	10.90	5.05	10.35	18.05	11.70	4.15	11.30	9.25
T2M2	5.15	12.25	3.95	7.12	14.90	12.05	5.40	10.73	17.45	11.50	4.75	11.23	9.71
T2M3	5.25	11.00	3.35	6.52	15.00	10.95	5.00	10.32	16.75	11.85	5.75	11.45	9.43
TxNx D Mean	5.08	10.87	3.82	6.59	15.00	11.30	5.15	10.48	17.42	11.68	4.88	11.33	9.46
T3M1	5.25	10.40	5.00	6.88	14.55	11.80	5.65	10.67	18.50	11.50	5.00	11.68	9.74
T3M2	5.05	11.00	4.95	7.00	14.60	11.55	5.80	10.65	17.50	12.05	5.30	11.63	9.76
T3M3	5.35	10.85	3.65	6.62	14.65	12.40	4.75	10.60	17.50	12.25	4.15	11.30	9.50
TxNx D Mean	5.22	10.75	4.53	6.83	14.60	11.92	5.40	10.64	17.83	11.95	4.83	11.54	9.67
Nx D Mean N Mean	5.16	10.78	4.39	6.77	14.71	11.65	5.20	10.47	17.47	11.83	4.83	11.38	-

SE _e	T	M	N	D	N x D
	-	-	0.22	0.22	0.38
CD (0.05)	NS	NS	0.44	0.44	0.76

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Table 48 Effect of tillage, organics and levels of N on the NH₄-N content of soil in different depths (ppm) at 10 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	4.95	10.60	5.50	7.02	19.05	11.35	5.05	11.82	23.25	11.95	8.25	13.48	10.77
T1M2	4.80	10.85	4.10	6.58	19.10	12.30	4.95	12.12	22.75	11.55	5.10	13.13	10.61
T1M3	4.75	10.65	4.40	6.60	18.85	10.85	5.90	11.87	22.60	11.15	4.40	12.72	10.32
TxNx D Mean	4.83	10.70	4.67	6.73	19.00	11.50	5.30	11.94	22.87	11.55	4.92	12.91	10.52
T2M1	5.75	10.20	5.05	7.00	18.05	12.65	4.80	11.83	23.20	10.70	4.55	12.82	10.55
T2M2	5.10	10.85	3.60	6.52	19.20	10.80	5.05	11.68	23.90	11.10	6.20	13.73	10.64
T2M3	5.20	11.00	4.30	6.83	19.45	12.00	4.30	11.92	23.40	12.25	4.45	13.37	10.70
TxNx D Mean	5.35	10.68	4.32	6.78	18.90	11.82	4.72	11.81	23.50	11.35	5.07	13.37	10.65
T3M1	5.80	11.45	4.70	7.32	19.40	12.30	4.35	12.02	22.55	11.50	5.95	13.33	10.89
T3M2	5.75	10.50	4.45	6.90	18.55	11.10	5.10	11.58	23.20	11.45	5.00	13.22	10.56
T3M3	4.50	11.40	4.65	6.85	18.50	12.55	3.75	11.60	23.50	11.35	4.20	13.02	10.49
TxNx D Mean	5.35	11.12	4.60	7.02	18.82	11.98	4.40	11.73	23.08	11.43	5.05	13.19	10.64
NxD Mean N Mean	5.12	10.94	4.52	6.86	19.09	11.76	4.80	11.82	23.15	11.44	5.01	13.15	

SE _e	T	M	N	D	N x D
CD (0.05)	-	-	0.27	0.27	0.46
	NS	NS	0.53	0.53	0.92

cent recommended dose (N2). The lowest value was recorded in control (N1). Treatment differed significantly. In subsurface layers (15-30 and 30-45 cm), all the N levels were on par with each other. At N1 level, significantly higher value of $\text{NH}_4\text{-N}$ was registered in second depth (15-30 cm), whereas the other two depths viz., D1 and D3 were comparable. In other two N levels (N2 and N3), the surface layer registered the highest value followed by second depth and the lowest value was registered in third depth.

The correlation studies showed the same trend as that of the results of $\text{NH}_4\text{-N}$ on 3 DAS (Appendix - III and V).

The statistical scrutiny of the data with respect to $\text{NH}_4\text{-N}$ content on 15 DAS (Table 49) indicated that the N application plots (N2 and N3) though registered the significantly superior values than plots with no N application (N1) they were comparable among themselves. As far as depths are concerned, second depth registered markedly higher value followed by surface layer which in turn registered significantly superior value than third depth. The interaction of D x N showed that irrespective of N levels, second depth registered significantly higher values. The other depths viz., D1 and D3 were comparable in N1 level, whereas in N2 and N3 levels, D1 recorded significantly superior values than third depth (D3). The T x D interaction indicated that irrespective of tillage treatments, the second depth registered the highest values followed by surface layer and the third layer recorded the lowest values. Each level showed significant difference from other levels. At D1 and D3 depths, all the tillage treatments behaved similarly. In second depth (15-30cm), the chiseling and mouldboard ploughing treatments (T3 and T2) registered the highest values but comparable and significantly different from country ploughing treatment (T1).

The correlation studies revealed the same trend as that of the results of correlation studies of $\text{NH}_4\text{-N}$ on 3 DAS (Appendix III and V).

Table 49 Effect of tillage, organics and levels of N on the NH_4 -N content of soil in different depths (ppm) at 15 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	5.05	10.60	5.10	6.92	9.80	12.85	6.00	9.55	9.75	11.75	5.35	8.95	8.47
T1M2	4.60	11.00	4.50	6.70	10.55	10.77	5.80	8.58	10.85	10.85	4.30	8.42	7.90
T1M3	4.95	11.15	3.45	6.52	10.45	11.95	5.55	9.32	10.60	12.00	4.20	8.93	8.25
TxNx D Mean	4.87	10.92	4.35	6.71	10.27	11.60	5.58	9.15	10.15	11.53	4.62	8.77	8.21
T2M1	5.35	10.50	5.25	7.03	10.60	13.15	5.10	9.62	10.00	14.00	4.55	9.52	8.72
T2M2	5.05	10.90	4.34	6.77	10.80	14.00	4.15	9.65	10.15	13.55	3.80	9.17	8.53
T2M3	4.35	10.75	4.35	6.48	10.00	14.00	4.45	9.48	10.00	14.00	5.20	9.73	8.56
TxNx D Mean	4.92	10.72	4.65	6.76	10.47	13.72	4.57	9.58	10.05	13.85	4.52	9.47	8.60
T3M1	5.20	9.90	5.15	6.75	10.95	14.05	5.25	10.08	10.15	14.80	6.20	10.38	9.04
T3M2	5.00	10.40	5.60	7.00	10.40	14.75	5.60	10.25	10.40	13.85	5.40	9.88	9.04
T3M3	5.40	10.15	3.90	6.48	11.00	14.05	5.00	10.02	10.10	14.25	4.35	9.57	8.69
TxNx D Mean	5.20	10.15	4.88	6.74	10.78	14.28	5.28	10.12	10.22	10.97	5.32	9.94	8.93
NxD Mean N Mean	4.99	10.59	4.62	6.73	10.48	13.20	5.14	9.61	10.14	12.11	4.82	9.39	

SE _e	T	M	N	D	T on D	D on T	N x D
	-	-	0.21	0.21	0.41	0.37	0.37
CD (0.05)	NS	NS	0.43	0.43	0.88	0.74	0.74

The results of the $\text{NH}_4\text{-N}$ on 30 DAS (Table 50) showed a similar trend as that of the results of $\text{NH}_4\text{-N}$ at 15 DAS regarding main effects of N and depth were concerned. In T x D interaction, except in second depth, the results were similar to $\text{NH}_4\text{-N}$ at 15 DAS. In second depth, the T3 and T2 treatments were on par and significantly different from T1. The N x D interaction was also similar to the results of $\text{NH}_4\text{-N}$ at 15 DAS. The other effects were found to be not significant.

The correlation studies revealed the same trend as that of the results of $\text{NH}_4\text{-N}$ at 3 DAS (Appendix III and V).

The statistical analysis of data on $\text{NH}_4\text{-N}$ pertaining to 45 DAS (Table 51) showed that neither the tillage practices nor the organic manures had a significant influence on it. The N and D levels alone had an influence over $\text{NH}_4\text{-N}$. The results indicated a trend akin to that of $\text{NH}_4\text{-N}$ at 30 DAS.

The correlation studies revealed the same trend as that of the results of $\text{NH}_4\text{-N}$ at 3 DAS (Appendix III and V).

The results with respect to $\text{NH}_4\text{-N}$ on 60 DAS (Table 52) showed that among the tillage treatments, chiseling registered significantly superior value than other two tillage practices. The T1 and T2 treatments were on par with each other. The N levels and depths indicated a similar trend akin to $\text{NH}_4\text{-N}$ at 45 DAS. The T x D interaction showed that irrespective of tillage treatments, second depth registered significantly higher values followed by surface layer which also registered markedly higher values compared to third depth. However, in chiseled plots the first and third depths were comparable. At first depth, country ploughing registered the highest value which is significantly superior over other two tillage treatments and were comparable among themselves. At second depth, though chiseling and mouldboard ploughing registered significantly higher values than

Table 50 Effect of tillage, organics and levels of N on the NH₄-N content of soil in different depths (ppm) at 30 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean		
	TxMxN			TxMxN			TxMxN					
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45
T1M1	6.05	11.80	6.00	7.95	5.85	11.60	5.25	7.57	5.95	11.75	5.55	7.75
T1M2	5.05	11.30	4.15	6.83	6.00	12.00	4.90	7.68	6.05	12.10	5.25	7.80
T1M3	5.10	10.60	3.45	6.38	6.60	11.65	4.35	7.53	6.25	12.70	5.60	8.
TxNx D Mean	5.40	11.23	4.53	7.05	6.15	11.75	4.83	7.58	6.08	12.18	5.47	7.91
T2M1	5.05	10.50	5.25	6.93	6.05	13.60	4.35	8.00	5.50	13.60	4.55	7.88
T2M2	4.90	11.35	4.20	6.82	5.75	13.00	4.35	7.70	5.30	13.15	4.55	7.67
T2M3	4.35	11.50	4.05	6.63	5.95	13.55	4.00	7.88	6.60	13.60	5.05	8.42
TxNx D Mean	4.77	11.12	4.50	6.79	5.92	13.38	4.23	7.84	5.80	13.45	4.72	7.99
T3M1	4.90	10.35	5.60	6.95	5.75	15.05	5.10	8.63	6.00	13.95	5.40	8.45
T3M2	5.30	11.10	4.00	6.80	5.30	14.60	5.00	8.30	6.10	14.90	4.95	8.65
T3M3	5.05	10.10	4.00	6.38	5.40	15.75	5.00	8.72	6.10	16.25	3.95	8.77
TxNx D Mean	5.08	10.52	4.53	6.71	5.48	15.47	5.03	8.55	6.07	15.03	4.77	8.62
NxD Mean N Mean	5.08	10.95	4.52	6.85	5.85	13.53	4.69	7.99	5.98	13.55	4.96	8.17

SE _e	T	M	N	D	T on D	D on T	N x D
	-	-	0.19	0.19	0.33	0.31	0.33
CD (0.05)	NS	NS	0.38	0.38	0.66	0.64	0.66

Table 51 Effect of tillage, organics and levels of N on the $\text{NH}_4\text{-N}$ content of soil in different depths (ppm) at 45 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxM Mean	0 - 15	15 - 30	30 - 45	TxM Mean	0 - 15		15 - 30	30 - 45	TxM Mean
T1M1	5.20	10.90	5.25	7.12	5.05	11.90	5.25	7.40	5.05	9.20	3.95	6.07	6.86
T1M2	4.85	10.00	3.80	6.22	5.75	11.60	4.55	7.30	5.80	11.50	5.30	7.53	7.01
T1M3	5.05	10.70	3.25	6.33	5.45	10.40	5.00	6.95	5.20	10.90	4.55	6.88	6.72
TxNx D Mean	5.03	10.53	4.10	6.57	5.42	11.30	4.93	7.22	5.35	10.53	10.53	4.60	6.83
T2M1	5.90	9.90	5.15	6.98	5.55	10.90	4.75	7.07	5.35	10.55	4.90	6.93	6.99
T2M2	4.90	10.50	4.90	6.77	5.60	11.10	4.90	7.20	5.75	11.70	4.60	7.35	7.10
T2M3	5.80	12.00	4.25	7.35	6.00	12.00	5.10	7.70	6.10	11.30	4.90	7.43	7.49
TxNx D Mean	5.53	10.80	4.77	7.03	5.72	11.83	4.92	7.32	5.73	11.18	4.80	7.24	7.19
T3M1	5.50	10.25	4.95	6.90	5.95	10.20	5.10	7.08	5.10	12.35	4.15	7.20	7.06
T3M2	5.10	11.15	4.05	6.77	5.05	12.95	4.50	7.50	5.15	12.30	5.40	7.62	7.29
T3M3	4.80	10.20	3.35	6.12	5.10	12.20	4.40	7.23	5.15	12.60	4.40	7.38	6.91
TxNx D Mean	5.13	10.53	4.12	6.60	5.37	11.78	4.67	7.27	5.13	12.42	4.65	7.40	7.09
NxD Mean N Mean	5.23	10.62	4.33	6.73	5.50	11.47	4.84	7.27	5.10	11.37	4.68	7.15	

SE _e	T	M	N	D
CD (0.05)	-	-	0.21	0.21
	NS	NS	0.41	0.41

Table S2 Effect of tillage, organics and levels of N on the NH₄-N content of soil in different depths (ppm) at 60 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	6.00	11.40	5.05	7.48	10.00	11.10	4.90	8.67	11.90	11.30	5.05	9.08	8.41
T1M2	5.00	10.35	3.60	6.32	11.05	11.25	4.60	8.97	11.80	11.50	6.10	9.80	8.36
T1M3	4.95	10.70	3.55	6.40	11.00	1.20	4.95	9.05	11.65	12.80	5.45	9.97	8.47
TxNx D Mean	5.32	10.82	4.07	6.74	10.70	11.18	4.82	8.90	11.45	11.87	5.53	9.62	8.42
T2M1	5.45	10.00	5.20	6.88	8.60	13.60	5.35	9.18	9.35	13.95	5.85	9.72	8.59
T2M2	5.10	10.60	4.00	6.57	8.50	13.85	5.10	9.15	9.20	14.00	4.60	9.27	8.33
T2M3	4.60	10.75	3.40	6.25	9.10	13.95	4.35	9.13	9.85	13.40	4.75	9.33	8.23
TxNx D Mean	5.05	10.45	4.20	6.57	8.73	13.80	4.93	9.15	9.47	13.78	5.07	9.44	8.38
T3M1	5.65	11.30	4.90	7.28	7.90	14.40	6.70	9.67	8.80	14.40	8.20	10.47	9.14
T3M2	5.25	11.05	5.00	7.10	8.05	14.25	7.85	10.05	9.00	14.15	8.20	10.45	9.20
T3M3	4.75	10.80	5.00	6.85	8.10	14.10	7.85	10.02	8.75	14.70	7.17	10.20	9.02
TxNx D Mean	5.22	11.05	4.97	7.08	8.02	14.20	7.47	9.91	8.85	14.42	7.85	10.37	9.12
NxD Mean N Mean	5.19	10.77	4.41	6.79	9.15	13.06	5.74	9.32	9.92	13.35	6.15	9.01	

	T	M	N	D	T on D	D on T	N x D
SE _p	0.17	-	0.21	0.21	0.34	0.36	0.36
CD (0.05)	0.39	NS	0.41	0.41	0.70	0.71	0.71

country ploughing, they were on par with each other. In third depth, chiseling registered markedly higher value than other two treatments and they were on par with each other. The N x D interaction revealed that irrespective of N levels, second depth registered the higher values followed by surface layer. The lower values were recorded in third depth and were significantly different from each other. In surface layer (0-15 cm), the N3 registered the highest value followed by N2 and N1 levels. These values were statistically different from one another, whereas in subsurface layers (D2 and D3), N application treatments (N2 and N3) registered highest values. Though these values, comparable among themselves, they were statistically different from no N treatment.

The correlation studies showed the same trend as that of the results of $\text{NH}_4\text{-N}$ on 3 DAS (Appendix III and V).

The results of the $\text{NH}_4\text{-N}$ on 75 DAS indicated that chiseling influenced the $\text{NH}_4\text{-N}$ content significantly than other two tillage treatments. The N application treatments registered significantly superior values than no N application. Among depths, second depth showed the highest value which was significantly different from other depths and comparable among themselves. The interaction effect of T x D revealed that irrespective of tillage treatments, second depth registered significantly higher value than other two depths. Except chiseling, the other two depths were on par with each other, whereas in chiseling, third depth registered markedly different value than first depth. The different treatments behaved similarly in D1 and D2 depths. In third depth (D3), chiseling registered significantly higher value than other two tillage treatments. Among the N levels viz., N3 and N2, the second depth registered the highest value followed by third depth and first depth, whereas in no N application treatment, second depth registered the highest value followed by first depth and the lowest value being registered under third depth. At first depth, all the N levels behaved similarly. In second and third depths,

Table 53 Effect of tillage, organics and levels of N on the $\text{NH}_4\text{-N}$ content of soil in different depths (ppm) at 75 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	5.50	10.90	5.00	7.13	5.55	11.80	5.60	7.65	5.10	11.65	4.70	7.15	7.29
T1M2	4.70	10.00	3.05	5.92	5.20	11.50	5.20	7.30	5.30	11.50	5.90	7.57	6.93
T1M3	6.20	12.10	4.05	7.45	5.55	11.60	5.65	7.60	6.05	12.30	4.65	7.67	7.57
TxNx D Mean	5.47	11.00	4.03	6.83	5.43	11.63	5.48	7.52	5.48	11.82	5.08	7.46	7.27
T2M1	5.05	11.00	4.95	7.00	5.35	11.00	5.15	7.17	5.55	11.85	5.10	7.50	7.22
T2M2	4.90	11.10	3.45	6.48	5.10	11.15	4.95	7.07	5.60	12.00	6.50	8.03	6.48
T2M3	4.85	10.35	5.25	6.82	5.55	12.55	6.00	8.03	6.10	11.50	5.25	7.62	7.49
TxNx D Mean	4.93	10.82	4.55	6.77	5.33	11.57	5.37	7.42	5.75	11.78	5.62	7.72	7.30
T3M1	5.35	11.05	4.15	6.85	5.05	12.10	8.00	8.38	6.10	11.95	8.20	8.75	7.99
T3M2	4.80	10.55	3.95	6.43	5.60	10.85	7.95	8.13	5.90	11.00	8.05	8.32	7.62
T3M3	5.00	11.00	3.45	6.48	6.05	12.05	7.80	8.63	5.45	11.45	7.45	8.12	7.74
TxNx D Mean	5.05	10.87	3.85	6.59	5.57	11.67	7.92	8.38	5.82	11.47	7.90	8.40	7.79
NxD Mean N Mean	5.15	10.89	4.12	6.73	5.44	11.62	6.25	7.77	5.68	11.69	6.20	7.86	

T	M	N	D	T on D	D on T	N x D
0.18	-	0.20	0.20	0.33	0.35	0.35
0.40	NS	0.40	0.40	0.69	0.70	0.70

N3 and N2 levels were on par with each other but registered statistically higher value than N1 level.

The correlation studies revealed a similar trend as that of the correlation studies of $\text{NH}_4\text{-N}$ at 3 DAS (Appendix III and V).

The results of the data on $\text{NH}_4\text{-N}$ at 90 DAS (Table 54) indicated that N application treatments (N3 and N2) recorded significantly higher values than no N application treatment (N1). The N3 and N2 leaves were on par with each other. The $\text{NH}_4\text{-N}$ content was found to be significantly superior in second depth over other two depths. The T x D interaction revealed that irrespective of tillage treatments, the second depth (15-30 cm) registered the significantly superior values than other two depths. Chiseling and mouldboard ploughing treatments were on par and significantly higher than country ploughing treatment at first depth. In second depth (15-30 cm) all the tillage practices behaved similarly. Chiseling had significantly influenced the $\text{NH}_4\text{-N}$ content in third depth than other two tillage treatments.

The correlation studies revealed a similar trend as that of the results of $\text{NH}_4\text{-N}$ at 3 DAS (Appendix III and V).

The statistical analysis of the data pertaining to $\text{NH}_4\text{-N}$ at 105 DAS and post harvest stage (Table 55 and 56) revealed that depths alone had significant influence on this parameter. The second depth registered the higher values followed by surface layer and third layer. The value of each layer was significant from one another.

The correlation studies of $\text{NH}_4\text{-N}$ at 105 DAS and at post harvest stage also showed a similar trend as that of the results of $\text{NH}_4\text{-N}$ at 3 DAS (Appendix III and V).



Table 55 Effect of tillage, organics and levels of N on the NH₄-N content of soil in different depths (ppm) at 105 DAS (sorghum)

Treatments	N1			N2			N3			x		T x M Mean T Mean	
	TxMxN			TxMxN			TxMxN			TxMxN			
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45		TxN Mean
T1M1	5.90	11.35	4.00	7.08	4.95	12.70	4.95	7.53	6.05	11.25	5.35	7.55	7.38
T1M2	5.70	10.95	4.10	6.92	5.95	9.30	5.50	6.92	6.75	11.90	4.85	7.83	7.22
T1M3	5.95	11.15	4.55	7.22	5.75	11.85	4.40	7.33	6.25	12.05	4.95	7.75	7.43
TxNxD Mean	5.85	11.15	4.22	7.07	5.55	11.28	4.95	7.26	6.35	11.73	5.05	7.71	7.34
T2M1	6.35	11.50	4.00	7.28	5.35	12.65	4.65	7.55	5.90	10.35	5.45	7.23	7.35
T2M2	4.95	11.45	4.00	6.80	5.10	10.55	4.65	6.77	5.65	11.10	5.70	7.48	7.01
T2M3	5.10	11.40	5.55	7.35	5.30	11.70	5.90	7.63	6.10	10.85	4.15	7.03	7.33
TxNxD Mean	5.47	11.45	4.52	7.14	5.25	11.63	5.07	7.32	5.88	10.77	5.10	7.25	7.23
T3M1	5.45	10.50	4.15	6.70	5.45	11.65	5.55	7.55	5.95	11.55	5.65	7.72	7.32
T3M2	4.95	10.85	4.00	6.60	5.70	11.80	5.70	7.73	5.75	12.45	5.95	8.05	7.46
T3M3	5.15	10.70	3.80	6.55	6.00	11.75	6.00	7.92	6.15	11.55	6.15	7.95	7.47
TxNxD Mean	8.18	10.68	3.98	6.62	5.72	11.73	5.75	7.73	5.95	11.85	5.92	7.91	7.42
NxD Mean N Mean	5.50	11.09	4.18	6.94	5.50	11.54	5.25	7.43	6.06	11.45	5.35	7.62	

T	-	NS	M	-	N	D
SE _e	-	NS	-	-	-	0.23
CD (0.05)	-	NS	NS	NS	NS	0.46

Table 56 Effect of tillage, organics and levels of N on the $\text{NH}_4\text{-N}$ content of soil in different depths (ppm) at harvest (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	5.05	11.20	4.75	7.00	5.40	11.70	4.40	7.17	5.75	12.10	4.55	7.47	7.21
T1M2	5.10	11.25	3.35	6.57	5.30	11.75	5.10	7.38	5.90	11.15	5.05	7.37	7.11
T1M3	5.90	11.50	4.40	7.27	6.25	12.45	5.75	8.15	6.50	10.80	5.15	7.48	7.63
TxNx D Mean	5.35	11.32	4.17	6.95	5.65	11.97	5.08	7.57	6.05	11.35	4.92	7.44	7.32
T2M1	4.90	11.55	3.90	6.78	6.45	11.90	4.10	7.48	6.80	11.90	4.95	7.88	7.38
T2M2	4.40	11.35	4.40	6.72	6.45	11.60	5.05	7.37	5.85	12.00	5.90	7.92	7.34
T2M3	5.75	11.50	3.45	6.90	5.05	12.25	4.65	7.32	5.55	12.00	3.75	7.10	7.11
TxMxD Mean	6.12	11.47	3.92	6.80	5.65	11.92	4.60	7.39	6.07	11.97	4.87	7.63	7.27
T3M1	5.10	10.90	4.10	6.70	5.45	13.00	4.55	7.67	5.95	11.40	4.65	7.33	7.23
T3M2	6.00	10.70	3.55	6.75	5.40	12.50	4.45	7.45	5.60	11.30	5.05	7.32	7.17
T3M3	4.95	11.00	3.45	6.47	5.35	10.10	6.10	7.18	6.30	10.70	6.10	7.70	7.12
TxNx D Mean	5.35	10.87	3.70	6.64	5.40	11.87	5.03	7.43	5.95	11.13	5.27	7.45	7.17
NxD Mean N Mean	5.61	11.22	3.93	6.80	5.57	11.92	4.90	7.46	6.02	11.48	5.02	7.51	

SE _p	T	M	N	D
CD (0.05)	NS	NS	NS	0.28
				0.56

4.3.9.2 Groundnut crop (Tables 57-61)

The statistical scrutiny of the data pertaining to $\text{NH}_4\text{-N}$ content at various stages of sampling viz., 15, 30, 45 and 60 DAS and at post harvest stage clearly indicated that various tillage practices, sources of organics and levels of N did not influence the $\text{NH}_4\text{-N}$ content. The different depths alone has a significant influence on the $\text{NH}_4\text{-N}$ at all stages. Among the various depths, the second depth (15-30 cm) had registered significantly higher $\text{NH}_4\text{-N}$ content followed by surface layer (0-15 cm) and the third depth (30-45 cm) which recorded the lowest value. All the interaction effects were found to be not significant.

The correlation studies of the $\text{NH}_4\text{-N}$ at different stages as mentioned above had no significant correlation with pod yield, dry matter, total N uptake and with $\text{NO}_3\text{-N}$ at various stages of sampling (Appendix VI).

4.3.10. Nitrate nitrogen

4.3.10.1. Sorghum crop (Tables 62-73)

The results of $\text{NO}_3\text{-N}$ at 3 DAS indicated that the different tillage treatments did not influence this parameter. The composted coir pith registered the highest $\text{NO}_3\text{-N}$ content followed by farm yard manure. The values differed significantly from one another. The lowest value was observed in control plots. Among depths, second depth (15-30 cm) registered significantly higher value followed by first (0-15 cm) and third layers. The M x D interaction also revealed that irrespective of manures, second depth registered higher values followed by surface layer and third depth. Each depth differed significantly. Composted coir pith treatment (M3) registered higher content in first depth, which was significantly superior over other two treatments viz., M2 and M1 and were comparable among themselves. In subsurface layers (15-30 and 30-45 cm), the different manurial treatment did not influence the $\text{NO}_3\text{-N}$ content at 3 DAS.

Table 57 Effect of tillage, organics and levels of N on the $\text{NH}_4\text{-N}$ content of soil in different depths (ppm) at 15 DAS (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	5.05	11.75	4.70	7.17	5.55	17.90	5.10	7.85	5.35	11.90	5.10	7.12	7.38
T1M2	5.90	11.95	4.60	7.48	6.50	10.90	4.90	7.43	5.55	11.85	5.00	7.47	7.46
T1M3	5.25	12.40	4.85	7.50	5.70	11.25	5.50	7.48	5.45	11.05	5.40	7.30	7.43
TxNx D Mean	5.40	12.03	4.72	7.38	5.92	13.35	5.17	7.59	5.45	11.60	5.17	7.30	7.42
T2M1	6.15	11.50	5.05	7.57	5.55	11.90	5.05	7.50	5.05	12.25	4.90	7.40	7.49
T2M2	5.25	11.05	5.15	7.15	5.05	12.35	5.10	7.50	6.10	11.70	5.50	7.77	7.47
T2M3	6.70	12.40	4.90	7.83	5.20	10.90	4.50	6.87	5.50	12.70	5.15	7.78	7.49
TxNx D Mean	6.03	11.65	5.03	7.52	5.27	11.72	4.88	7.29	5.55	12.22	5.18	7.65	7.48
T3M1	5.65	13.00	4.60	7.75	5.45	11.90	5.70	7.52	5.70	11.65	5.00	7.28	7.52
T3M2	5.55	11.35	4.95	7.28	5.60	12.05	4.90	7.52	5.45	11.90	4.50	7.28	7.36
T3M3	6.10	11.60	4.60	7.43	5.35	12.40	4.95	7.57	5.30	12.40	5.05	7.58	7.53
TxNx D Mean	5.77	11.98	4.72	7.49	5.47	12.12	5.18	7.54	5.48	11.98	4.85	7.38	7.47
NxD Mean N Mean	5.73	11.89	4.82	7.46	5.55	12.40	5.08	7.47	5.49	11.93	5.07	7.44	

SE_e	T	M	N	D
CD (0.05)	NS	NS	NS	0.22 0.44

Table 58 Effect of tillage, organics and levels of N on the NH₄-N content of soil in different depths (ppm) at 30 DAS (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	6.10	11.50	5.35	7.65	5.60	11.10	5.25	7.32	5.80	11.60	5.50	7.63	7.53
T1M2	6.35	11.50	4.90	7.58	4.55	12.85	6.10	7.83	6.10	11.35	5.00	7.48	7.63
T1M3	5.75	11.20	5.60	7.52	6.00	11.75	5.35	7.70	6.10	11.65	5.50	7.75	7.66
TxNx D Mean	6.07	11.40	5.28	7.58	5.38	11.90	5.57	7.62	6.00	11.53	5.33	7.62	7.61
T2M1	5.30	12.10	4.95	7.45	5.25	12.65	5.90	7.93	6.05	12.85	4.90	7.93	7.77
T2M2	6.40	12.55	5.35	8.10	6.05	12.35	4.85	7.75	6.45	11.75	5.50	7.90	7.92
T2M3	6.00	11.90	4.80	7.57	6.05	11.50	4.70	7.42	5.35	12.75	5.60	7.73	7.57
TxNx D Mean	5.90	12.18	5.03	7.71	5.78	12.17	5.15	7.70	5.95	12.45	5.33	7.85	7.75
T3M1	5.10	11.50	5.60	7.40	6.10	12.90	5.15	8.05	5.35	12.25	5.20	7.60	7.68
T3M2	5.80	12.15	6.15	8.03	5.95	12.70	5.70	8.12	5.55	11.65	3.90	7.03	7.73
T3M3	5.30	11.40	4.85	7.18	5.75	11.40	5.50	7.55	6.25	12.20	5.90	8.12	7.62
TxNx D Mean	5.40	11.68	5.53	7.54	5.93	12.33	5.45	7.91	5.72	12.03	5.00	7.58	7.68
NxD Mean N Mean	5.79	11.75	5.28	7.61	5.70	12.13	5.39	7.74	5.89	12.00	5.22	7.68	

SE _e	T	M	N	D
CD (0.05)	-	-	-	0.23
	NS	NS	NS	0.40

Table S9 Effect of tillage, organics and levels of N on the $\text{NH}_4\text{-N}$ content of soil in different depths (ppm) at 45 DAS (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean		
	TxMxN			TxMxN			TxMxN					
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45
T1M1	6.15	11.05	5.00	7.40	5.85	10.95	5.00	7.27	5.10	11.50	4.95	7.18
T1M2	5.00	11.95	4.50	7.15	5.30	11.35	5.35	7.33	5.75	11.65	6.15	7.85
T1M3	5.90	11.50	5.25	7.55	5.30	11.90	4.35	7.18	5.60	12.40	4.20	7.40
TxNx D Mean	5.68	11.50	4.92	7.37	5.48	11.40	4.90	7.26	5.48	11.85	5.10	7.48
T2M1	5.25	12.00	4.90	7.38	5.00	12.00	4.75	7.25	5.25	11.60	5.05	7.30
T2M2	5.05	12.85	4.75	7.55	5.95	11.55	5.40	7.63	5.90	11.40	5.00	7.43
T2M3	5.40	11.60	5.65	7.55	5.00	11.50	5.55	7.35	5.90	12.05	5.25	7.73
TxNx D Mean	5.23	12.15	5.10	7.49	5.32	11.68	5.23	7.41	5.68	11.68	5.10	7.49
T3M1	5.20	12.70	5.50	7.80	5.10	12.95	5.25	7.77	5.25	12.80	5.05	7.70
T3M2	5.80	11.95	4.20	7.32	5.55	12.45	5.25	7.75	5.15	11.95	5.55	7.55
T3M3	5.20	12.40	5.45	7.68	5.25	11.50	5.15	7.30	5.40	11.60	4.80	7.27
TxNx D Mean	5.40	12.35	5.05	7.60	5.30	12.30	5.22	7.61	5.27	12.12	5.13	7.51
NxD Mean N Mean	5.44	12.00	5.02	7.49	5.37	11.79	5.12	7.43	5.48	11.88	5.11	7.49

T

M

N

D

SE_e

CD (0.05)

-

-

-

-

NS

NS

NS

0.24

0.48

Table 60 Effect of tillage, organics and levels of N on the $\text{NH}_4\text{-N}$ content of soil in different depths (ppm) at 60 DAS (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	5.95	11.40	4.90	7.42	5.05	12.40	5.10	7.52	6.15	11.75	5.20	7.70	7.54
T1M2	5.10	11.55	5.00	7.22	5.95	11.25	4.95	7.38	5.45	12.65	4.75	7.62	7.40
T1M3	5.05	12.50	4.45	7.33	5.10	12.45	4.35	7.30	5.65	11.20	5.20	7.35	7.32
TxNx D Mean	5.36	11.81	4.78	7.32	5.36	12.03	4.80	7.4	5.75	11.86	5.06	7.55	7.42
T2M1	5.75	11.20	4.50	7.15	6.10	11.45	5.20	7.58	4.85	12.40	4.70	7.32	7.35
T2M2	5.10	12.40	4.85	7.45	5.90	12.10	4.15	7.38	5.70	11.35	5.30	7.45	7.42
T2M3	5.85	11.45	5.05	7.45	6.15	11.85	4.55	7.52	5.45	12.30	5.60	7.78	7.58
TxNx D Mean	5.56	11.68	4.80	7.35	6.05	11.8	4.63	7.49	5.33	12.01	5.20	7.51	7.45
T3M1	4.85	12.50	5.00	7.45	5.30	11.95	5.60	7.62	5.50	11.60	4.35	7.15	7.40
T3M2	5.50	12.65	5.05	7.73	5.75	12.85	5.05	7.88	5.95	11.45	4.95	7.45	7.68
T3M3	5.10	11.65	4.70	7.15	5.60	11.95	5.55	7.70	5.60	12.00	4.30	7.30	7.38
TxNx D Mean	5.15	12.26	4.91	7.44	5.55	12.25	5.40	7.73	5.68	11.68	4.53	7.30	7.49
NxD Mean N Mean	5.35	11.91	4.83	7.37	5.65	12.02	4.94	7.54	5.58	11.85	4.92	7.45	

SE _e	T	M	N	D
CD (0.05)	-	-	-	0.24
	NS	NS	NS	0.49

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Table 61 Effect of tillage, organics and levels of N on the $\text{NH}_4\text{-N}$ content of soil in different depths (ppm) at harvest (groundnut)

Treatments	N1				N2				N3				T x M Mean T Mean
	TxMxN				TxMxN				TxMxN				
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	
T1M1	5.70	12.10	5.00	7.60	5.40	12.65	5.60	7.88	5.95	11.70	4.35	7.33	7.60
T1M2	5.30	11.60	5.05	7.32	5.75	12.60	5.30	7.88	5.45	11.75	5.05	7.42	7.54
T1M3	5.05	11.95	5.50	7.50	5.80	12.40	5.10	7.77	5.35	11.90	5.10	7.45	7.57
TxNx D Mean	5.35	11.88	5.18	7.47	5.65	12.55	5.33	7.84	5.58	11.78	4.83	7.40	7.57
T2M1	5.85	11.50	5.10	7.48	5.35	11.65	5.00	7.33	5.90	12.10	4.45	7.48	7.43
T2M2	5.60	13.25	5.25	8.03	5.30	12.40	4.40	7.37	5.50	11.75	4.65	7.30	7.56
T2M3	6.20	12.35	5.20	7.92	5.55	12.05	5.05	7.55	5.65	12.40	5.00	7.68	7.71
TxNx D Mean	5.88	12.36	5.18	7.81	5.40	12.03	4.81	7.41	5.68	12.08	4.70	7.48	7.56
T3M1	5.90	11.85	5.55	7.77	5.20	13.40	5.40	8.00	5.05	11.95	4.85	7.28	7.68
T3M2	5.65	11.55	4.55	7.25	5.45	11.45	5.30	7.40	5.00	10.75	5.20	6.98	7.21
T3M3	5.65	11.75	4.90	7.43	6.00	12.10	5.30	7.80	5.10	12.70	5.15	7.65	7.62
TxNx D Mean	5.73	11.71	5.00	7.48	5.55	12.31	5.33	7.73	5.05	11.80	5.06	7.30	7.50
NxD Mean N Mean	5.65	11.98	5.12	7.58	5.53	12.29	5.15	7.66	5.43	11.88	4.86	7.39	

SE _e	T	M	N	D
CD (0.05)	NS	NS	NS	0.25 0.49

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The correlation studies indicated that the $\text{NO}_3\text{-N}$ on 3 DAS had no significant relationship with $\text{NO}_3\text{-N}$ content on different stages of sampling except two stages. However, it had significant correlation with grain yield of sorghum (Appendix III and IV).

The results of the $\text{NO}_3\text{-N}$ at 5 and 7 DAS (Tables 63 and 64) revealed a similar trend as that of the results of $\text{NO}_3\text{-N}$ on 3 DAS (Table 62).

The correlation studies also indicated the same trend as that of the results of $\text{NO}_3\text{-N}$ on 3 DAS (Appendix III and IV).

The statistical scrutiny of the data pertaining to $\text{NO}_3\text{-N}$ at 10 DAS (Table 65) showed a similar trend as for as manurial sources, depths and their interactions were concerned. At this stage, the N levels had a significant influence on $\text{NO}_3\text{-N}$ content. The 100 and 75 per cent N application plots showed significantly superior values than control. However, the 100 and 75 per cent treatments were on par with each other. The N x D interaction indicated that, irrespective of N level, second depth registered significantly higher values followed by surface layer which inturn showed markedly superior value than third depth. The 100 per cent N application registered significantly superior value followed by 75 per cent N application treatment. The lowest value was obtained in control plots as for as first depth was concerned, whereas in second and third depths, all the N levels behaved similarly.

The correlation studies of $\text{NO}_3\text{-N}$ at 10 DAS showed a significant positive correlation with $\text{NO}_3\text{-N}$ at 30, 45, 60, 75, 90 and 105 DAS and at harvest stage. It also had significant positive correlation with $\text{NH}_4\text{-N}$ at all stages of sampling (Appendix III and IV).

Table 62 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 3 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	35.10	44.70	22.20	34.00	36.85	43.55	23.10	34.50	37.10	44.25	20.60	33.98	34.16
T1M2	35.75	43.35	22.60	33.90	37.45	41.70	22.45	33.87	36.60	43.35	22.00	33.98	33.92
T1M3	39.60	43.30	20.60	34.50	40.45	44.95	21.60	35.67	41.15	43.30	22.70	35.72	35.30
TxNx D Mean	36.82	43.78	21.80	34.13	38.25	43.40	22.38	34.68	38.28	43.63	21.77	34.56	34.46
T2M1	35.80	42.20	21.90	33.30	36.50	43.10	21.95	33.85	37.25	43.90	21.30	34.15	33.77
T2M2	36.05	42.75	20.90	33.23	37.55	42.35	21.80	33.90	34.95	42.00	21.90	32.95	33.36
T2M3	40.30	42.00	21.90	34.73	41.30	42.60	21.75	35.22	41.75	43.60	22.40	35.92	35.29
TxNx D Mean	37.38	42.32	21.57	33.75	38.45	42.68	21.83	34.32	37.98	43.17	21.87	34.34	34.14
T3M1	36.10	42.70	22.55	33.78	37.60	43.00	21.45	34.02	37.70	43.10	22.80	34.53	34.11
T3M2	34.10	41.50	21.70	32.43	34.55	42.55	21.90	33.00	36.40	42.40	21.80	33.53	32.99
T3M3	40.90	42.50	22.10	35.17	41.30	42.65	22.25	35.40	41.05	43.00	22.15	35.40	35.32
TxNx D Mean	37.03	42.23	22.12	33.79	37.82	42.73	21.87	34.14	38.38	42.83	22.25	34.49	34.14
NxD Mean N Mean	37.08	42.78	21.83	33.89	38.17	42.94	22.03	34.38	38.21	43.21	21.96	34.46	

T	-	NS	M	N	D	M on D	D on M
SE _e			0.26	0.24	0.24	0.42	0.41
CD (0.05)			0.60	0.47	0.47	0.89	0.81
							112

Table 63 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 5 DAS (sorghum)

Treatments	N1				N2				N3				T x M Mean T Mean
	TxMxN				TxMxN				TxMxN				
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	
T1M1	34.20	44.05	22.85	33.70	33.25	44.00	23.35	33.53	34.70	43.10	22.45	33.42	33.55
T1M2	33.70	43.05	21.60	32.78	33.70	43.50	22.60	33.27	34.05	43.15	23.90	33.70	33.25
T1M3	40.20	43.20	24.85	36.08	41.05	42.95	23.15	35.72	41.60	43.05	22.25	35.63	35.81
TxNx D Mean	36.03	43.43	23.10	34.19	36.00	43.48	23.03	34.17	36.78	43.10	22.87	34.25	34.20
T2M1	35.05	41.90	21.20	32.72	34.55	42.10	2.70	33.12	34.05	43.30	23.10	33.48	33.11
T2M2	33.60	43.10	24.00	33.57	33.40	43.25	22.50	33.05	33.95	44.70	22.45	33.70	33.44
T2M3	40.40	44.05	22.80	35.75	41.10	43.30	22.75	35.72	40.85	42.25	21.25	34.78	35.42
TxNx D Mean	36.35	43.02	22.67	34.01	36.35	42.88	22.65	33.96	36.28	43.42	22.27	33.99	33.99
T3M1	33.00	41.90	23.00	32.63	33.35	44.00	22.20	33.18	34.80	43.05	22.50	33.45	33.09
T3M2	33.20	43.10	22.60	32.97	34.25	42.55	22.45	33.08	35.20	42.65	23.30	33.72	33.26
T3M3	41.20	42.50	21.50	35.07	41.25	43.75	22.40	35.80	41.55	44.95	22.70	36.40	35.76
TxNx D Mean	35.80	42.50	22.37	33.56	36.28	43.43	22.35	34.02	37.18	43.55	22.83	34.52	34.03
NxD Mean N Mean	36.06	42.98	22.71	33.92	36.21	43.26	22.68	34.05	36.75	43.36	22.66	34.25	

SE _e	T	M	N	D	M on D	D on M
	-	0.28	-	0.26	0.47	0.46
CD (0.05)	NS	0.65	NS	0.52	0.98	0.91

Table 64 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 7 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	33.35	43.55	23.80	33.57	33.75	43.20	22.30	33.08	33.70	42.60	22.45	32.92	33.19
T1M2	33.10	42.30	22.50	32.63	34.20	41.10	21.85	32.38	34.05	42.60	22.60	33.08	32.70
T1M3	40.60	43.70	22.45	35.58	40.55	43.05	21.85	35.15	41.80	41.25	21.30	34.78	35.17
TxNx D Mean	35.68	43.18	22.92	33.93	36.17	42.45	22.00	33.54	36.52	42.15	21.12	33.59	33.69
T2M1	35.05	42.10	21.35	32.83	32.25	42.25	22.80	32.43	33.35	43.30	22.75	33.13	32.80
T2M2	32.45	42.55	21.20	32.07	32.80	41.70	22.45	32.32	34.50	42.60	22.90	33.33	32.57
T2M3	40.05	42.50	22.10	34.88	40.55	41.90	22.00	34.82	40.40	41.50	21.75	34.55	34.75
TxNx D Mean	35.85	42.38	21.55	33.26	35.20	41.95	22.42	33.19	36.08	42.47	22.47	33.67	33.37
T3M1	33.10	43.00	22.70	32.93	33.25	42.35	22.65	32.75	33.55	42.25	21.20	32.33	32.67
T3M2	33.20	42.20	21.25	32.22	34.20	42.75	22.60	33.18	34.65	42.20	22.30	33.05	32.82
T3M3	40.55	42.20	23.25	35.33	41.10	42.35	21.90	35.12	41.15	43.10	22.50	35.58	35.34
TxNx D Mean	35.62	42.46	22.40	33.49	36.18	42.48	22.38	33.68	36.45	42.52	22.00	33.65	33.61
NxD Mean N Mean	35.72	42.67	43.49	33.56	35.85	42.29	22.27	33.47	36.35	42.38	21.86	33.64	

T	-	NS	M	0.29	0.67	N	-	NS	D	0.20	0.40	M on D	0.41	0.88	D on M	0.35	0.69
SE_e																	
CD (0.05)																	

Table 65 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 10 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean		
	TxMxN			TxMxN			TxMxN					
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45
T1M1	34.00	43.05	21.35	32.80	41.10	41.85	21.95	34.97	42.20	41.85	22.15	35.40
T1M2	34.70	41.75	21.25	32.57	41.25	42.45	22.60	35.43	42.20	42.20	21.60	35.33
T1M3	38.00	42.25	23.10	34.45	43.70	43.55	22.10	36.45	44.95	41.60	22.05	36.20
TxNxM Mean	35.57	42.35	21.90	33.27	42.02	42.62	22.22	35.62	43.12	41.88	21.93	35.64
T2M1	34.75	40.60	21.75	32.37	41.10	42.20	22.65	35.32	42.30	41.25	21.85	35.13
T2M2	33.60	42.35	21.10	32.35	41.65	43.45	23.10	36.07	43.05	42.40	22.25	35.90
T2M3	36.90	42.05	22.10	33.68	42.70	42.35	21.20	35.42	44.05	41.95	22.45	36.15
TxNxM Mean	35.08	41.67	21.65	32.80	41.82	42.67	22.32	35.60	43.13	41.87	22.18	35.73
T3M1	34.35	41.70	21.40	32.48	40.70	42.80	23.10	35.53	41.70	41.65	20.75	34.70
T3M2	34.75	41.45	22.20	32.80	41.10	42.65	21.75	35.17	42.30	43.50	21.15	35.65
T3M3	37.45	42.15	22.70	34.10	43.10	42.65	21.70	35.82	44.30	40.90	22.20	35.80
TxNxM Mean	35.52	41.77	22.10	33.13	41.63	42.70	22.18	35.51	42.77	42.02	21.37	35.38
NxD Mean N Mean	35.39	41.93	21.88	33.07	41.82	42.66	22.24	35.58	43.01	41.92	21.83	35.58

T	M	N	D	N x D	M on D	D on M
-	0.24	0.20	0.20	0.35	0.38	0.35
NS	0.56	0.40	0.40	0.70	0.80	0.70
SE _b						
CD (0.05)						

The results of the $\text{NO}_3\text{-N}$ on 15 DAS (Table 66) indicated a similar trend as ~~that of~~ the results of $\text{NO}_3\text{-N}$ at 10 DAS with respect of N levels and depths and their interaction effect. The effect of source of manure and tillage treatments were on par with each other.

The correlation studies indicated positive significant correlation with grain yield ($r = 0.767^{**}$), total N uptake ($r = 0.780^{**}$) and grain N uptake ($r = 0.777^{**}$). It also had significant positive correlation with $\text{NH}_4\text{-N}$ at various stages (Appendix III and IV).

The results of statistical analysis of $\text{NO}_3\text{-N}$ at 30 DAS (Table 67) indicated that N3 and N2 levels were comparable and significantly superior over N1 level. As for as depths are concerned, second depth registered the highest value followed by first and third depths. Each depth varied markedly. The N x D interaction revealed that in N1 level, second depth (15-30 cm) recorded markedly higher value than first and third depths, whereas in other two N levels namely N2 and N3, the first depth registered the highest value followed by second and third depth. Each depth differed significantly. The increase in N levels showed significantly higher value at top layer (0-15 cm). Whereas in other two depths, all the N levels were found to be not significant.

The correlation studies indicated a similar trend as that of the results of $\text{NO}_3\text{-N}$ on 10 DAS (Appendix III and IV).

The results of the $\text{NO}_3\text{-N}$ at 45 DAS (Table 68) revealed a similar trend as that of $\text{NO}_3\text{-N}$ on 30 DAS with respect to N levels, depths and N x D interaction. At this stage, the different tillage practices tried also had significant influence on $\text{NO}_3\text{-N}$ content. The chiseling treatment registered significantly lower value than other two treatments which were comparable among themselves.

Table 66 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 15 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMrN			TxMrN			TxMrN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	31.20	43.90	21.95	32.35	41.00	42.00	21.85	35.28	42.45	42.20	22.80	35.82	34.48
T1M2	32.05	41.85	21.75	31.88	41.50	42.50	22.10	35.37	43.55	43.20	21.95	36.23	34.49
T1M3	31.55	42.70	22.10	32.12	41.15	43.75	21.75	35.55	43.00	41.95	22.05	35.67	34.45
TxNx D Mean	31.60	42.82	21.93	32.12	41.22	43.08	21.90	35.40	43.00	42.45	22.27	35.91	34.48
T2M1	30.75	40.85	22.10	31.23	41.10	41.75	22.05	34.97	43.85	41.50	22.75	36.03	34.08
T2M2	30.95	42.60	21.10	31.55	42.05	42.25	21.30	35.20	43.25	43.40	22.60	36.42	34.39
T2M3	32.05	42.60	22.10	32.25	41.25	43.20	23.30	35.92	43.20	43.10	22.35	36.22	34.80
TxNx D Mean	31.25	42.02	21.77	31.68	41.47	42.40	22.22	35.36	43.43	42.67	22.57	36.22	34.42
T3M1	31.90	42.05	22.35	32.10	41.95	42.85	19.95	34.92	43.70	41.40	20.55	35.22	34.08
T3M2	30.15	41.75	22.15	31.35	41.20	42.75	21.25	35.07	44.50	43.45	21.45	36.47	34.30
T3M3	31.55	42.10	22.25	31.97	40.00	41.75	20.35	34.03	42.30	42.40	20.45	35.05	33.68
TxNx D Mean	31.20	41.97	22.25	31.81	41.05	42.45	20.52	34.67	43.50	42.42	20.82	35.58	34.02
NxD Mean N Mean	31.35	42.27	21.98	31.87	41.25	42.64	21.55	35.14	43.31	42.51	21.89	35.90	

SE _e	T	M	N	D	N x D
	-	-	0.23	0.23	0.39
CD (0.05)	NS	NS	0.45	0.45	0.79
					117

Table 67 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 30 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	26.05	42.85	23.10	30.67	44.20	43.70	23.05	36.98	46.65	41.15	21.25	36.35	34.67
T1M2	25.15	41.80	22.70	29.88	43.05	41.75	23.20	36.00	44.70	41.45	22.80	36.33	34.07
T1M3	25.05	41.40	21.20	29.22	42.40	41.10	22.10	35.20	43.80	41.45	22.10	35.78	33.40
TxNx D Mean	25.42	42.02	22.33	29.92	43.22	42.18	24.45	36.06	45.05	41.35	22.05	36.15	34.04
T2M1	25.55	42.35	22.00	29.97	42.35	42.40	21.55	35.43	45.00	41.75	22.60	36.45	33.95
T2M2	24.90	43.80	21.30	30.00	42.30	41.80	21.45	35.18	45.15	42.35	21.00	36.17	33.78
T2M3	26.20	42.75	21.40	30.12	43.15	42.45	22.30	35.97	44.95	42.80	22.70	36.82	34.30
TxNx D Mean	25.72	42.97	21.57	30.03	42.60	42.22	21.77	35.53	45.03	42.30	22.10	36.48	34.01
T3M1	28.10	39.55	21.90	29.85	44.85	40.10	20.70	35.22	47.35	38.60	22.05	36.00	33.69
T3M2	28.55	39.25	22.75	30.18	44.55	39.40	21.55	35.17	47.70	39.45	20.75	35.97	33.77
T3M3	29.45	39.10	21.85	30.13	44.70	39.00	23.05	35.58	47.30	38.85	21.05	35.73	33.81
TxNx D Mean	28.70	39.30	22.17	30.05	44.70	39.50	21.77	35.32	47.45	38.97	21.28	35.90	33.76
NxD Mean N Mean	26.61	41.43	22.02	30.0	43.51	41.30	22.66	35.64	45.84	40.87	21.81	36.18	

SE _e	T	M	N	D	N x D
CD (0.05)	-	-	0.28	0.28	0.48
	NS	NS	0.55	0.55	0.96

Table 68 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 45 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	24.10	42.50	22.35	29.65	41.10	42.10	22.25	35.15	42.05	42.00	22.45	35.50	33.43
T1M2	24.10	42.05	20.20	28.78	41.25	22.15	35.67	41.00	42.35	22.10	35.45	33.30	33.30
T1M3	24.10	44.10	22.75	30.30	40.05	43.20	21.65	34.97	40.45	42.05	22.60	35.03	33.43
TxNx D Mean	24.08	42.88	21.77	29.58	40.80	42.97	22.02	35.26	41.17	42.13	22.48	35.33	33.39
T2M1	24.70	42.30	22.10	29.73	40.25	42.10	23.00	35.12	42.10	42.15	22.00	35.42	33.41
T2M2	24.55	42.20	22.45	29.73	40.50	42.95	22.55	35.33	41.65	42.40	22.30	35.45	33.50
T2M3	24.15	43.55	22.95	30.22	40.55	42.85	21.85	35.08	41.50	41.05	21.60	34.72	33.34
TxNx D Mean	24.47	42.68	22.50	29.88	40.43	42.43	22.47	35.18	41.75	41.87	21.97	35.20	33.42
T3M1	27.05	39.10	22.30	29.48	44.00	38.00	21.85	34.62	43.85	37.20	21.85	34.30	32.80
T3M2	27.05	37.35	21.35	28.58	44.15	37.40	22.05	34.53	43.85	38.55	21.60	34.67	32.59
T3M3	27.05	37.95	23.10	29.37	44.00	38.10	22.40	34.83	44.20	37.70	22.20	34.70	32.70
TxNx D Mean	27.05	38.13	22.25	29.14	44.05	37.83	22.10	34.66	43.97	37.82	21.88	34.56	32.79
NxD Mean N Mean	25.2	41.23	22.17	29.53	41.76	41.14	22.20	35.03	42.30	40.61	22.11	35.03	

SE _e	T	M	N	D	N x D
CD (0.05)	0.21	-	0.21	0.21	0.36
	0.49	NS	0.41	0.41	0.71

The correlation studies showed the same trend as that of $\text{NO}_3\text{-N}$ on 10 DAS with respect to $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$. Besides, it had significant positive correlation with grain yield ($r = 0.760^{**}$), total N uptake ($r = 0.784^{**}$) and grain uptake ($r = 0.765^{**}$) (Appendix III and V).

The statistical scrutiny of the results of $\text{NO}_3\text{-N}$ content on 60 DAS (Table 69) indicated that among the tillage practices, country ploughing and mouldboard ploughing treatments behaved similarly and showed significantly superior values than chiseling. In N treatments, N3 and N2 levels registered significantly superior values than N1 level. D1 and D2 depths recorded and markedly higher and comparable among themselves and were statistically superior over D3. The T x D interaction showed that in T1 and T2 treatments, the $\text{NO}_3\text{-N}$ values were higher in second depth followed by first depth. The lowest value was recorded in third depth. Each depth differed statistically, whereas in chiseled plots, the surface layer (0-15 cm) indicated significantly higher value followed by D2 and D3 treatments. At first depth, chiseling indicated markedly higher value than other two tillage treatments, whereas in other two depths (15-30 and 30-45 cm), chiseling registered significantly lower value than other two treatments. The N x D interaction showed a similar trend as that of the results of $\text{NO}_3\text{-N}$ at 45 DAS.

The correlation studies indicated the same trend as that of the results of $\text{NO}_3\text{-N}$ on 10 DAS. It also had positive significant correlation with pod yield ($r = 0.707^{**}$), total N uptake ($r = 0.736^{**}$) and grain N uptake ($r = 0.721^{**}$) (Appendix III and IV).

The results of $\text{NO}_3\text{-N}$ on 75 DAS (Table 70) revealed a similar trend as that of $\text{NO}_3\text{-N}$ on 60 DAS with respect to tillage, N and depth treatments and also the interaction of T x N and N x D. At this stage, the interaction effect of T x N also found to be significant. Irrespective of tillage treatments, the application of N (N2 and N3) registered markedly higher values than no N treatment (N1). In control both the country ploughing

Table 69 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 60 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	22.95	43.05	22.35	29.45	48.25	43.10	22.75	38.03	50.25	42.10	22.00	38.12	35.20
T1M2	22.30	43.90	22.25	29.48	47.35	42.65	22.10	37.37	48.50	42.45	21.40	37.45	34.77
T1M3	22.40	42.30	22.10	28.93	47.60	42.55	22.25	37.47	49.20	42.95	21.35	37.83	34.74
TxNxM Mean	22.55	43.08	22.23	29.29	47.78	42.77	22.37	37.62	49.32	42.50	21.58	37.80	34.90
T2M1	22.60	43.00	22.95	29.52	48.25	42.25	23.05	37.85	49.05	43.05	22.70	38.27	35.21
T2M2	22.45	42.50	21.85	28.93	48.60	42.30	22.80	37.90	49.10	42.95	22.25	38.10	34.97
T2M3	22.43	42.67	22.20	29.10	48.45	42.05	23.02	37.84	49.23	42.77	22.67	38.22	35.05
TxNxM Mean	22.43	42.67	22.20	29.10	48.45	42.05	23.02	37.84	49.23	42.77	22.67	38.22	35.05
T3M1	24.10	36.95	20.10	27.05	53.20	37.30	18.60	36.37	53.00	36.35	18.30	35.88	33.10
T3M2	24.20	37.00	18.70	26.63	52.95	37.05	18.15	36.05	53.60	36.70	18.10	36.13	32.94
T3M3	23.80	37.05	17.85	26.23	52.25	37.90	18.05	36.07	52.60	36.45	17.90	35.65	32.65
TxNxM Mean	24.03	37.00	18.88	26.64	52.97	37.42	18.27	36.16	53.07	36.50	18.10	35.89	32.90
NxD Mean N Mean	23.00	40.92	21.10	28.34	49.73	40.75	21.22	37.21	50.54	40.59	20.78	37.30	

	T	M	N	D	T on D	D on T	N x D
SE _e	0.26	-	0.23	0.23	0.39	0.41	0.39
CD (0.05)	0.60	NS	0.45	0.45	0.78	0.87	0.78

Table 70 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 75 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxM Mean	0 - 15	15 - 30	30 - 45	TxM Mean	0 - 15		15 - 30	30 - 45	TxM Mean
T1M1	18.95	43.80	22.10	28.28	38.25	43.20	22.20	34.55	38.45	42.05	22.50	34.33	32.39
T1M2	18.55	42.65	21.40	27.53	37.25	43.20	22.10	34.18	37.70	42.25	22.20	34.05	31.92
T1M3	18.10	42.15	22.00	27.42	38.15	43.50	22.20	34.62	38.25	42.70	22.70	34.55	32.20
TxNx D Mean	18.53	42.87	21.83	27.74	37.88	43.30	22.17	34.45	38.13	42.33	22.47	34.37	32.19
T2M1	18.30	42.75	21.25	27.43	38.50	42.70	21.75	34.32	38.30	43.55	22.00	34.62	32.12
T2M2	18.15	42.25	20.80	27.07	38.00	42.25	21.10	33.78	37.05	42.80	21.10	33.65	31.50
T2M3	17.95	42.65	20.60	27.07	38.40	42.75	21.05	34.07	37.85	42.10	21.80	33.92	31.69
TxNx D Mean	18.13	44.22	20.88	27.19	38.30	42.57	21.30	34.06	37.73	42.82	21.63	34.08	31.78
T3M1	21.10	36.05	18.40	25.18	48.95	35.75	17.10	33.93	49.00	34.80	17.85	33.88	31.00
T3M2	21.60	35.25	17.05	24.63	49.05	36.20	17.80	34.35	49.40	35.80	16.80	34.00	30.99
T3M3	22.25	36.20	17.40	25.28	48.65	36.00	17.05	33.90	49.20	35.00	16.60	32.60	30.93
TxNx D Mean	21.65	35.83	17.61	25.03	48.55	35.98	17.32	34.06	49.20	35.20	17.08	33.83	30.95
NxD Mean N Mean	19.44	40.97	20.12	26.65	41.69	40.62	20.26	34.17	41.69	40.12	20.39	34.09	

T	M	N	D	T on N	N on T	T on D	D on T	N x D
SE _e	-	0.19	0.19	0.37	0.32	0.37	0.32	0.32
CD (0.05)	NS	0.37	0.37	0.79	0.64	0.79	0.64	0.64

and mouldboard ploughing treatments showed significantly superior values than chiseling, whereas in other two N levels (N2 and N3) all the tillage treatments were comparable among themselves.

The correlation studies indicated a similar trend as that of $\text{NO}_3\text{-N}$ on 10 DAS pertaining to $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ values were concerned. It also had significant correlation with pod yield ($r = 0.707^{**}$), total N uptake ($r = 0.736^{**}$) and grain N ($r = 0.721^{**}$) uptake (Appendix III and V).

The results of data pertaining to $\text{NO}_3\text{-N}$ on 90 DAS (Table 71) revealed a similar trend as that of $\text{NO}_3\text{-N}$ on 75 DAS except in T x N interaction. The T x N interaction showed that at all N levels, the country ploughing and mouldboard ploughing treatments registered markedly higher values than the chiseling treatment. As for as N levels in different tillage treatments are concerned, the same trend as that of the previous sampling was observed.

The trend akin to results of $\text{NO}_3\text{-N}$ on 10 DAS was observed at this stage with respect to correlation (Appendix III and IV).

The statistical analysis of the data pertaining to $\text{NO}_3\text{-N}$ on 105 DAS and at post harvest stage (Tables 72 and 73) showed a similar trend as that of $\text{NO}_3\text{-N}$ on 90 DAS.

The correlation studies of the data with respect to $\text{NO}_3\text{-N}$ on 105 DAS and at post harvest stage also had a similar trend with the results of $\text{NO}_3\text{-N}$ on 10 DAS (Appendix III and IV).

Table 71 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 90 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean		
	TxMxN			TxMxN			TxMxN					
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45
T1M1	17.55	42.95	22.35	27.62	35.80	43.05	22.10	33.65	36.60	42.75	20.95	33.43
T1M2	17.70	43.20	22.10	27.67	36.05	42.05	22.40	33.50	36.35	43.30	22.10	33.92
T1M3	18.10	42.35	22.10	27.52	36.05	43.00	22.35	33.80	36.05	42.70	22.25	33.67
TxNx D Mean	17.78	42.83	22.18	27.60	35.97	42.70	23.95	33.65	36.33	42.92	21.77	33.67
T2M1	17.55	42.90	22.10	27.52	36.05	42.25	22.05	33.45	35.05	43.00	22.10	33.38
T2M2	18.15	43.45	22.10	27.90	36.50	42.90	21.95	33.78	36.50	42.65	21.80	33.65
T2M3	17.65	42.40	22.15	27.40	35.80	42.35	22.55	33.57	35.45	42.70	21.10	33.08
TxNx D Mean	17.78	42.98	22.12	27.61	36.12	42.50	22.18	33.60	35.77	42.78	21.67	33.37
T3M1	20.00	34.75	17.40	24.05	44.80	35.10	17.05	32.32	44.90	33.95	17.15	32.00
T3M2	20.60	34.75	16.35	23.90	43.30	34.25	16.65	31.40	45.05	34.00	16.90	31.98
T3M3	21.10	34.55	16.90	24.18	45.25	33.35	16.35	31.65	44.35	33.80	16.60	31.52
TxNx D Mean	20.57	34.68	16.88	24.04	44.62	34.23	16.68	31.79	44.77	33.85	16.88	31.83
NxD Mean N Mean	18.71	40.70	20.95	26.42	38.90	39.81	20.94	33.01	38.96	39.85	20.11	32.96

SE _e	T	M	N	D	T on N	N on T	T on D	D on T	N x D
	0.17	-	0.15	0.15	0.28	0.27	0.28	0.27	0.27
CD (0.05)	0.39	NS	0.31	0.31	0.59	0.53	0.59	0.53	0.53

Table 72 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 105 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	17.10	43.05	22.05	27.40	32.30	43.25	22.10	32.55	31.42	42.00	22.75	32.07	30.67
T1M2	16.85	42.10	22.40	27.12	32.20	42.20	22.35	32.25	31.30	42.25	21.35	31.63	30.33
T1M3	16.85	42.95	21.10	26.97	31.55	43.75	20.75	32.02	31.40	42.35	21.10	3162	30.20
TxNx D Mean	16.93	44.37	21.85	27.16	32.02	43.07	21.73	32.27	31.38	42.20	21.73	31.77	30.40
T2M1	16.75	42.95	20.60	26.77	31.35	42.90	21.95	32.07	31.55	42.10	22.25	31.97	30.27
T2M2	17.05	42.15	22.80	27.33	31.35	42.00	22.10	31.82	31.55	42.35	21.75	31.88	30.34
T2M3	16.75	42.35	21.90	27.00	31.10	42.00	21.60	31.57	30.95	42.15	21.30	31.47	30.01
TxNx D Mean	16.85	42.48	21.77	27.03	31.27	42.30	21.88	31.82	31.35	42.20	21.77	31.77	30.21
T3M1	18.10	32.35	15.05	21.83	40.00	32.05	15.10	29.05	39.80	32.00	16.05	29.28	26.72
T3M2	18.00	32.95	16.00	22.32	39.85	32.40	15.25	29.17	40.75	32.60	15.45	29.60	27.03
T3M3	18.05	33.10	16.15	22.43	40.60	31.50	16.25	29.45	40.25	32.90	15.75	29.63	27.17
TxNx D Mean	18.05	34.47	15.78	22.19	40.15	31.98	15.53	29.22	40.27	32.50	15.75	29.50	26.97
NxD Mean N Mean	17.28	40.44	19.78	25.46	34.48	39.12	19.75	31.10	34.33	38.97	19.75	31.01	

T	M	N	D	T on N	N on T	T on D	D on T	N x D
0.27	-	0.2	0.24	0.43	0.42	0.43	0.42	0.13
0.61	NS	0.8	0.48	0.91	0.83	0.91	0.83	0.26

SE_e

CD (0.05)

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Table 73 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at harvest (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	16.15	42.35	22.30	26.93	29.90	42.95	22.55	31.80	29.10	42.90	22.80	31.60	30.11
T1M2	15.40	42.65	21.80	26.62	30.50	42.00	22.55	31.68	29.75	42.40	21.85	31.33	29.88
T1M3	15.10	42.50	22.10	26.57	30.50	42.95	23.15	32.20	30.60	41.80	22.45	31.62	30.13
TxNx D Mean	15.55	42.50	22.07	26.71	30.30	42.63	22.75	32.06	29.82	42.37	22.37	31.52	30.10
T2M1	15.40	42.55	22.40	26.78	30.05	43.05	20.85	31.32	29.90	42.25	21.60	31.25	29.78
T2M2	15.05	43.85	22.75	27.22	30.15	41.85	22.60	31.53	29.55	42.90	23.45	31.97	30.24
T2M3	15.60	43.00	22.45	27.02	30.50	42.40	22.75	31.88	29.05	42.40	22.55	31.33	30.08
TxNx D Mean	15.35	43.13	22.53	27.01	30.23	42.43	22.07	31.58	29.50	44.18	22.53	31.52	30.04
T3M1	17.35	32.10	15.00	21.48	38.15	32.30	15.00	28.48	38.75	31.80	15.85	28.80	26.25
T3M2	18.05	32.55	15.50	22.03	37.40	32.30	15.10	28.27	28.80	32.00	14.90	28.57	26.29
T3M3	17.90	31.85	15.00	21.58	37.10	32.10	15.00	28.07	38.30	31.85	15.15	28.43	26.03
TxNx D Mean	17.77	32.17	15.17	21.70	37.55	32.23	15.03	28.27	38.62	31.88	15.30	28.60	26.19
NxD Mean N Mean	16.22	39.27	19.94	25.14	32.69	39.10	19.95	30.64	32.65	39.48	20.07	30.55	

T	M	N	D	T on N	N on T	T on D	D on T	N x D
SE _e	-	0.16	0.16	0.30	0.28	0.30	0.28	0.28
CD (0.05)	NS	0.33	1.33	0.64	0.56	0.64	0.56	0.56

4.3.10.2. Groundnut crop (Tables 74-78)

The results of $\text{NO}_3\text{-N}$ on 15 DAS (Table 74) indicated that among tillage treatments, T1 and T2 registered significantly superior values than T3. The values of T1 and T2 were on par. The N application treatments (N3 and N2) recorded markedly higher values than control treatment (N1). The different depths also had significant influence on $\text{NO}_3\text{-N}$ content. The second depth registered the highest value followed by first depth. The T x N interaction showed that irrespective of tillage treatments, the N application plots showed significantly superior values than control (N1). At 100 and 75 per cent N treatments (N3 and N2), the T1 and T2 registered markedly higher values than chiseling (T3), whereas in non application of N plots, all the tillage treatments behaved similarly. The T x D interaction revealed that except in chiseling treatment, the second depth registered markedly higher values followed by first and third depths, whereas in chiseling plot, both D1 and D2 recorded significantly superior values than D3. In D2 and D3 depths, country ploughing and mouldboard ploughing treatments showed markedly higher values of $\text{NO}_3\text{-N}$ than chiseled plots. Whereas in surface layer (0-15 cm), chiseled plots registered significantly higher value than other two treatments which were comparable among themselves. The N x D interaction indicated that in N2 and N3 levels, second depth showed markedly higher value followed by D1 and D3 depths. Whereas in N1 treatment, the D1 showed significantly lower value than D3. The second depth continued to register markedly higher value. The different N levels behaved similarly with respect to D2 and D3, whereas in surface layer, application of N at 100 and 75 per cent (N3 and N2) levels registered markedly higher values than control (N1).

The correlation studies indicated a significant positive correlation with pod yield ($r = 0.471^*$), kernel yield ($r = 0.472^*$), total dry matter ($r = 0.390^*$), total N uptake ($r = 0.420^*$), kernel N uptake ($r = 0.463^*$), available N at 45 DAS ($r = 0.486^*$) and at

Table 74 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 15 DAS (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	16.25	42.70	22.50	27.17	32.20	40.90	22.95	32.02	33.05	42.20	23.05	32.77	30.65
T1M2	16.15	43.10	21.80	27.02	33.60	42.90	23.50	33.33	33.35	41.85	22.25	32.48	30.94
T1M3	16.05	41.95	21.75	26.58	32.20	42.05	22.55	32.27	33.90	43.10	23.05	33.35	31.27
TxNx D Mean	16.15	42.58	22.01	26.92	32.66	41.95	23.00	32.54	33.43	42.38	22.78	32.86	30.77
T2M1	15.95	42.50	23.20	27.22	31.55	42.35	21.95	31.95	33.40	42.55	21.95	32.63	30.60
T2M2	16.25	41.95	21.45	26.55	31.90	42.95	22.65	32.50	34.10	42.35	21.30	32.58	30.54
T2M3	18.00	47.60	22.00	27.53	34.30	41.10	22.10	32.50	33.15	41.30	22.30	32.25	30.76
TxNx D Mean	16.73	44.01	22.21	27.1	32.58	42.13	22.23	32.31	33.55	42.06	21.85	32.48	30.63
T3M1	18.00	31.95	14.90	21.62	39.55	33.30	15.50	29.47	41.75	33.00	14.80	29.85	26.98
T3M2	17.90	31.80	14.90	21.53	40.50	31.60	15.40	29.17	42.10	32.05	15.10	29.75	26.81
T3M3	17.05	33.25	15.85	27.05	40.10	32.60	15.55	29.42	41.25	31.80	15.95	29.67	28.71
TxNx D Mean	17.61	32.33	15.21	23.4	40.05	32.50	15.48	29.35	41.70	32.28	15.28	29.75	27.50
NxD Mean N Mean	16.84	39.64	19.81	25.80	35.09	38.86	20.23	31.40	36.22	38.9	19.97	31.69	

	T	M	N	D	T on N	N on T	T on D	D on T	N x D
SE _e	0.36	-	0.32	0.32	0.58	0.56	0.58	0.56	0.56
CD (0.05)	0.63	NS	0.65	0.65	1.22	1.12	1.22	1.12	1.12

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post harvest stage ($r = 0.491^{**}$). It also had significant positive correlation with $\text{NO}_3\text{-N}$ at 30 and 45 DAS and at post harvest stage (Appendix IV and VI).

The results of $\text{NO}_3\text{-N}$ on 30 and 45 DAS (Tables 75 and 76) revealed the same trend as that of $\text{NO}_3\text{-N}$ on 15 DAS.

The correlation studies indicated that the $\text{NO}_3\text{-N}$ on 30 DAS had a trend akin to $\text{NO}_3\text{-N}$ at 15 DAS, whereas the data on $\text{NO}_3\text{-N}$ on 45 DAS had no significant influence on pod yield, kernel yield, total dry matter, total N uptake and kernel N uptake. It had positive significant correlation with available N at all stages of sampling (Appendix IV and VI).

The statistical analysis of the $\text{NO}_3\text{-N}$ on 60 DAS (Table 77) showed that the tillage did not influence the parameter at this stage. The main effects of N and D were similar to the previous stage.

The interaction effect of T x M indicated that in control and farm yard manure treatments, T1 and T2 treatments were on par with each other and significantly different from chiseling treatment (T3). Irrespective of tillage treatments, all the manurial treatments behaved in a similar manner. The M x N interaction showed that in N1 and N2 levels, all the manurial treatments were on par with each other, whereas in N3 treatment M1 and M2 were on par with each other and showed significantly higher value than composted coir pith treatment (M3). The T x N interaction indicated that irrespective of tillage treatments, N3 and N2 levels registered significantly superior value than N1 level. The N3 and N2 were comparable among themselves. The country ploughing and mouldboard ploughing treatments were on par under all N levels and superior over T3 treatment. The T x D interaction revealed that irrespective of tillage treatments, second depth registered markedly higher value than other depths. In T1 and T2 treatments, D3

Table 75 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 30 DAS (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	15.80	42.90	22.60	27.10	31.90	43.60	23.20	32.90	33.40	43.00	22.30	32.90	30.96
T1M2	15.45	43.10	22.20	26.92	32.20	43.35	22.30	32.62	33.75	45.20	21.90	33.62	31.05
T1M3	14.95	44.05	22.20	27.07	31.20	41.75	22.30	31.75	33.85	42.35	22.55	32.92	30.58
TxNx D Mean	15.40	43.35	22.33	27.03	31.76	42.90	22.60	32.42	33.66	43.51	22.25	33.14	30.86
T2M1	15.10	43.25	21.60	26.65	32.00	42.85	22.30	32.38	33.00	42.85	21.65	32.57	30.53
T2M2	16.15	42.25	22.20	26.87	31.45	42.75	22.20	32.13	33.00	43.00	23.00	33.00	30.66
T2M3	15.50	42.70	22.10	26.77	32.90	41.70	22.60	32.40	33.95	43.05	21.85	32.95	30.70
TxNx D Mean	15.70	42.73	21.96	26.76	32.11	42.43	22.36	32.30	33.38	42.96	22.16	32.84	30.63
T3M1	15.65	32.45	14.95	21.02	40.10	32.35	15.95	29.47	41.15	33.35	15.70	30.07	26.85
T3M2	15.90	32.60	15.05	21.18	40.50	33.40	15.05	29.65	43.00	32.05	15.30	30.12	26.98
T3M3	16.15	32.25	15.55	21.32	40.85	32.50	15.45	29.60	41.25	31.80	15.20	29.43	26.78
TxNx D Mean	15.90	32.43	15.18	14.15	40.48	32.75	15.48	29.57	41.80	32.40	15.31	29.87	24.53
NxD Mean N Mean	15.66	39.50	19.82	22.64	34.78	39.36	20.14	21.76	36.28	39.62	19.90	31.95	

T	M	N	D	T on N	N on T	T on D	D on T
SE _p	-	0.28	0.28	0.47	0.48	0.47	0.48
CD (0.05)	NS	0.55	0.55	0.98	0.96	0.98	0.96

Table 76 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at 45 DAS (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean		
	TxMxN			TxMxN			TxMxN					
	0 - 15	15 - 30	30 - 45	TxM Mean	0 - 15	15 - 30	30 - 45	TxM Mean	0 - 15		15 - 30	30 - 45
T1M1	15.05	43.00	22.55	26.87	29.90	43.80	22.10	31.93	30.50	43.35	21.90	31.77
T1M2	15.15	43.20	21.55	26.63	29.40	42.90	21.70	31.33	29.25	42.05	21.95	31.08
T1M3	15.05	43.30	22.05	26.80	29.05	43.95	22.10	31.70	29.30	43.55	21.70	31.52
TxNx D Mean	15.23	43.16	22.05	26.76	29.45	43.55	21.96	31.65	29.68	42.98	21.85	31.45
T2M1	15.70	43.30	22.35	27.12	31.30	41.85	21.90	31.68	30.25	42.10	21.95	31.43
T2M2	15.20	42.35	22.45	26.67	30.70	43.10	21.65	31.82	30.60	42.90	22.00	31.83
T2M3	14.75	42.40	21.25	26.13	29.95	42.05	21.55	31.18	30.20	42.25	22.05	31.50
TxNx D Mean	15.21	42.68	22.01	26.64	30.65	42.33	21.70	31.56	30.35	42.41	22.00	31.58
T3M1	14.05	31.20	15.75	20.17	37.20	30.90	15.60	27.90	36.10	31.15	15.70	27.65
T3M2	15.30	31.80	15.45	20.85	36.15	30.85	15.80	27.60	36.30	30.90	15.50	27.58
T3M3	15.85	31.80	15.05	20.90	36.70	31.35	14.95	27.67	36.55	31.80	15.30	27.88
TxNx D Mean	15.06	31.60	15.41	20.64	36.68	31.03	15.45	27.72	36.31	31.28	15.50	27.70
NxD Mean N Mean	15.16	39.14	19.82	24.68	32.26	38.97	19.70	30.31	32.11	38.89	19.78	30.24

SE _e	T	M	N	D	T on N	N on T	T on D	D on T	N x D
0.15	0.15	-	0.27	0.27	0.41	0.46	0.41	0.46	0.46
CD (0.05)	0.35	NS	0.53	0.53	0.84	0.92	0.84	0.92	0.92

and D1 were on par. Whereas D1 registered markedly higher value than third depth. At surface layer (0-15 cm), the chiseling treatment had recorded significantly higher value than other tillage treatment, whereas in D2 and D3 depths, country ploughing and mouldboard ploughing treatments registered markedly higher values than chiseling but comparable among themselves.

The correlation studies revealed a significant positive correlation with available N on 45 and 90 DAS and at harvest stage. However, it had no significant correlation with yield, dry matter and uptake parameters (Appendix IV and VI).

The results of $\text{NO}_3\text{-N}$ at harvest stage (Table 78), showed that T2 and T1 registered markedly higher value than T3 but comparable among themselves. With respect to N levels and depths, the results showed a similar trend to that of the results of previous stage of sampling. The T x D interaction indicated that irrespective of tillage, second depth registered significantly superior value than other depths. In chiseling treatment, surface layer recorded markedly higher value than third depth, whereas in other two tillage treatments, the surface layer recorded markedly lower values than third depth. Chiseling registered significantly higher value in first depth than other treatments, whereas country ploughing and mouldboard ploughing treatment recorded markedly higher values in D2 and D3 depths than chiseling, but were on par with each other. The N x D interaction revealed a similar trend to that of the results of $\text{NO}_3\text{-N}$ at 45 DAS.

The correlation studies of $\text{NO}_3\text{-N}$ at harvest stage had a similar trend as that of $\text{NO}_3\text{-N}$ 60 DAS (Appendix IV and VI).

Table 78 Effect of tillage, organics and levels of N on the NO₃-N content of soil in different depths (ppm) at harvest (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	Tx/N Mean	0 - 15	15 - 30	30 - 45	Tx/N Mean	0 - 15		15 - 30	30 - 45	Tx/N Mean
T1M1	14.90	42.40	22.75	26.68	20.60	42.70	22.20	28.53	20.50	42.50	21.90	28.30	27.83
T1M2	14.15	42.95	22.25	26.45	20.40	41.75	21.90	28.02	19.70	43.15	22.50	58.45	27.64
T1M3	13.90	43.20	21.80	26.30	21.75	42.20	22.25	28.73	21.25	42.70	22.25	28.73	27.92
TxNx D Mean	14.31	42.85	22.26	26.47	20.91	42.21	22.15	28.42	20.48	42.78	22.20	28.49	27.79
T2M1	14.75	41.60	21.90	26.08	20.50	43.20	22.65	28.78	20.05	43.25	22.65	28.65	27.83
T2M2	14.75	42.60	22.00	26.45	21.45	41.40	22.50	28.45	20.70	43.35	22.75	28.93	27.94
T2M3	14.10	41.60	22.70	26.13	19.65	42.65	22.20	28.17	21.75	42.60	22.75	29.03	27.77
TxNx D Mean	14.53	41.93	22.20	26.22	20.53	42.41	22.45	28.46	20.83	43.06	22.71	28.87	27.85
T3M1	15.05	30.40	15.05	20.17	23.10	30.55	15.65	23.10	22.35	31.45	15.70	23.17	22.14
T3M2	15.10	30.30	15.15	20.18	21.30	30.50	14.70	22.17	22.20	30.90	15.60	22.93	21.76
T3M3	15.05	30.20	15.75	20.33	22.05	29.95	15.90	22.63	22.95	29.45	15.20	22.53	21.83
TxNx D Mean	15.06	30.30	15.31	20.22	22.15	30.33	15.41	22.63	22.53	30.60	15.50	22.87	21.90
NxD Mean N Mean	14.63	38.36	19.92	24.30	21.19	38.31	20.00	26.50	21.28	38.81	20.13	26.74	

SE _e	T	M	N	D	T on D	D on T	N x D
0.22	0.22	-	0.27	0.27	0.45	0.48	0.48
CD (0.05)	0.50	NS	0.55	0.55	0.92	0.95	0.95

4.3.11. Available nitrogen

4.3.11.1. Sorghum crop (Tables 79-81)

The results of available N content on 45 DAS (Table 79) indicated that tillage and manurial treatments had no significant influence on this parameter. The available N was found to be significantly higher in 100 per cent N level (N3) followed by 75 per cent N treatment (N2), which in turn registered markedly higher value than control (N1). The different depths also had significant influence on available N content on 45 DAS. The second depth registered significantly superior value over other two depths. The lowest value was recorded in third depth. The N x D interaction revealed that, irrespective of N levels, second depth registered markedly higher value followed by surface layer (0-15 cm) and third depth (30-45 cm). In first depth, N3 registered markedly higher value followed by N2 and N1 levels. The N1 registered the lowest value which was significantly different from N2 level. In other two depths (15-30 and 30-45 cm), the different N levels had no significant influence on available N.

The correlation studies indicated a significant positive relationship with sorghum grain yield ($r = 0.823^{**}$), total dry matter ($r = 0.918^{**}$), total N uptake ($r = 0.834^{**}$) and grain N uptake ($r = 0.829^{**}$).

The statistical scrutiny of data on available N on 90 DAS (Table 80) indicated that country ploughing and mouldboard ploughing treatments though on par registered significantly higher value than chiseling treatment. Among different manures tried, composted coir pith treatment recorded markedly higher value than farm yard manure which in turn superior over control. Among N levels, N3 registered markedly higher value followed by N2 and N1 levels. The N1 recorded significantly lower value than N2 level. The different depths also had significant influence on available N content on 90 DAS. The second depth registered the highest value followed by D1 and D3 depths. Each depth

Table 79 Effect of tillage, organics and levels of N on the available N content of soil in different depths (kg her⁻¹) at 45 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	128.40	192.35	111.80	144.18	167.60	190.15	114.15	157.30	175.85	193.95	111.70	160.50	153.99
T1M2	129.65	194.70	111.85	145.40	168.10	192.15	112.35	157.53	178.00	193.60	115.05	167.22	156.71
T1M3	132.30	194.90	114.60	147.27	167.00	187.70	109.90	154.87	175.75	192.40	110.65	159.60	153.91
TxNx D Mean	130.11	193.98	112.75	145.61	167.56	190.0	112.13	156.56	177.53	193.31	112.46	162.44	154.87
T2M1	126.50	192.45	112.65	144.53	170.10	194.10	113.50	159.23	177.10	193.10	109.85	160.02	154.59
T2M2	131.75	190.45	112.80	145.00	165.65	195.15	111.50	157.43	176.20	189.90	113.40	159.83	154.08
T2M3	126.55	195.20	115.85	145.87	167.35	192.60	112.50	157.48	176.10	193.80	110.85	160.08	154.47
TxNx D Mean	128.93	192.70	113.76	145.13	167.70	193.95	112.50	158.04	176.46	192.26	111.2	159.97	154.38
T3M1	127.00	196.10	114.00	145.70	168.35	191.65	112.40	157.47	175.85	192.20	112.60	160.22	154.46
T3M2	128.15	194.70	110.00	144.28	170.10	196.30	115.50	160.63	177.90	191.75	111.70	160.45	155.12
T3M3	129.05	194.45	112.30	145.27	168.10	192.10	111.40	157.20	175.80	196.60	111.85	161.42	154.63
TxNx D Mean	128.06	195.08	112.10	145.08	168.85	193.35	113.10	158.43	176.51	193.51	112.05	160.69	154.73
Nx D Mean N Mean	129.03	193.92	112.87	145.27	168.03	192.43	112.57	157.67	176.83	193.02	111.90	161.03	

SE _D	T	M	N	D	N x D
CD (0.05)	-	-	0.91	1.82	1.58
	NS	NS	0.91	1.82	3.15

Table 80 Effect of tillage, organics and levels of N on the available N content of soil in different depths (kg ha⁻¹) at 90 DAS (sorghum)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	106.80	189.30	114.60	136.90	122.00	191.30	116.00	143.10	126.70	192.50	113.05	144.08	141.36
T1M2	114.40	191.50	114.10	140.00	130.70	191.60	114.80	145.70	137.50	192.70	113.35	147.85	144.52
T1M3	131.20	193.60	112.90	145.90	148.70	187.85	115.05	150.53	152.95	188.60	115.25	152.26	149.56
TxNxM Mean	117.47	191.47	113.87	140.93	133.80	190.25	119.28	147.78	139.05	191.27	113.88	148.07	145.59
T2M1	109.05	191.25	111.75	137.35	124.25	190.95	115.30	143.50	131.30	190.75	117.35	146.47	142.44
T2M2	119.70	190.60	115.30	141.87	133.95	190.50	116.10	146.85	141.05	191.35	112.60	148.33	145.68
T2M3	132.50	192.10	113.30	145.97	148.70	193.50	113.20	151.80	149.80	191.10	113.05	151.32	149.70
TxNxM Mean	120.42	191.32	113.45	141.73	135.63	191.65	114.87	147.38	140.72	191.07	114.33	148.70	145.93
T3M1	113.50	171.30	99.40	128.07	129.50	174.90	102.10	135.33	142.35	170.35	102.55	138.42	133.94
T3M2	132.65	172.00	101.10	135.25	143.75	174.10	102.30	140.05	149.50	172.00	102.45	141.32	138.87
T3M3	142.45	171.10	103.05	138.87	155.70	170.40	102.10	142.73	161.50	172.20	101.80	145.17	142.25
TxNxM Mean	129.53	171.47	101.18	134.06	142.98	173.13	102.17	139.42	151.12	171.52	102.27	141.63	138.37
NxD Mean N Mean	122.47	184.75	109.50	138.90	137.47	184.68	110.77	144.86	143.63	184.62	110.16	146.13	

T	1.17	1.17	2.70	1.49	0.75	1.49	1.58	3.42	1.30	2.59	1.30	2.59	1.30	2.59
SE _D	1.17	1.17	2.70	1.49	0.75	1.49	1.58	3.42	1.30	2.59	1.30	2.59	1.30	2.59
CD (0.05)	1.17	1.17	2.70	1.49	0.75	1.49	1.58	3.42	1.30	2.59	1.30	2.59	1.30	2.59

differed markedly. The interaction effect of T x D revealed that irrespective of tillage treatments, second depth registered markedly higher values followed by surface layer (0-15 cm) and third depth. The chiseling treatment registered significantly higher value in first depth than other two tillage treatments. In second and third depths, though country ploughing and mouldboard ploughing treatments were on par recorded markedly higher values than chiseling treatment. The M x D interaction indicated that irrespective of manurial treatments the depth D2 registered markedly higher value than D1 and D3 depths. The composted coir pith registered significantly higher available N followed by farm yard manure treatment control in surface layer. In other two depths (15-30 and 30-45 cm) the manurial treatments had no effect. The N x D interaction showed that irrespective of N levels, D2 registered markedly higher value followed by D1 and D3. The 100 per cent N level (N3), had registered significantly superior value than 75 per cent N level (N2) and N1 level in first depth. In subsurface layers (15-30 and 30-45 cm), all the N levels behaved in a similarly manner.

The correlation studies showed a similar trend as that of available N on 45 DAS (Appendix V).

The results of available N content at post harvest stage (Table 81) indicated the same trend to that of available N on 90 DAS.

The correlation studies revealed the non existence of significant correlation with sorghum grain yield, total dry matter, total N uptake and grain N uptake (Appendix V).

4.3.11.2. Groundnut crop (Tables 82-84)

The statistical analysis of data pertaining to available N on 30 DAS (Table 82) revealed the same trend as that of available N of sorghum crop at post harvest stage.

Table 81 Effect of tillage, organics and levels of N on the available N content of soil in different depths (kg ha⁻¹) at harvest (sorghum)

Table 82 Effect of tillage, organics and levels of N on the available N content of soil in different depths (kg ha⁻¹) at 30 DAS (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	97.10	191.00	117.30	135.13	97.05	192.45	112.45	133.98	103.35	193.05	113.00	136.47	135.19
T1M2	127.50	191.60	117.70	145.60	133.00	191.20	114.05	146.08	137.10	192.30	112.35	147.25	146.31
T1M3	132.45	191.40	112.45	145.43	137.05	192.20	111.80	147.01	141.10	192.50	114.15	149.23	147.22
TxNx D Mean	117.35	191.33	112.48	140.38	122.37	191.95	112.77	142.36	127.18	192.62	113.17	144.29	142.34
T2M1	94.00	193.00	133.80	133.60	98.63	192.55	122.90	194.68	104.15	191.15	112.75	136.01	134.76
T2M2	127.55	192.30	112.60	144.15	131.90	192.30	114.70	146.30	138.15	193.70	114.30	148.71	146.38
T2M3	129.00	192.55	113.95	145.16	137.15	192.65	113.20	147.67	142.10	193.15	113.35	149.53	147.45
TxNx D Mean	116.85	192.65	113.45	140.97	127.57	192.50	113.60	144.55	128.13	192.67	113.47	144.75	143.43
T3M1	99.60	166.30	106.00	123.97	114.20	167.25	106.60	129.35	124.50	165.20	106.00	131.90	128.40
T3M2	122.05	165.00	105.80	130.95	131.35	165.55	105.55	134.25	138.30	166.55	105.80	136.88	134.02
T3M3	125.60	165.35	107.00	132.65	145.05	465.60	466.30	158.98	147.35	166.50	105.85	140.57	144.06
TxNx D Mean	115.75	165.55	106.27	129.19	130.20	166.13	106.25	134.19	137.38	166.08	105.88	136.44	133.27
NxD Mean N Mean	116.65	153.17	110.73	136.84	126.71	183.52	110.87	140.37	130.89	183.79	110.84	141.82	

SE _e	T	M	N	D	M on D	D on M	T on D	D on T	N x D
	0.81	0.81	0.73	0.73	1.31	1.26	1.31	1.26	1.26
CD (0.05)	1.87	1.87	1.45	1.45	2.77	2.51	2.77	2.51	2.51

The correlation studies indicated that the available N on 30 DAS had a significant positive correlation with pod yield ($r = 0.414^*$), kernel yield ($r = 0.414^*$), total dry matter ($r = 0.389^*$), total N uptake ($r = 0.400^*$) and kernel N uptake ($r = 0.405^*$) (Appendix VI).

The results of available N on 60 DAS (Table 83) revealed that chiseling registered significantly lower value than other two treatments. The composted coir pith (M3) and farm yard manure (M2) treatments registered markedly higher value than control. However, M3 and M2 were on par. The different N levels and depths and M x D interaction showed the same trend as that of the available N at post harvest stage of sorghum crop. The T x D interaction showed that irrespective of tillage treatments, second depth showed markedly higher value followed by D1 and D3 depths. The third depth recorded significantly lower value than surface layer. The N x D interaction revealed that irrespective of N levels, second depth registered markedly superior value. At N1 level, D1 and D3 were comparable. At N2 and N3 treatments, D1 recorded markedly higher value than third depth.

The correlation studies showed the presence of any significant correlation between available N on 60 day and other yield parameters (Appendix VI).

The results of available N at post harvest stage (Table 84) indicated that manurial and N treatment did not influence the parameter. The tillage treatments, depth, and T x D interaction showed the same trend to that of the available N on 60 DAS. The M x D interaction showed that in surface layer, M3 and M2 were on par and significantly higher than M1. In other two depths, the manurial treatments had no effect. Irrespective of manurial sources, second depth registered markedly higher value followed by third depth and surface layer.

Table 83 Effect of tillage, organics and levels of N on the available N content of soil in different depths (kg ha⁻¹) at 60 DAS (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	89.95	192.90	113.70	132.18	96.00	191.80	113.80	133.87	101.65	192.10	113.45	135.73	133.93
T1M2	124.70	193.95	114.30	144.32	121.75	193.25	113.50	142.83	131.90	192.55	113.65	146.03	144.39
T1M3	126.15	193.00	113.35	144.17	129.50	192.55	112.60	144.88	132.25	193.70	112.60	146.18	145.08
TxNx D Mean	113.60	193.28	113.78	140.22	117.75	192.53	113.30	141.19	121.93	192.78	113.23	142.65	141.35
T2M1	91.30	193.10	113.35	132.58	96.70	192.70	109.40	132.93	100.00	192.90	114.55	135.82	133.78
T2M2	123.60	196.10	113.15	144.28	128.20	194.55	112.65	145.13	131.00	194.45	113.30	146.25	145.22
T2M3	125.10	193.70	112.90	143.90	130.55	193.80	112.10	145.48	135.10	193.70	113.20	147.33	145.57
TxNx D Mean	113.33	194.30	113.13	140.25	118.48	193.68	111.38	141.18	122.03	193.68	113.68	143.13	141.52
T3M1	92.95	165.75	105.85	121.52	92.95	165.75	105.85	121.52	101.50	165.50	106.45	124.48	122.51
T3M2	119.45	168.35	106.45	131.42	119.45	168.35	106.45	131.42	126.55	166.80	106.95	113.43	132.09
T3M3	122.35	166.80	108.25	134.47	122.35	166.80	108.25	132.47	137.80	137.05	107.30	137.38	134.77
TxNx D Mean	111.58	166.97	106.85	128.47	111.58	166.97	106.85	128.47	121.95	166.45	106.90	131.77	129.57
NxD Mean N Mean	112.84	184.85	111.25	136.31	115.94	184.39	110.51	136.95	121.97	184.30	111.27	139.18	

	T	M	N	D	M on D	D on M	T on D	D on T	N x D
SE _b	0.88	0.88	0.77	0.77	1.41	1.34	1.41	1.34	1.34
CD (0.05)	2.04	2.04	1.54	1.54	2.97	2.67	2.97	2.67	2.66

Table 84 Effect of tillage, organics and levels of N on the available N content of soil in different depths (kg ha⁻¹) at harvest (groundnut)

Treatments	N1			N2			N3			T x M Mean T Mean			
	TxMxN			TxMxN			TxMxN						
	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15	15 - 30	30 - 45	TxN Mean	0 - 15		15 - 30	30 - 45	TxN Mean
T1M1	86.20	194.60	112.55	131.12	88.65	192.00	112.65	131.10	88.85	193.20	114.45	132.07	131.43
T1M2	96.35	193.20	113.60	134.35	96.25	189.55	114.60	133.47	97.05	194.05	112.75	134.62	134.15
T1M3	95.40	194.15	11.95	133.83	97.00	193.50	113.40	134.70	94.90	194.10	112.80	134.60	134.38
TxNx D Mean	92.65	193.98	112.67	133.10	94.03	191.68	113.55	133.09	94.17	193.78	113.33	133.76	133.32
T2M1	87.95	190.35	114.00	130.77	90.10	191.75	114.25	132.03	91.40	194.70	114.35	133.48	132.09
T2M2	94.80	193.00	111.05	132.95	95.40	194.10	113.00	134.17	95.70	193.10	112.85	133.88	133.67
T2M3	95.35	193.10	113.55	134.00	96.05	193.10	113.55	134.00	96.05	191.40	112.15	133.58	133.86
TxNx D Mean	92.70	192.15	112.87	132.57	93.85	192.98	113.60	133.40	94.38	193.07	113.12	133.65	133.21
T3M1	90.65	166.35	108.70	121.90	92.90	168.50	108.30	123.23	95.10	166.05	107.30	127.82	122.65
T3M2	97.20	167.10	107.80	174.03	98.80	170.35	116.50	128.55	101.30	164.80	106.90	124.33	142.30
T3M3	96.70	178.75	108.30	127.92	100.20	167.65	105.30	124.38	101.70	167.25	105.95	124.97	125.76
TxNx D Mean	94.85	170.73	108.27	141.28	97.30	168.83	110.03	125.39	99.37	166.03	106.72	124.04	130.24
NxD Mean N Mean	93.40	185.62	111.27	135.65	95.06	184.50	112.39	130.62	95.97	184.29	11.06	130.48	

	T	M	N	D	T on D	D on T	M on D	D on M
SE _b	1.28	-	-	0.88	1.79	1.52	1.79	1.52
CD (0.05)	2.96	NS	NS	1.75	3.85	3.03	3.85	3.03

The correlation studies indicated the same trend as that of available N on 60 DAS (Appendix VI).

4.3.12. Organic carbon

4.3.12.1. Sorghum crop (Table 85-87; Fig 9)

The results of the data on organic carbon content of soil 45 DAS (Table 85) revealed that chiseling (T3) and mouldboard ploughing (T2) treatments registered significantly superior values than country ploughing treatment (T1). However, T3 and T2 were on par. Among organics treatment, composted coir pith and farm yard manure treatments were on par but registered markedly higher value than control. In country ploughing treatment, farm yard manure (M2) registered significantly superior value than M1 and M3, whereas in T2 and T3 treatments, M2 and M3 were on par and recorded significantly higher value over M1. All the tillage practices behaved similarly in M1 and M2 treatments, but in M3, T2 and T3 were on par and significantly higher than T1. The T1 recorded the lowest value.

The results of statistical scrutiny of organic carbon on 90 DAS (Table 86) and at post harvest stage (Table 87) revealed that the different manurial treatments alone had significant influence on this parameter. Application of composted coir pith and farm yard manure (M3 and M2) registered markedly higher value followed by control (M1). The M3 and M2 treatments were comparable.

4.3.12.2. Groundnut crop (Tables 88-90)

The results of organic carbon content on 30 DAS (Table 88) showed that among manurial application treatments, M3 and M2 registered significantly higher value than M1. However they were on par with each other. The effect of other treatments and all interactions were found to be not significant.

Table 85 Effect of tillage, organics and levels of N on the organic carbon content of soil (%) at 45 DAS (sorghum)

Treatments	T1			T2			T3			N Mean			
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3	TxN Mean
N1	0.250	0.565	0.220	0.345	0.215	0.540	0.540	0.432	0.240	0.520	0.575	0.445	0.407
N2	0.280	0.580	0.255	0.372	0.265	0.550	0.590	0.468	0.255	0.555	0.580	0.463	0.473
N3	0.235	0.595	0.240	0.357	0.195	0.580	0.565	0.447	0.240	0.585	0.550	0.458	0.421
TxM Mean T Mean	0.255	0.580	0.238	0.358	0.225	0.557	0.565	0.449	0.245	0.553	0.568	0.455	

SE_n 0.012
CD (0.05) 0.028

T M N T x M
0.012 - 0.021
0.028 NS 0.049

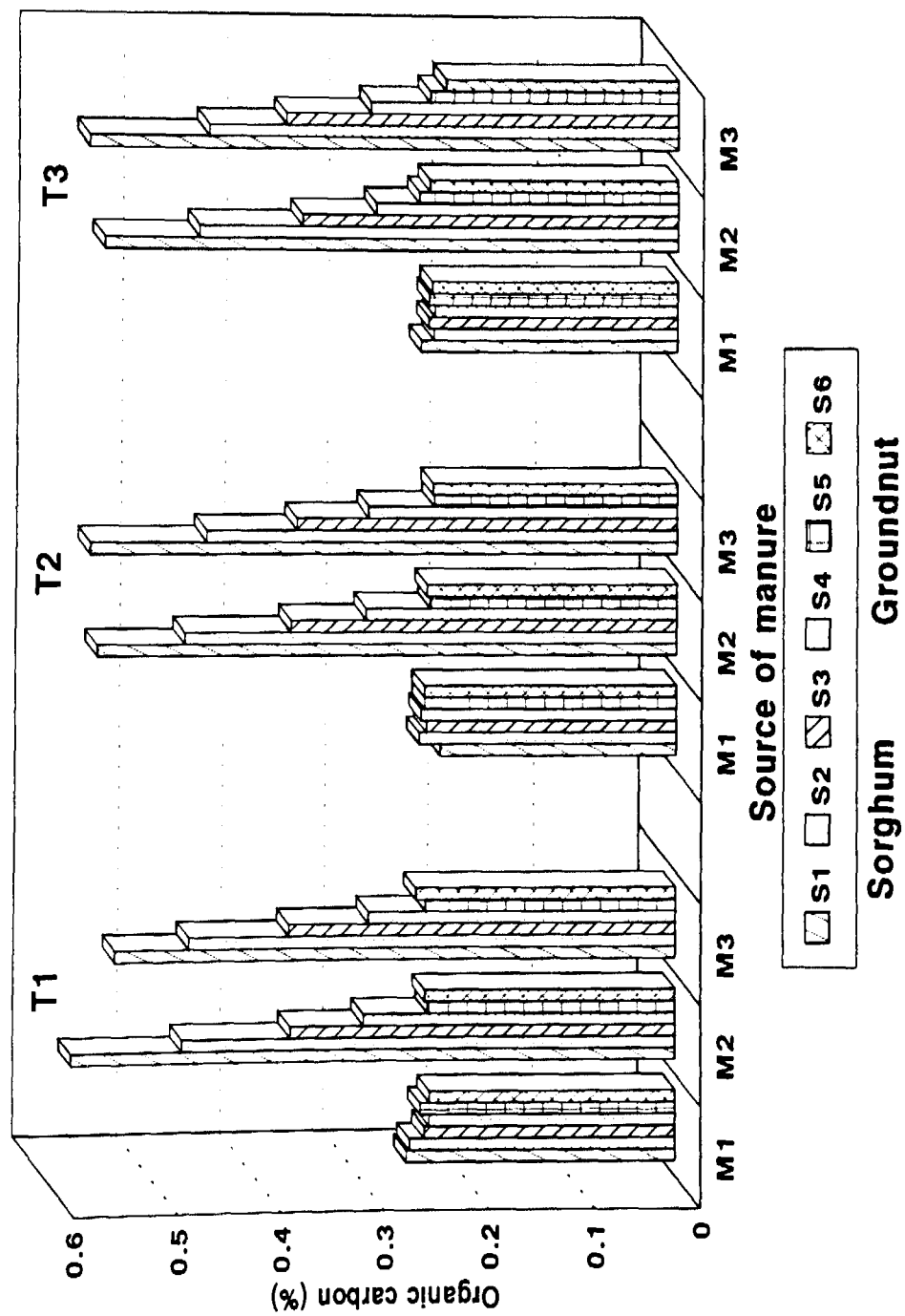
Table 86 Effect of tillage, organics and levels of N on the organic carbon content of soil (%) at 90 DAS (sorghum)

Treatments	T1			T2			T3			N Mean			
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3	TxN Mean
N1	0.260	0.510	0.455	0.408	0.240	0.490	0.480	0.403	0.220	0.490	0.465	0.392	0.401
N2	0.250	0.460	0.470	0.393	0.240	0.475	0.455	0.390	0.225	0.465	0.450	0.380	0.388
N3	0.255	0.450	0.475	0.393	0.255	0.455	0.425	0.378	0.255	0.430	0.445	0.377	0.383
TxM Mean T Mean	0.255	0.473	0.467	0.398	0.245	0.473	0.453	0.390	0.233	0.462	0.453	0.383	

SE_n -
CD (0.05) NS

T M N
- 0.011 -
NS 0.026 NS

Fig 9 Effect of manure application on the organic carbon content in sorghum - groundnut sequence



The results of organic carbon content on 60 DAS (Table 89) and at post harvest stage (Table 90) of groundnut crop indicated that none of the treatments and their interaction had a significant influence on this parameter.

4.3.1 3. Nitrogen content and uptake of plant, grain and straw (sorghum crop)

4.3.13.1. Nitrogen content of plant (Table 91)

The statistical scrutiny of the data with respect to N content of plant at various stages indicated that, N3 and N2 levels registered significantly higher value than N1 level. However, N3 and N2 were on par with each other. The different tillage and manurial treatments did not influence this parameter. As for as stages are concerned, the first stage registered markedly higher value. As the stage advanced a significant decline was observed. The N x S interaction revealed that, upto third stage (45 DAS), the N3 and N2 levels were on par and significantly superior over N1 level. From fourth stage to eighth stage, all the N levels behaved similarly. Irrespective of N levels, the first stage (15 DAS) registered markedly higher value. As the stage advanced, the N content showed a significant and concomitant decline.

4.3.13.2. Nitrogen content of grain (Table 92)

The results of N content of grain revealed that all the treatments and their interaction had no significant influence on this parameter.

4.3.13.3. Nitrogen content of straw (Table 93)

The results of N content of straw indicated the same trend as that of N content of grain.

4.3.13.4. Total Nitrogen uptake (Table 94; Fig 10)

The results of the uptake of N at different stages showed that among the tillage treatments, chiseling registered significantly higher N uptake than other two tillage

Table 89 Effect of tillage, organics and levels of N on the organic carbon content of soil (%) at 60 DAS (groundnut)

Treatments	T1			T2			T3			N Mean		
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3
N1	0.245	0.230	0.250	0.242	0.235	0.230	0.225	0.230	0.225	0.235	0.250	0.237
N2	0.255	0.260	0.235	0.250	0.235	0.250	0.225	0.237	0.230	0.240	0.235	0.235
N3	0.225	0.215	0.230	0.223	0.250	0.225	0.245	0.240	0.230	0.270	0.230	0.243
TxM Mean T Mean	0.242	0.235	0.238	0.238	0.240	0.235	0.232	1.236	0.228	0.248	0.238	0.238

All effect not significant

Table 90 Effect of tillage, organics and levels of N on the organic carbon content of soil (%) at harvest (groundnut)

Treatments	T1			T2			T3			N Mean			
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3	TxN Mean
N1	0.245	0.245	0.240	0.243	0.245	0.250	0.240	0.245	0.235	0.225	0.230	0.230	0.239
N2	0.225	0.240	0.250	0.238	0.230	0.240	0.215	0.228	0.225	0.240	0.225	0.230	0.232
N3	0.230	0.230	0.250	0.237	0.245	0.225	0.245	0.238	0.245	0.250	0.245	0.247	0.241
TxM Mean T Mean	0.233	0.238	0.247	0.239	0.240	0.238	0.233	0.237	0.235	0.238	0.233	0.235	

All effect not significant

Table 91 Effect of tillage, organics and levels of N on plant N content (%) at different stages (sorghum)

Treat ments	M1			TxSxM	M2			TxSxM	M3			TxSxM	TxS T
				TxM				TxM				TxM	T
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	Mean
T1S1	1.94	2.02	2.06	2.00	1.95	2.05	2.02	2.00	2.04	2.04	2.01	2.03	2.01
T1S2	1.86	1.92	1.90	1.89	1.86	1.89	1.90	1.88	1.89	1.92	1.92	1.90	1.89
T1S3	1.65	1.71	1.71	1.69	1.66	1.71	1.71	1.69	1.66	1.72	1.72	1.70	1.69
T1S4	1.49	1.49	1.50	1.49	1.52	1.50	1.52	1.51	1.49	1.50	1.53	1.51	1.50
T1S5	1.31	1.33	1.32	1.32	1.30	1.31	1.31	1.30	1.30	1.31	1.31	1.30	1.30
T1S6	1.05	1.05	1.09	1.06	1.05	1.09	1.07	1.07	1.09	1.05	1.05	1.06	1.06
T1S7	0.76	0.73	0.72	0.72	0.71	0.75	0.76	0.74	0.71	0.74	0.71	0.72	0.73
T1S8	0.51	0.50	0.52	0.51	0.49	0.52	0.46	0.49	0.49	0.51	0.49	0.50	0.50
TxNxM Mean	1.32	1.34	1.35	1.33	1.31	1.35	1.34	1.33	1.33	1.34	1.34	1.28	1.31
T2S1	1.99	2.04	1.99	2.01	2.00	2.03	2.03	2.02	1.98	2.00	2.05	2.01	2.01
T2S2	1.86	1.89	1.91	1.88	1.93	1.89	1.95	1.92	1.85	1.93	1.92	1.90	1.90
T2S3	1.69	1.72	1.71	1.70	1.65	1.69	1.72	1.68	1.71	1.68	1.71	1.68	1.69
T2S4	1.48	1.52	1.53	1.51	1.50	1.52	1.51	1.51	1.51	1.53	1.52	1.52	1.51
T2S5	1.28	1.30	1.28	1.29	1.31	1.30	1.32	1.31	1.31	1.29	1.29	1.29	1.30
T2S6	1.09	1.07	1.10	1.08	1.05	1.07	1.05	1.06	1.10	1.07	1.05	1.07	1.07
T2S7	0.74	0.74	0.70	0.73	0.72	0.76	0.74	0.74	0.69	0.73	0.74	0.72	0.73
T2S8	0.49	0.52	0.52	0.51	0.49	0.50	0.50	0.50	0.50	0.52	0.48	0.50	0.50
TxNxM Mean	1.32	1.35	1.34	1.33	1.33	1.34	1.35	1.34	1.32	1.34	1.34	1.33	1.33
T3S1	1.92	2.03	2.04	2.00	1.98	2.03	2.05	2.02	1.96	2.02	2.05	2.01	2.01
T3S2	1.82	1.90	1.93	1.88	1.81	1.83	1.88	1.84	1.82	1.90	1.88	1.87	1.86
T3S3	1.64	1.68	1.69	1.67	1.67	1.69	1.71	1.69	1.68	1.71	1.72	1.70	1.69
T3S4	1.49	1.51	1.49	1.50	1.52	1.52	1.48	1.51	1.50	1.52	1.52	1.51	1.50
T3S5	1.30	1.29	1.31	1.30	1.31	1.29	1.30	1.30	1.30	1.28	1.31	1.30	1.30
T3S6	1.07	1.05	1.06	1.06	1.07	1.07	1.05	1.06	1.07	1.05	1.07	1.06	1.06
T3S7	0.74	0.74	0.72	0.73	0.72	0.70	0.69	0.70	0.73	0.74	0.76	0.74	0.72
T3S8	0.52	0.52	0.51	0.51	0.51	0.51	0.50	0.51	0.50	0.50	0.54	0.51	0.51
TxNxM Mean	1.31	1.34	1.34	1.33	1.32	1.33	1.33	1.32	1.32	1.34	1.35	1.33	1.33
MxN N Mean	1.32	1.34	1.34	1.33	1.32	1.34	1.34	1.33	1.32	1.34	1.34	1.31	

	N	S	N x S
SED	0.004	0.006	0.01
CD(0.05)	0.01	0.01	0.02

Table 92 Effect of tillage, organics and levels of N on grain N content of sorghum (%)

Treatments	T1			T2			T3			N Mean		
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3
N1	1.670	1.680	1.660	1.670	1.700	1.680	1.680	1.687	1.690	1.710	1.725	1.708
N2	1.695	1.650	1.700	1.682	1.690	1.710	1.725	1.708	1.720	1.720	1.730	1.723
N3	1.660	1.700	1.680	1.680	1.705	1.730	1.730	1.722	1.700	1.720	1.680	1.700
TxM Mean T Mean	1.675	1.677	1.680	1.677	1.698	1.707	1.712	1.706	1.703	1.717	1.712	1.711

All effect not significant

Table 93 Effect of tillage, organics and levels of N on straw N content of sorghum (%)

Treatments	T1			T2			T3			N Mean			
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3	TxN Mean
N1	0.510	0.490	0.490	0.497	0.490	0.490	0.495	0.492	0.520	0.510	0.495	0.508	0.499
N2	0.500	0.520	0.505	0.508	0.520	0.500	0.520	0.513	0.515	0.505	0.500	0.507	0.509
N3	0.520	0.455	0.490	0.488	0.515	0.500	0.500	0.505	0.505	0.500	0.535	0.513	0.502
TxM Mean T Mean	0.510	0.488	0.495	0.498	0.508	0.497	0.505	0.503	0.513	0.505	0.510	0.509	

All effect not significant

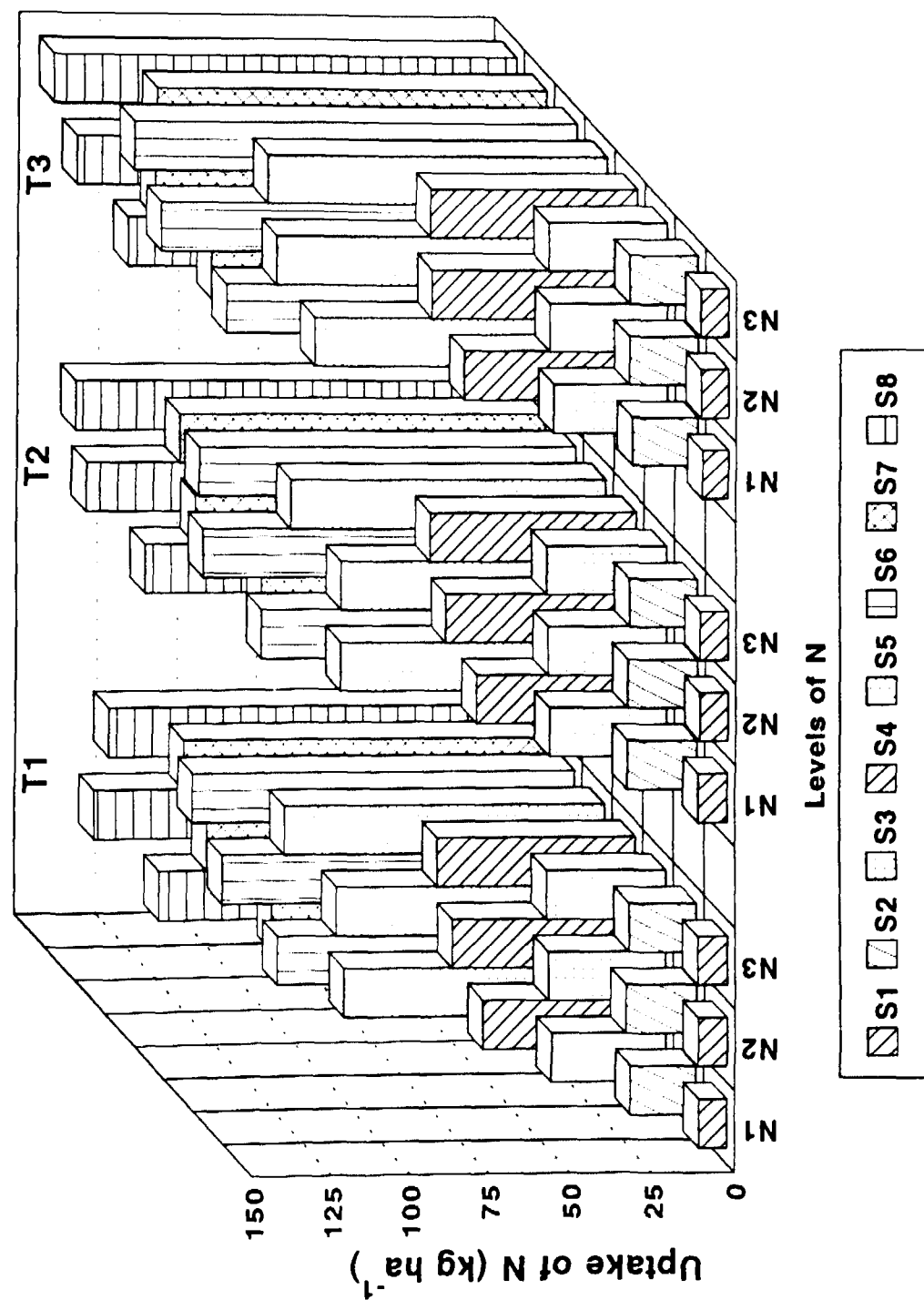
treatments. The composted coir pith and farm yard manure treatments were on par with each other and significantly superior over control. The different N levels and stages also had significant influence on N uptake. Among N levels, N3 registered markedly higher value than N2 and N1 levels. The N uptake was the highest at harvest stage (S8) and the lowest at first stage (15 DAS). Along with the advancement of crop, the N uptake also increased significantly. The T x S interaction showed that upto fourth stage (60 DAS), all the tillage treatments behaved similarly. from fifth stage to harvest, chiseling (T3) recorded significantly higher values than country ploughing (T1) and mouldboard ploughing (T2) treatments. However, T1 and T2 were comparable. Irrespective of the tillage treatments, post harvest stage (S8) registered markedly higher values and the lowest values were recorded in S1. Each stage differed significantly. The M x S interaction revealed that upto fifth stage, all the manurial treatments were on par. After sixth stage upto harvest, the M3 and M2 were on par and significantly higher than M1. Irrespective of manurial treatment, the N uptake paralleled the crop growth significantly. The N x S interaction was also found to be significant and indicated that upto 4th stage (60 DAS), all the N levels behaved similarly. Thereafter, N3 registered higher values followed by N2 and N1 treatments. Irrespective of N levels, the values were significantly higher with advancement in stages.

The correlation studies revealed the existence of a significant positive correlation between N uptake and grain yield ($r = 0.949^{**}$), grain N uptake ($r = 0.957^{**}$) besides, the physical properties like hydraulic conductivity, capillary, non capillary and total porosity at all stages of sampling. However, it had significant negative correlation with bulk density values at all stages of sampling (Appendix I).

Table 94 Effect of tillage, organics and levels of N on N uptake (kg ha⁻¹) at different stages (sorghum)

Treatments	M1			TxSxM	M2			TxSxM	M3			TxSxM	TxS T
				TxM				TxM				TxM	T
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	Mean
T1S1	8.13	8.73	9.30	8.72	7.93	8.39	8.16	8.16	9.20	9.18	9.49	9.29	8.72
T1S2	20.70	21.26	22.56	21.49	20.32	22.20	19.28	20.60	19.14	21.53	20.17	20.28	20.79
T1S3	33.86	36.12	36.50	35.49	35.69	35.24	36.59	35.84	35.26	36.65	36.65	36.18	35.84
T1S4	45.71	52.14	57.60	51.81	44.57	56.90	60.59	54.02	50.52	60.54	65.87	58.98	54.94
T1S5	79.53	96.37	98.31	90.73	80.62	98.35	101.41	93.46	84.82	57.87	102.41	81.70	88.63
T1S6	92.29	103.72	115.78	103.93	94.95	111.03	122.52	109.40	93.83	118.30	123.18	111.77	68.37
T1S7	81.30	104.41	111.72	99.14	85.44	103.92	119.51	102.96	91.19	111.60	110.98	104.59	102.23
T1S8	100.83	128.18	135.16	121.37	115.45	132.96	134.60	127.62	120.25	136.30	114.97	132.84	127.28
TxNxM Mean	57.79	68.86	73.37	66.39	60.38	71.12	75.33	75.76	63.03	68.96	72.97	69.45	71.60
T2S1	8.35	8.11	8.17	8.21	8.75	9.02	9.00	8.92	8.62	8.60	8.59	8.60	8.58
T2S2	20.99	20.96	20.25	20.73	22.24	21.89	21.23	21.79	20.91	21.27	21.07	21.08	21.20
T2S3	36.09	37.31	37.02	36.80	35.73	36.23	36.97	36.31	35.60	35.67	36.51	35.93	36.35
T2S4	46.65	56.02	59.00	53.89	48.83	57.97	65.18	57.32	52.25	63.17	67.88	61.10	57.44
T2S5	79.49	95.41	96.09	90.34	83.61	98.46	99.14	93.74	86.54	55.67	102.45	81.55	88.54
T2S6	96.94	111.03	121.69	109.89	98.11	120.88	119.34	112.77	102.57	120.95	122.68	115.40	112.68
T2S7	86.80	111.06	117.11	104.99	94.20	108.13	113.80	105.38	88.35	113.11	116.84	106.10	105.49
T2S8	109.46	125.58	139.75	124.93	109.03	139.54	141.62	130.06	116.92	141.31	135.69	131.30	128.76
TxNxM Mean	60.60	70.69	74.89	68.72	62.56	74.02	75.79	70.79	63.97	69.97	76.46	70.13	69.88
T3S1	7.87	8.22	8.45	8.18	7.81	8.38	8.55	8.23	7.99	8.69	8.56	8.41	8.27
T3S2	19.29	20.98	21.56	20.61	20.82	21.32	20.66	20.93	20.43	21.13	20.87	20.81	20.78
T3S3	35.64	35.44	35.20	35.42	35.46	36.33	37.19	36.33	33.60	36.86	37.54	36.00	35.91
T3S4	51.56	63.32	64.34	59.74	54.51	64.93	59.51	59.65	54.49	63.23	69.42	62.38	60.59
T3S5	84.51	103.75	104.58	97.61	92.54	104.41	106.70	101.21	99.02	104.60	110.34	104.65	101.16
T3S6	109.24	125.85	133.84	122.97	111.16	131.18	142.96	128.43	111.78	136.82	142.63	130.41	127.27
T3S7	104.06	122.09	117.91	114.69	105.35	121.33	126.22	117.63	109.00	128.58	134.81	124.13	118.82
T3S8	109.93	133.94	141.45	128.44	127.48	140.45	143.02	136.98	131.23	142.69	153.98	142.63	136.01
TxNxM Mean	65.26	76.70	78.42	73.46	69.39	78.54	80.60	76.17	70.94	80.33	84.77	78.68	76.10
MxN N Mean	61.22	72.08	75.56	69.59	64.18	74.56	77.24	74.24	65.98	73.09	78.07	72.75	
	T	M	N	S	M on S	S on M	T on S	S on T	N x S				
SED	0.71	0.71	0.92	1.50	2.45	2.60	2.45	2.60	2.60				
CD(0.05)	1.65	1.65	1.81	2.96	4.90	5.13	4.90	5.13	5.13				

During different stages of sorghum crop



4.3.13.5. Grain Nitrogen uptake (Table 95)

The results of grain uptake of N showed that, among tillage treatments chiseling registered significantly superior value than mouldboard ploughing and country ploughing treatments. In manurial treatments, composted coir pith and farm yard manure treatments were on par and registered markedly superior values than control. Among N levels, N3 registered markedly superior value followed by N2 and N1. All the interaction effects were found to be not significant.

The correlation studies of grain N uptake values showed a similar trend as that of the results of correlation studies on total N uptake (Appendix I).

4.3.13.6. Straw Nitrogen uptake (Table 96)

The results of the statistical analysis of straw N uptake indicated that the different N levels alone had a significant influence on this parameter. The N3 and N2 levels behaved similarly and registered significantly higher value over N1 level.

4.3.14. Nitrogen content and uptake of plant, kernel and haulm (Groundnut crop)

4.3.14.1. Nitrogen content of plant (Table 97)

The results of N content of plant samples at various stages revealed the significant influence of stages on this parameter. The first stage registered significantly higher value followed by other stages. The values decreased significantly with advancement in growth stages. All the interaction effects were found to be not significant.

4.3.14.2. Kernel Nitrogen content (Table 98)

The results of the kernel N content of groundnut crop indicated that the different treatments tried had no significant influence on this parameter.

Table 97 Effect of tillage, organics and levels of N on plant N content (%) at different stages (groundnut)

Treat ments	M1			TxSxM	M2			TxSxM	M3			TxSxM	TxS
				TxM				TxM				TxM	T
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	Mean
T1S1	3.18	3.21	3.24	3.21	3.17	3.21	3.21	3.20	3.16	3.19	3.22	3.19	3.12
T1S2	2.99	3.04	3.09	3.04	2.91	3.01	3.07	2.99	3.04	3.02	3.02	3.02	3.01
T1S3	2.61	2.73	2.70	2.68	2.62	2.62	2.60	2.61	2.65	2.57	2.60	2.60	2.63
T1S4	2.41	2.46	2.39	2.42	2.48	2.46	2.43	2.45	2.52	2.39	2.42	2.44	2.43
T1S5	1.77	1.82	1.73	1.77	1.78	1.76	1.78	1.77	1.80	1.69	1.73	1.73	1.75
TxNxM Mean	2.59	2.65	2.63	2.62	2.59	2.61	2.62	2.60	2.63	2.57	2.60	2.60	2.60
T2S1	3.17	3.18	3.21	3.18	3.19	3.23	3.20	3.20	3.14	3.22	3.19	3.18	3.18
T2S2	3.04	3.12	2.95	3.03	3.04	3.04	2.91	2.99	3.04	3.08	3.06	3.06	3.02
T2S3	2.59	2.60	2.57	2.58	2.59	2.59	2.60	2.59	2.58	2.59	2.64	2.60	2.69
T2S4	2.43	2.45	2.41	2.43	2.44	2.49	2.41	2.44	2.45	2.49	2.46	2.46	2.44
T2S5	1.74	1.81	1.75	1.76	1.73	1.75	1.81	1.76	1.77	1.75	1.71	1.74	1.75
TxNxM Mean	2.59	2.63	2.58	2.6	2.60	2.62	2.59	2.60	2.59	2.62	2.61	2.60	2.6
T3S1	3.22	3.22	3.25	3.23	3.23	3.21	3.23	3.22	3.21	3.22	3.24	3.22	3.22
T3S2	2.97	3.03	3.03	3.01	3.05	3.05	3.07	3.05	2.97	3.01	3.03	3.00	3.02
T3S3	2.65	2.52	2.51	2.56	2.55	2.54	2.58	2.55	2.64	2.63	2.55	2.60	2.57
T3S4	2.47	2.42	2.38	2.42	2.50	2.43	2.49	2.47	2.41	2.48	2.48	2.45	2.44
T3S5	1.69	1.83	1.71	1.94	1.70	1.74	1.78	1.74	1.80	1.74	1.76	1.76	1.74
TxNxM Mean	2.60	2.60	2.58	2.59	2.61	2.59	2.63	2.61	2.60	2.61	2.61	2.60	2.60
MeN N Mean	2.31	2.62	2.59	2.60	2.60	2.60	2.61	2.60	2.60	2.60	2.60	2.60	

	T	M	N	S	T on S
SED	-	-	-	0.01	0.017
CD(0.05)	NS	NS	NS	0.02	0.03

Table 98 Effect of tillage, organics and levels of N at kernel N content of groundnut at harvest (%)

Treatments	T1			T2			T3			N Mean			
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3	TxN Mean
N1	4.32	4.53	4.40	4.42	4.44	4.42	4.37	4.41	4.47	4.30	4.33	4.37	4.40
N2	4.34	4.43	4.32	4.36	4.71	4.46	4.30	4.49	4.36	4.44	4.33	4.38	4.41
N3	4.40	4.41	4.33	4.38	4.49	4.32	4.38	4.40	4.40	4.42	4.39	4.40	4.39
TxM Mean T Mean	4.35	4.46	4.35	4.39	4.55	4.40	4.35	4.43	4.41	4.39	4.35	4.38	

All effect not significant

Table 99 Effect of tillage, organics and levels of N on haulm N content of groundnut at harvest (%)

Treatments	T1			T2			T3			N Mean		
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3
N1	1.77	1.78	1.80	1.78	1.74	1.73	1.77	1.75	1.69	1.70	1.80	1.73
N2	1.82	1.76	1.69	1.76	1.81	1.75	1.75	1.77	1.83	1.74	1.74	1.77
N3	1.73	1.78	1.73	1.75	1.75	1.81	1.71	1.76	1.71	1.78	1.76	1.75
TxM Mean T Mean	1.77	1.77	1.74	1.76	1.77	1.76	1.74	1.76	1.74	1.74	1.77	1.75

All effects not significant

4.3.14.3. Haulm Nitrogen content (Table 99)

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The statistical analysis of haulm N content revealed a similar trend to that of kernel N content.

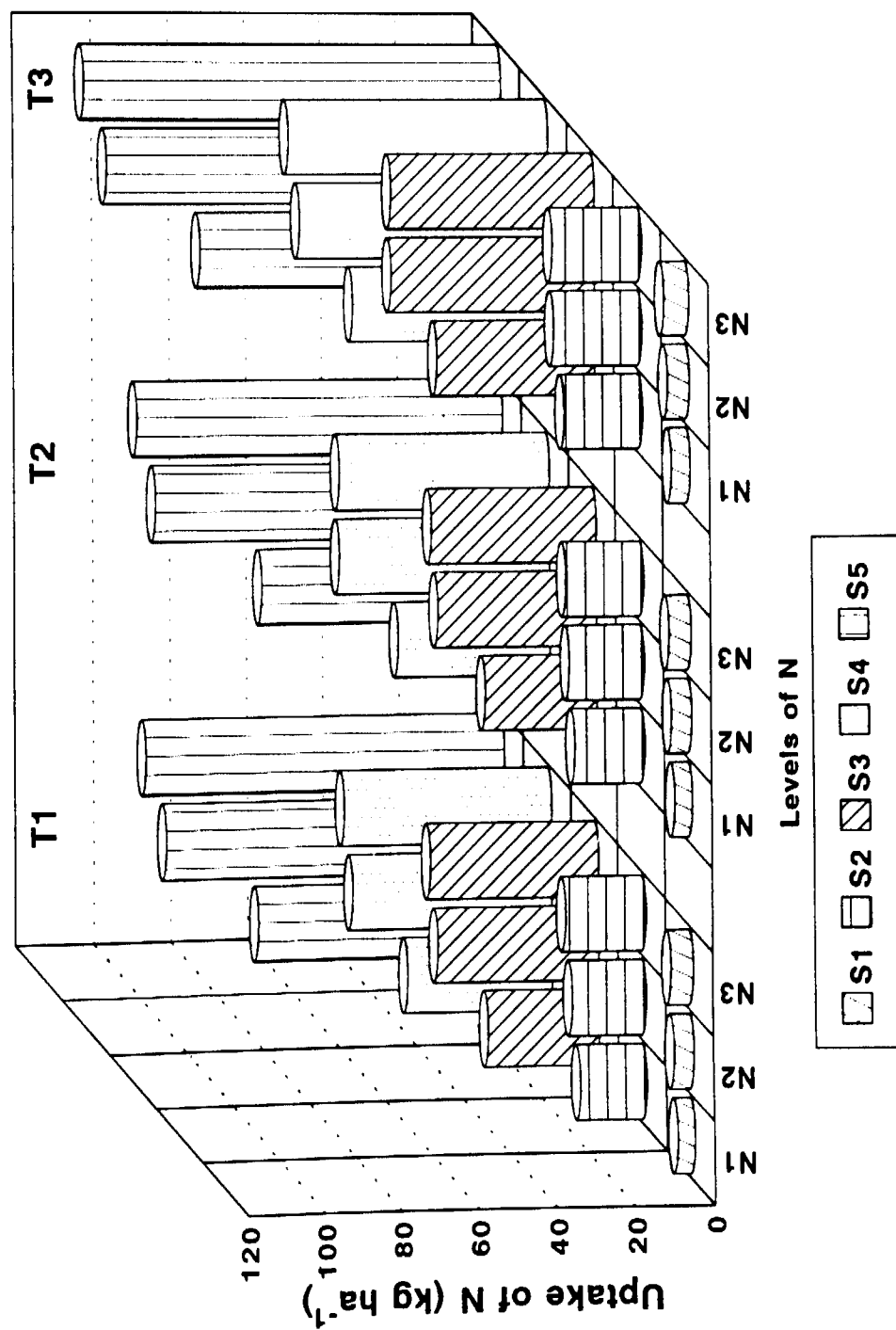
4.3.14.4. Total Nitrogen uptake (Table 100; Fig 11)

The results of the total N uptake at different stages showed that among the tillage treatments, chiseling registered statistically higher value than other two tillage treatments. The manurial sources showed that M2 and M3 were on par but markedly superior over M1. Among N levels, N3 recorded significantly higher value followed by N2 and N1 levels. With respect to stages, the values were significantly superior in stage S5 followed by S4, S3, S2 and S1 stages. Each stage differed markedly. The T x S interaction revealed that irrespective of tillage treatments, T5 registered significantly superior value. The N uptake paralleled the crop growth stages significantly. All the tillage treatments behaved similarly at first stage. In subsequent stages, chiseled plots registered higher values than other two tillage treatments. The other two treatments were comparable among themselves. The M x S interaction indicated that irrespective of manurial treatments, the stages behaved similarly as mentioned above in T x S interaction. The composted coir pith and farm yard manure treatments were registered significantly superior values than control in all the N levels. In M x N interaction, irrespective of manurial treatments, N3 registered markedly superior value followed by N2 and N1 levels. The N x S interaction showed that irrespective of N levels, S5 registered markedly higher value than other levels. The uptake values increased along with the stage of crop significantly. All the N levels behaved similarly at first stage (S1). In second stage, N3 and N2 were on par and significantly superior over N1. From third to fifth stages N3 registered markedly superior value followed by N2 and N1 levels.

Table 100 Effect of tillage, organics and levels of N on plant N uptake (kg ha⁻¹) at different stages (groundnut)

Treat ments	M1			TxSxM		M2			TxSxM		M3			TxSxM		TxS	
				TxM					TxM					TxM		T	
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	Mean
T1S1	3.81	4.42	5.18	4.47	4.53	5.22	5.90	5.22	4.66	5.43	6.03	5.37					5.02
T1S2	15.03	16.78	19.86	17.22	16.42	19.80	21.49	19.23	19.76	20.32	20.46	20.18					18.87
T1S3	18.54	36.85	40.78	32.05	32.97	44.33	43.02	40.11	33.93	43.08	46.03	41.01					37.72
T1S4	25.90	44.02	49.78	39.90	43.24	58.16	54.34	51.92	42.60	52.65	57.17	50.80					47.54
T1S5	44.06	74.75	81.44	66.75	75.48	96.16	101.08	90.90	73.25	93.93	97.94	88.37					82.00
TxNxM Mean	21.47	35.36	39.40	32.07	34.53	44.73	45.14	41.48	34.84	43.08	45.53	41.14					38.23
T2S1	4.12	4.29	5.06	4.49	4.87	5.66	5.68	5.40	4.49	5.55	6.22	5.42					5.10
T2S2	15.89	17.02	18.15	17.02	18.59	20.06	20.22	19.62	19.47	20.62	21.58	20.55					19.06
T2S3	20.48	35.94	37.36	31.26	31.80	43.38	44.57	39.91	34.01	43.58	45.77	41.12					37.43
T2S4	26.47	45.45	49.39	40.43	44.83	58.50	55.33	52.88	46.66	60.12	59.29	55.36					49.55
T2S5	44.89	79.47	83.73	69.36	72.21	97.80	102.62	90.87	72.07	95.22	100.57	89.29					83.17
TxNxM Mean	22.37	37.03	38.74	32.51	34.46	45.08	45.68	41.74	35.34	45.01	46.68	42.35					38.86
T3S1	4.26	5.23	5.77	5.09	5.01	6.01	6.85	5.95	5.06	5.55	6.48	5.63					5.55
T3S2	18.86	22.31	22.34	21.17	21.09	22.96	23.63	22.56	20.43	22.69	23.03	22.05					21.92
T3S3	29.47	40.89	44.58	38.31	45.29	56.29	58.27	53.28	47.90	57.89	55.37	53.72					48.44
T3S4	37.39	56.73	56.25	50.12	59.33	68.30	73.52	67.05	56.02	69.33	73.10	66.15					61.10
T3S5	58.67	90.42	95.98	81.69	84.46	109.93	114.78	103.06	93.71	109.52	116.23	106.49					97.08
TxNxM Mean	29.73	43.12	44.98	39.28	43.04	52.70	55.41	50.38	44.62	52.99	54.84	50.80					46.82
MrN N Mean	24.52	38.50	41.04	34.62	37.34	47.50	48.74	44.53	38.27	47.03	49.02	44.76					
	T	M	N	S	Mon N	Non M	Mon S	Son M	Ton S	Son T	N x S						
SED	0.34	0.34	0.32	0.41	0.75	0.55	0.72	0.70	0.72	0.70	0.70						
CD(0.05)	0.79	0.79	0.62	0.81	1.50	1.00	1.48	1.39	1.48	1.39	1.39						

different stages of groundnut crop



The total N uptake had positive significant correlation with total dry matter ($r = 0.985^{**}$), pod yield ($r = 0.996^{**}$) besides, hydraulic conductivity at all stages of sampling and with capillary, non capillary and total porosity at 60 DAS (Appendix II).

4.3.14.5. Kernel N uptake (Table 101)

The results of kernel N uptake values revealed a similar trend as that of total N uptake values of groundnut with respect to main effects of tillage, manures and N levels and M x N interactions are concerned. The remaining interactions had no significant influence on this property.

The correlation studies also showed a similar trend as that of the results of total uptake of N of groundnut crop (Appendix II).

4.3.14.6. Haulm N uptake (Table 102)

The results of haulm N content of groundnut showed that tillage had no significant influence on this parameter. The composted coir pith and farm yard manure treatments were on par and recorded markedly higher value than control. With respect to N levels, N3 registered significantly superior value followed by N2 and N1. The M x N interaction indicated that irrespective of manurial treatments, N3 and N2 were on par and significantly superior over N1 level. Composted coir pith and farm yard manure treatments behaved similarly in all N levels which were significantly superior over control.

4.4. Linear multiple regression analysis

4.4.1. Physical properties with yield, root growth and uptake of nitrogen (Tables 103-108)

The multiple regression analysis carried out between the physical properties at 45 DAS of sorghum crop and yield, root growth and uptake (Table 103) revealed that the physical properties viz., bulk density, hydraulic conductivity and pore size distribution

Table 101 Effect of tillage, organics and levels of N on kernel N uptake of groundnut (kg ha⁻¹) at harvest

Treatments	T1			T2			T3			N Mean			
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3	TxN Mean
N1	14.45	25.13	25.25	21.61	15.39	25.52	25.22	22.04	20.35	29.99	30.64	26.99	23.55
N2	24.35	34.64	33.06	30.68	27.56	33.40	32.80	31.25	32.17	37.22	36.82	35.40	32.44
N3	29.59	36.45	36.20	34.08	29.36	36.46	36.90	34.24	34.59	39.89	40.23	38.23	35.52
TxM Mean T Mean	22.80	32.07	31.50	28.79	24.10	31.79	31.64	29.18	29.04	35.70	35.90	33.54	

T M N M on N N on M

SE_n 0.53 0.53 0.43 0.81 0.75

CD (0.05) 1.21 1.21 0.91 1.77 1.58

Table 102 Effect of tillage, organics and levels of N on haulm N uptake of groundnut (kg ha⁻¹) at harvest

Treatments	T1			T2			T3			N Mean			
	M1	M2	M3	TxN Mean	M1	M2	M3	TxN Mean	M1		M2	M3	TxN Mean
N1	29.61	49.86	48.01	42.01	29.50	46.69	46.86	41.02	38.32	54.48	63.07	51.96	45.16
N2	50.40	61.52	60.87	57.60	51.91	64.40	62.42	59.58	58.25	71.44	72.70	67.46	61.55
N3	51.85	64.63	61.75	59.41	54.37	66.16	63.67	61.40	61.39	74.89	76.01	70.76	63.86
TxM Mean T Mean	43.05	58.67	56.88	52.87	45.26	59.08	57.65	54.00	52.65	66.94	70.59	63.39	

T M N M on N N on M

SE_n 0.98 0.98 0.78 1.43 1.27

CD (0.05) 2.27 2.27 1.54 3.14 2.67

favoured for a successful prediction of the grain yield ($R^2 = 0.99^{**}$), root length ($R^2 = 0.99^{**}$), root volume ($R^2 = 0.98^{**}$) and grain N uptake ($R^2 = 0.98^{**}$). Among the physical properties, the bulk density significantly and negatively contributed to the prediction of grain yield, root length and root volume. The hydraulic conductivity had significantly contributed to the prediction of root length and root volume. However, the various physical properties failed to predict the dry matter production of sorghum ($R^2 = 0.74^{NS}$). In groundnut crop, the physical properties on 45 DAS when regressed with yield and uptake (Table 104) showed that the physical parameters failed to indicate their significant contribution towards the pod yield, kernel yield, total dry matter, total N uptake and kernel N uptake.

The physical properties on 90 DAS when regressed with grain yield, root growth and uptake characteristics of sorghum crop (Table 105) indicated a significant overall contribution of physical properties towards the grain yield and total N uptake to the tune of 98 per cent. However, the individual contribution of grain could not be assessed. The bulk density showed a marked negative contribution for the root length and root volume. Again, the contribution of physical properties for the total dry matter production ($R^2 = 0.93^{NS}$) and grain N uptake ($R^2 = 0.95^{NS}$) was not significant. In groundnut crop, the physical properties at 90 DAS (Table 106) did not predict the pod yield, kernel yield, dry matter, total N uptake and kernel N uptake significantly as was observed at 45 DAS.

The contribution of physical properties for the grain yield and grain N uptake of sorghum were predicted upto 96 and 98 per cent, respectively, though the individual physical properties at post harvest stage failed to contribute (Table 107). The bulk density at this stage contributed negatively and significantly to the prediction of root length and root volume. The contribution of physical properties at post harvest stage on dry matter production and total N uptake could not be predicted significantly. In groundnut crop, the

Table 103. Multiple regression analysis between various physical properties and grain yield, total drymatter, root length, root volume, total nitrogen uptake and grain nitrogen uptake (Sorghum crop) (n=9)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Grain yield	BD,HC,CP,NCP and TP (45)	0.99**	$Y = -21891.84 - 5407.1BD45^* - 36.8HC45^{NS} + 969.9CP45^{NS} + 907.8NCP45^{NS} - 580.1TP45^{NS}$	9
2.	Total Drymatter production	BD,HC,CP,NCP and TP (45)	0.74 ^{NS}	---	9
3.	Root length	BD,HC,CP,NCP and TP (45)	0.99**	$Y = 496.36 - 144.7BD45^{**} + 18.2HC45^{**} + 34.7CP45^{NS} + 34.4NCP45^{NS} - 40.9TP45^{NS}$	9
4.	Root volume	BD,HC,CP,NCP and TP (45)	0.99**	$Y = 201.26 - 51.7BD45^{**} + 8.1HC45^{**} + 19.6CP45^{NS} + 20.7NCP45^{NS} - 22.3TP45^{NS}$	9
5.	Total Nitrogen uptake	BD,HC,CP,NCP and TP (45)	0.98**	$Y = -734.78 + 158.9BD45^* - 14.2HC45^{NS} - 18.8CP45^{NS} - 29.9NCP45^{NS} + 35.6TP45^{NS}$	9
6.	Grain Nitrogen uptake	BD,HC,CP,NCP and TP (45)	0.98**	$Y = -446.63 + 78.2BD45^{NS} - 13.7HC45^{NS} + 9.3CP45^{NS} + 8.1NCP45^{NS} + 0.2TP45^{NS}$	9

Table 104. Multiple regression analysis between various physical properties and pod yield, kernel yield, total drymatter, total N uptake and kernel N uptake (Groundnut crop) (n=9)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Pod yield	BD,HC,CP,NCP and TP (45)	0.87 ^{NS}	---	9
2.	Kernel yield	BD,HC,CP,NCP and TP (45)	0.91 ^{NS}	---	9
3.	Total Drymatter production	BD,HC,CP,NCP and TP (45)	0.84 ^{NS}	---	9
4.	Total Nitrogen uptake	BD,HC,CP,NCP and TP (45)	0.79 ^{NS}	---	9
5.	Kernel Nitrogen uptake	BD,HC,CP,NCP and TP (45)	0.90 ^{NS}	---	9

Table 105. Multiple regression analysis between various physical properties and grain yield, total drymatter, root length, root volume, total nitrogen uptake and grain nitrogen uptake (Sorghum crop) (n=9)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Grain yield	BD,HC,CP,NCP and TP (90)	0.98**	$Y = 487.50 + 1023.3BD90^{NS} + 940.7HC90^{NS} + 5869.8CP90^{NS} + 5719.1NCP90^{NS} - 5831.2TP90^{NS}$	9
2.	Total Drymatter production	BD,HC,CP,NCP and TP (90)	0.93 ^{NS}	---	9
3.	Root length	BD,HC,CP,NCP and TP (90)	0.99**	$Y = 401.88 - 162.4BD90^{**} - 1.8HC90^{NS} + 77.4CP90^{NS} + 85.2NCP90^{NS} - 81.7TP90^{NS}$	9
4.	Root volume	BD,HC,CP,NCP and TP (90)	0.98**	$Y = 159.56 - 60.3BD90^{**} + 1.9HC90^{NS} + 31.2CP90^{NS} + 34.6NCP90^{NS} - 33.3TP90^{NS}$	9
5.	Total Nitrogen uptake	BD,HC,CP,NCP and TP (90)	0.98**	$Y = 180.51 + 46.1BD90^{NS} + 10.2HC90^{NS} + 104.7CP90^{NS} + 89.8NCP90^{NS} - 96.1TP90^{NS}$	9
6.	Grain Nitrogen uptake	BD,HC,CP,NCP and TP (90)	0.95*	---	9

Table 106. Multiple regression analysis between various physical properties and pod yield, kernel yield, total drymatter, total N uptake and kernel N uptake (Groundnut crop) (n=9)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Pod yield	BD,HC,CP,NCP and TP (90)	0.78 ^{NS}	---	9
2.	Kernel yield	BD,HC,CP,NCP and TP (90)	0.82 ^{NS}	---	9
3.	Total Drymatter production	BD,HC,CP,NCP and TP (90)	0.89 ^{NS}	---	9
4.	Total Nitrogen uptake	BD,HC,CP,NCP and TP (90)	0.74 ^{NS}	---	9
5.	Kernel Nitrogen uptake	BD,HC,CP,NCP and TP (90)	0.85 ^{NS}	---	9

physical properties at post harvest stage again failed to predict the pod yield, kernel yield, dry matter, total N uptake and grain N uptake significantly (Table 108).

4.4.2. Ammoniacal N and nitrate N on yield, root growth and uptake of nitrogen (Tables 109-111)

The commercial N at various stages of sampling in sorghum crop when regressed with grain yield, dry matter N uptake and root growth characteristics (Table 109) indicated a significant contribution of $\text{NH}_4\text{-N}$ to the tune of 81.2 per cent for grain yield, 92.6 per cent for dry matter, 79.4 per cent for total N uptake, 82.3 per cent for grain N uptake 74.8 per cent for root length and 77.3 per cent for root volume. Though the contribution of an individual stage of sampling for a significant prediction for grain yield, dry matter, total N uptake and grain N uptake, could be found, an overall significant contribution is found. The ammoniacal N on 45 and 90 DAS had significantly contributed to the prediction of root length and volume. However, in groundnut crop, the ammoniacal N at various stages did not help in predicting the yield and uptake significantly.

In sorghum, the grain yield and grain N uptake parameters were successfully predicted to the tune of 93-94 per cent when they regressed with $\text{NO}_3\text{-N}$ at various stages of sampling (Table 110). A significant contribution of $\text{NO}_3\text{-N}$ on 10 and 45 DAS for the prediction of above parameters was clearly found. The $\text{NO}_3\text{-N}$ though successfully predicted the dry matter production, total N uptake, root length and root volume to the tune of 87-93 per cent, the contribution of the individual stages was not significant. In groundnut crop also the contribution of $\text{NO}_3\text{-N}$ for pod yield, kernel yield, dry matter, total N uptake and grain N uptake (Table 111) though was significant to the tune of 63-66 per cent the contribution of the individual stages was not significant. However, the $\text{NO}_3\text{-N}$ at post harvest stage significantly contributed to the total dry matter production and total N uptake characteristics.

Table 107. Multiple regression analysis between various physical properties and grain yield, total drymatter, root length, root volume, total nitrogen uptake and grain nitrogen uptake (Sorghum crop) (n=9)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Grain yield	BD,HC,CP,NCP and TP (PH)	0.96*	$Y = 1887.43 - 612.7BDPH^{NS} + 619.3HCPH^{NS} - 841.1CPPH^{NS} - 973.7NCPH^{NS} + 916.5TPPH^{NS}$	9
2.	Total Drymatter production	BD,HC,CP,NCP and TP (PH)	0.82 ^{NS}	---	9
3.	Root length	BD,HC,CP,NCP and TP (PH)	0.96*	$Y = 251.51 - 191.4BDPH^{NS} - 2.1HCPH^{NS} - 0.4CPPH^{NS} - 17.6NCPH^{NS} + 6.5TPPH^{NS}$	9
4.	Root volume	BD,HC,CP,NCP and TP (PH)	0.96*	$Y = 114.50 - 76.5BDPH^{NS} - 1.7HCPH^{NS} + 0.5CPPH^{NS} - 4.6NCPH^{NS} + 6.5TPPH^{NS}$	9
5.	Total Nitrogen uptake	BD,HC,CP,NCP and TP (PH)	0.93 ^{NS}	---	9
6.	Grain Nitrogen uptake	BD,HC,CP,NCP and TP (PH)	0.98**	$Y = 158.73 + 36.4BDPH^{NS} + 12.7HCPH^{NS} - 10.9CPPH^{NS} - 20.2NCPH^{NS} + 15.3TPPH^{NS}$	9

Table 108. Multiple regression analysis between various physical properties and pod yield, kernel yield, total drymatter, total N uptake and kernel N uptake (Groundnut crop) (n=9)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Pod yield	BD,HC,CP,NCP and TP (PH)	0.72 ^{NS}	---	9
2.	Kernel yield	BD,HC,CP,NCP and TP (PH)	0.68 ^{NS}	---	9
3.	Total Drymatter production	BD,HC,CP,NCP and TP (PH)	0.83 ^{NS}	---	9
4.	Total Nitrogen uptake	BD,HC,CP,NCP and TP (PH)	0.79 ^{NS}	---	9
5.	Kernel Nitrogen uptake	BD,HC,CP,NCP and TP (PH)	0.71 ^{NS}	---	9

Table 109. Multiple regression analysis between ammoniacal nitrogen and grain yield, total drymatter, total N uptake, grain N uptake, root length and root volume (Sorghum crop) (n=27)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Grain yield	AN3,AN5,AN7,AN10,AN15, AN30,AN45,AN60,AN75, AN90,AN105 and ANPH	0.812**	$Y = 2854.44 - 66.15AN3^{NS} - 27.97AN5^{NS} + 76.03AN7^{NS} + 67.49AN10^{NS} + 45.28AN15^{NS} - 135.79AN30^{NS} - 158.71AN45^{NS} + 124.07AN60^{NS} + 96.38AN75^{NS} + 356AN90^{NS} - 137.58AN105^{NS} - 174.07ANPH^{NS}$	27
2	Total Drymatter production	AN3,AN5,AN7,AN10,AN15, AN30,AN45,AN60,AN75, AN90,AN105 and ANPH	0.926**	$Y = 12.66 - 0.03AN3^{NS} - 0.22AN5^{NS} + 0.11AN7^{NS} + 0.34AN10^{NS} - 0.16AN15^{NS} - 0.62AN30^{NS} - 0.32AN45^{NS} + 0.70AN60^{NS} - 0.17AN75^{NS} + 0.59AN90^{NS} + 0.17AN105^{NS} - 0.05ANPH^{NS}$	27
3	Total N uptake	AN3,AN5,AN7,AN10,AN15, AN30,AN45,AN60,AN75, AN90,AN105 and ANPH	0.794**	$Y = 84.75 + 1.72AN3^{NS} - 2.19AN5^{NS} - 1.59AN7^{NS} + 1.32AN10^{NS} + 1.90AN15^{NS} - 6.55AN30^{NS} - 3.71AN45^{NS} + 3.86AN60^{NS} + 0.253AN75^{NS} + 6.86AN90^{NS} - 0.60AN105^{NS} + 0.05ANPH^{NS}$	27
4.	Grain N uptake	AN3,AN5,AN7,AN10,AN15, AN30,AN45,AN60,AN75, AN90,AN105 and ANPH	0.823**	$Y = 35.64 + 0.17AN3^{NS} - 0.89AN5^{NS} + 0.90AN7^{NS} + 1.12AN10^{NS} + 1.42AN15^{NS} - 2.56AN30^{NS} - 2.17AN45^{NS} + 1.85AN60^{NS} + 1.46AN75^{NS} + 6.59AN90^{NS} - 2.87AN105^{NS} - 2.65ANPH^{NS}$	27
5.	Root length	AN3,AN5,AN7,AN10,AN15, AN30,AN45,AN60,AN75, AN90,AN105 and ANPH	0.748*	$Y = 46.75 - 4.42AN3^{NS} - 2.17AN5^{NS} - 5.98AN7^{NS} + 0.54AN10^{NS} + 2.60AN15^{NS} + 5.21AN30^{NS} - 9.61AN45^{NS} + 4.08AN60^{NS} + 10.73AN75^{NS} + 13.11AN90^{NS} - 9.62AN105^{NS} - 5.51ANPH^{NS}$	27
6.	Root volume	AN3,AN5,AN7,AN10,AN15, AN30,AN45,AN60,AN75, AN90,AN105 and ANPH	0.773**	$Y = 10.86 - 1.46AN3^{NS} - 0.29AN5^{NS} - 1.46AN7^{NS} - 0.03AN10^{NS} + 0.70AN15^{NS} + 1.45AN30^{NS} - 2.34AN45^{NS} + 1.32AN60^{NS} + 2.70AN75^{NS} + 2.90AN90^{NS} - 1.78AN105^{NS} - 1.75ANPH^{NS}$	27

Table 110. Multiple regression analysis between nitrate nitrogen and grain yield, total drymatter, total N uptake, grain N uptake, root length and root volume (Sorghum crop) (n=27)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Grain yield	NN3, NN5, NN7, NN10, NN15, NN30, NN45, NN60, NN75, NN90, NN105 and NNPH	0.936**	$Y = -6866.36 - 135.59NN3^{NS} + 151.99NN5^{NS} - 103.85NN7^{NS} + 414.99NN10^{NS} - 99.33NN15^{NS} - 110.85NN30^{NS} + 382.14NN45^{NS} - 89.02NN60^{NS} + 36.57NN75^{NS} - 22.01NN90^{NS} - 217.84NN105^{NS} + 133.49NNPH^{NS}$	27
2.	Total Drymatter production	NN3, NN5, NN7, NN10, NN15, NN30, NN45, NN60, NN75, NN90, NN105 and NNPH	0.927**	$Y = -7.86 - 0.41NN3^{NS} + 0.57NN5^{NS} - 0.13NN7^{NS} + 0.24NN10^{NS} + 0.17NN15^{NS} + 0.49NN30^{NS} - 0.01NN45^{NS} + 0.02NN60^{NS} - 0.08NN75^{NS} + 0.06NN90^{NS} - 0.02NN105^{NS} - 0.21NNPH^{NS}$	27
3.	Total N uptake	NN3, NN5, NN7, NN10, NN15, NN30, NN45, NN60, NN75, NN90, NN105 and NNPH	0.872**	$Y = -104.41 - 3.58NN3^{NS} + 4.14NN5^{NS} - 0.37NN7^{NS} + 5.71NN10^{NS} - 0.14NN15^{NS} + 3.54NN30^{NS} - 1.51NN45^{NS} + 0.89NN60^{NS} + 0.05NN75^{NS} + 0.57NN90^{NS} - 1.77NN105^{NS} - 1.12NNPH^{NS}$	27
4.	Grain N uptake	NN3, NN5, NN7, NN10, NN15, NN30, NN45, NN60, NN75, NN90, NN105 and NNPH	0.935**	$Y = -107.62 - 2.54NN3^{NS} + 2.46NN5^{NS} - 1.37NN7^{NS} + 6.60NN10^{NS} - 1.43NN15^{NS} - 2.09NN30^{NS} + 5.38NN45^{NS} - 0.78NN60^{NS} + 0.81NN75^{NS} - 0.76NN90^{NS} - 4.01NN105^{NS} + 2.36NNPH^{NS}$	27
5.	Root length	NN3, NN5, NN7, NN10, NN15, NN30, NN45, NN60, NN75, NN90, NN105 and NNPH	0.931**	$Y = 58.23 - 1.90NN3^{NS} + 1.97NN5^{NS} - 2.07NN7^{NS} - 3.34NN10^{NS} - 2.44NN15^{NS} - 3.66NN30^{NS} + 0.27NN45^{NS} - 2.77NN60^{NS} + 4.84NN75^{NS} - 1.15NN90^{NS} - 4.97NN105^{NS} + 0.20NNPH^{NS}$	27
6.	Root volume	NN3, NN5, NN7, NN10, NN15, NN30, NN45, NN60, NN75, NN90, NN105 and NNPH	0.908**	$Y = 25.25 - 0.36NN3^{NS} + 0.59NN5^{NS} - 0.73NN7^{NS} + 0.31NN10^{NS} - 0.44NN15^{NS} + 0.64NN30^{NS} + 0.24NN45^{NS} - 0.68NN60^{NS} + 1.55NN75^{NS} - 0.41NN90^{NS} - 1.13NN105^{NS} - 0.11NNPH^{NS}$	27

4.4.3. Available Nitrogen on yield, root growth and uptake of nitrogen

(Table 112 and 113)

The regression analysis carried out between available N at different stages and yield, root growth and N uptake characteristics (Table 112) had clearly shown that, except root length, all the other parameters were successfully and significantly predicted (grain yield), 85 per cent (dry matter), 72 per cent (Total N uptake), 70 per cent (train N uptake) and 53 per cent (root volume). Among the stages, 45 DAS sampling significantly contributed to the prediction of above parameters. In groundnut crop, the available N at different stages when regressed with pod yield, kernel yield dry matter, total N uptake and kernel N uptake (Table 113) significantly predicted at 5 per cent level to the tune for 63-68 per cent for the different parameters. Again, the available N on 30 DAS significantly contributed to the prediction of above mentioned parameters.

Table 111. Multiple regression analysis between nitrate nitrogen and pod yield, kernel yield, total drymatter, total N uptake and kernel N uptake (Groundnut crop) (n=27)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Pod yield	NN15,30,45,60 and PH	0.64**	$Y = 615.27 + 46.7 \text{ NN15}^{NS} + 104.3 \text{ NN30}^{NS} - 85.6 \text{ NN45}^{NS} + 3.1 \text{ NN60}^{NS} - 57.5 \text{ NNPH}^{NS}$	27
2.	Kernel yield	NN15,30,45,60 and PH	0.65**	$Y = 366.01 + 28.9 \text{ NN15}^{NS} + 61.2 \text{ NN30}^{NS} - 50.4 \text{ NN45}^{NS} + 3.7 \text{ NN60}^{NS} - 35.8 \text{ NNPH}^{NS}$	27
3.	Total Drymatter production	NN15,30,45,60 and PH	0.63**	$Y = 2992.75 + 76.1 \text{ NN15}^{NS} + 348.4 \text{ NN30}^{NS} - 171.9 \text{ NN45}^{NS} + 57.7 \text{ NN60}^{NS} - 259.8 \text{ NNPH}^{NS}$	27
4.	Total Nitrogen uptake	NN15,30,45,60 and PH	0.64**	$Y = 61.76 + 2.1 \text{ NN15}^{NS} + 7.7 \text{ NN30}^{NS} - 4.8 \text{ NN45}^{NS} + 0.2 \text{ NN60}^{NS} - 5.8 \text{ NNPH}^{NS}$	27
5.	Kernel Nitrogen uptake	NN15,30,45,60 and PH	0.66**	$Y = 15.43 + 1.2 \text{ NN15}^{NS} + 3.9 \text{ NN30}^{NS} - 3.1 \text{ NN45}^{NS} + 0.2 \text{ NN60}^{NS} - 1.4 \text{ NNPH}^{NS}$	27

Table 112. Multiple regression analysis between available nitrogen at different stages and grain yield, total drymatter, total N uptake, grain N uptake, root length and root volume (Sorghum crop) (n=27)

Sl.No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Grain yield	AVN45, 90 and PH	0.68**	$Y = -6455.50 + 62.2 \text{ AVN45}^{**} + 13.24 \text{ AVN90}^{NS} - 0.915 \text{ AVNPH}^{NS}$	27
2.	Total Drymatter production	AVN45, 90 and PH	0.85**	$Y = -15.90 + 0.2 \text{ AVN45}^{**} + 0.03 \text{ AVN90}^{NS} - 0.01 \text{ AVNPH}^{NS}$	27
3.	Total N uptake	AVN45, 90 and PH	0.72**	$Y = -145.73 + 1.46 \text{ AVN45}^{**} + 0.072 \text{ AVN90}^{NS} - 0.37 \text{ AVNPH}^{NS}$	27
4.	Grain N uptake	AVN45, 90 and PH	0.70**	$Y = -118.83 + 1.11 \text{ AVN45}^{**} + 0.26 \text{ AVN90}^{NS} - 0.19 \text{ AVNPH}^{NS}$	27
5.	Root length	AVN45, 90 and PH	0.27 ^{NS}	—	27
6.	Root volume	AVN45, 90 and PH	0.53**	$Y = 32.58 + 0.17 \text{ AVN45}^{**} - 0.27 \text{ AVN90}^{NS} - 0.06 \text{ AVNPH}^{NS}$	27

Table 113. Multiple regression analysis between available nitrogen and pod yield, kernel yield, total dry matter, total N uptake and kernel N uptake (Groundnut crop) (n=27)

Sl No.	Dependent variable	Independent variable	R ²	Equation	n
1.	Pod yield	AVN30, 60 and PH	0.36*	$Y = 2331.90 + 20.9 \text{ AVN30}^* + 6.4 \text{ AVN60}^{\text{NS}} - 37.8 \text{ AVNPH}^*$	27
2.	Kernel yield	AVN30, 60 and PH	0.36*	$Y = 1396.94 + 12.7 \text{ AVN30}^* + 4.6 \text{ AVN60}^{\text{NS}} - 22.1 \text{ AVNPH}^*$	27
3.	Total Drymatter production	AVN30, 60 and PH	0.40*	$Y = 10490.01 + 72.8 \text{ AVN30}^{**} + 25.7 \text{ AVN60}^{\text{NS}} - 151.4 \text{ AVNPH}^{**}$	27
4.	Total Nitrogen uptake	AVN30, 60 and PH	0.38*	$Y = 190.01 + 1.9 \text{ AVN30}^* + 0.5 \text{ AVN60}^{\text{NS}} - 3.3 \text{ AVNPH}^*$	27
5.	Kernel Nitrogen uptake	AVN30, 60 and PH	0.36*	$Y = 61.58 + 1.9 \text{ AVN30}^* + 0.2 \text{ AVN60}^{\text{NS}} - 1.7 \text{ AVNPH}^*$	27

DISCUSSION

CHAPTER V

DISCUSSION

Due to the ever increasing demand for food grains to feed the unabated population growth there is a dire need for intensive agriculture which necessitates higher production from unit area, besides maintaining the productivity level of soils for sustainability of agriculture. In this process, the constraints for crop production either of physical, chemical or biological nature have to be tackled to meet the above objective. Literature is replete with references on soils having chemical constraints viz., soil salinity, sodicity, acidity and deficiency and toxicity of nutrient elements, while it is scanty on the constraints related to the soil physical conditions.

Soil texture and structure influence most of the soil physical properties like bulk density, hydraulic conductivity, poresize distribution, water retention characteristics and availability, gaseous exchange between soil and atmosphere, solute movement etc. Thus, the crop growth is a function of not only soil fertility, but also the above characteristics which affects the water and nutrient mobility within the soil, from soil to root system and ultimately the transmission of the solute within the plant system. Hence, higher production could be achieved only if favourable physical environment is prevalent in the soil from the germination of seed till harvest.

Among the soil physical constraints related to soil texture, soil with high or low permeability is very important since, it regulates the water and nutrient movement to the root zones which ultimately influences the root and shoot growth. Suitable technologies are available to manage such soils. The constraints related to soil structure are surface crusting, fluffiness and subsoil hardpan at shallow depth.

In Tamil Nadu, red soil occupies about 62 per cent of the total geographical area. Subsoil hardpan is the widely prevalent soil physical constraint in these soils leading to lower productivity. The causes of hardpan at shallow depth in red soils have been discussed elaborately in Chapter II. Only limited works were carried out to manage and reclaim such soils. Scanning of the earlier reports indicated the favourable effect of chiseling the hardpan soil for improving the productivity (Ramanathan *et al.*, 1983; Gopalasamy, 1984). The depth and distance between which the chiseling has to be done were optimised by the ICAR scheme on Improvement of Soil Physical Conditions in *Problematic Areas to Increase Agricultural Production, which is in operation in Tamil Nadu Agricultural University since 1967* (Anonymous, 1986).

The present investigation is aimed at studying the interaction effect of tillage, organics and nitrogen application in improving the soil physical properties and yield of crops. The N transformation and mobility as influenced by these interactions were also studied. The residual effect of tillage and organics on the subsequent crop was also investigated. The study was carried out in an Alfisol (Typic Haplustalf - Pichanur series) at Nachipalayam of Coimbatore district, Tamil Nadu where the actual problem of subsoil hardpan is existing.

Two field experiments were conducted to meet the objectives set forth in chapter with sorghum Co 26 as the main crop and the groundnut Co 2 as the residual crop. The results thus obtained are discussed hereunder.

5.1. Characterisation of soils having subsoil hardpan

The major physical constraints of the soils having subsoil hardpan is the high bulk density layer at shallow depth restricting the root growth, its proliferation and thereby affecting the water and nutrient uptake. The formation of hardpan at shallow depth is due to the mobilisation of the clay and sesquioxides to lower layers along with the irrigation

rain water. When the water is not sufficient enough to leach them to deeper layers, they settle at shallow depth leading to the formation of hardpan. Ramanathan *et al.* (1983) opined that hardpan in arid climates is due to long periods of weathering coupled with the cementing action in the sub surface layer favoured by the age, proportion of mobile silica in the solution. Hardpans are also developed due to the formation of plough sole on medium textured soils, wherein clay accumulates in B horizon under humid climates (Ghildyal and Gupta, 1991). These soils become less fertile within a short spell, since limited volume of soil is available for root exhaustion.

The profile characteristics of the soil chosen for the present investigation revealed the presence of subsoil hardpan even at a depth of 15 cm below the soil surface (bulk density 1.82 Mg m^{-3}). This has resulted in poor hydraulic conductivity, reduced non capillary porosity and very low infiltration rate of the soil. Such a relationship between the bulk density and other physical properties have been well documented (Gopalasamy, 1984; Basker *et al.*, 1995) significant negative relationship established by the correlation between the bulk density and other soil physical properties at various stages of sampling recorded in the present study lend support to above results (Appendix I and II).

The high available nutrient status of the subsurface soil as compared to the surface layer (Table 3) might be due to the non-utilisation of nutrients by the crops from these layers due to the restricted foraging ability of the roots. The findings of Stypa *et al.* (1987) also confirms the poor root growth in subsoil hardpan soils. Presence of very few to none number of roots in the layer during the systematic profile description further vouched the fact. The marked negative relationship established by correlation between the bulk density and root length and volume at all stages of sampling (Appendix-I) further confirmed the above findings. The higher content of clay and sesquioxides present in the subsoil as a contributing cause for the development of hardpan has been reported by

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Basker *et al.* (1995). The higher amount of clay in the subsurface soil than the surface as could be seen from the particle size distribution analysis lends support for further confirmation (Table. 3)

5.2. Changes in physical properties immediately after imposing tillage treatments

Chiseling was found to be beneficial in improving the physical properties of the soil having hardpan at shallow depth (Gupta and Abrol, 1993). In the present investigation, the changes in physical properties were monitored after imposing the tillage treatments *viz.*, country ploughing twice (T1), mouldboard ploughing twice (T2) and chiseling once followed by country ploughing twice (T3).

The reduction in the bulk density from 1.81 to 1.58 Mg m⁻³ revealed the positive influence of chiseling in reducing the bulk density in the second depth (15-30 cm). The other two tillage treatments did not alter the bulk density of the subsoil which might be due to the shallow depth of ploughing. The positive effect of chiseling was also observed in hydraulic conductivity, pore size distribution and infiltration rate. With respect to surface soil, obviously no spectacular change was noticed among the different tillage treatments. The reduction in the bulk density and the increase in hydraulic conductivity and poresize distribution might be due to the chisel plough shattering the hardpan upto a depth of 35-40 cm. This was evidenced by a slight decrease in bulk density and almost the same hydraulic conductivity of the third layer (Fig 3). This corroborates with the findings of Ramanathan *et al.* (1983) and Gupta and Abrol (1993).

5.3. Effect of tillage and organics on the physical properties of the soil and plant growth

As seen in the earlier section (5.2), the physical properties of soils having hardpan at shallow depth were positively influenced by chiseling. The studies carried out by ICAR scheme on Improvement of Soil Physical Conditions in Problematic Areas to Increase

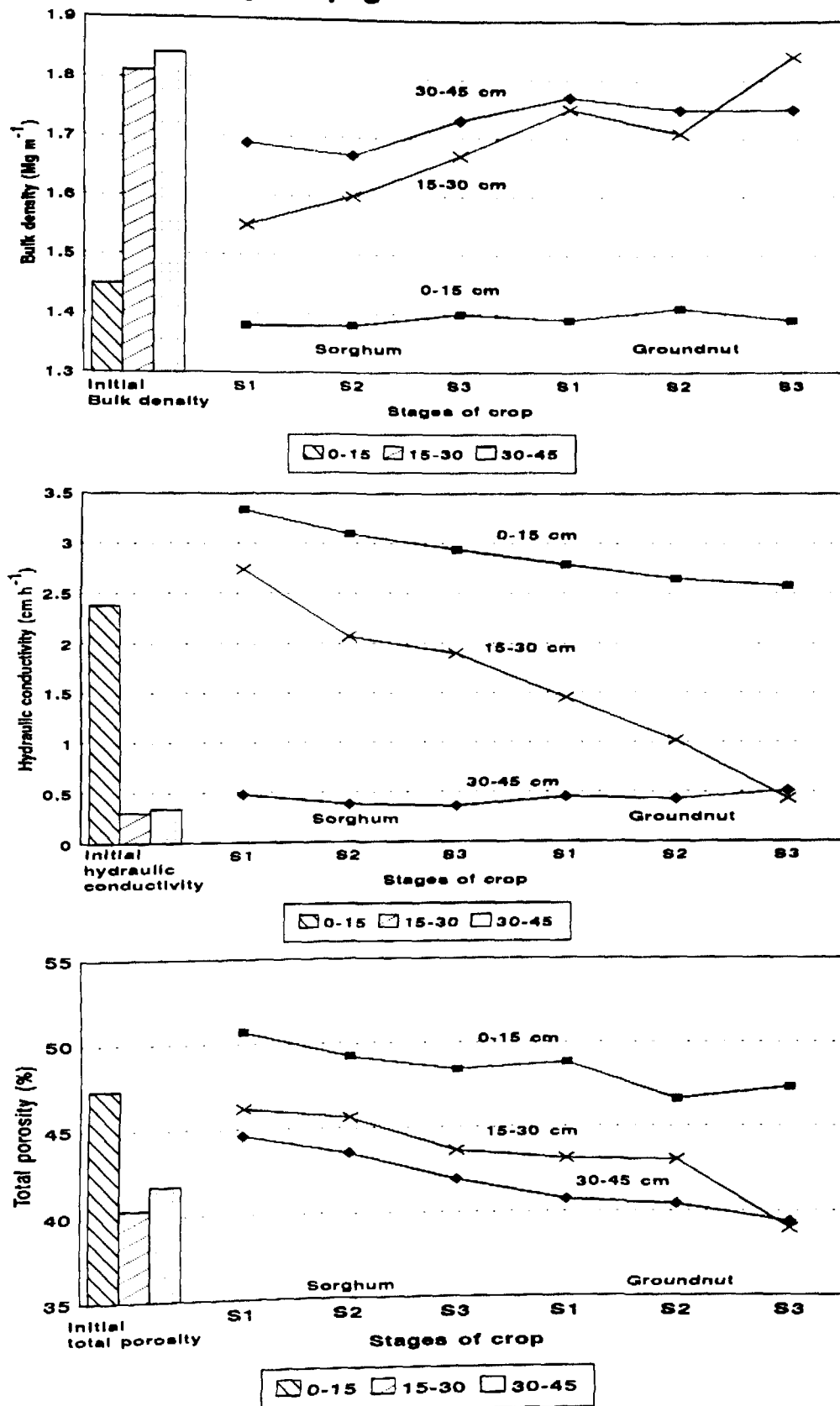
Agricultural Production also revealed the beneficial effect of chiseling. In the present study, efforts were made to monitor the physical properties over the entire cropping period of sorghum as well as the residual crop of groundnut.

Immediately after chiseling the bulk density of the subsoil (15-30 cm) decreased from 1.82 to 1.58 Mg m⁻³ and then found to vary as 1.55 Mg m⁻³ on 45 DAS, 1.60 Mg m⁻³ on 90 DAS and 1.67 Mg m⁻³ after the harvest of sorghum crop. In the residual crop of groundnut, it was observed to be 1.75 Mg m⁻³ on 45 DAS, 1.71 Mg m⁻³ on 90 DAS and 1.84 Mg m⁻³ at harvest (Fig 12). This gradual increasing trend gives testimony to the earlier conclusions indicating the resettling of clay and sesquioxides for the above phenomena and again in accordance with the findings of Gupta and Abrol (1993).

Among the organics tried, composted coir pith and farm yard manure decreased the bulk density of the surface soil. This finding is in line with the findings of Havangai and Mann (1970). Suresh Lal and Mathur (1989), Anderson *et al.* (1990) who have reported on the reduction of bulk density due to continuous application of farm yard manure. Mahimairaja *et al.* (1986) reported that combined application of organic manures with inorganic fertilisers reduced the bulk density in the surface soil. Similar results were also reported by Parameswar *et al.* (1989), Bharadwaj and Omanvar (1992), and Gupta and Abrol (1993). In the present study, however the bulk density in the subsurface layers were not influenced due to application of organic manures *viz.*, farm yard manure and composted coir pith. This might probably be due to the incorporation of organic manure only in the top layer prior to sowing. Irrespective of the stage of crop, the interaction effect of manures with tillage was not significant indicating that the effect of organic manures on the sustenance of soil physical properties are possible only, if the organic manures incorporated to the depth of chiseling (35-40 cm).

Fig 12 Physical properties as influenced by chiseeling during crop growth

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The hydraulic conductivity of the surface layer did not alter much due to tillage treatments. However, significant increase in hydraulic conductivity was observed in subsoil due to chiseling. This is in line with the findings of Ramanathan *et al.* (1983) and Basker *et al.* (1995). The initial hydraulic conductivity of 0.3 cm h^{-1} in the second layer (15-30 cm) drastically increased to 2.78 cm h^{-1} immediately after chiseling. It got slightly reduced to 2.74 cm h^{-1} on 45 DAS, 2.07 cm h^{-1} on 90 DAS and 1.90 cm h^{-1} at post harvest stage of sorghum crop. During the residual crop of groundnut, it steeply reduced to 1.45 cm h^{-1} on 45 DAS, 1.02 cm h^{-1} on 90 DAS and 0.43 cm h^{-1} at harvest (Fig 12). This trend again confirmed the earlier conclusions on the effect of irrigation or rainfall on the resettling of clay and sesquioxides. As was true in bulk density, the effect of organic manures was seen only in the surface layer. The results of Becher and Kainz (1983), Nagarajan *et al.* (1985) and Anderson *et al.* (1990) lend support for the above finding. They have also reported the positive influence of various organics on hydraulic conductivity. However, in the present study, the organic manures did not affect the hydraulic conductivity of soil over the entire cropping sequence.

The poresize distribution of the soil at different depths indicated that there was a positive influence due to chiseling at all the depths, whereas the effect was observed only in the surface layer due to other tillage treatments. This finding is in agreement with the findings of the ICAR scheme on Improvement of Soil Physical Conditions in Problematic Areas to Increase Agricultural Production (Anonymous, 1986). As in the case of bulk density and hydraulic conductivity, the poresize distribution also attained its original value at the end of the residual crop (fig 12) due to the reasons attributed earlier. This result is in accordance with the report of Gupta and Abrol (1993). Application of organics favourably influenced the poresize distribution of the surface soil. The findings of Anderson *et al.* (1990), Kahle *et al.* (1992) and Bharadwaj and Omanwar (1992) also

confirmed the above finding. However, the effect was not observed in subsurface layers possibly due to the incorporation of organic manures only in the top layer prior to sowing.

It is worthwhile to mention here that the effect of organic manures sustained only for one season in favourably influencing the soil physical properties. This result adds evidence to the already existing recommendation of application of organics to individual crops. This practice gradually vanished due to non-availability of organics, but in the recent times, an awakening on the addition of organics and recycling of available wastes either from agriculture or from industry for a sustainable agriculture and to protect the environment as well is emphasised.

The correlation and regression analysis carried out to study the inter relationship between the physical properties and also the yield parameters revealed that there was a strong negative relationship between bulk density and other physical properties at all stages of sampling (Appendix I and II). This might probably be due to the higher bulk density contributing to the compaction and thus reducing hydraulic conductivity and porosity. Similar findings were also reported by Gopalasamy (1984) and Gupta and Abrol (1993). The simple correlation studies revealed the negative relationship of bulk density and the positive relationship of hydraulic conductivity and poresize distribution with the grain yield, root length, root volume, total nitrogen uptake and grain N uptake of sorghum crop. (Appendix-I). However, this trend was not observed in the residual crop of groundnut (Appendix-II). To quantify the individual contribution by the physical properties towards to grain yield, dry matter production, root length, root volume, total N uptake and grain N uptake, a multiple regression analysis was carried out which indicated that the bulk density of the soil on 45 DAS of sorghum crop was crucial in determining the grain yield. This result clearly brought out the profound influence of the lower bulk density levels at early stage of crop growth. The lower bulk density was conducive for

better root growth and proliferation into the subsoil having higher nutrient status thus leading to a better growth and higher productivity. As the crop advanced, the resettling of clay and sesquioxides did not affect the grain yield of the sorghum crop as it had affected the residual crop of groundnut. The same was true with respect to other physical properties. Regarding root length and volume, obviously the bulk density of the soil is very crucial than other physical properties.

5.4 Rooting pattern in subsoil hardpan soils

The rooting pattern *viz.*, length, volume and distribution is a function of resistance offered by the soil to the growing roots. The resistance of the soil is governed by texture and structure which influences the various physical parameters of the soil. A compacted layer not only results in the decrease of pore space, but also reduces the size of pores and thus offers increased resistance to the penetration of roots (Bodman and Constantin, 1965). The rooting pattern was also influenced by soil strength which was found to increase with increase in bulk density and soil moisture tension (Taylor *et al.*, 1966).

In general, roots grow in macropores (Hatano *et al.*, 1988). The soils having hardpan did not have optimum ratio of macro and micro pores as explained in the results. This might be due to the higher bulk density resulting in reduced non capillary porosity which hampered the root proliferation culminating in lower grain yield. In the present experiment, the root length and root volume of sorghum crop was monitored at 15 days interval to substantiate the above conclusions. The results clearly indicated the positive influence of chiseling as compared to other tillage practices in increasing the root length and root volume (Fig 5) irrespective of stages. This is in line with the findings of Sundara Sarma *et al.* (1978). This conclusion is well supported by the simple correlation studies, which reveals a very high level of relationship between root length and root volume and the physical properties. The root length increased with increasing level of nitrogen

application. The root volume increased linearly with increasing levels of N possibly due to higher N availability. Further, this effect to nitrogen application was perceptible only in chiseled plots, which might be due to the favourable environment created for the efficient utilisation of applied N in comparison with other tillage treatments. The results of Rice *et al.* (1987) and Sarkar *et al.* (1989) corroborate with the present findings.

5.5 Yield of crops

Providing favourable condition for the better growth of crops by way of deep tillage practices, addition of organics and adequate nutrient supply improves the yield levels of crops. In the present study, chiseling the soil resulted in spectacular increase in grain yield of sorghum (3948 kg ha^{-1}) which might be due to the favourable physical environment provided for the crop growth. The works of Mallick and Nagarajarao (1972), Gopalasamy (1984), Gupta *et al.* (1984), Campbell and Akhtar (1989), Erbach *et al.* (1992), Skrebelis and Aleksynas (1993), Gupta and Abrol (1993) and Gupta and Satyendra Kumar (1994) also confirmed the above finding. Besides, chiseling also improved the nutrient and water movement thereby increasing the nutrient uptake by the crop. The increased grain yield (3830 kg ha^{-1}) registered in the plots that received composted coir pith might be due to its manurial value under the physical favourable environment. As could be expected, increased N availability with increased levels of N influenced the grain yield significantly. The simple correlation studies revealed the positive and significant relationship of $\text{NH}_4\text{-N}$ at all stages of sampling and $\text{NO}_3\text{-N}$ after 7 DAS upto harvest stage again confirmed the above findings. It is known that under normal favourable soil conditions, it takes about 7-10 days for the applied urea to get hydrolysed and mineralised as $\text{NO}_3\text{-N}$. Similar results were reported by Bhuiya *et al.* (1974) and Maclean and McRae (1987). It is interesting to note that chiseling along with 75 per cent of recommended N registered the yield on par with the treatment receiving 100 per cent recommended N along with mouldboard or country ploughing, and adoption

of this technology can help in the saving of 25 per cent of fertiliser N. This might be due to the chiseling, that would have created a favourable physical environment for the increased mineralisation and mobility of fertiliser N resulting in higher nutrient uptake and enhanced grain yield. This finding is in line with the findings of Carefoot (1990).

The organic manures applied at the rate of 12.5 t ha^{-1} also increased the grain yield, which might be due to the favourable physical environment created due to its application. The yield increase in different crops due to the application of various organic manures have been well documented (Mallick and Nagarajao (1972), Gupta *et al.* (1984), Gupta and Satyendra Kumar (1994).

The favourable effect of chiseling and organic were observed in the residual crop, even though the physical properties tended to reach their original values during the crop growth period. Groundnut being a shallow rooted crop, the settling of clay in the subsurface layers did not affect the growth of the crop even though the spectacular effect of chiseling was not that much pronounced as in the case of first crop. The poor relationship established between the pod yield of groundnut and soil physical properties through correlation and multiple regression analysis lend support to this finding (Appendix-II).

The multiple regression analysis to predict the critical stages of N requirement for crop growth revealed that ammoniacal N content of the soil at all stages of sampling (3, 5, 7, 10, 15, 30, 45, 60, 75, 90 and 105 DAS and at post harvest) contributed successfully and significantly to predict the grain yield of sorghum ($R^2 = 0.81^{**}$). The $\text{NH}_4\text{-N}$ content at a given stage did not significantly contribute to the grain yield. This showed that the contribution of $\text{NH}_4\text{-N}$ was not direct but it indirectly affected the $\text{NO}_3\text{-N}$ status of the soil, the form of N, the most garden land crops prefer. The multiple regression analysis carried out between $\text{NO}_3\text{-N}$ content at different stages of crop growth

and grain yield revealed that the $\text{NO}_3\text{-N}$ content of the soil at 10 and 45 DAS was found to contribute significantly to the grain yield. The prediction level is significant at 1 per cent level ($R^2 = 0.94^{**}$), indicating that these two stages are critical for obtaining higher grain yields.

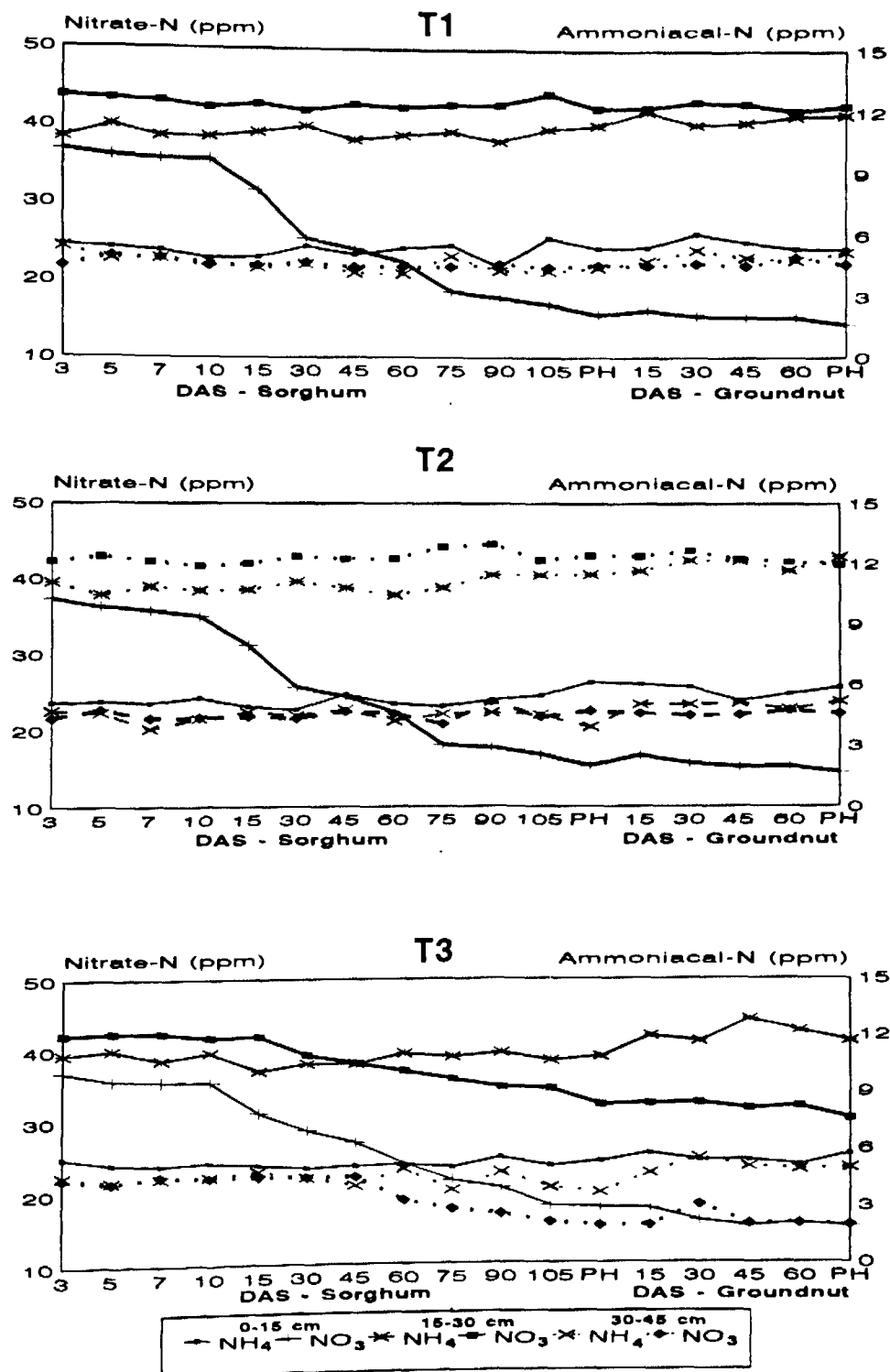
The ammoniacal N content of the soil did not influence the pod yield of groundnut crop. However, the $\text{NO}_3\text{-N}$ content of the soil at 15 and 30 DAS was found to be significantly related to the pod yield (Appendix-VI). The results of multiple regression analysis indicated the highest level of prediction by the $\text{NO}_3\text{-N}$ content and an insignificant level by $\text{NH}_4\text{-N}$ content of the soil at all stages of sampling (15, 30, 45 and 60 DAS and at harvest) towards the pod yield. However, the $\text{NO}_3\text{-N}$ content at any single stage of sampling failed to predict the pod yield. This result is not in agreement with the results of the main crop of sorghum.

5.6 Transformation and mobility of nitrogen (Fig 13,14 and 15)

Out of the total N content of the soil, only about 2 per cent is of inorganic nature (Black, 1968) and the rest is in organic form. In general, N is taken as NO_3^- form by the plants for which the organic nitrogen need to be mineralised and released into the soil system at a steady rate. In soil, N exists in different forms viz., ammonium, nitrate, nitrite, nitrous oxide, nitric oxide and elemental inert N. Most part of the inorganic N is either in the form of $\text{NH}_4\text{-N}$ or $\text{NO}_3\text{-N}$. There exist a dynamic equilibrium between these two forms of N which is highly influenced by the physical and chemical processes in the soil system (Savant and De Datta, 1982).

Under the present soil conditions, the transformation and mobility of N plays a vital role in regulating the yield level of crops. The soils with hardpan at shallow depth mostly possess a moderately textured surface soil which facilitate easy leaching of $\text{NO}_3\text{-N}$, while in heavy textured subsoil layer, the potential of fixing the $\text{NH}_4\text{-N}$ is more. Further, the

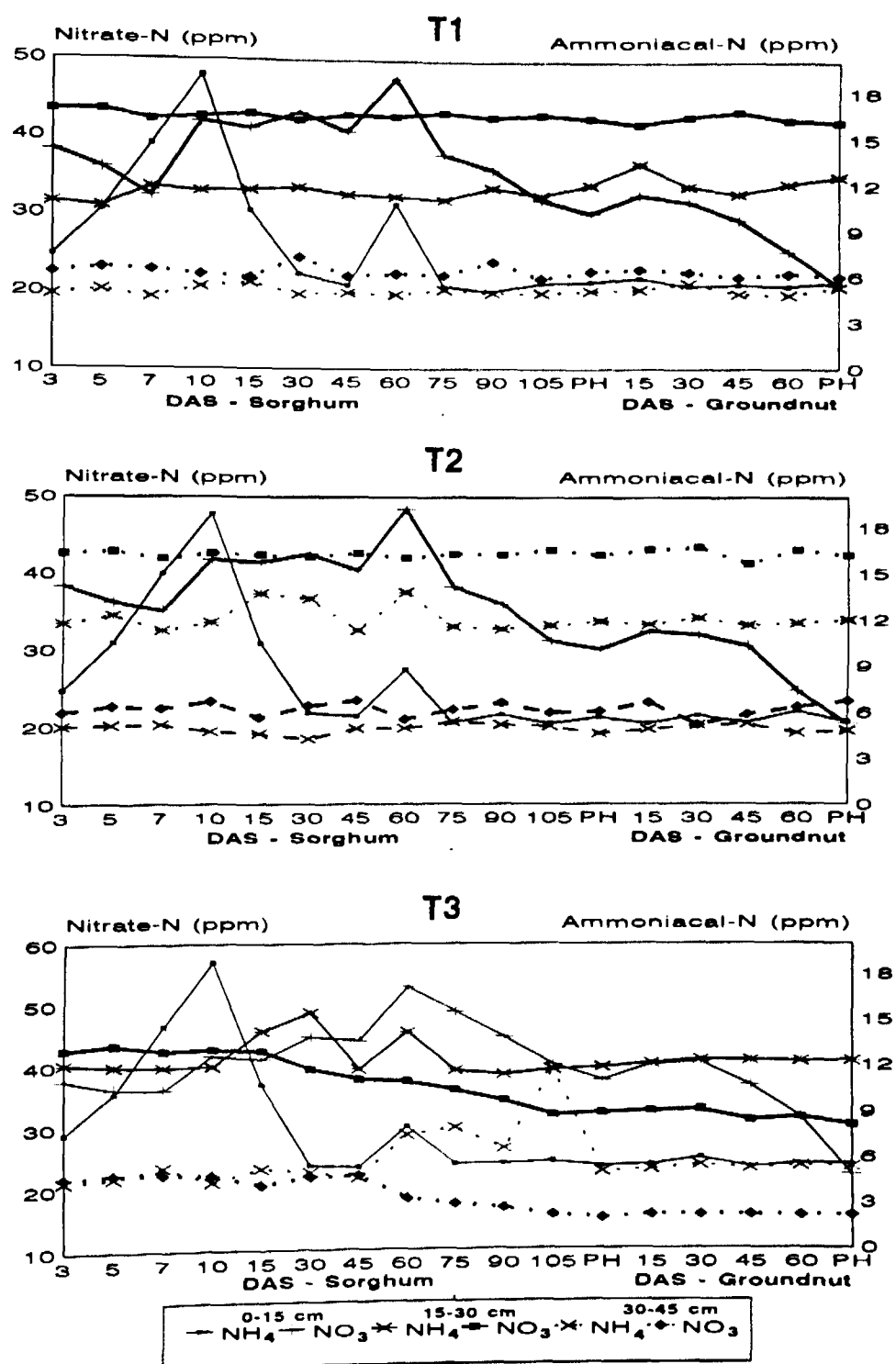
Fig 13 Effect of tillage on the transformation and mobility of N in the cropping sequence (N1 level) ¹⁸⁰



subsoil being a dense layer having a high bulk density prevents the gaseous exchange and thus affects the nutrient transformations. Hence, a study to investigate the N transformation in a special situation like the present study was envisaged to derive more information.

The $\text{NH}_4\text{-N}$ content was not much influenced by the tillage and organics treatments. As could be expected, increased level of N increased the $\text{NH}_4\text{-N}$ at all stages of sampling. The results are in agreement with Fischer and Parks (1958) and Bhuiya *et al.* (1974). The interaction effect of N with depth revealed some interesting findings. It was observed that irrespective of N levels, the second depth registered higher $\text{NH}_4\text{-N}$ content in most of the sampling stages. This might be due to the higher clay content of the second layer facilitating fixation of $\text{NH}_4\text{-N}$. Further, it was observed that upto 15 DAS, the surface layer registered an increase in $\text{NH}_4\text{-N}$ content corresponding to the increased level of N application. In second and third layers, there was not much variation. This trend could possibly be due to the applied N in the form of urea being in the early stages of transformation. As the stages advanced, application of N recorded higher $\text{NH}_4\text{-N}$ content in the first two layers, showing the mobility of NH_4^+ to the deeper layers. However, this trend changed on 75 DAS wherein, the N levels did not have any influence on the surface layer but significantly influenced the subsurface layers revealing a clear trend of N mobility and transformation. From 90 DAS, the $\text{NH}_4\text{-N}$ content did not vary within the layers probably due to the higher N accumulation rates from flowering to harvest stage. The interaction of T and D clearly brought out the higher content of $\text{NH}_4\text{-N}$ in the second layer of sampling which might probably be due to the higher clay content (42.3 per cent). Significant differences were observed among the tillage treatments at different depths which showed that, in the earlier stages of crop growth, higher $\text{NH}_4\text{-N}$ contents were recorded in chiseling and mouldboard ploughing treatments, might be due to the deep ploughing by the implements facilitating better mobility. As the

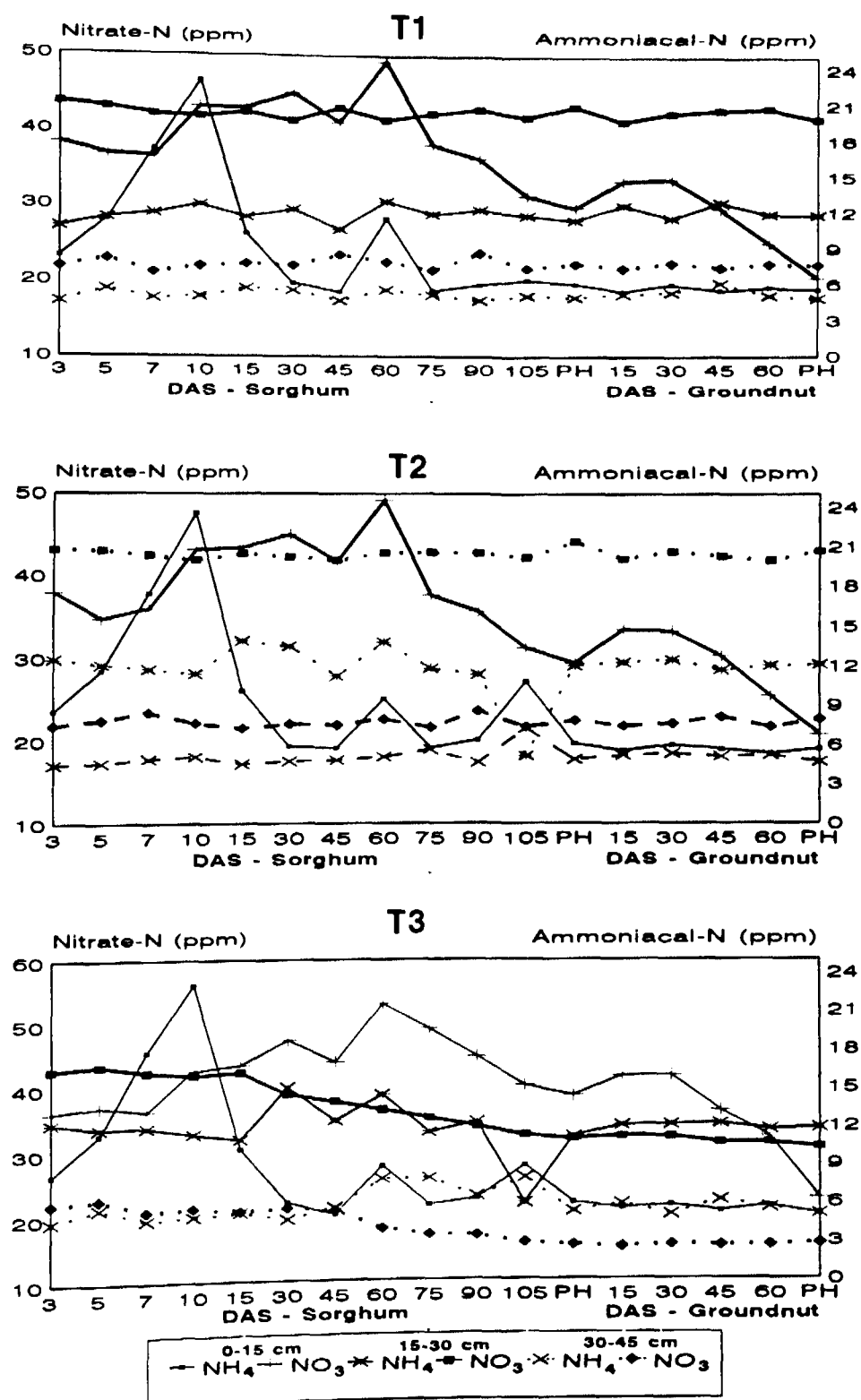
Fig 14 Effect of tillage on the transformation and mobility of N in the cropping sequence (N2 level)



stage of the crop advanced, the $\text{NH}_4\text{-N}$ content of the chiseled plots were significantly higher in the second and third layers which clearly showed the superiority of chisel plough over other implements in breaking open the hardpan effectively (Anonymous, 1986). In other words, it could also be stated that chiseling increased the leaching of nutrients. This is in line with the findings of Shipitalo and Edwards (1987) and Basker (1995). The possibility of nutrients moving down to the lower layers and the subsoil nutrient contribution to the crop growth is there. In the present study, chiseling improved the rooting depth and proliferation, thus favouring a better foraging environment for effective utilisation of nutrients that are available even in the subsurface layers. Same is not true in case of other tillage treatments due to root restriction caused by the hardpan. Reports on the hampering of root growth due to the presence of compacted subsurface layer at shallow depth and the roots unable to utilise the nutrients available in deeper layers have been well documented. (Baligar *et al.*, 1975; Jordon and Miller, 1980; Atwell, 1990; Henderson, 1991 and Martino, 1991).

The $\text{NO}_3\text{-N}$ content of the soil was found to be unaffected by the tillage treatments upto 45 DAS. The lowest $\text{NO}_3\text{-N}$ content in soil was recorded in the chiseled plots at 45 DAS might be due to higher depletion of $\text{NO}_3\text{-N}$ favoured by the better root proliferation (Section 5.4). The higher N uptake values registered in chiseled plots (Section 5.8) gives evidence to the findings. Application of nitrogen significantly increased the $\text{NO}_3\text{-N}$ levels of soil starting from 15 DAS till harvest stage. Though the 75 and 100 per cent of N application were comparable but superior over control. Among the organic manures applied, composted coir pith registered significantly higher $\text{NO}_3\text{-N}$ upto 10 DAS which might be due to the addition of urea to the coir pith for composting purpose. Higher $\text{NO}_3\text{-N}$ contents were observed in second depth as compared to first and third depths. It might be due to the downward movement of $\text{NO}_3\text{-N}$ along with clay and sesquioxides along with water.

Fig 15 Effect of tillage on the transformation and mobility of N in the cropping sequence (N3 level)



It is also interesting to observe that N application markedly increased the $\text{NO}_3\text{-N}$ content in the surface soil irrespective of stages of sampling has been well reflected in the higher uptake values recorded during the crop growth. The tillage and depth interaction revealed that in the surface layer, chiseling resulted in higher $\text{NO}_3\text{-N}$ content and in the sub surface it registered comparatively lower values. The concordant higher uptake values suggest the beneficial effect of chiseling in not only utilising the higher $\text{NO}_3\text{-N}$ present in the surface soil but also from the subsurface soil by providing better proliferation and foraging action of roots. The higher $\text{NO}_3\text{-N}$ per cent in second depth in plots which received country ploughing and mouldboard ploughing give evidence for the above statement. This effect has been reflected even in the residual crop of groundnut. Thus, the superiority of chiseling for better nutrient availability from the second and third layers to the crop growth has been well exemplified.

5.7 Available N and organic carbon status of the soil

The availability of particular nutrient depends on many factors including the original status of the given nutrient in the soil. The release of the nutrient is regulated by the physical and chemical properties of the soil. The available N status is governed by the rate at which it is being mineralised from the organic sources (Mandal *et al.*, 1991). Though the mineral N content of the soil *viz.*, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ forms a part of the available N status determined, the rate of release is also important. Hence, in the present study, which involved the application of inorganic fertiliser and organic manures, the availability has been monitored for the entire cropping sequence.

The results indicated the depletion of available N status, wherever chiseling was done, which corroborates with high N uptake values. The works of Carefoot (1990) is in line with the above finding. Increased available soil N status with increasing levels of N application was found. The works of Mandal *et al.* (1991) and Bhardwaj and Omanwar

(1992) are in accordance with the above finding. At harvest of main crop of sorghum and residual crop of groundnut, there was not much variation in the available N status due to N application which could be attributed to the higher N uptake. This is clearly evidenced from higher levels of N application giving higher yields consequently resulting in greater depletion of the given nutrient by uptake/removal. Increasing levels of available N observed in the residual crop of groundnut in organic manures, applied plots might be due to the slow and steady release of nutrients from organic sources, besides the test crop itself being a leguminous crop (Rabindra and Gowda, 1986). The interaction effect of tillage, manure, nitrogen and depth clearly indicated the following conclusions. Irrespective of the stage of sampling, higher available N status of the surface soil in chiseled plots revealed the subsoil contribution to crop growth and lower values in the deeper layers indicated better utilisation of N by foraging roots under the favourable physical environment created. A just opposite trend of higher levels of available N in deeper layers with other two tillage treatments clearly brought out the poor utilisation from lower layers which might be due to the ineffective tillage treatments on the hardpan.

The correlation and multiple regression analysis revealed the positive and significant relationship of the available N status at 45 and 90 DAS to the grain yield, dry matter production, total N uptake and grain N uptake of sorghum crop and available N status at 30 DAS with pod yield, kernel yield, dry matter production, total N uptake and kernel N uptake of groundnut crop. The multiple regression analysis revealed that available N status at 45 DAS positively and significantly predicted the grain yield of sorghum ($R^2 = 0.72^{**}$) and grain N uptake ($R^2 = 0.70^{**}$) added additional support to the above conclusion. In groundnut, similar observations were made with available N status at 30 DAS. Further, it is interesting to note that the available N status at harvest showed a significant negative relationship with Kernel yield, dry matter production, total N uptake

and kernel N uptake of groundnut crop, indicating the effective utilisation of nutrient in enhancing the yield components.

The organic carbon status of the soil was found to be increased due to the application of farm yard manure and composted coir pith. This is in accordance with the reports of Mani and Ramanathan (1980), Udayasoorian *et al.* (1988), Sarkar *et al.* (1989) and Holford (1990). However, at harvest stage of the residual crop of groundnut, there was not much variation in the organic carbon content of the soil in manured and unmanured plots, which might be due to the faster mineralisation of applied manure favoured by the temperature and time *viz.*, two seasons.

5.8 Uptake of N by main and residual crops

Literature is replete with references on the nutrient availability to the crop growth with different chemical extractants. The plant uptake is the best scale to quantify the availability of nutrients. Based on this, in the present investigation, the uptake of N was monitored in the plant at periodical intervals and in the grain/kernel at harvest. A concomitant increase in nutrient uptake for higher yields was found in the chiseled plots. This is in conformity with the results of Sundara Sarma *et al.* (1978), Gupta *et al.* (1984), Gupta and Abrol (1993), Gupta and Satyendra Kumar (1994) and Basker *et al.* (1995). Advancement of crop growth resulted in higher dry matter production coupled with corresponding increase in the uptake of N. The contribution of manuring to the N uptake was realised only after 60 DAS, which could be attributed to the slow release of nutrients from the organic manures. Similarly, higher N uptake recorded in the chiseled plots only after 60 DAS might be due to the time needed for the effective proliferation of the roots to forage into the deeper layers.

As discussed in the earlier sections the uptake of N was significantly related to the $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$ and the available N content at almost all the stages of sampling. The regression analysis carried out clearly indicated that the $\text{NH}_4\text{-N}$ content at all stages of sampling significantly predicted the total N uptake ($R^2 = 0.79^{**}$) and grain N uptake ($R^2 = 0.83^{**}$) even though the $\text{NH}_4\text{-N}$ content at any given stage failed to markedly contribute to N uptake. With respect to $\text{NO}_3\text{-N}$ content, the results again confirmed the earlier findings of the crucial contribution of $\text{NO}_3\text{-N}$ content at 10 and 45 DAS for the total N uptake ($R^2 = 0.87^{**}$) and grain N uptake ($R^2 = 0.94^{**}$).

The favourable effect of chiseling the soil having hardpan at shallow depth in improving the grain yield, dry matter production, nitrogen uptake, root length and volume by providing favourable physical environment by reducing the bulk density, increasing the hydraulic conductivity and infiltration rate besides an optimum poresize distribution has been explicitly brought out. The study also brought out the benefit of breaking the hardpan for better exploitation of subsoil layer. The present investigation had also shown that the effect of chiseling can sustain only for one cropping sequence (Sorghum-Groundnut) and the need for chiseling once in a year at the beginning of the cropping season. The manurial application though proved beneficial for the entire cropping sequence, its intricacies on sustaining the soil physical properties needs to be studied further, including deep incorporation of manures. Implements recently developed for the above purpose may help in throwing more light on this problem. Regarding N management, the present study indicated that chiseling along with 75 per cent of recommended N registered the yield on par with the treatment receiving 100 per cent recommended N along with mouldboard or country ploughing. Hence, adoption of this technology can help in the saving of 25 per cent of fertiliser N.

SUMMARY AND CONCLUSIONS

CHAPTER VI

SUMMARY AND CONCLUSIONS

The present investigation was carried out to study the interaction effect of tillage, organics and nitrogen application for improving the soil physical properties and yield of crops in soil having hardpan at shallow depth. Nitrogen transformation and mobility, the residual effect of tillage and organics were studied in sorghum groundnut cropping sequence in an Alfisol (Typic Haplustalf - Pichanur series) at Nachipalayam village of Coimbatore district, TamilNadu where such problem is existing.

Three types of tillage practices viz., country ploughing twice (T1), mouldboard ploughing twice (T2) and chiseling once followed by two country ploughing (T3), organic treatments viz., control (M1), farm yard manure at 12.5 t ha^{-1} (M2) and composted coir pith at 12.5 t ha^{-1} (M3) and three levels of N application viz., control (N1), 75 per cent recommended dose (N2) and 100 per cent recommended dose (N3) were the treatments imposed.

Soil and plant samples were collected at periodical intervals for both sorghum and groundnut crops and analysed for the $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, available N and organic carbon contents using disturbed soil samples and physical properties viz., bulk density, hydraulic conductivity and poresize distribution using undisturbed core samples, while in plant samples N content, root length and root volume were estimated. The salient findings emanated from the study are furnished below :

- * The bulk density of the soil reduced significantly due to chiseling of the field. This effect was more pronounced in the second and third depths (15-30 and 30-45 cm) where, the bulk density steeply reduced from 1.82 to 1.58 Mg m^{-3} . In the other two

tillage treatments viz., country ploughing twice (T1) and mouldboard ploughing twice (T2), the effect of tillage on bulk density in surface soil was comparable.

- * Application of either farm yard manure or composted coir pith at 12.5 t ha^{-1} appreciably reduced the bulk density as compared to control. The effect among these two organics were comparable.
- * A steep increase in hydraulic conductivity was evidenced due to chiseling in second depth (0.30 to 2.78 cm h^{-1}). However, the effect was not reflected in the third layer. No perceptible change was observed in the surface layer due to different tillage practices.
- * Organics viz., farm yard manure and composted coir pith had a marked favourable effect on the hydraulic conductivity of the surface soil as compared to control but the effect was not found in subsurface layers.
- * The poresize distribution of the soil indicated the positive influence of chiseling in all the three depths, whereas it was true only in surface layer in other two tillage treatments. The organics tried recorded a favourable influence on the poresize distribution.
- * The correlation and regression analysis revealed the presence of a negative relationship of bulk density and a positive relationship of hydraulic conductivity and poresize distribution with the grain yield, root length, root volume, total N uptake and grain N uptake of sorghum crop. However, this trend was not observed in the residual crop of groundnut.
- * The favourable physical environment created by chiseling was more pronounced in the first crop of sorghum. As the sequence of cropping advanced, due to the gradual

settling of soil particles, a tendency of reverting back to the original physical condition was found as evidenced from the scrutiny of the results of the residual crop of groundnut.

- * The remarkable influence of chiseling (T3) on the root length and root volume of sorghum might be due to the shattering of the hardpan to a depth of 35-40 cm thus facilitating better foraging of roots in these layers. The root length increased with increasing levels of nitrogen. The N effect was spectacular in chiseled plots. Organics had no influence on this parameter.
- * A negative relationship of bulk density and positive relationship of other physical properties viz., hydraulic conductivity and poresize distribution was observed with the root length and root volume of the sorghum crop.
- * Chiseling significantly increased the grain yield of sorghum. Among the organics, the composted coir pith registered the highest grain yield. N availability increased with increasing levels of N and markedly influenced the grain yield also. However, the effect of chiseling was not that much pronounced in the residual crop of groundnut.
- * The grain yield of sorghum due to chiseling and 75 per cent of recommended N was on par with the mouldboard or country ploughing with 100 per cent recommended N indicated the scope of saving 25 per cent of fertiliser N by adopting the chiseling with 75 per cent of recommended N.
- * The multiple regression analysis between grain yield and $\text{NO}_3\text{-N}$ at different stages of crop growth revealed that the $\text{NO}_3\text{-N}$ content of the soil at 10 and 45 DAS contributed significantly to the grain yield of sorghum ($R^2 = 0.94^{**}$). In groundnut, though $\text{NO}_3\text{-N}$ was positively correlated with the pod yield, $\text{NO}_3\text{-N}$ in any specific

stage failed to predict the pod yield. The $\text{NH}_4\text{-N}$ content at all stages of sampling contributed successfully and significantly in predicting the grain yield of sorghum ($R^2 = 0.81^{**}$).

- * Ammoniacal-N content was not much influenced by the tillage and organics treatment. However, increased level of N paralleled the $\text{NH}_4\text{-N}$ content. In general, higher ammoniacal N contents were observed in the surface layer upto 15 DAS due to higher level of N application and a gradual reduction thereafter. The $\text{NO}_3\text{-N}$ content was comparatively low during initial stages (15 DAS), followed by a gradual increase but subsequently beyond 60 DAS, it slowly declined.
- * In chiseled plot, the $\text{NH}_4\text{-N}$ content was higher in second layer as compared to other two layers and this trend was not found in other tillage practices.
- * Chiseling accomplished for the perceptible depletion of available N. Increased available N status with concomitant increase in N levels was found upto 90 DAS in sorghum. Not much variation in the available N status was observed at harvest of either sorghum or the residual crop of groundnut. However, higher available N content in the organic manure added treatments of the residual crop of groundnut was observed.
- * A significant positive correlation was observed between available N on 45 and 90 DAS and grain yield, dry matter production, total N uptake and grain N uptake of sorghum. The multiple regression analysis revealed the contribution of available N status at 45 DAS in positively and significantly predicting the grain yield of sorghum ($R^2 = 0.70^{**}$). In groundnut crop, the available N status at 30 DAS showed a significant positive influence on pod yield.

- * Though the organic carbon content of the soil increased owing to the application of composted coir pith and farm yard manure, a gradual decline along with the growth of crops was found. The different tillage practices and levels of N did not affect the organic carbon content.
- * A concomitant increase in N uptake for higher yields was found. Among the tillage treatments, chiseling favoured for higher N uptake resulting in increased yield. Advancement of crop growth resulted in higher dry matter production coupled with corresponding increase in the uptake of N. Higher N uptake paralleled higher level of N application.
- * The uptake of N was significantly related to the $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ and the available N at all stages of sampling. The regression analysis revealed the significant contribution of $\text{NH}_4\text{-N}$ content in predicting the total N uptake ($R^2 = 0.79^{**}$) and grain N uptake ($R^2 = 0.83^{**}$). The $\text{NO}_3\text{-N}$ at 10 and 45 DAS was found to be crucial for N uptake of sorghum crop.
- * The present study, succinctly brought out the favourable effect of chiseling the soil having hardpan at shallow depth by providing a favourable physical environment, besides paving way for better exploitation of nutrients from the subsurface layers for achieving higher productivity. However, the effect was found to last only for two seasons, thus warranting the need for chiseling once in a year at the start of the cropping sequence. Chiseling with 75 per cent of the recommended N is sufficient to achieve the yield akin to that realised in conventional ploughing with 100 per cent of the recommended dose, thereby saving 25 per cent of fertiliser N. The application of organics helped in providing favourable soil physical conditions for bettering the yield.

REFERENCES

REFERENCES

- Agarwal, R.P. 1991. Water and nutrient management in sandy soils by compaction. *Soil Tillage Res.* 19 : 121-130.
- Agarwal, R.P. and B.S. Jhorar. 1989. Reducing nitrogen leaching in sandy soils. *Int. Symp. on managing sandy soils*. Central Arid Zone Research Institute, Jodhpur, India, Abstr., Part 1. pp.414-417.
- Anderson, S.H., C.J. Gantzer and J.R. Brown. 1990. Soil physical properties after 100 years of continuous cultivation. *J. Soil and Water Cons.*, 45 : 117-121.
- Angle, J.S., C.M. Gross, R.L. Hill and M.S. McIntosh. 1993. Soil nitrate concentrations under corn as affected by tillage, manure and fertiliser applications. *J. Environ. Qual.*, 13 : 431-435.
- Anonymous, 1986. Annual progress report for 1985-86. All India Coordinated Research Project on Improvement of Physical conditions to Increase Agricultural Production of the Problematic areas (ICAR). Indian Agricultural Research Institute, New Delhi.
- Anonymous, 1992. Annual progress report for 1991-92. All India Coordinated Research Project on Tillage Requirement of Major Indian Soils for Different Cropping Systems (ICAR). Indian Agricultural Research Institute, New Delhi.
- Atwell, B.J. 1990. The effect of soil compaction on wheat during early tillering. 1. growth, development and root structure. *New phytologist*. 115: 29-35.
- Bakken, L.R., T. Borresen and A. Njos, 1987. Effect of soil compaction by tractor traffic on soil structure, denitrification and yield of wheat. *J. Soil Sci.*, 38 : 541-552.
- Baligar, V.C., V.E. Nash, M.L. Hare and J.A. Price. 1975. Soybean root anatomy as influenced by soil bulk density. *Agron. J.* 67 : 842-844.



-
- Barracclough, P.B. and P.B. Tinker. 1981. The determination of ionic diffusion coefficients in field soil. 1. Diffusion coefficients in sieved soils in relation to water content and bulk density. *J. Soil Sci.*, 32 : 225-236.
- Basker, A., C. Paulraj, B. Rajkannan, S. Avudainayagam, S. Poongothai, R. Natesan, K. Appavu, K.K. Mathan and Raniperumal. 1995. Twenty five years of soil physics Research in Tamilnadu (1967-1992). Bulletin published from Dept. of Soil Sci. & Agrl. Chem. TNAU, Coimbatore.
- Becher, H.H. and M. Kainz. 1983. (Effect of long term manuring on soil structure) Auswirkungen einer langjahrigen stallmistdungung auf das Bodengefuge im cossgebie bei straubing zeitschrift fur Acker-und Pflanzenbau (1983) 152(2) 152-158 Abstracted from *Soil Fertl.* 46: 7679.
- Bhadoria, P.B.S., J. Kaselowsky, N. Classen and A. Jungk. 1991. Impedance factor for chloride diffusion in soil as affected by bulk density and water content. *Z. Pflanzenernaetir. Bodenkd.*, 154 : 69-72.
- Bharadwaj, V. and P.K. Omanwar. 1992. Impact of long term fertility treatments on bulk density, Water contents and microbial population of soil. *J. Indian Soc. Soil Sci.*, 40 : 553-555.
- Bhuiya, Z.H., M.A. Sahar and M.S. Islam. 1974. Transformation of urea-N in Madupur red soil. *J. Indian Soc. Soil Sci.*, 22 : 31-35.
- Biswas, T.D., B.M. Ingol and K.K. Jha. 1969. Changes in the physical properties of the soils by fertiliser and manure application. *Fert. News*, 14 : 23-26.
- Black, C.A. 1968. Soil plant relationship. 2nd Edn. John Wiley and Sons. Inc. New York. London. pp.403-414.
- Bodman, G.B. and G.K. Constantin. 1965. Influence of particle size distribution in soil compaction. *Hilgardia*, 36: 567-591.

-
- Braim, M.A., K. Chaney and D.R. Hodgson. 1992. Effects of simplified cultivation on the growth and yield of spring barley on a sandy loam soil. 2. Soil physical properties and root growth, root shoot relationships, inflow rates of nitrogen and water use. *Soil Tillage Res.*, 22 : 173-178.
- Broadbent, F.E., K.B. Tyler and G.N. Hill. 1958. Transformation and movement of urea in soils. *Soil Sci. Soc. Am. J.* 22 : 303-307.
- Bremner, J.M. 1965. Inorganic and organic forms of nitrogen. In : *Methods of soil Analysis. part 2 (Ed.)*. C.A. Black. Am. Soc. Agron-Madison. Wisconsin, pp.1179-1255.
- Campbell, J.A. and M.E. Akhtar. 1989. Impact of tillage on soil water regimes in the rainfed areas of Pakistan. *Proc. Int. Sym. on applied soil physics in stress environments*. 22-26 January 1989, Islamabad, Pakistan, pp.126-129.
- Carefoot, J.M., M. Nyborg and C.W. Lindwall. 1990. Differential fertiliser immobilisation in two tillage systems influence on grain N concentration. *Can. J. of Soil Sci.* 70 : 215-225.
- Castillo, R.S., R.H. Dowdy, J.M. Bradford and W.E. Larson, 1982. Effects of applied mechanical stress on plant growth and nutrient uptake. *Agron. J.*, 74 : 526-530.
- Chambers, R., S. Nathojina, C. Weid and I. Mckyes. 1990. Crop rotations and subsoiling on compacted clay soils. *ASAE.*, 90 : 1102-1110.
- Chen, Z.M. 1981. Relationships between structure and fertility in porous soils. *Acta Pedologica Sinica*. 18 : 167-175.
- Cheng, H.H. and Kurtz. 1963. Chemical distribution of added nitrogen in soils. *Soil Sci., Soc. Am. J.*, 27 : 313-316.
- Clarson, D., P.P. Ramasamy and U.S. Sreeramulu. 1983. Efficient utilisation of farm and industrial based water material for reclamation of saline sodic soils. *Nat. Sem. on utilisation of organic water*. pp.117-119.

- Das, D.K., Gurucharan Singh and R.N. Gorg. 1995. Research high lights. Research bulletin. IARI, New Delhi.
- Erbach, D.C., J.G. Benjamin, R.M. Cruse, M.A. Elamin, S. Mikhtar and C.H. Choi. 1992. Soil and corn response to tillage with paraplow transactions of the ASAE. 35 : 1347-1354.
- Ferrero, A.F. 1994. Soil physical characteristics of till slope pastures under repeated animal and machinery traffic. Int. Agro physics 8 : 47-51.
- Fischer, W.B. and Parks. 1958. Influence of soil temperature on urea hydrolysis and subsequent nitrification. Soil Sci. Soc. Am. J., 22 : 247-248.
- Fitter, A.H. 1991. The ecological significance of root system architecture - an economic approach. In: Plant Root Growth - An ecological perspective. (Ed.) D. Atkinson, Blackwell, Oxford. Spec. Publ. 10. British ecological society. pp.224-243.
- Fredrick, L.R. 1956. Transformation of nitrate from ammonium nitrogen in soil : 1. Effect of temperature. Soil Sci. Soc. Am. J., 20 : 496-500.
- Garcia, F., R.M. Cruse and R.M. Blackner. 1988. Compaction and nitrogen placement effects on root growth, water depletion and nitrogen uptake. Soil Sci. Soc. Am. J., 52 : 792-798.
- Ghildyal, B.P. and R.P. Gupta. 1991. Soil structure problems and management. ICAR, New Delhi.
- Glinski, J. and J. Lipiec. 1990. Soil physical conditions and plant roots. CRC Press, Boca Raton, F.L. 250 p.
- Glinski, J. and W. Stepniewski 1985. Soil aeration and its role for plants. CRC Press, Boca Raton, F.L. 200 p.
- Gopalasamy, A. 1984. Chisel plough to crack hard pans. The Hindu. 112: 16

-
- Grath, T. and I. Hakansson. 1992. Soil compaction studies in Swedish pea fields with uneven crop growth. Proc. Int. Conf. Soil compaction and soil management. 8-12 June 1992. Tallinn, Estonia, pp.175-178.
- Greacen, E.L., D.A. Farrell and B. Cockcroft. 1968. Soil resistance to metal probes and plant roots. Trans. of the 9th congress of the Int. Soc. of Soil Sci., 1 : 769-779.
- Greacen, E.L. and J.S. Oh. 1972. Physics on root growth. Nature (Lond). New Biol., 235 : 24-25.
- Grevers, M.C.J. and E. Jong. 1993. Soil structure and crop yield over a five year period following subsoiling solonetzic and chernozemic soils in Saskatchewan. Canadian J. of Soil Sci., 73 : 81-91.
- Grewal, S.S., S.P. Mittal, K. Singh and P. Singh. 1985. Effect of manure and fertiliser on soil water retention and use by rainfed maize-wheat in Siwalik region. J. Indian Soc. Soil Sci., 33 : 728-731.
- Gupta, R.P. and I.P. Abrol. 1993. A study of some tillage practices for sustainable crop production in India. Soil Tillage Res., 27 : 253-272.
- Gupta, R.P. and C. Dakshinamurthi. 1980. Procedures for physical analysis of soils and collection of Agrometeorological Data. Division of Agricultural Physics. IARI, New Delhi.
- Gupta, R.P. and Satyendra Kumar. 1994. Highlights of Research, S.P.C. Bulletin No.7, IARI, New Delhi.
- Gupta, R.P., Satyendra Kumar and Tirlok Singh. 1984. Highlights of Research, S.P.C. Bulletin No.3, IARI, New Delhi.
- Hadas, A., A. Feigin, S. Feigenbaum and R. Portnoy. 1989. Nitrogen mineralisation in the field of various soil depths. J. Indian Soc. Soil Sci., 37 : 131-137.
- Hamblin, A.P. 1985. The influence of soil structure on water movement, crop root growth and water uptake. Adv. Agron., 38 : 95-158.

-
- Harmsen, G.W. and D.A. Van Schreven. 1995. Mineralisation of organic nitrogen in soil. *Adv. Agron.*, 7 : 299-398.
- Harper, J.E. 1984. Uptake of organic nitrogen forms by roots and leaves. In : Nitrogen in crop production. (Ed) R.D. Hauck, ASA, CSSA, Madison, Wisconsin pp. 165-170
- Hatano, R., K. Iwanaga, H. Okajima and T. Sakuma. 1988. Relationship between the distribution of soil macropores and root elongation. *Soil Sci. Pl. Nut.*, 34 : 535-546.
- Havangai, G.V. and H.S. Mann. 1970. Effect of rotations and continuous application of manures and fertilisers on soil properties under dry farming conditions. *J. Indian Soc. Soil Sci.*, 18 : 45-47.
- Henderson, C.W.L. 1991. Sensitivity of eight cereal and legume species to the compaction status of deep sandy soils. *Aust. J. Exp. Agric.*, 31 : 347-355.
- Holford, I.C.R. 1990. Effect of 8 year rotations of grain sorghum with lucerne, annual legume, wheat and long fallow on nitrogen and organic carbon in two contrasting soils. *Aust. J. Soil Res.*, 28 : 277-291.
- Horn, R., W. Stepniewski, G. Walenzik and F.E.P. Eckhardt. 1994. Denitrification rate and microbial distribution within homogeneous soil aggregates. *Int. Agrophys.*, 8 : 65-74.
- Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice-Hall of India Pvt. Ltd., New Delhi.
- Jena, D., C. Misra and C. Pradhan. 1980. Effect of fertiliser dose on soil water profile and root distribution of wheat grown under residual moisture and partially irrigated conditions. *J. Indian Soc. Soil Sci.*, 28 : 436-443.
- Jian Luo, Zhaohuang Lian and Xiaolong Yan. 1993. Urea transformation and the adaptability of three leafy vegetables to urea as a source of nitrogen in hydroponic culture. *Pl. Nutr.*, 16 : 792-812.

- Jordan, W.R. and F.R. Miller. 1980. Genetic variability in sorghum root systems - Implications for drought tolerance. In: Adaptation of plants to water and high temperature stresses (Eds.) N.C. Turner and P.J. Kramer. Wiley, New York pp. 383-399.
- Kahle, P., P. Leinweber and P. Menning. 1992. Influence of soil organic matter on physical properties of soils. *Agro Biol. Res.*, 45 : 18-27.
- Kanwar, J.S. and S.S. Prihar. 1962. Effect of continuous application of manures and fertilisers on some physical properties of Punjab Soil. *J. Indian Soc. Soil Sci.*, 10 : 243-248.
- Keeney, D.R. and J.M. Bremner. 1964. Effect of cultivation on the nitrogen distribution in soils. *Soil Sci. Soc. Am. J.*, 28 : 653-656.
- Kemper, W.D., B.A. Stewart and L.K. Porter. 1971. Effects of compaction on soil nutrient status. In : *Compaction of Agricultural Soils* (Eds.) K.K. Barnes, W.M. Carleton, H.M. Taylor, R.I. Throckmorton and G.L. Vanden Berg. ASAE Monogr., Amer. Soc. of Agrl. Engi., St. Joseph. ml. pp.178-189.
- Kulkarni, B.K. and N.K. Savant. 1977. Effect of soil compaction on root cation exchange of crop plants. *Plant Soil*, 48 : 269-276.
- Larson, W.E., A. Eynard, A. Hadas and J. Lipiec, 1994. Control and avoidance of soil compaction. In: *Practice in soil compaction in crop production*. (Ed.) B.D. Soane, C. Ouwerkerk, Van. Amsterdam Netherlands, Elsevier Science Publishers, pp 597-625. Abstracted from *Soil Fertl.*, 58 : 1995 2580.
- Lindemann, E.C., G.E. Ham and G.W. Randall. 1982. Soil compaction effects on soybean nodulation. $N_2(C_2H_2)$ fixation and seed yield. *Agron. J.*, 74 : 307-311.
- Lipiec, J. and W. Stepniewski. 1995. Effects of soil compaction and tillage systems on uptake and losses of nutrients. *Soil Tillage Res.*, 35 : 37-52.
- MacLean, A.A. and K.B. McRae. 1987. Rate of hydrolysis and nitrification of urea and implications of its use in potato production. *Can. J. Soil Sci.*, 67 : 679-696.

- Mahimairaja, S., J. Helkiah and A. Gopalasamy. 1986. Long term effect of graded doses of fertilisers and manures on soil physical conditions. *Madras Agric. J.*, 73 : 340-347.
- Mallick, S. and Y. Nagarajao. 1972. Effect of tillage on soil structure and plant growth under rainfed conditions. *Indian J. Agric. Sci.*, 42 : 827-831.
- Mandal, B.C., M.N. Saha and M. Adhikari. 1991. Yield of rice and nutrient status of soil due to continuous cropping and manuring in a jute-rice-wheat sequence on Indo-Gangetic alluvial soil. *J. Indian Soc. Soil Sci.*, 39 : 689-692.
- Mani, S. and K.M. Ramanathan. 1980. Studies on the available potassium status of soil as influenced by the application of nitrogen and potassium. *Madras Agric. J.*, 67 : 777-779.
- Manickam, T.S. and C.R. Venkataramanan. 1972. Effect of continuous application of manure and fertilisers on some of the physical properties of soil under dry cultivation. *Madras Agric. J.*, 59 : 309-311.
- Martino, D.L. 1991. Soil physical properties and root density under zero and conventional tillage in three Manitoba soils. M.Sc. Thesis. Department of Soil Science, University of Manitoba, Winnidog.
- Miller, M.H. 1983. Soil limitations to crop productivity in Canada. *Can. J. Plant Sci.*, 63 : 23-32.
- Muthuvel, P., P. Kandasamy and K.K. Krishnamoorthy. 1982. Effect of long term fertilisation on the soil structural indices. *Madras Agric. J.*, 69 : 263-266.
- Nagarajan, R., T.S. Manickam, G.V. Kothandaraman, K. Ramasamy and G.A. Palanisamy. 1985. Coir pith as manure for groundnut. *TNAU, Newsletter*, 15 : 2.
- Nicou, R., C. Charreau and J.L. Chopart. 1993. Tillage and soil physical properties in semi arid west Africa. *Soil Tillage Res.*, 27 : 125-147.

- Nosko, B.C., Medvedev, W.W. and W.W. Litvinenko. 1979. Efficiency of mineral fertilisers at various compactness levels of plough layer of phaeozem. *Agrokimiya*, 12 : 49-54.
- Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate U.S.D.A. C17., 939.
- Panayiotopoulos, K.P., C.P. Papadopoulou and A. Hatjiloannidou. 1994. Compaction and penetration resistance of an alfisol and entisol and their influence on root growth of maize seedlings. *Soil Tillage Res.*, 31 : 323-337.
- Panse, V.G. and Sukhatme. 1978. Statistical methods for Agricultural workers. ICAR, New Delhi.
- Parameswar, M., V. Shatain, M. Singa Rao, A. Prasad Rao and P. Nageswara Rao. 1989. Effect of long term fertilisation under intensive cropping on some soil physical properties and rice yield. *The Andhra Agric. J.*, 36 : 152-156.
- Pemberton, H. 1945. Estimation of total phosphorus. *J. Amer. Chem. Soc.*, 30 : 563-565.
- Pignedoli, S. 1993. Subsoiling: Many tools, one operation. *Subsolado : muchos aperos, una operation. Maquinas Y Tractores Agricolas* (1993) 4: 56-99. Abstracted from *Soil Fertl.*, 57 : 9978.
- Piper, C.S. 1966. Soil and plant analysis. Hans Publishers, Bombay.
- Prasad, B., R.P. Singh, H.K. Roy and H. Sinha. 1983. Effect of fertilisers, lime and manure on some physical and chemical properties of a red loam soil under multiple cropping. *J. Indian Soc. Sol Sci.*, 31 : 601-603.
- Pratt, P.F. 1965. In : *Methods of Analysis* (Ed.). C.A. Black, American Society of Agronomy Inc., Pub., Madison. Wisconsin. pp. 1019-1021.
- Rabindra, B. and H. Gowda. 1986. Long range effect of fertilisers, lime and manures on soil fertility and sugarcane yield on a red sandy loam soil. *J. Indian Soc. Soil Sci.*, 34 : 200-202.

- Ramanathan, K.M., S. Ramanathan, C. Jayaraman, V. Ravikumar and S. Palanivel. 1983. Effect of chiseling and amendments on the management of soil having impervious layer at shallow depths. *Madras Agric. J.*, 70 : 246-250.
- Rice, C.W., J.H. Grove and M.S. Smith. 1987. Estimating soil net nitrogen mineralisation as affected by tillage and soil drainage due to topographic position. *Can. J. Soil Sci.*, 67 : 513-520.
- Russell, R.S. 1977. *Plant Root Systems : Their function and interaction with the soil.* McGraw Hill Book Co. New York, p.193.
- Russell, R.S. 1981. Root growth in relation to maximizing yields. In: *Agricultural yield potentials in continental climates. Proc. 16th Collg. Int. potash. Inst. Warsaw, Poland.* 1981. Int. Potash Inst. Bern. Switzerland pp. 23-47.
- Russell, R.S. and Goss, M.J. 1974. Physical aspects of soil fertility. The response of roots to mechanical impedance. *Neth. J. Agric. Sci.*, 22 : 305-318.
- Sarkar, A.K., B.S. Mathur, S. Lal and K.P. Singh. 1989. Long term effects of manure and fertilisers on important cropping systems in sub-humid, red and laterite soils. *Fertil. News*, 34 : 71-80.
- Savant, N.K. and S.K. De Datta. 1982. Nitrogen transformations in wetland rice soils. *Adv. Agron.*, 35 : 241-302.
- Savithiri, P. 1971. Root growth and yield in Ragi Co 7 ion migration and physical properties of soils in relation to soil compaction and moisture regime. M.Sc.(Ag.), Thesis submitted to Dept. of Soil Sci. and Agrl. Chem., TNAU, Coimbatore.
- Seghal, J. 1995. Land Resources Appraisal for Land Use Planning to meet the challenges of 21st century. *J. Indian Soc. Soil Sci.*, 43 : 504-528.
- Sextone, A.J., T.B. Parkin and J.M. Tiedje. 1988. Denitrification response to soil wetting in aggregated and unaggregated soil. *Soil Biol. Biochem.*, 20 : 767-769.

- Sfeyn, J.T., J.P.C. Tolmay, J.J. Human and W.J. Kilian. 1995. The effect of tillage systems on soil bulk density and penetrometer resistance of a sandy clay loam soil. *South African J. of Soil and Plant*, 12: 86-90.
- Shipilalo, M.J. and W.M. Edwards. 1993. Seasonal patterns of water and chemical movement in tilled and no-till column lysimeters. *Soil Sci. Soc. Am. J.*, 57 : 218-223.
- Simmons, F.W. 1992. Tillage and compaction effects of root distribution. In: *Proc. Roots of plant nutrition*. (Ed.) H.F. Reetz Jr., Champrign, Jppinois. Potash and Phosphate Institute, Atlanta. GA. pp 61-68.
- Skrebelis, S. and A. Aleksynas. 1993. Usage possibilities and combination of tillage machines for deep and surface ploughing of soil. *Gilumiovio ir pauirsinio Zemes dirbimo masinu suderinimo ir naudojimo galimybes. mechanizacija ir Elektrifikacija mokslo Dasbai* (1993) No.24, 69-80. Abstracted from *Soil Fertl.* 57: 3822.
- Soane, B.D., Ouwerkerk, C. Van. 1994. Soil compaction problems in world agriculture. In: *Soil compaction in crop production*. (Eds.) B.D. Sonne, C. Ouwerkerk, Van. Amsterdam, Netherlands. Elsevier Science Publishers, B.V. Abstracted from *Soil Fertl.*, 58 : 2593.
- Srivastava, A.P., J.S. Panwar, R.N. Garg and Gurucharan Singh. 1994. Tillage effects on rice based wheat crop. *Indian J. Agric. Eng.*, 4 : 39-44.
- Stanford, S. and L. English. 1949. Use of flame photometer in rapid soil tests of potassium and calcium. *Agron. J.*, 41 : 440-447.
- Stypa, M., A. Nunez-Barrios, D.A. Barry, M.H. Miler and W.A. Mitchel. 1987. Effects of sub soil bulk density, nutrient availability and soil moisture on corn root growth in the field. *Can J. Soil Sci.*, 67 : 293-308.

Subagio, I., Mumwandono. 1992. Method of soil cultivation for replanting by deep tillage. Cara peurgalatian tanah untuk replanting deugan olan tanah minimum dalam Berita. Pusar penelitian Perkebunan Gula Indonesia (1992). No.6, 24-88 (In) : Pusat Penelitian perkebunan Gula Indonesia (PB G1), Pasuruan Indonesia. Abstracted from Soil Fertl., 56 : 1867.

Subbiah, B.V. and G.L. Asija. 1956. A rapid procedure for estimation of available nitrogen in soils. Curr. Sci., 25 : 259-260.

Subbiah, S. and G.V. Kothandaraman. 1980. Effect of neem cake blending of urea on ammonium and nitrate N content is soils under field condition. J. Indian Soc. Soil Sci., 28 : 136-137.

Sundara Sarma, K.S., Y. Nagarajao and Gurucharan Singh. 1978. Soil physical environment and root distribution of irrigated maize and wheat under different soil management practices. Indian J. Agron., 23 : 295-300.

Suresh Lal and B.S. Mathur. 1989. Effect of long term fertilisation, manuring and liming of an Alfisol on maize, wheat and soil properties. II Soil physical properties. J. Indian Soc. Soil Sci., 37 : 815-817.

Taylor, H.M., G.M. Robertson and J.J.Parker. 1966. Soil strength-root penetration relations for medium to coarse textured soil materials. Soil Sci., 102 : 18-22.

Taylor, H.M. and L.F. Ratliff. 1969. Root elongation rate of cotton and peanuts as a function of soil strength and soil water content. Soil Sci., 108 : 113-119.

Tebrugge, F. 1992. Soil management the environmental implication on tillage systems. In: Problems in modern soil management. Proc. The Int. conf. Aug. 31 - Sep. 5, Czechoslovakia.

Thoma, K. 1991. A study of tillage systems for vegetable production and their effect on downstream water quality in the Mount Lofty Ranges, South Australia. Environ. Tech., 12 : 1157-1166.

- Thompson, J.P. 1992. Soil biotic and biochemical factors in a long term tillage and stubble management experiment on a Vertisol. 2. Nitrogen deficiency with zero tillage and stubble retention. *Soil Tillage Res.*, 22 : 339-361.
- Torbert, H.A. and C.W. Wood. 1992. Effect of soil compaction and water filled porespace on soil microbial activity and N losses. *Commun. Soil Sci. Plant Anal.*, 23 : 1321-1331.
- Toth, S.J. and A.L. Prince. 1949. Estimation of cation exchange capacity and exchangeable calcium, potassium and sodium contents of soil by flame photometer techniques. *Soil Sci.*, 67 : 439-445.
- Tricot, F., Y. Crozat, A.M. Domenach, J.P. Giller, M. Sabillotte and F. Tardieu. 1990. Root and nodules distribution. N uptake and N₂ fixed in pea (*Pisum sativum* cv. *solara*) as affected by compaction of the ploughed layer. Proc. 1st Congress of the European society of Agronomy. December 1990. Paris. Session 3. pap. 51, 2pp.
- Udayasoorian, C., K.K. Krishnamoorthy and U.S. Sreeramulu. 1988. Effect of continuous application of organic manure and fertilisers on organic carbon, cation exchange capacity and exchangeable cations in submerged soil. *Madras Agric. J.*, 75 : 346-350.
- Varade, S.B. and B.P. Ghildyal. 1967. Effect of varying bulk densities of low land rice growth. *I.L. RISO*. 16 : 33-40.
- Varade, S.B. and K.T. Mahajan, 1970. Investigations on the influence of oxygen levels and mechanical impedance as related to plant growth and tillage requirements for flooded paddy. Ann. Rep. PL.480 Res. Project.A7, SWC 471. I.I.T. Kharagpur. India.
- Veen, B.W., M. Van Noordwijk, P. deWilligen, F.R. Boone and M.J. Kooistra. 1992. Root Soil contact of maize, as measured by a thin section technique. III. Effect on shoot growth, nitrate and water uptake efficiency. *Plant Soil*, 193 : 131-138.
- Veen, B.W. 1982. The influence of mechanical impedance on the growth of maize roots. *Plant Soil*, 66 : 101-106.

- Voorhees, W.B., V.A. Carlson and C.G. Senst. 1976. Soybean nodulation as affected by wheel traffic. *Agron. J.*, 68 : 976-985.
- Walkley, A. and I.A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sci.*, 37 : 29-38.
- Warneke, D.D. and S.A. Barber. 1972. Diffusion of zinc in soil. II. The influence of soil bulk density and its interaction with soil moisture. *Soil Sci. Soc. Am. J.*, 36 : 42-46.
- Weier, K.L. and MacRae. 1993. Net mineralisation, net nitrification and potentially available nitrogen in the subsoil beneath a cultivated crop and a permanent pasture. *J. Soil Sci.*, 44 : 451-458.
- Williams, J. and C.F. Shaykewich. 1970. The influence of soil water matric potential on the strength properties of unsaturated soil. *Soil Sci. Soc. Am. J.*, 34 : 835-840.
- Wittsell, L.E. and J.A. Hobbs. 1965. Soil compaction effects on field plant growth. *Agron. J.*, 57 : 534-537.
- Wolkowski, R.P. 1990. Relationship between wheel traffic induced soil compaction, nutrient availability and crop growth: a review. *J. Prod.Agric.*, 3 : 460-469.
- Wollersheim, R., G. Trolldenier and H. Beringer. 1987. Effect of bulk density and soil water tension on denitrification in the rhizosphere of spring wheat (*Triticum vulgare*). *Biol. Fertil. Soil*, 5 : 181-187.
- Yadav, M.D. and K.D.N. Singh. 1991. Transformation of applied nitrogen in relation to its availability to sugarcane in calcareous soil. *J. Indian Soc. Soil Sci.*, 39 : 292-297.

APPENDICES

Table 1. Sample correlation matrix of physical properties at different stages, total drymatter (TDM), Koot length (RL), Koot volume (RV), Total N uptake (TUP), Grain N uptake (GUP) and Grain Yield (GY) (Sorghum crop).

	BD45	HC45	CP45	NCP45	TP45	BD90	HC90	CP90	NCP90	TP90	BDPH	HCPH	CPPH	NCPPH	TPPH	TDM	RL	RV	TUP	GUP	GY
BD45	1.000																				
HC45	-0.944**	1.000																			
CP45	-0.960**	0.977**	1.000																		
NCP45	-0.962**	0.993**	0.984**	1.000																	
TP45	-0.964**	0.988**	0.977**	0.995**	1.000																
BD90	0.956**	-0.965**	-0.961**	-0.965**	-0.966**	1.000															
HC90	-0.880**	0.979**	0.961**	0.973**	0.971**	-0.910**	1.000														
CP90	-0.879**	0.942**	0.962**	0.954**	0.963**	-0.893**	0.974**	1.000													
NCP90	-0.913**	0.949**	0.951**	0.975**	0.966**	-0.904**	0.961**	0.968**	1.000												
TP90	-0.900**	0.952**	0.965**	0.970**	0.972**	-0.904**	0.977**	0.955**	0.989**	1.000											
BDPH	0.935**	-0.987**	-0.952**	-0.971**	-0.959**	0.962**	-0.941**	-0.878**	-0.904**	-0.896**	1.000										
HCPH	-0.846**	0.954**	0.959**	0.955**	0.951**	-0.876**	0.993**	0.974**	0.963**	0.978**	-0.908**	1.000									
CPPH	-0.920**	0.942**	0.956**	0.943**	0.953**	-0.934**	0.934**	0.899**	0.899**	0.906**	-0.916**	0.912**	1.000								
NCPPH	-0.924**	0.952**	0.925**	0.941**	0.936**	-0.896**	0.974**	0.925**	0.926**	0.933**	-0.625**	0.973**	0.947**	1.000							
TPPH	-0.901**	0.961**	0.959**	0.958**	0.962**	-0.930**	0.965**	0.929**	0.929**	0.936**	-0.931**	0.952**	0.990**	0.981**	1.000						
TDM	-0.343	0.563	0.532	0.529	0.536	-0.418	0.651	0.671*	0.569	0.634	-0.510	0.661	0.361	0.564	0.463	1.000					
RL	-0.984**	0.930**	0.922**	0.937**	0.931**	-0.978**	0.841**	0.819**	0.864**	0.844**	-0.947**	0.797*	0.885**	0.817**	0.868**	0.314	1.000				
RV	-0.970**	0.922**	0.906**	0.923**	0.916**	-0.970**	0.827**	0.794*	0.834**	0.825**	-0.947**	0.778*	0.961**	0.804**	0.848**	0.323	0.997**	1.000			
TUP	-0.726*	0.842**	0.882**	0.840**	0.868**	-0.762**	0.917**	0.950**	0.865**	0.922**	0.754*	0.923**	0.839**	0.884**	0.878**	0.733*	0.648	0.620	1.000		
GUP	-0.864**	0.921**	0.961**	0.932**	0.952**	-0.862**	0.956**	0.968**	0.937**	0.963**	-0.853**	0.952**	0.904**	0.928**	0.954**	0.576	0.741*	0.762*	0.957**	1.000	
GY	-0.847**	0.948**	0.957**	0.942**	0.953**	-0.863**	0.978**	0.964**	0.934**	0.959**	-0.897**	0.968**	0.908**	0.942**	0.941**	0.690*	0.796*	0.780*	0.949**	0.977**	1.000

BD - Bulk density, HC - Hydraulic conductivity, CP - Capillary porosity, NCP - Non-capillary porosity, TP - Total porosity
45 and 90 indicates sampling time in DAS ; PH - Post harvest.

Appendix II Simple correlation matrix of physical properties at different stages, Pod yield (PY), Total Drymatter (TDM), Total N uptake (TUP) and Kernel N uptake (KUP) (Groundnut crop).

	BD45	HC45	CP45	NCP45	TP45	BD90	HC90	CP90	NCP90	TP90	BDPH	HCPH	CPPH	NCPH	TPPH	PY	TDM	TUP	KUP
BD45*	1.000																		
HC45	-0.785*	1.000																	
CP45	-0.878**	0.847	1.000																
NCP45	-0.611	0.577	0.549	1.000															
TP45	-0.812*	0.838**	0.944**	0.727*	1.000														
BD90	0.525	-0.443	-0.424	-0.701*	-0.442	1.000													
HC90	-0.754*	0.961**	0.779*	0.413	0.740*	-0.220	1.000												
CP90	0.540	0.716*	0.589	0.338	0.542	-0.179	0.728*	1.000											
NCP90	-0.703*	0.857**	0.792*	0.472	0.841**	-0.087	0.882**	0.682*	1.000										
TP90	-0.631	0.863**	0.717*	0.391	0.710*	-0.070	0.906**	0.901**	0.906**	1.000									
BDPH	-0.452	0.257	0.443	-0.269	0.230	0.022	0.337	0.141	0.206	0.152	1.000								
HCPII	-0.389	0.694*	0.389	0.120	0.333	0.033	0.774*	0.863**	0.646	0.880**	0.000	1.000							
CPPH	0.108	-0.068	0.150	0.240	0.343	0.247	-0.127	0.130	0.307	0.179	-0.311	-0.086	1.000						
NCPH	0.516	0.353	-0.560	0.162	-0.493	0.095	-0.367	0.230	-0.303	-0.063	-0.548	0.219	0.170	1.000					
TPPH	0.544	0.546	-0.260	-0.087	-0.141	0.168	-0.670	-0.386	0.354	-0.444	-0.431	-0.525	0.711*	0.234	1.000				
PY	-0.475	0.848**	0.549	0.298	0.549	-0.043	0.905**	0.801**	0.823**	0.938**	0.032	0.942**	-0.012	-0.015	-0.543	1.000			
TDM	0.490	0.886**	0.594	0.332	0.586	-0.156	0.908**	0.811**	0.802**	0.925**	0.049	0.928**	-0.037	-0.020	-0.514	0.988**	1.000		
TUP	-0.479	0.870**	0.594	0.293	0.580	-0.099	0.903**	0.807**	0.817**	0.934**	0.052	0.934**	-0.007	-0.027	-0.492	0.991**	0.997**	1.000	
KUP	-0.479	0.852**	0.574	0.275	0.561	-0.022	0.913**	0.784*	0.822**	0.936**	0.059	0.935**	-0.020	-0.072	-0.533	0.996**	0.985**	0.991**	1.000

BD - Bulk density, HC - Hydraulic conductivity, CP - Capillary porosity, NCP - Non-capillary porosity, TP - Total porosity
45 and 90 indicates sampling time in DAS ; PH - Post harvest.

Table 1. Grain yield (kg/ha) of sorghum grown under different irrigation treatments (AN) and nitrogen levels (NN) at different stages of crop growth (Sorghum crop)

	AN3	AN5	AN7	AN10	AN15	AN30	AN45	AN60	AN75	AN90	AN105	ANPH	NN3	NN5	NN7	NN10	NN15	NN30	NN45	NN60	NN75	NN90	NN105	NNPH
AN3#	1.000																							
AN5	0.889**	1.000																						
AN7	0.868**	0.947**	1.000																					
AN10	0.855**	0.953**	0.983**	1.000																				
AN15	0.864**	0.907**	0.920**	0.911**	1.000																			
AN30	0.842**	0.849**	0.815**	0.817**	0.871**	1.000																		
AN45	0.498**	0.485**	0.439**	0.480**	0.502**	0.532**	1.000																	
AN60	0.886**	0.931**	0.948**	0.945**	0.935**	0.919**	0.809**	1.000																
AN75	0.808**	0.702**	0.778**	0.757**	0.803**	0.782**	0.562**	0.823**	1.000															
AN90	0.683**	0.701**	0.703**	0.685**	0.683**	0.649**	0.448**	0.77**	0.638**	1.000														
AN105	0.678**	0.622**	0.655**	0.664**	0.651**	0.710**	0.432**	0.710**	0.771**	0.594**	1.000													
ANPH	0.692**	0.750**	0.788**	0.767**	0.713**	0.283**	0.343*	0.720**	0.683**	0.456**	0.558**	1.000												
NN3	0.311	0.229	0.270	0.270	0.216	0.251	0.133	0.230	0.238*	0.077	0.236*	0.182	1.000											
NN5	0.299	0.184	0.229	0.188	0.121	0.171	0.072	0.187	0.301	0.215	0.321	0.275	0.778**	1.000										
NN7	0.150	-0.020	0.197	0.007	-0.049	0.007	0.015	-0.003	0.169	0.048	0.230	0.134	0.773**	0.900**	1.000									
NN10	0.778**	0.853**	0.895**	0.878**	0.810**	0.662**	0.377*	0.811**	0.675**	0.614**	0.560**	0.789**	0.478**	0.460**	0.322	1.000								
NN15	0.843**	0.931**	0.956**	0.962**	0.855**	0.732**	0.489**	0.885**	0.718**	0.622**	0.605**	0.784**	0.270*	0.182	0.028	0.886**	1.000							
NN30	0.823**	0.929**	0.963**	0.980**	0.917**	0.795**	0.522**	0.918**	0.716**	0.631**	0.623**	0.738**	0.280	0.160	-0.020	0.866**	0.962**	1.000						
NN45	0.807**	0.917**	0.956**	0.963**	0.895**	0.744**	0.500**	0.892**	0.714**	0.640**	0.629**	0.808**	0.278	0.199	0.021	0.909**	0.956**	0.973**	1.000					
NN60	0.792**	0.923**	0.939**	0.948**	0.893**	0.741**	0.495**	0.863**	0.658**	0.554**	0.594**	0.793**	0.243**	0.140	-0.051	0.869**	0.947**	0.971**	0.975**	1.000				
NN75	0.836**	0.918**	0.944**	0.947**	0.919**	0.800**	0.478**	0.899**	0.732**	0.590**	0.683**	0.804**	0.294	0.191	0.007	0.876**	0.939**	0.965**	0.977**	0.978**	1.000			
NN90	0.722**	0.846**	0.870**	0.882**	0.799**	0.659**	0.492**	0.776**	0.606**	0.473**	0.558**	0.773**	0.254	0.144	-0.054	0.830**	0.903**	0.914**	0.949**	0.961**	0.957**	1.000		
NN105	0.685**	0.780**	0.789**	0.807**	0.723**	0.583**	0.450**	0.675**	0.518**	0.354*	0.550**	0.747**	0.265	0.160	-0.018	0.768**	0.846**	0.851**	0.887**	0.925**	0.915**	0.969**	1.000	
NNPH	0.644**	0.745**	0.760**	0.770**	0.674**	0.522**	0.456**	0.622**	0.488**	0.308	0.504**	0.736**	0.261	0.152	-0.208	0.738**	0.824**	0.814**	0.855**	0.903**	0.879**	0.953**	0.991**	1.000

3,5,7,10,15,30,45,60,75,90 and 105 indicates sampling time in DAS PH - Post harvest

Appendix IV Simple correlation matrix of Ammoniacal N (AN), Nitrate N (NN), Available N (AVN), Pod yield (PY), Kernel yield (KY), Total N uptake (TUP) and Kernel N uptake (KUP) (Groundnut crop)

	AN15	AN30	AN45	AN60	ANPH	NN15	NN30	NN45	NN60	NNPH	AVN45	AVN90	AVNPH	PY	KY	TDM	TUP	KUP
AN15*	1.000																	
AN30	-0.010	1.000																
AN45	0.300	0.270	1.000															
AN60	0.049	0.273	0.130	1.000														
ANPH	0.287	0.227	0.956**	0.080	1.000													
NN15	-0.046	0.123	0.020	0.146	-0.023	1.000												
NN30	-0.050	0.132	-0.010	0.204	-0.059	0.992**	1.000											
NN45	-0.028	0.141	0.054	0.140	-0.004	0.980**	0.976**	1.000										
NN60	0.041	0.059	-0.198	0.067	-0.171	-0.041	-0.011	-0.092	1.000									
NNPH	-0.025	0.049	0.124	0.009	0.056	0.779**	0.767**	0.862**	-0.291	1.000								
AVN45	0.024	0.012	0.091	0.086	0.128	0.486*	0.489**	0.491**	-0.164	0.498**	1.000							
AVN90	-0.178	-0.041	0.063	-0.054	0.086	0.348	0.337	0.399*	-0.372	0.571**	0.690**	1.000						
AVNPH	-0.008	0.032	0.087	-0.092	0.053	0.491**	0.478*	0.594**	-0.426*	0.866**	0.556**	0.756**	1.000					
PY	-0.012	0.168	0.235	0.286	0.197	0.471*	0.490*	0.354	0.269	-0.024	0.414*	0.159	-0.121	1.000				
KY	-0.010	0.168	0.237	0.284	-0.199	0.472*	0.491**	0.355	0.272	-0.024	0.414*	0.159	-0.122	0.981**	1.000			
TDM	-0.008	0.129	-0.241	0.273	-0.201	0.390*	0.412*	0.275	0.324	-0.115	0.389*	0.120	-0.187	0.978**	0.978**	1.000		
TUP	-0.004	0.156	-0.258	0.258	-0.223	0.420*	0.441*	0.303	0.288	-0.087	0.400*	0.137	-0.153	0.988**	0.989**	0.991**	1.000	
KUP	-0.024	0.188	-0.258	0.273	-0.223	0.463*	0.485*	0.343	0.282	-0.034	0.407*	0.156	-0.123	0.996**	0.996**	0.973**	0.989**	1.000

15, 30, 45 and 60 indicates sampling time in DAS PH - Post harvest

Appendix V Results of correlation analysis among the Ammoniacal N(AN), Nitrate N(NN), Available N(AVN) at different stages of crop growth and yield, drymatter and uptake (Sorghum crop)

	Grain yield	Total drymatter	Total N uptake	Grain N uptake
N3 ¹	0.720**	0.778**	0.741**	0.752**
N5	0.787**	0.866**	0.790**	0.805**
N7	0.842**	0.921**	0.848**	0.849**
N10	0.828**	0.921**	0.831**	0.836**
N15	0.791**	0.821**	0.792**	0.814**
N30	0.680**	0.716**	0.651**	0.699**
N45	0.333*	0.358*	0.316	0.368**
N60	0.841**	0.903**	0.830**	0.853**
N75	0.669**	0.694**	0.672**	0.686**
N90	0.774**	0.770**	0.737**	0.788**
N105	0.541**	0.633**	0.563**	0.544**
NPH	0.577**	0.694**	0.649**	0.590**
N3	0.332*	0.286	0.340*	0.310
N5	0.385**	0.345*	0.424**	0.361*
N7	0.224	0.151	0.259	0.204
N10	0.838**	0.859**	0.852**	0.833**
N15	0.767**	0.866**	0.780**	0.777**
N30	0.791**	0.884**	0.794**	0.801**
N45	0.760**	0.862**	0.784**	0.765**
N60	0.707**	0.820**	0.736**	0.721**
N75	0.712**	0.823**	0.743**	0.721**
N90	0.592**	0.731**	0.638**	0.594**
N105	0.471**	0.633**	0.536**	0.477**
NPH	0.425**	0.586**	0.490**	0.433**
VN45	0.823**	0.918**	0.834**	0.829**
VN90	0.429**	0.494**	0.500**	0.424*
VNPH	0.228	0.297	0.266	0.214

3,5,7,10,15,30,45,60,75,90 and 105 indicates sampling time in DAS
 -1 - Post harvest.

Appendix VI Results of correlation analysis among the Ammoniacal N(AN), Nitrate N(NN), Available N(AVN) at different stages of crop growth and yield, Pod yield (PY), Kernel yield (KY), Total drymatter(TDM), Total N uptake(TUP) and Kernal N uptake(KUP) (Groundnut crop)

	PY	KY	TDM	TUP	KUP
AN15#	-0.012	-0.010	-0.008	-0.004	-0.024
AN30	0.168	0.168	0.129	0.156	0.188
AN45	0.235	0.237	-0.241	-0.258	-0.258
AN60	0.286	0.284	0.273	0.258	0.273
ANPH	0.197	-0.199	-0.201	-0.223	-0.223
NN15	0.471*	0.472*	0.390*	0.420*	0.463*
NN30	0.490**	0.491**	0.412*	0.441*	0.485*
NN45	0.354	0.353	0.275	0.303	0.343
NN60	0.269	0.272	0.324	0.288	0.282
NNPH	-0.024	-0.024	-0.115	-0.087	-0.034
AVN30	0.414*	0.414*	0.389*	0.400*	0.407*
AVN60	0.159	0.159	0.120	0.137	0.156
AVNPH	-0.121	-0.122	-0.187	-0.153	-0.123

15,30,45 and 60 indicates sampling time in DAS
H - Post harvest

