TILLAGE AND NUTRITION FOR PRODUCTIVITY ENHANCEMENT IN TANNIA
(*Xanthosoma sagittifolium* (L.) Schott)

by

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(2013-21-105)

THESIS
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DECLARATION

I, hereby declare that this thesis entitled **"TILLAGE AND NUTRITION FOR PRODUCTIVITY ENHANCEMENT IN TANNIA (*Xanthosoma sagittifolium* (L.) Schott)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
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CERTIFICATE

Certified that this thesis entitled **"TILLAGE AND NUTRITION FOR PRODUCTIVITY ENHANCEMENT IN TANNIA (*Xanthosoma sagittifolium* (L.) Schott)"** is a record of research work done independently by Mr. Atul Jayapal (2013-21-105) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

Al	Aluminium
BCR	Benefit cost ratio
Ca	Calcium
CD	Critical difference
cm	Centimetre
CTCRI	Central Tuber Crops Research Institute
CPC	Coir pith compost
EC	Electrical conductivity
et al	Co-workers/ co-authors
Fig.	Figure
FYM	Farmyard manure
g	Gram
ha	Hectare
HI	Harvest index
ICAR	Indian Council of Agricultural Research
INM	Integrated nutrient management
K	Potassium
KAU	Kerala Agricultural University
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index
MAP	Months after planting
meq	Milli equivalent

Mg	Magnesium
Mg m^{-3}	Mega gram per cubic metre
N	Nitrogen
NS	Not significant
P	Phosphorus
PGPR	Plant growth promoting rhizobacteria
$Plant^{-1}$	per plant
PLW	Physiological loss in weight
S	Significant
SEm	Standard error of means
t ha^{-1}	Tonnes per hectare
TDMP	Total dry matter production
viz.	Namely

LIST OF SYMBOLS

@	at the rate of
°C	degree Celsius
%	per cent

INTRODUCTION

1. INTRODUCTION

Tannia (*Xanthosoma sagittifolium* (L.). Schott) or new cocoyam, belonging to the family Araceae is one of the six most important tuber crops grown world-wide. It is a herbaceous monocotyledonous plant having a large corm (mother corm) or main underground stem in the form of a rhizome, from which swollen secondary shoots or cormels (side corms) sprout. The flesh of tuber is usually white. The cormels, corm and leaves of tannia are rich in carbohydrates, vitamins and minerals and used for human consumption and as animal feed. The cormels contain 17 to 26 per cent carbohydrate mostly starch, 1.3 to 3.7 per cent protein and 65 to 77 per cent water (Onwume and Charles, 1994).The tubers are having 6 per cent average protein and 390 calories energy $100g^{-1}$ dry matter (Jyoti *et al.*, 2011).The tubers are considered more nutritious than colocasia and potato. The tubers are ready for harvest by 9 to 11 months after planting (MAP) when the leaves begin to dry up. The tubers are used as vegetable and possess good keeping quality compared to other vegetables.

Tannia is mainly cultivated by small farmers in Asia, Africa and Latin America. In India, it is grown in Kerala, parts of Tamil Nadu, Andhra Pradesh, Maharashtra, Odisha, West Bengal and in the North East. Tannia is one of the most shade tolerant food crops and hence suited for intercropping and mixed cropping systems. In Kerala, tannia is grown in the homesteads and as an intercrop in coconut gardens in uplands and with Nendran banana in lowlands.

Soil compaction of agricultural soils is a well recognized global problem. One of the most effective ways to reduce soil compaction is tillage in which the physical manipulation of soil is attempted to break hard soil layers and facilitate root penetration. Moreover, this practice destroys weeds, incorporates crop residues and amendments into soil, increases infiltration and reduces evaporation. Tillage and mulching are important cultural practices that can be used to increase the yield of tannia. Although tannia can be grown in a wide variety of soil, significant variation in yield has been observed when it is grown in different soil

Tannia plant

Corm Cormels

Plate 1. Plant, mother corm and cormels of tannia (*Xanthosoma sagittifolium* (L.) Schott)

types. It is understood that the physico-chemical properties of the soil can be improved by tillage which will be reflected in the growth and yield of tannia.

For optimum yields, tannia requires a deep well drained nutrient rich soil with a pH ranging from 5.5 to 6.5 (John, 2011). Tannia is very susceptible to Mg deficiency and is considered as an indicator plant for Mg deficiency. Studies conducted at ICAR- Central Tuber Crops Research Institute (ICAR- CTCRI) indicated that subsoil acidity due to Al^{3+} ions inducing multi nutrient disorder involving K, Ca and Mg is a major yield limiting factor in tannia. Dolomite @ 1 t ha^{-1} is identified as a suitable liming material to rectify the problem (CTCRI, 2011).

Utilization of crop residues is a viable preposition for retention of soil moisture and maintenance of soil fertility. Hence, appropriate quantity of crop residues can be applied in a cost effective manner to enhance crop productivity. Coir pith, which is an under - utilized crop residue and which may otherwise cause environmental pollution can be used as a soil conditioner for growing tuber crops. Coirpith has high water holding capacity which can serve for longer retention of soil moisture when used as soil conditioner. When grown in soil conditioned with coir pith, increase in tuber yield of sweet potato, elephant foot yam and colocasia has been reported (Mukherjee, 2001). The use of rice husk as a soil conditioner is followed among traditional tannia farmers and has found to result in better tuber yield.

Traditionally, tuber crops are fertilized with organic manures such as farmyard manure (FYM) and ash only. Studies have revealed the positive response of tannia to organic manures and chemical fertilizers. The integrated nutrient management (INM) strategy derived for tannia at ICAR - CTCRI involves FYM @ 25 t ha^{-1} + 80:50:150 kg $NPKha^{-1}$ (CTCRI, 2011). Split application at planting and at two, four and six MAP is recommended for tannia.According to Suja *et al.* (2009), tannia has great potential for organic production and prefer organic cultivation. Application of FYM @ 20 t ha^{-1}, neem cake @ 1 t ha^{-1} and ash @ 2 t ha^{-1} combined with *in situ* green manuring with cowpea is recommended for organic farming of tannia.

A lot of potential exists for the commercial cultivation of tannia since there is a great demand for organically produced tuberous vegetables in Europe, USA and Middle East. But the crop is still under-exploited in our state and no package of practices has been developed for getting sustained yield of the crop. Being shade tolerant, tannia is a highly suited crop in the homesteads of Kerala. Considering all these factors, the present study was undertaken with the following objectives:

- To identify ideal tillage system for productivity enhancement in tannia
- To study the effect of soil conditioners on growth, yield and quality of tannia
- To compare the effects of integrated and organic nutrition on growth, yield and quality of tannia
- To work out the economics of cultivation.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Edible aroids belonging to the family Araceae are an important group of tropical tuber crops, the tubers of which are mainly used as vegetable. Popular aroids cultivated in India are taro or old cocoyam (*Colocasia esculenta* L.), tannia or new cocoyam (*Xanthosoma sagittifolium* (L). Schott) and elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). Tannia has originated in tropical America. It closely resembles taro. However, the plants as well as the tubers are larger than those of taro. Taro has peltate leaves while tannia has sagittate or hastate leaves. Tannia prefers warm humid climate prevalent in the tropical regions of the world. The crop is suited to high rainfall areas receiving an annual precipitation of 140 to 200 cm but it can also grow well with an annual rainfall as low as 100 cm, provided it is evenly distributed (Ramesh *et al.*, 2007). Even though the growth habit of tannia is similar to taro, it is comparatively drought tolerant and sensitive to water logging (Sunitha *et al.*, 2013).

Tannia is cultivated for its edible tubers (mother corm and cormels) and tender leaves. The starchy tubers occupy an important place in the diet of people in many tropical countries. The subterranean cormels are used as high-energy food (17 to 26 per cent carbohydrates) and have nutritional value comparable to potato (Onwume and Charles, 1994; Agueguia, 2000). Young tender leaves with protein content of 22.2 g 100 g^{-1} is also consumed, similar to spinach. The carbohydrate present in tubers is mostly starch. The starch has relatively large grains with average diameter of 17 to 20 µm (Onwume, 1978). Industrially the cormels are used for production of starch (Lauzon *et al.*, 1995) and foliage as poultry feed. The mother corms are more acrid than the cormels but are also used as human food or animal feed after cooking, besides as planting material. Minute bundles of calcium oxalate crystals present in the corms have an irritating effect, which get leached out in water during boiling (Agueguia, 2000). In some places, flesh scrapings of corms and cormels are applied to stop bleeding of wounds and are used as anti-tetanus and anti-poison agents against tarantula, scorpion and snake bites.

Pushpakumari and Sasidhar (1996) have classified tannia as a shade loving crop since shading upto 50 per cent solar radiation was found beneficial for the crop. According to Ramesh *et al*. (2007), tannia is one of the most shade tolerant food crops. Hence it is suited for intercropping with plantation crops. Under intercropping situations in coconut garden, medium spacing of 75 cm x 75 cm was found optimum for tannia (Pushpakumari *et al*., 1999). From studies at ICAR-CTCRI, it was found that the effect of different spacings (60 cm x 60 cm, 75 cm x 75 cm, 90 cm x 90 cm and 120 cm x 120 cm) were on a par in recording maximum cormel yield (CTCRI, 2000). Considering the labour involved and the quantity of planting material required, a plant spacing of 75 cm x 75 cm can be adopted for tannia.

Considerable variation in yield has been observed when tannia is grown in different soil types. There is scope for productivity enhancement in tannia by adopting proper tillage practices. There are reports of increased tuber yield of sweet potato, elephant foot yam and colocasia due to use of soil conditioners like coir pith. Tannia responds well to organic manures and chemical fertilizers. But there are no specific studies on the effect of tillage system, soil conditioner and nutrient management for productivity enhancement in tannia. Hence relevant literature on the effects of tillage, soil conditioners, INM and organic nutrition on growth, yield and quality of tannia and nutrient uptake by the crop as well as on soil properties are reviewed in this chapter. Wherever sufficient information is lacking, relevant literature on other tuber crops are also reviewed.

2.1 EFFECT OF TILLAGE ON CROP GROWH AND SOIL PROPERTIES

Tillage is defined as the physical manipulation of soil to produce a suitable tilth for better growth and yield of crops. Tillage affects the soil physical environment through its effect on physical properties of soil. The change in bulk density, which always accompanies tillage, alters the porosity and pore size distribution and particle to particle contact. The latter changes in the physical properties affect soil water regime, soil aeration, soil temperature and soil mechanical resistance to root growth. Progress in tillage research has been greatly hindered due to the soil and weather conditions which affect tillage results.

Soil compaction can cause unfavourable physical, chemical and biological conditions in subsoil which hinder root growth and crop yield (Hamza and Anderson, 2005; Mosaddeghi *et al.*, 2009). According to Zhang *et al.* (2006), subsoil compaction is caused by inappropriate tillage and untimely field operations. Soil compaction of agricultural soils is mainly due to deteriorated soil environments (Hamza *et al.*, 2011). Daniells (2012) opined that tillage is one of the most effective ways to reduce soil compaction.

Soil physical properties and crop growth are affected by tillage systems (Mosaddeghi *et al.*, 2009).Griffith *et al.* (1977) and Gantzer and Blake (1978) observed a drastic increase in bulk density with no-till compared to mouldboard ploughing of clay loam soil. Cassel (1982) opined that one of the soil physical properties always altered by tillage operations is bulk density and most changes in soil's physical environment caused by tillage are reflected through its effect on bulk density. Increased bulk density values with conventional and no-till systems and lower bulk density with chisel tillage in poorly drained soil were also found by Blevins *et al.* (1983). Chaudhary *et al.* (1985) reported that bulk density was lower in the 10 to 30 cm layer in plots dug 45cm deep than that in the corresponding layers of 10 cm deep tilled plots.

A change in bulk density is always associated with a change in total porosity and pore size distribution in soil (Burwell and Larson, 1969). In compacted soils, the total porosity decreases largely at the expense of large pores while loosening has the reverse effect. Burwell and Larson (1969) also reported that disc harrowing and ploughing increased the porosity of 0 to 15 cm soil layer from 53 to 60 and 66 per cent respectively.

Tillage also affects soil water retention by changing surface water detention, infiltration and redistribution and evaporation of water from soil. Burwell and Larson (1969) reported that lowering of bulk density increased the soil water retention. Rough soil surface and depressions caused by tillage decrease runoff by storing some amount of the rain water. Water retained in the surface depressions increases the opportunity time and therefore, the water intake into the soil. Lindstrom *et al.* (1974) found considerably higher water content with chiselling compared to no tillage. Gantzer and Blake (1978) pointed out that infiltration rates and porosity in tilled soil decrease over time as rainfall, irrigation and settling decrease the initial increases provided by tillage. Henderson (1979) stated that the major factor determining the effect of tillage on infiltration was the structural stability of the surface soil. A loose rough surface was reported to help rain water entry into the soil. Zachman *et al.* (1987) observed that till-residue and no-till residue had higher infiltration rate than the corresponding no residue treatments.

Surface roughness caused by loosening of the upper soil layer by tillage reduces albedo, increases the area of soil exposed to atmosphere and allows greater penetration of wind (Ojeniyi and Dexter, 1979) which improves the microbial activity. Laddha and Totawat (1997) reported that deep tillage reduced soil strength and soil bulk density, improved water storage in the soil, enhanced root growth and increased crop production. According to Hakansson *et al.* (1998), it may be profitable to plough sandy soils annually as deep as 30 cm, but in clay and clay loam soils, ploughing deeper than 20 to 25 cm generally cannot be recommended. Ji *et al.* (2013) reported that soil compaction was positively correlated with bulk density or penetration resistance and deep tillage improved the soil physical characters.

Howeler *et al.* (1993) observed that under soil compaction, top growth of tuber crops flourished at the expense of tuberous root thickening. Conventional tillage enhanced tuber yield compared to zero tillage. This might be due to improvement in soil porosity produced by tillage (Ojeniyi and Adekayode, 1999; Adediran *et al.*, 1999). When tillage to a depth of 10, 20 and 30 cm depth were studied in potato, it was found that all levels of tillage improved the physical and chemical properties of soil. The bulk density decreased with increased depth of tillage. Soil pH, EC, organic carbon and soil nutrient status increased with increase in depth of tillage. Plant height, number of branches, number of leaves and yield of potato crop also increased with increase in depth of tillage. Combined application of tillage at 30 cm depth and FYM @ 30 t ha^{-1} was found beneficial in increasing the productivity of potato and improving the physico-chemical properties of soil (Kumar *et al.*, 2015).

Studies conducted at Puerto Rico revealed that the yield of tannia increased on an average from 1.8 to 15.1 t ha^{-1} due to better land preparation. But the yield was considerably reduced due to soil resistance to penetration when it was more than or equal to 25 kg cm^{-2} at 15 cm depth (Mercado *et al.*, 1978). Hullugalle *et al.* (1985) reported that physico-chemical properties of the soil were significantly improved by tillage and mulching which reflected in the growth and yield of tannia in the Ultisol in eastern Nigeria. Soil physical and chemical conditions prevailing at planting depth is closely related to germination process, emergence, nutrient uptake and survival of tannia (Ramesh *et al.*, 2007). As in the case of other tuber crops, the land should be made to a fine tilth for proper tuberisation. Ploughing to a depth of 20 to 40 cm followed by the formation of ridges and furrows can improve the growth and production of tubers especially in heavy textured soils. According to Agbede (2008), the actual yield and tillage requirement of cocoyam has not yet been properly documented.

A degree of soil manipulation appears to be indispensible for cocoyam production on tropical Alfisols (Adekiya *et al.*, 2011). The differences in bulk density dictated the differences in the growth and yield of cocoyam between manual clearing, manual tillage and mechanized tillage systems. Ploughing + harrowing, manual ridging and manual mounding increased growth and yield of cocoyam relative to manual clearing and ploughing + harrowing twice. These tillage systems (ploughing + harrowing, manual ridging and manual mounding) showed promising potential in conserving soil fertility in an Alfisol compared with ploughing + harrowing twice. Ploughing + harrowing twice was found to be most disadvantageous to soil and cocoyam productivity and therefore not recommended for cocoyam cultivation. On a small scale, either manual ridging or manual mounding is recommended. For large scale cocoyam production, ploughing + harrowing is recommended.

2.2 EFFECT OF SOIL CONDITIONERS

A soil conditioner is a product which is added to soil to improve the soil's physical qualities, especially its ability to provide nutrition for plants. Usually, organic materials like crop residues are used as soil conditioner. Utilisation of crop residues and farm animal waste in crop production ensures organic recycling and increases productivity of crops through improvement in physical, chemical and biological properties of soil. Recycling of crop residues is an integral part of integrated plant nutrition which is now being increasingly recognized as the strategy for sustaining high crop yield level with minimal depletion of soil fertility or fall in its other quality aspects (Bhardwaj, 1995).

After the incorporation of crop residues, heterotrophic microorganisms bring about mineralization of carbon and other elements contained in the residue. Thus, there is a large increase in the soil microbial population and evolution of CO_2 from the residue treated soil (Sedha *et al*., 1991). Lal *et al*. (2000) reported significant increase in population of aerobic, non symbiotic, nitrogen fixing, phosphate solubilising and sulphur oxidizing microorganisms due to incorporation of crop residues of *Lantana camera*, *Ipomoea cornea*, water hyacinth, leaves of *Pongamiaglabra*, subabul leaves, lentil straw, maize stover and rice straw in acid clay loam soil.

More (1994) reported that addition of farm wastes and organic manures improved the status of organic carbon and available NPK in soil. Gupta *et al.* (2000) opined that crop residue incorporation resulted in decreased bulk density and increased water holding capacity of the soil. Nedunchezhiyan*et al*. (2013) reported lower soil resistance in FYM and paddy straw applied sweet potato fields. Lower soil resistance in the rhizosphere facilitates rapid bulking of the corms. As crop residues are poor conductors of heat that effectively moderates soil temperature, maintain soil moisture and increase fertility, their use in crop production is a viable preposition to retain soil moisture and nutrients. But, costs are also incurred in their application. Thus it is necessary that a suitable amount of crop residue can be applied in a cost effective manner to enhance crop productivity (Choudhary *et al*., 2016).

2.2.1 Utilization of Coir Pith

India ranks third in the world coconut production. The pith material forming non fibrous tissues of the husk is generally referred to as coir pith or as coco-peat (Bhowmic and Debnath, 1985). Coirpith constitutes about 70 per cent of the coconut husk and hence, coconut husk is mainly used for extracting coir fibre. There are about 84,000 retting and coir extracting units located in Kerala, producing white fibre (Arumughan and Damodharan, 1993). According to Doraisamy and Ramasamy (1994), coir pith is the recalcitrant complex molecule which causes solid waste pollution problems. Annual production of coir pith in India is about 7.5 million tonnes (Kamaraj, 1994), out of which 11 lakh tonnes is from Kerala alone. Mukherjee (2001) reported that for every tonne of the fibre, about two tonnes of coir dust is produced which occupies large space due to its low density (ρ= 0.2 g cc^{-1}).

Hume (1949) had reported the beneficial use of coir pith waste in agriculture as rooting medium, mulch and soil conditioner to improve soil drainage. It has high potassium content and low bulk density and particle density. The low particle density is due to high specific surface which gives it a high cation exchange capacity (Mapa and Kumara, 1995). High cation exchange capacity of coir pith was also reported by Mbah and Pdili (1998). Verhagen and Papadopoulos (1997) found that the high cation exchange capacity, varying from 38.9 to 60 meq100g^{-1}, enables coir dust to retain large amounts of nutrients and the absorption complex has high contents of exchangeable K, Na, Ca and Mg. Studies conducted by Prabhu and Thomas (2002) revealed that coir pith could prevent the loss of nutrients due to its high nutrient storage capacity by virtue of high cation exchange capacity. Coir pith can also curtail the loss of N through leaching by reducing the rate of nitrification due to the presence of nitrification inhibitors.

Increase in water holding capacity of the soil due to coirpith application has been reported by Bhowmic and Debnath (1985). Studies by Menon (1987) revealed that coir pith can absorb water by about eight times its weight. Das (1992), after studying the physical properties of coir pith, also found that it has a porosity of about 70 per cent and has a water holding capacity of above 500 per cent. Numerous studies were conducted on the water holding capacity of coir pith. The water holding capacity of raw coir pith was 624 per cent as reported by Rajanna (1988), 400 to 600 per cent as reported by Savithri and Khan (1994) and 775.31 per cent by Anand *et al.* (1998).

The pH of coirpith samples collected from different parts of Tamil Nadu were tested and found that the pH ranged between 6.2 to 7.1 (Savithri *et al.*, 1997) while that of the sample from Karnataka was 6.12 (Anand *et al.*, 1998). According to Mukherjee (2001), the coir pith is acidic in nature.

Nambiar *et al.* (1983) observed that the organic carbon status of the soil was improved with continuous application of coir dust for eight years. The organic carbon content of raw coir pith varied with sample and it was reported to be 29 per cent by Nagarajan *et al.* (1985), 29.05 per cent by Theradimani and Marimuthu (1992), 48.12 per cent by Anand *et al.* (1998), 28.97 per cent by Ramamoorthy *et al.* (1999) and 28.94 per cent by Ramamoorthy *et al.* (2000).

Coir pith, which is abundantly available in Kerala, can be a good source of organic manure. But we cannot directly apply coir pith alone to the field crops as nutrient source because it has got wider C:N ratio (112:1) coupled with low nitrogen content, presence of soluble tannin related phenolic compounds (8 to 12 per cent), its slow and difficult biodegradability due to high lignin content as observed by Fan *et al.* (1982).But coir pith can be used as an organic manure after narrowing down its C : N ratio by composting with suitable microbial inoculants.

The use of coirpith as a soil conditioner in tropical farming is well established (Nagarajan *et al.*, 1990). Loganathan (1990) reported that the application of coir dust resulted in improved soil physical characteristics like infiltration, total porosity and hydraulic conductivity of red soil with hard pan. Further studies by Cresswell (1992) found that the beneficial properties of coir dust, like high water holding capacity, excellent drainage, absence of weeds and pathogens, physically resilient, renewable resource with no known ecological drawbacks, slow decomposition, easily wettable, and no sticks or other extraneous materials, make it suitable as a substrate component. Logmadevi (1997) reported that when coir pith was applied to soil, it reduced the bulk density and increased water holding capacity of soil. Even with these characters, coirpith is still an underutilized by-product of coconut.

Studies by Ayyaswamy *et al.* (1996) revealed significant increase in tuber yield of cassava due to incorporation of coir waste @ 10 t ha^{-1} compared to FYM @ 12.5 t ha^{-1} and coir waste @ 5 t ha^{-1}. Mukherjee (2001) observed significant increase in yield of sweet potato, taro and elephant foot yam when soil was amended with coir pith (1:1 or 50 per cent) over control (100 per cent soil) which can be attributed to the unique properties of coir pith like longer retention of moisture and slow release of nutrients.

2.2.2 Utilization of Rice Husk

Rice (*Oryza sativa L.*) is the most staple food for more than half of the world's population. Ricehusk is the natural sheath or protective cover which forms the cover of rice grains during their growth. It represents about 20 per cent by the weight of the rice harvested. During rice refining processes, the husks are removed from grains. Rice husk contains 75 to 90 per cent organic matter such as cellulose, lignin etc. and rest mineral components such as silica, alkalis and trace elements and hence it can be used as a value added raw material for different purposes (Kumar *et al.*, 2013). Because of its high silicon dioxide content, it is not useful to feed either human or cattle. It has a bulk density of 96 to 160 kg m^{-3}, 31 to 37 per cent oxygen, 0.23 to 0.32 per cent N and 0.04 to 0.08 per cent sulphur (Kumar *et al.*, 2013). It has good adsorption capacity for heavy metals. It can be used to treat heavy metals either in the untreated or modified form using different methods (Srinivas and Naidu, 2013).

The use of fresh crop residue has been found to bring about more favourable physical improvements in soil than composted materials. Application of rice husk @ 10 to 15 t ha^{-1}on alkali soil having low water permeability is reported to bring about significant increase in its infiltration rate (Khosla, 1976). Henpithaksa (1993) observed increased yield of elephant foot yam from soil amended with rice hulls, maize cobs, cattle manure and coir peat. Organic modification of soil with rice husk was found effective to enhance the yield of many crops like cowpea and rice (Ebaid and El-Refaee, 2007; Aliyu *et al.*, 2011) which might be attributed to the effect of rice husk in improving the soil porosity enabling better proliferation of plant roots in soil resulting in increased nutrient absorption.

2.3 EFFECT OF NUTRIENT MANAGEMENT

Tannia responds well to application of organic manures and chemical fertilizers (Karikari,1971; Giacometti and Leon, 1994).Wilson (1984) reported that the leaf growth and cormel yield increased due to fertilizer application in tannia. High fertilization was found to reduce the time required for cormels to reach the maximum size. However, in traditional tannia cultivation in Africa, Central America and parts of pacific islands, little or no fertilizers are used particularly when the crop is grown on land that has been cleared from bush fallow (Onwume and Charles, 1994). This indicates that tannia prefers soil rich in nutrients and organic management (Suja *et al.*, 2009).

John *et al.* (2006) have reported the prevalence of wide spread deficiencies of K, Ca and Mg (due to complex multi nutrient interaction) in tannia in the acid laterite soils resulting in complete crop failure. John and Suja (2007) observed the interplay of three basic cations, K, Ca and Mg as interfering with the growth of the crop. The nutrient disorders can be corrected to some extent by altering the pH through addition of lime or gypsum. Increasing the organic matter content of the soil by incorporation of crop residues or addition of compost or mulching also has a beneficial effect by providing a steady supply of available plant nutrients.

2.3.1 Effect of INM

Judicious combination of organic and inorganic sources of plant nutrients has been found to be the best option for increasing productivity and maintaining sustainability in crop production. Combined application of available organic sources along with inorganic fertilizers augments uptake of nutrients resulting in higher and sustained crop yield and soil productivity (Manna *et al*., 2003). The supplementary use of organic manures and inorganic fertilizers enhances the efficiency of both to maintain soil productivity (Ayoola and Adeniyan, 2006). Nutrient disorders can be alleviated to a great extent by supplying nutrients through inorganic fertilisers, organic manures and biofertilizers in an integrated approach (John *et al*., 2006). Sole application of inorganic fertilizers leads to their imbalance and inadequate use resulting in poor yield, deterioration of soil fertility and multiple nutrient deficiencies (Acharya and Mondal, 2007).Hence integrated use of all sources of plant nutrients ensures balanced nutrition to crops and sustains soil fertility.

Studies conducted at ICAR - CTCRI established the significance of INM practices in enhancing yield and quality of tropical tuber crops (John, 2010a). KAU (2011) has also given recommendation of INM practices in tuber crops except tannia. CTCRI (2011) has reported the INM strategy for tannia which involves FYM @ 25 t ha^{-1} + 80:50:150 kg NPK ha^{-1}.Split application at planting and at two, four and six MAP is recommended for tannia (Giacometti and Leon, 1994; CTCRI, 2011).

2.3.1.1 Effect on Tuber Productivity and Profitability

Saud *et al.* (2013) reported that the yield and economic returns from upland taro, which is cultivated as a cash crop by the small and marginal farmers of Assam, can be maximised by adopting INM practice involving vermicompost (1 t ha^{-1}), FYM (10 t ha^{-1}) and NPK @ 60:45:90 kg ha^{-1}as chemical fertilizers.

Sahoo *et al.* (2014) observed higher leaf area $plant^{-1}$, corm bulking efficiency and corm yield of elephant foot yam plants supplied with FYM along with graded dose of inorganic nutrition over the plants that were supplied with graded dose of inorganic nutrition alone.

Suja (2001) obtained higher tuber yield and higher profit in white yam intercropped in coconut garden due to integrated application of coir pith compost @ 5 t ha^{-1} along with 80:60:80 kg NPK ha^{-1}.

Combined use of NPK and FYM in cassava could produce a yield increase of four times higher when FYM or any other nutrients (N, P or K) were applied individually as reported by Mohankumar (2000). Integration of both inorganic fertilizers and organic manure is important for obtaining good yield in cassava (Joseph and Abraham, 2004). According to Sekhar (2004), a fertilizer dose of 50:50:100 kg NPK ha^{-1} along with FYM at 12.5 t ha^{-1} was found optimum for short duration cassava var. Vellayani Hraswa which produced maximum tuber yield of 47.09 t ha^{-1} and a higher benefit cost ratio (BCR) of 3.32. Geetha (2004) reported that, for cassava var. M4, application of 53:12.5: 34.5 kg NPK ha^{-1} along with 12.5 t ha^{-1} of FYM was found optimum for higher yields when grown in coconut gardens. Pamila *et al.* (2006) pointed out that application of FYM @ 12.5 t ha^{-1} or poultry manure @ 5 t ha^{-1} along with 75:50:100 kg NPK ha^{-1} resulted in higher returns from cassava var. Sree Vijaya and Kariyilapothiyan cultivated in lowlands. Integrated application of cattle manure or compost @ 12.5 t ha^{-1} as basal dose and NPK @ 100:50:100 kg ha^{-1} is usually recommended for high yielding cassava varieties. For M4 and local varieties, half the above dose is sufficient (John, 2010b). Growth characters like plant height, main and sub branches, leaf length, leaf breadth and fresh total biomass and yield attributes like length and girth of tubers, number of tubers, average tuber weight and tuber yield plant^{-1} were significantly influenced by combined application of organic manures, green manure and inorganic fertilizers in cassava (Mhaskar *et al*., 2013).

For economic production of coleus, integrated application of FYM @ 10 t ha^{-1} along with 60:30:120 kg NPK ha^{-1} was suggested by Geetha and Nair (1993). KAU (2011) recommends a fertilizer dose of 60:60:100 kg NPK ha^{-1} along with FYM @10 t ha^{-1} for coleus during the normal planting season. Anju *et al*. (2015) have modified the nutrient dose to 60:30:120 kg NPK ha^{-1} through fertilizers + FYM @ 10 t ha^{-1} + neem cake @ 1 t ha^{-1} for getting higher tuber yield of coleus var. Suphala during the off season.

According to Maheswarappa *et al*. (1997) combined application of FYM and NPK could produce increased yield of arrowroot intercropped in coconut garden. Veenavidyadharan and Swadija (2000) also observed that combined application of 10 t ha^{-1} FYM and 120:50:80 kg NPK ha^{-1} is most advantageous for arrowroot intercropped in coconut garden which resulted in the highest net income and benefit cost ratio.

2.3.1.2 Effect on Tuber Quality

Balanced application of NPK @ 100:50:100 kg ha^{-1} along with FYM @ 12.5 t ha^{-1}was found to be effective in improving the starch content (20.68 per cent on fresh weight basis) and decreasing the cyanogenic glucoside content of cassava tubers (88.16 μg g^{-1}) compared to the application of N, P, K singly or in two nutrient combination both alone and together with FYM (John *et al*., 2005). John *et al*. (2007) reported that for cassava var. Sree Vijaya, application of 100:300:300 kg NPK ha^{-1} along with FYM @ 12.5 t ha^{-1} is beneficial for obtaining enhanced plant dry matter content and good quality tubers.

Maheswarappa *et al*. (1997) observed higher starch and crude protein contents of arrowroot due to conjoint use of FYM and fertilizers.

John (2010a) reported the significance of INM practices for improving the tuber quality of tropical tuber crops.

Protein content of potato (on dry weight basis) was significantly higher (10.18 per cent) in the treatment combination of 50 per cent recommended dose of nutrients through FYM and 50 per cent through inorganic fertilizers (Kumar *et al.*, 2011).

2.3.1.3 Effect on Nutrient Uptake

John *et al.* (2007) reported enhanced uptake of nutrients by cassava var. Sree Vijaya due to combined application of 100:300:300 kg NPK ha^{-1} and FYM @ 12.5 t ha^{-1}.

Favourable effect of integrated nutrient management using inorganic fertilizers and organic manures in increasing the uptake of N, P and K by potato was also noticed by Kumar *et al.* (2008) and Baishya (2009).

2.3.1.4 Effect on Soil Properties

Panda (2011) reported that the soil physical conditions in terms of soil structure, aggregate stability, soil moisture retentivity and hydraulic conductivity can be improved by INM practices.

Application of graded levels of fertilizers (NPK @ 100:60:100, 80:60:80 and 60:60:60 kg ha^{-1}) along with FYM 10 t ha^{-1} recorded lower level of soil resistance than application of only graded levels of inorganic fertilizers at 3 MAP and 5 MAP of elephant foot yam (Sahoo *et al.*, 2014).

2.3.2. Effect of Organic Nutrition

Organic farming has a potential for reducing some of the negative impacts of conventional agriculture to the environment and an option to restore the productivity of degraded soils. Kumar *et al.* (2005) recorded prolonged effect of organic manures on fertility and soil moisture balance. It also reduces the chemicals needed for pest control, besides improving the soil physical properties in the long run (Kumar *et al.*, 2011).

Farmyard manure is the most commonly used organic manure which contains both macro and micro nutrients although in smaller quantities. Being organic and bulky in nature, it improves the physico-chemical and biological properties of soil. It acts as a buffering agent which reduces the toxicity of excessive acid, alkali or salts present in the soil. Kumar *et al.* (2015) reported that soil bulk density was lowered due to application of FYM over control and showed a decreasing trend with increasing levels of FYM. Similarly soil pH, electrical conductivity (EC) and nutrient status increased with increasing levels of FYM.

Wood ash is the residue powder left after the combustion of wood such as burning wood in a home fireplace or an industrial power plant. It contains calcium carbonate as its major component (25 or even 45 per cent). Wood ash can be used as a concentrated organic manure to enrich soil fertility as a source of potassium and calcium carbonate, the latter acting as a liming agent to neutralize acidic soils. In the present study, household wood ash is mainly used as a source of potassium. Household wood ash contains 0.5 to 1.9 per cent N, 1.6 to 4.2per cent P_2O_5 and 2.3 to 12per cent K_2O (Sharma, 2005).

Tannia has great potential for organic production. Suja *et al.* (2009) reported that, among the various nutrient management practices tried (organic and inorganic sources of nutrients as well as their combinations), application of FYM @ 12.5 t ha^{-1} and ash @ 3 t ha^{-1} favoured plant height, leaf production, number of cormels, cormel yield, mother corm yield and dry biomass yield of corms and cormels. In the subsequent studies, organic farming involving the use of organic manures *viz.* FYM @ 20 t ha^{-1}, green manuring with cowpea to generate 15 to 20 t ha^{-1} of green matter in 45 to 60 days, neem cake @ 1 t ha^{-1} and ash @ 2 t ha^{-1}profoundly favoured plant height and leaf production and produced significantly higher cormel yield (11.25 t ha^{-1}) and mother corm yield (22.96 t ha^{-1}).

2.3.2.1 Effect on Tuber Productivity and Profitability

Application of FYM @ 30 t ha^{-1} to elephant foot yam produced a higher corm yield in Gujarat (Patel and Mehta, 1987).Organic nutrition is a viable approach to maximise productivity and quality of elephant foot yam while maintaining soil fertility (Suja *et al.*, 2006; 2012a; 2012b). Elite and local varieties responded equally well to organic and conventional farming in elephant foot yam (Suja *et al.*, 2012a). In a study conducted to standardize organic nutrition for elephant foot yam, application of 50per cent of the recommended dose of N as organic along with the basal dose of FYM was found to be economical (Girijadevi *et al.*, 2013).

According to Suja and Sreekumar (2014) organic farming is an eco-friendly farming strategy in yams for getting higher yield of quality tubers and safe food besides maintaining soil health. The technology for organic production in yams comprised of application of FYM @ 15 t ha^{-1}, green manure (to yield 15 to 20 t ha^{-1} of green matter in 45 to 60 days), ash @ 1.5 t ha^{-1}, neemcake @ 1 t ha^{-1} and biofertilizers (Azospirillum @ 3 kg ha^{-1}, mycorrhiza @ 5 kg ha^{-1} and phosphobacteria @ 3 kg ha^{-1}) (Suja and Sreekumar, 2014).

Dhanya (2011) observed that organic production system is economically feasible in sweet potato. The full recommended dose of nutrients through organic manures was required for expressing the yield potential of the crop. Substitution of 100 per cent recommended dose of nutrients with poultry manure was the best treatment followed by FYM which fetched BCR of 2.03 and 1.81 respectively.

According to Radhakrishnan *et al.* (2013), organic management in cassava enhanced tuber yield by 8 per cent over conventional practice.

Application of 100 per cent recommended dose of NPK (60:60:100 $kgha^{-1}$) through organic manures (6t FYM + 3t CPC + 3 t wood ash ha^{-1}) along with PGPR mix 1 and the recommended basal dose of FYM @ 10 t $ha^{-1}$was required for getting higher yields of organic coleus (Jayapal *et al.*, 2013). Higher net income and BCR could be obtained by the application of 100per cent or 75 per cent level of organic manure (Jayapal *et al.*, 2016).

Organic nutrition had significant influence on rhizome yield of arrow root (Swadija *et al.*, 2013a).Application of even the lowest dose of FYM (10 t ha^{-1}) produced significantly higher rhizome yield (15.46 t ha^{-1}- 46 per cent higher yield) over control (no manure - 10.59 t ha^{-1}). The highest rhizome yield (18.62 t ha^{-1}), net income (₹ 74,450 ha^{-1}) and BCR (1.99) could be obtained by the application of FYM @ 15 t ha^{-1} + biofertilizers.

2.3.2.2. Effect on Tuber Quality

In elephant foot yam, organic farming improved the tuber quality with significantly higher dry matter and starch contents and lower oxalate content (Suja *et al.*, 2010; 2012a; 2012b; Suja, 2013). Kolambe *et al.* (2013) also reported significantly higher total sugar and starch contents and improvement in protein content of corms of elephant foot yam due to organic management. In yams, organic tubers had slightly higher dry matter and crude protein contents (Suja, 2013). Kaswala *et al.* (2013) reported significant improvement in starch and carbohydrate contents of yam tuber under organic management.

Kurian *et al.* (1976) observed increase in bitterness and cyanogen content in cassava due to application of cowdung alone. A mixture of cowdung and ash tended to reduce the cyanogens. Application of ash (7 to 8 per cent K_2O) in place of K fertilizers like muriate of potash improved the quality of cassava tubers apart from maintaining the available K status of the soil (John *et al.*, 2005).

Dhanya (2011) obtained higher starch content of tuber when full recommended dose of nutrients for sweet potato was substituted through FYM.

When 100 per cent, 75 per cent and 50 per cent substitution of recommended dose of nutrients for coleus with organic manures was studied, Jayapal *et al.* (2016) obtained increased starch and protein contents of coleus tubers with increase in the level of organic manure.

According to Swadija *et al.* (2013b), the quality characters of rhizome of arrowroot *viz.* dry matter, starch, crude protein and crude fibre contents improved due to application of even 10 t ha^{-1} of FYM alone over control. The study revealed the sufficiency of FYM @ 15 t ha^{-1} + biofertilizers for improved rhizome quality of arrowroot intercropped in coconut.

2.3.2.3 Effect on Nutrient Uptake

In sweet potato, the highest NPK uptake was registered by supplying full recommended dose of nutrients through organic manures (Dhanya, 2011). 41

Uptake of N, P and K increased with incremental levels of organic manure in coleus (Jayapal *et al.*, 2014).

2.3.2.4 Effect on Soil Properties

Organic nutrition not only improves the yield but also improves the fertility status of the soil. Srivastava (1985) and More (1994) also reported that addition of organic manures increased the status of organic carbon and available N, P and K in soil. Kabeerathumma *et al.* (1993) reported increased Ca and Mg in the soil due to application of wood ash. Clark *et al.* (1998) reported increase in soil organic matter, soil pH and available P and K in organic systems. Increased aeration, porosity and water holding capacity of soils have been observed under organic management (Gerhardt, 1997). Organic farming envisages a comprehensive management approach to improve the soil health underlying the productivity of a soil (Palaniappan and Annadurai, 1999).Colla *et al.* (2000) reported that *in situ* water holding capacity was the highest in organic system.

According to Suja *et al.* (2010), organic farming proved significantly superior in elephant foot yam at all farm sites tested due to overall improvement in soil physico-chemical properties under the influence of organic manures. Suja *et al.* (2012b) reported significantly higher water holding capacity and porosity and slightly lower bulk density and particle density in organic plots under elephant foot yam. Almost similar trend was observed in the water holding capacity and particle density of organic plots under yams. Organic farming resulted in significant improvement in pH and soil organic matter over conventional systems in both elephant foot yam and yams. Post harvest soil analysis indicated higher N and P status in the case of both crops and also significant improvement in soil available K after yams.

Application of organic manures continuously from 2005 to 2011 lowered the bulk density. The lowering of bulk density coupled with greater mineralization of organic matter was found to be beneficial for a tuber crop like elephant foot yam (Kolambe *et al.*, 2013). Kaswala *et al.* (2013) observed higher organic 42 carbon, macro and micro nutrient contents in the soil due to organic nutrition for greater yam.

Radhakrishnan *et al.* (2013) found significant increase in soil pH due to organic management after two years of cropping with cassava. Organic carbon status was increased by 9.5per cent over the conventional practice. But no significant difference in the status of available N, P and K was observed after the second crop. However, exchangeable Ca, Mg, Fe, Cu and Zn were slightly favoured under organic practice. The physical properties of the soil *viz.* bulk density, particle density and water holding capacity were unaffected due to various production systems except a slight lowering of bulk density and particle density and higher water holding capacity and porosity due to organic management.

Archana (2001) also reported that there was no depletion of soil nutrients when organic manure was applied to coleus. Organic carbon and available P and K contents showed significant increase with incremental levels of organic manure after growing coleus and improvement in available N content which indicates that organic nutrition improves the fertility status of the soil (Jayapal *et al.*, 2014).

Several studies conducted on potato indicated that soil resistance against tuber growth was reduced by compost application (Tu *et al.*, 2006; Taheri *et al.*, 2012). Sahoo *et al.* (2014) also opined that organic source of nutrients enhanced soil structure and reduced the soil resistance for cultivation of tuber crops.

2.3.3 Comparison of INM and Organic Nutrition

2.3.3.1 Effect on Tuber Productivity and Profitability

There is ample scope for organic production of aroids since these crops respond well to organic manures (Ray *et al.*, 2006; Suja and Nayar, 2006; Suja *et al.*, 2006). Tannia is more adapted to organic cultivation and has great potential for organic production (Suja *et al.*, 2009). Application of FYM @ 12.5 t ha^{-1} along with wood ash @ 3 t ha^{-1} favoured growth and yield of tannia compared to INM (FYM @ 12.5 t ha^{-1} + NPK @ 80:50:100 kg ha^{-1}).

The superiority of organic nutrition in elephant foot yam, another important aroid, has been reported by many scientists. Ray *et al*. (2006) reported the highest yield (45.89 t ha^{-1}) of elephant foot yam with organic manures alone followed by inorganic fertilizers alone (42 t ha^{-1}). Among organic manures, the highest yield was obtained for *Karanj* cake @ 500 g plant^{-1} followed by paddy husk @ 1 kg plant^{-1} compared to FYM @ 5 kg plant^{-1}. Organic nutrition package standardised in elephant foot yam comprising FYM, green manuring, neem cake and wood ash profoundly favoured growth and yield of elephant foot yam over conventional (INM) practice (Suja *et al*., 2008; 2010; 2012a). On farm validation of organic farming technology in elephant foot yam revealed that organic farming resulted in higher corm yield (34.6 t ha^{-1}) and additional income of ₹ 43,651 ha^{-1} (BCR of 1.49) over INM (BCR of 1.40) in farmer's field trials (Suja *et al*., 2010). Studies at ICAR-CTCRI indicated that organic farming resulted in 20 per cent yield increase in elephant foot yam with an additional income of ₹ 47,716 ha^{-1} over conventional practice (Suja *et al*., 2012b). Kolambe *et al*. (2013) reported that the organic treatments were on a par with chemical based farming for the growth parameters like plant height, pseudo stem girth and canopy spread as well as corm yield of elephant foot yam. Higher net return of ₹ 2,81,434 ha^{-1} and BCR of 2.7 were registered due to application of FYM @ 10 t ha^{-1} + NPK @ 80:60:100 kg ha^{-1} for elephant foot yam compared to organic nutrition (net income of ₹ 2,55,500 ha^{-1} and BCR of 2.5).If premium price is obtained, organic production of elephant foot yam would become more profitable than chemical based farming. The BCR in all the organic treatments can be further raised if organic manures would be on-farm generated. According to Sahoo *et al*. (2014), application of FYM @ 10 t ha^{-1} + 100:60:100 kg NPK ha^{-1} or FYM @ 25 t ha^{-1} was required for better growth and higher corm yield. These treatments produced 105.7 per cent and 97.1 per cent higher corm yield respectively, over control.

White yam, greater yam and lesser yam responded equally well to organic and conventional farming with slightly higher yield under organic farming. The yield increase observed under organic farming in white yam, greater yam and lesser yam were 9.35, 10.51 and 6.85per cent respectively over conventional practice (Suja *et al*., 2012a). But Kaswala *et al*. (2013) observed the highest tuber yield of greater yam in INM treated plants followed by organically managed plants. The INM treatment for greater yam generated higher net income of ₹ 204959 ha^{-1} and BCR of 2.7 followed by organic treatment (net income of ₹ 1,88,643 and BCR of 2.4).

When different nutrient management systems including INM and organic nutrition were compared in cassava, Radhakrishnan *et al*. (2013) observed that growth and yield were favoured under organic nutrition compared to INM. Organic nutrition enhanced yield by 8 per cent over conventional (INM) practice. Girijadevi *et al*. (2013) reported that INM for cassava produced the highest yield of 32.4 t ha^{-1} which was on a par with organic nutrition at 100 per cent, 75 per cent and 50 per cent N dose. Among these organic treatments, 50 per cent N as organic generated higher BCR of 3.17 followed by 100per cent N as organic. The maximum BCR was recorded by INM in cassava.

On comparing INM and organic nutrition practices in coleus, Anju *et al*. (2015) observed that modified nutrient dose of 60:30:120 kg NPK ha^{-1} through fertilizers + FYM @ 10 t ha^{-1} + neem cake @ 1 t ha^{-1} resulted in higher tuber yield compared to organic nutrition.

2.3.3.2 Effect on Tuber Quality

Organic farming improved the quality of elephant foot yam. Organically produced corms of elephant foot yam had significantly higher dry matter and starch contents and lower oxalate content compared to INM as reported by Suja *et al*. (2010). Kolambe *et al*. (2013) also reported higher total sugar and starch contents of elephant foot yam for the organic treatment than the INM treatment. Though the protein content was not significantly affected, the organic treatment resulted in higher protein content than chemical treatment.

In yams, organic tubers had slightly higher dry matter and crude protein contents (Suja *et al*., 2012a). Starch and carbohydrate contents of greater yam 45 tuber were significantly enhanced under organic nutrition compared to INM (Kaswala, 2013).

In potato, maximum dry matter and specific gravity were found with the treatment 100 per cent recommended dose of nutrients through organic manures compared to combination of organic manure and inorganic fertilizers (Kumar *et al.*, 2011).

2.3.3.4 Effect on Soil Properties

Organic farming of tuber crops, involving the use of organic manures, helps to restore and improve soil health by enhancing organic matter levels, neutralising soil acidity, supplying almost all essential nutrients in available form and thereby maintaining soil fertility (Suja *et al.*, 2012a; 2012b). There was significant improvement in soil pH due to organic farming (0.77 and 0.46 unit increase over conventional system) in both elephant foot yam and yams. After five years of cultivation of elephant foot yam and yams, the soil organic matter increased by 19 per cent and 11 per cent respectively in organic plots over conventional plots. In both the crops, available N and P were higher and in yams, there was significant improvement of available K under organic management. Kolambe *et al.* (2013) opined that there was an overall improvement in soil physico-chemical properties under the influence of continuous application of organic manures for elephant foot yam. Organic treatments had higher organic carbon content whereas chemical based farming had the least content. Available P was appreciably higher in chemical farming.

George and Mittra (2001) observed significant increase in organic carbon content with increase in the level of FYM. Organic carbon content was significantly higher with 100per cent nutrient requirement for sweet potato as FYM alone on N equivalent basis followed by 50 per cent as FYM and 50 per cent as chemical fertilizers. Also substantial increase in available N and P, but decrease in K content of the soil were noticed in 100per cent FYM than 50 per cent as FYM and 50 per cent as chemical fertilizers.

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Nedunchezhiyan *et al.* (2013) reported lower soil resistance in FYM and paddy straw applied sweet potato fields. Lower soil resistance in the rhizosphere facilitates rapid bulking of tubers.

Among soil properties, significant effects on organic carbon and available N contents, decreased bulk density and improvement in water stable aggregates were observed in the soil after the harvest of greater yam (Kaswala *et al.* 2013).

The physical properties of the soil *viz.* bulk density, particle density and water holding capacity were unaffected by various production systems in cassava (Radhakrishnan *et al.*, 2013). However, the bulk density and particle density were slightly lower and water holding capacity and porosity were slightly higher in organic plots as compared to conventional plots. At the end of the second year, the pH was significantly higher in organic practice (5.86) and organic C status was raised by 9.5per cent over the conventional system. There was no significant difference in the status of available N, P and K.

A scan of literature revealed that yield of tannia can be improved by suitably modifying the physico-chemical and biological properties of soil by adopting proper tillage and nutrient management. Use of soil conditioner may loosen the soil reducing soil compactness for tuber growth, improve the water holding capacity of the soil and facilitate slow release of nutrients on decomposition. Tannia responds favourably to INM practice. It has also potential for organic production. The chemical fertilizers may be substituted with commonly used organic manures like FYM and ash to meet the NPK requirement of the crop. The favourable soil physico-chemical and biological conditions under the influence of these organic manures may contribute to higher production of tannia. In this context, the present study is undertaken to identify ideal tillage system, soil conditioner and nutrient management for productivity enhancement in tannia.

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MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was carried out at Instructional Farm attached to College of Agriculture, Vellayani to identify ideal tillage system, soil conditioner and nutrient management for productivity enhancement in tannia. The details of the materials used and the methods adopted are presented in this chapter.

3.1 MATERIALS

3.1.1 Experimental Site

The experiment was conducted in the Instructional Farm attached to College of Agriculture, Vellayani, Kerala which is situated at 8.5° North latitude and 76.9° East longitude and at an altitude of 29 m above mean sea level. The field experiments during 2014-15 and 2015-16 were conducted in two separate fields with uniform characteristics.

3.1.2 Soil

The soil of the experimental site was sandy clay loam belonging to the order Oxisol of Vellayani series. The important physico-chemical properties of the soil and methods adopted for analysis are presented in Table 1. The soil was strongly acidic with pH 5.25 to 5.65. It was high in organic carbon and available P and K and low in available N.

3.1.3 Cropping History of the Field

The experimental area (during both the years) was coconut garden previously intercropped with cassava. The coconut palms were in the age group of 30 to 35 years and 25 to 30 per cent shade was experienced in the area.

3.1.4 Season

The first crop was raised during August 2014 to May 2015 and the second crop during May 2015 to February 2016.

Table 1.Physico-chemical properties of the soil of the experimental site

Sl. No.	Parameter	Experimental area I	Experimental area II	Method
A. Mechanical composition				
1.	Coarse sand (%)	18.50	19.25	International pipette method (Piper, 1966)
2.	Fine sand (%)	32.50	30.35	
3.	Silt (%)	27.35	25.50	
4.	Clay (%)	21.65	24.90	
	Texture -	Sandy clay loam		

B. Physical properties

Sl. No.	Parameter	Experimental area I		Experimental area II		Method
		0-15cm depth	15-30cm depth	0-15cm depth	15-30cm depth	
1.	Bulk density (Mg m^{-3})	1.59	1.70	1.67	1.73	Core method (Gupta and Dakshinamoorthi, 1980)
2.	Particle density (Mg m^{-3})	2.41	2.50	2.45	2.48	
3.	Porosity (%)	34.02	32.00	31.84	30.24	
4.	Water holding capacity (%)	23.00	21.20	21.11	20.40	

C. Chemical properties

Sl. No	Parameter	Experimental area I		Experimental area II		Method
		0-15cm depth	15-30cm depth	0-15cm depth	15-30cm depth	
1.	Soil reaction (pH)	5.65	5.26	5.58	5.25	pH meter with glass electrode (Jackson, 1973)
2.	Organic carbon (%)	1.12	0.99	1.38	1.20	Walkley and Black's rapid titration method (Jackson, 1973)
3.	Available N (kg ha^{-1})	212.50	204.88	225.79	200.70	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
4.	Available P (kg ha^{-1})	149.63	136.51	177.17	169.68	Bray colorimetric method (Jackson, 1973)
5.	Available K (kg ha^{-1})	197.08	185.36	229.65	212.07	Ammonium acetate method (Jackson, 1973)

3.1.5 Weather

Vellayani enjoys a tropical humid climate. The monthly data on weather parameters *viz.* maximum and minimum temperatures, relative humidity and rainfall during the cropping periods has been collected from the meteorological observatory at College of Agriculture, Vellayani and presented in Fig 1. and Appendix I.

3.1.6 Planting Material

Corm pieces weighing about 100g (George, 2000) were used as planting material. No improved varieties have been released in tannia so far. Hence, good quality planting material of local variety has been used.

3.1.7 Manures and Fertilizers

The organic manures that were used in the experiment were FYM and wood ash and fertilizers were urea, rajphos and muriate of potash, the nutrient contents of which are given in Table 2.

Table 2. Nutrient contents of manures and fertilizers, %

Manure/Fertilizer	N	P_2O_5	K_2O
Farmyard manure	0.52	0.28	0.22
Wood ash	0.48	1.10	6.10
Urea	46	-	-
Rajphos	-	20	-
Muriate of potash	-	-	60

3.2 METHODS

3.2.1 Experimental Design and Layout

The experiment was laid out in split plot design. The layout plan is given in Fig. 2.

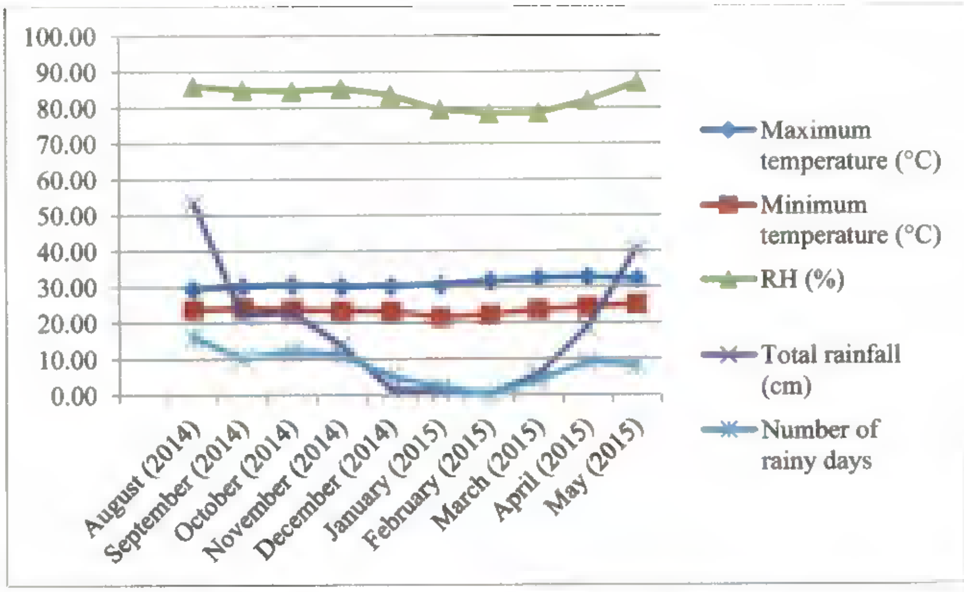

Fig 1a. Weather parameters during I year

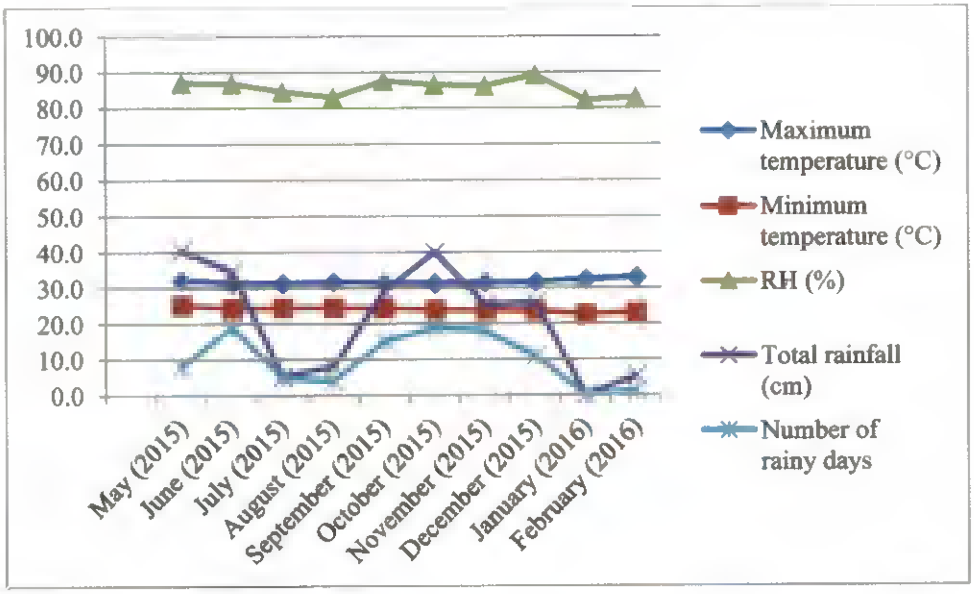

Fig 1b. Weather parameters during II year

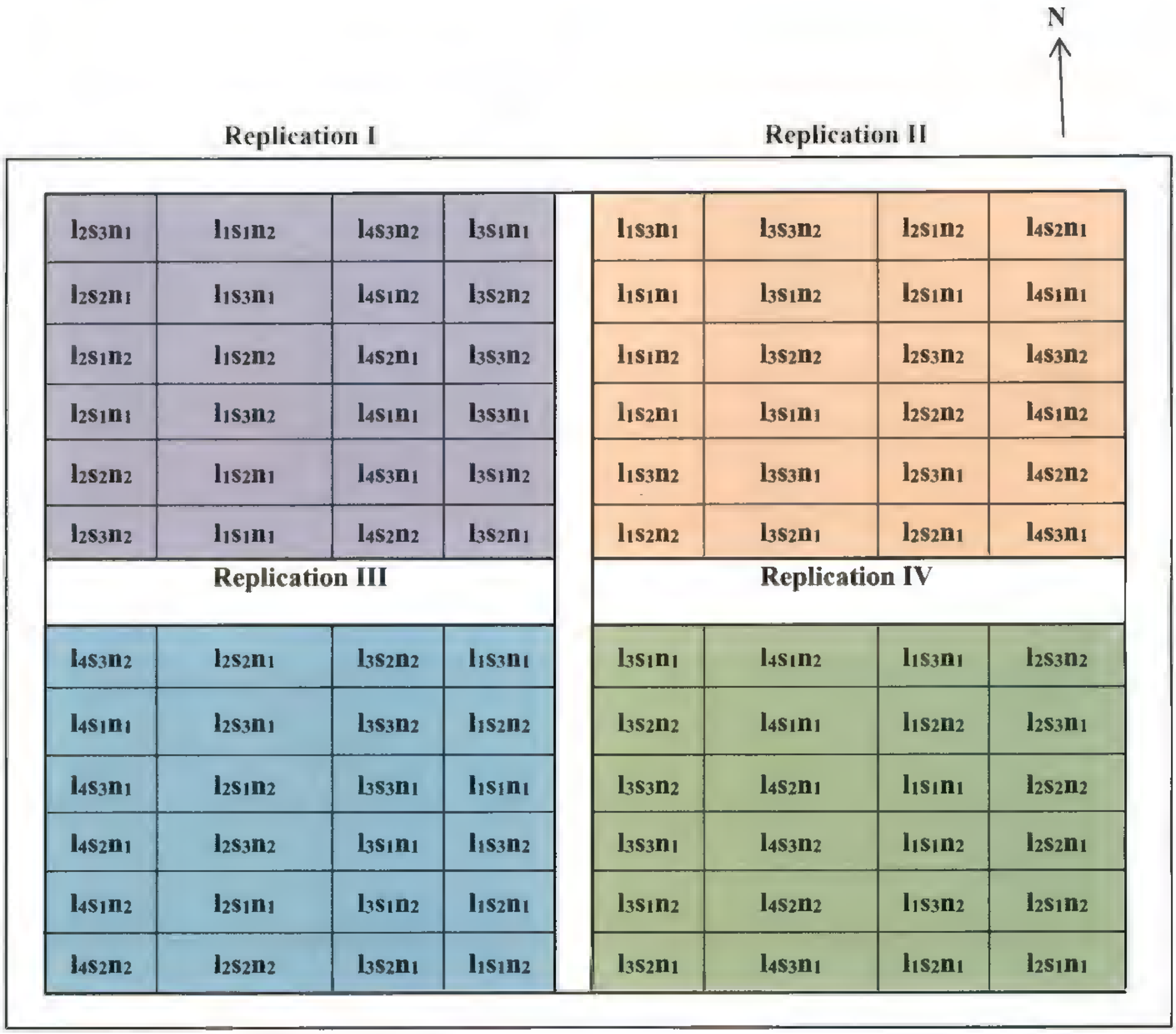

Fig. 2 Layout of the experimental field

The details of the experiment are given below:

Design	- Split plot
Treatment combinations	- 24
Replications	- 4
Total number of plots	- 96
Plot size (sub plot)	- 3 m x 3 m
Spacing	- 75 cm x 75 cm

3.2.2 Details of Treatments

The treatments consisted of combinations of four types of tillage systems with and without soil conditioner under integrated and organic nutrition.

Main plot Treatments (4)

Tillage systems (L) - 4

l_1 – Conventional tillage followed by pit system

l_2 – Conventional tillage followed by mound system

l_3 – Deep tillage followed by pit system

l_4 – Deep tillage followed by mound system

Sub Plot Treatments (3 x 2 = 6)

A) Soil conditioners (S) - 3

s_1 - Control

s_2 – Coir pith @ 500 g plant^{-1}

s_3 – Rice husk @ 500 g plant^{-1}

B) Nutrient management (N) - 2

n_1 – INM – FYM @ 25 t ha^{-1} + 80:50:150 kg NPK ha^{-1}

n_2 – Organic nutrition- FYM @37.5 t ha^{-1} + Wood ash @ 2 t ha^{-1}

Treatment combinations

T_1- $l_1s_1n_1$	T_5- $l_1s_2n_2$	T_9- $l_2s_3n_1$	T_{13}- $l_3s_1n_1$	T_{17}- $l_3s_2n_2$	T_{21}- $l_4s_3n_1$
T_2- $l_1s_2n_1$	T_6- $l_1s_3n_2$	T_{10}- $l_2s_1n_2$	T_{14}- $l_3s_2n_1$	T_{18}- $l_3s_3n_2$	T_{22}- $l_4s_1n_2$
T_3- $l_1s_3n_1$	T_7- $l_2s_1n_1$	T_{11}- $l_2s_2n_2$	T_{15}- $l_3s_3n_1$	T_{19}- $l_4s_1n_1$	T_{23}- $l_4s_2n_2$
T_4- $l_1s_1n_2$	T_8- $l_2s_2n_1$	T_{12}- $l_2s_3n_2$	T_{16}- $l_3s_1n_2$	T_{20}- $l_4s_2n_1$	T_{24}- $l_4s_3n_2$

3.2.3 Details of Cultivation

3.2.3.1 Preparation of Field

The experimental area was cleared, stubbles were removed and clods were broken using cultivator. The land was tilled to a depth of 15 cm (conventional tillage) and 30 cm (deep tillage) as per the treatments using rotavator with custom made settings. Dolomite @ 1 t ha^{-1}was applied uniformly in the experimental area and incorporated into the soil along with tillage operations. The field was laid out as per the design and pits (size of 45 cm x 45 cm x 15 cm) and mounds (with 30 cm diameter and 15 cm height) were taken in each plot as per the lay out.

3.2.3.2 Application of Manures and Fertilizers

For INM, half the dose of FYM (12.5 t ha^{-1}) was applied as basal dose along with full dose of rajphos (@ 50 kg P_2O_5 ha^{-1}). Half the dose of FYM (12.5 t ha^{-1}), urea (@ 80 kg N ha^{-1}) and muriate of potash (@ 150 kg K_2O ha^{-1}) were topdressed in three equal splits each at two, four and six MAP. For organic nutrition, 2/3rd dose of FYM (25 t ha^{-1}) was applied as basal dose. Remaining 1/3rd dose of FYM and wood ash (2 t ha^{-1}) were applied in three equal splits each at two, four and six MAP. The total quantities of NPK supplied through organic manures and fertilizers under INM and organic nutrition treatments are given in Table 3.

Table 3.Quantity of nutrients (NPK) supplied, kg ha^{-1}

Treatments	Nutrients supplied		
	N	P_2O_5	K_2O
INM (n_1)	210	120	205
Organic nutrition (n_2)	204.6	127	204.5

3.2.3.3 Application of Soil Conditioners

Soil conditioners *viz*. coir pith and rice husk were applied @ 500g in each pit or mound as per the treatments and mixed with soil.

3.2.3.4 Planting

Corms were cut into pieces weighing approximately 100 g ensuring atleast one sprouted bud in each piece. The corm pieces were planted in the main field in pits and mounds as per the treatments at spacing of 75 cm x 75cm. The crop was planted during the last week of August 2014 during the first year and during last week of May 2015 during the second year. The crop was mulched with green leaves immediately after planting.

3.2.3.5 After Cultivation

The crop was raised under rainfed condition. Interculture, weeding and earthing up were done at two, four and six MAP along with split application of FYM, wood ash and fertilizers as per the treatments.

3.2.3.6 Harvest

The crop was harvested at 9 MAP when the leaves started to dry up. The first year crop was harvested during May 2015 and the second year crop was harvested during February 2016. Harvesting was done by digging out the tubers

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Plate 2a. General view of the experimental field during I year


Plate 2b. General view of the experimental field during II year

carefully without breakage and were separated into corms and cormels. The observational plants and border rows were harvested separately from each plot.

3.3 BIOMETRIC OBSERVATIONS

The outer row of plants in each plot was left out as border row. Four plants in each net plot were tagged as observational plants.

3.3.1 Growth Characters

Growth characters were recorded from four observational plants in each plot at monthly interval from 2 MAP (when all the plants have emerged) upto harvest and the average was worked out.

3.3.1.1 Plant Height

Height of the plant was measured from the ground (base of plant) to the tip of the longest petiole at the blade joint (Mohankumar, 1986) and expressed in cm.

3.3.1.2Number of Leaves Plant^{-1}

·Number of fully opened green leaves of the observational plants at the time of observation were counted and recorded.

3.3.1.3 Leaf Area Index (LAI)

The leaf area was worked out by adopting the non destructive method as reported by Venkateswarlu and Biradar (1980). The LAI was calculated by the formula

$$\text{LAI} = \frac{5.395 \text{ x leaf number x } B'^{\,1.793}}{\text{spacing}}$$

The B' was measured from the base of midrib to one of the free lobes of leaf at the base through which a prominent vein traverse from the midrib laterally.

3.3.2 Yield and Yield Components

3.3.2.1 Number of CormelsPlant^{-1}

Number of cormels in the observational plants was counted at harvest and the average was worked out.

3.3.2.2 Mean Weight of Cormel

The total weight of the cormels in the observational plants was divided by the total number of cormels and expressed in grams (g).

3.3.2.3 Cormel Yield Plant^{-1}

Weight of the cormels in the observational plants was recorded and the average was worked out and expressed in g plant^{-1}.

3.3.2.4 Corm YieldPlant^{-1}

Weight of the corms in the observational plants was recorded and the average was worked out and expressed in g plant^{-1}.

3.3.2.5 Cormel to Corm Ratio

This was calculated as the ratio of the weight of cormels to the weight of corm plant^{-1}.

3.3.2.6 Cormel Yield ha^{-1}

Yield of cormels obtained from each net plot was expressed in t ha^{-1}.

3.3.2.7 Corm Yield ha^{-1}

Yield of corms obtained from each net plot was expressed in t ha^{-1}.

3.3.2.8 Dry Matter Production

Dry matter production was recorded at harvest. The sample plants uprooted were separated into blade and petiole (leaf or pseudo stem), corm and cormels. Fresh weight of each part was recorded and sub samples were taken for estimating the dry weight. The sub samples were dried in a hot air oven at 65 ± 5 ^{O}C to constant dry weight. The dry weight of each part was worked out and total dry matter production (TDMP) was computed in t ha^{-1}.

3.3.2.9 HarvestIndex

It is the ratio of cormel yield to total biomass on dry weight basis (Suja *et al*., 2009). This was worked out from the observational plants.

3.3.3 Quality Characters of Cormel

3.3.3.1 Starch Content

Starch content of cormel was estimated by using potassium ferri cyanide method (Ward and Pigman, 1970). The values were expressed as percentage on dry weight basis.

3.3.3.2 Protein Content

Protein content (%) of cormel on dry weight basis was calculated by multiplying N content (%) in cormel with the factor 6.25 (Simpson *et al*., 1965).

3.3.3.3 Shelf Life

Samples of cormels weighing 100g each taken from each treatment were spread on floor over newspaper under ambient conditions and observed for shelf life. The cormels were observed daily for sprouting and decay. The weight of samples was recorded once in three days to calculate physiological loss in weight (PLW) using the formula as given below.

$$\text{PLW (\%)} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100$$

3.4 PLANT ANALYSIS AT HARVEST

The observational plants uprooted were separated into cormels, corm, blade and petiole and the sub samples were taken and oven dried at 65 ± 5 ^{O}C. The plant samples were then ground to pass through a 0.5 mm sieve and digested for the analysis of NPK contents.

3.4.1 Uptake of Nutrients

Uptake of N, P and K were worked out based on N, P and K contents in plant parts and their respective dry weights.

3.4.1.1 N Uptake

The N content in each plant part was estimated by the modified micro kjeldhal method (Jackson, 1973). Total uptake of N was calculated by multiplying the N content of each plant part with the respective dry weight and summing up the values. The uptake values were expressed in kg ha^{-1}.

3.4.1.2 P Uptake

The P content in plant sample was colorimetrically determined by wet digestion of sample and colour development by ascorbic acid method and read in a spectrophotometer (Bray and Kurtz, 1964). Total uptake of P was calculated by multiplying the P content of each plant part with the respective dry weight and summing up the values. The uptake values were expressed in kg ha^{-1}.

3.4.1.3 K Uptake

The K content in plant sample was determined by flame photometer method (Piper, 1966). Total uptake of K was calculated by multiplying the K content of each plant part with the respective dry weight and summing up the values. The uptake values were expressed in kg ha^{-1}.

3.5 SOIL ANALYSIS BEFORE AND AFTER THE EXPERIMENT

Soil samples were taken from both the experimental area before and after the experiment from two depths (0 to 15 cm and 15 to 30 cm). The composite samples from the field before the experiment were collected, air dried, powdered and passed through a 2 mm sieve and analysed for mechanical composition and physico - chemical properties except organic carbon status as outlined in Table 1. The soil samples passed through 0.2 mm sieve were used for organic carbon estimation. After the experiment, composite samples were collected from each plot, processed as mentioned above and analysed for bulk density, porosity, water holding capacity, soil reaction, organic carbon and available NPK status using the standard procedures as indicated in Table 1.

3.6 INCIDENCE OF PEST AND DISEASE

Incidence of pest and disease was monitored throughout the crop period.

3.7 ECONOMICS OF CULTIVATION

The economics of cultivation of the crop in terms of net income and benefit cost ratio (BCR) was worked out as follows.

Net income (₹ ha^{-1}) = Gross income - Cost of cultivation

BCR = Gross income ÷ Cost of cultivation.

3.8 STATISTICAL ANALYSIS

The statistical analysis of the data was done by applying the technique of analysis of variance (ANOVA) for split plot design and the significance was tested by F test (Cochran and Cox, 1965). Critical difference has been provided wherever F test was significant. Contrast analysis was done in order to elucidate the effect of conventional versus deep tillage and pit versus mound system of planting separately and significance was tested by F test. Correlation analysis of yield versus LAI, yield components, nutrient uptake and soil physical properties as well as TDMP versus LAI, yield and nutrient uptake were done.

RESULTS

4. RESULTS

The field experiments were conducted in the Instructional Farm attached to College of Agriculture, Vellayani from August 2014 to May 2015 and from May 2015 to February 2016 to identify ideal tillage system, soil conditioner and nutrient management for productivity enhancement in tannia. The experiment was laid out in split plot design with 24 treatment combinations and four replications. The experimental data was statistically analysed and the results are presented in this chapter.

4.1 GROWTH CHARACTERS

4.1.1 Height of the Plant

The effects of different tillage systems, soil conditioners and nutrient management and their interactions on plant height of tannia during 2014-15 and 2015-16 at monthly interval from 2 MAP are given in Table 4a, 4b, 4c, 5a, 5b and 5c.

In general, the height of plants increased upto 5 MAP during I year and upto 6 MAP during II year after which the height reduced upto harvest.

The main effects of the treatments on plant height were significant during both the years. During I year (Table 4a), deep tillage followed by pit system (l_3) produced taller plants during initial stage upto 5 MAP and at harvest. At 6 MAP, 7 MAP and 8 MAP, conventional tillage followed by pit system (l_1) produced the tallest plants and at 8 MAP, this treatment was on a par with l_3. Contrast analysis indicated the significant effect of tillage on plant height at all stages except at 2 MAP and 8 MAP and deep tillage produced taller plants over conventional tillage. Pit system of planting was found superior to mound system at all stages except at 3 MAP and 6 MAP.

The significant effect of application of soil conditioner from 3 MAP onwards is evident from significantly lower values of plant height for the control treatment (s_1). Coir pith as soil conditioner (s_2) recorded significantly taller plants

Table 4a. Effect of tillage systems, soil conditioners and nutrient management on plant height during I year, cm

Treatments	Plant height							
	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
Tillage systems (L)								
l_1- Conventional tillage- pit system	28.66	36.47	45.71	54.95	46.13	46.93	40.80	34.15
l_2- Conventional tillage-mound system	28.31	36.48	44.12	53.01	44.51	43.07	35.25	29.51
l_3- Deep tillage-pit system	30.19	38.67	50.31	58.70	43.44	42.95	40.48	37.21
l_4 - Deep tillage-mound system	27.05	37.19	46.65	54.82	44.01	40.75	34.18	30.43
SEm±	0.237	0.412	0.502	0.525	0.403	0.405	0.352	0.227
CD (0.05)	0.877	1.526	1.862	1.946	1.492	1.499	1.306	0.840
Contrast analysis- Conventional vs Deep tillage								
Conventional tillage	28.48	36.47	44.91	53.98	45.32	45.00	38.02	31.83
Deep tillage	28.62	37.93	48.48	56.75	43.72	41.85	37.33	33.82
F test	NS	S	S	S	S	S	NS	S
Contrast analysis – Pit vs Mound system of planting								
Pit system	29.42	37.57	48.00	56.82	44.78	44.94	40.64	35.68
Mound system	27.68	36.83	45.38	53.91	44.26	41.9	34.71	29.96
F test	S	NS	S	S	NS	S	S	S
Soil conditioners (S)								
s_1- Control	27.31	34.49	42.61	50.70	41.66	40.15	34.00	29.71
s_2- Coir pith	31.20	39.94	50.92	60.06	47.28	46.52	40.93	34.72
s_3- Rice husk	27.15	37.17	46.55	55.35	44.63	43.61	38.10	34.04
SEm±	0.334	0.318	0.406	0.366	0.381	0.397	0.375	0.278
CD (0.05)	0.945	0.899	1.148	1.036	1.076	1.123	1.061	0.785
Nutrient management (N)								
n_1- INM	27.94	34.70	44.02	52.82	43.17	41.54	35.36	30.80
n_2- Organic nutrition	29.16	39.70	49.37	57.92	45.88	45.31	39.99	34.85
SEm±	0.273	0.260	0.331	0.299	0.311	0.324	0.306	0.227
CD (0.05)	0.772	0.734	0.938	0.846	0.879	0.917	0.866	0.641

S- Significant NS- Not significant

Table 4b. Interaction effect of tillage systems, soil conditioners and nutrient management on plant height during I year, cm

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
L x S interaction								
l_1s_1	28.64	33.05	44.44	53.11	42.96	42.44	34.79	30.36
l_1s_2	30.92	39.23	47.71	57.43	48.99	50.55	44.88	35.48
l_1s_3	26.41	37.12	44.98	54.32	46.45	47.81	42.72	36.62
l_2s_1	27.34	33.86	41.07	49.35	41.13	38.22	32.38	26.81
l_2s_2	31.58	39.38	47.26	55.91	47.46	47.72	37.84	31.76
l_2s_3	26.01	36.21	44.02	53.77	44.96	43.27	35.54	29.94
l_3s_1	27.88	35.70	44.16	52.18	41.24	40.97	36.44	33.71
l_3s_2	31.91	41.84	55.42	64.67	46.37	45.59	44.48	39.47
l_3s_3	30.78	38.48	51.34	59.24	42.70	42.29	40.53	38.46
l_4s_1	25.38	35.36	40.78	48.17	41.30	38.97	32.41	27.96
l_4s_2	30.39	39.33	53.30	62.22	46.32	42.22	36.53	32.17
l_4s_3	25.39	36.88	45.87	54.07	44.41	41.05	33.60	31.15
SEm±	0.668	0.636	0.811	0.733	0.761	0.793	0.750	0.554
CD (0.05)	1.891	NS	2.297	2.074	NS	2.244	2.123	1.568
L x N interaction								
l_1n_1	27.55	35.32	44.79	54.05	43.44	43.81	37.09	30.01
l_1n_2	29.77	37.61	46.63	55.85	48.82	50.05	44.51	38.29
l_2n_1	27.98	33.68	40.80	49.82	43.34	41.17	31.96	27.58
l_2n_2	28.64	39.29	47.43	56.20	45.69	44.97	38.54	31.43
l_3n_1	29.57	35.57	46.20	54.53	42.21	42.12	38.98	35.45
l_3n_2	30.81	41.77	54.42	62.86	44.67	43.78	41.99	38.98
l_4n_1	26.68	34.25	44.31	52.88	43.68	39.03	33.43	30.17
l_4n_2	27.42	40.13	48.99	56.75	44.34	42.46	34.93	30.69
SEm±	0.546	0.519	0.663	0.598	0.621	0.648	0.613	0.453
CD (0.05)	NS	1.468	1.876	1.693	1.757	1.834	1.735	1.282
S x N interaction								
s_1n_1	26.38	32.35	38.12	46.48	39.24	37.65	29.97	26.11
s_1n_2	28.24	36.63	47.10	54.92	44.08	42.65	38.04	33.31
s_2n_1	30.96	37.35	48.53	57.46	46.75	45.21	39.72	33.13
s_2n_2	31.44	42.53	53.32	62.65	47.81	47.83	42.14	36.31
s_3n_1	26.50	34.41	45.43	54.52	43.51	41.75	36.40	33.16
s_3n_2	27.80	39.94	47.68	56.18	45.75	45.47	39.80	34.93
SEm±	0.473	0.449	0.574	0.518	0.538	0.582	0.530	0.393
CD (0.05)	NS	NS	1.620	1.466	1.523	NS	1.500	1.112

NS- Not significant

Table 4c. Effect of L x S x N interaction on plant height during I year, cm

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
$l_1s_1n_1$	27.84	31.55	43.79	52.85	40.67	38.33	28.37	23.45
$l_1s_1n_2$	29.45	34.56	45.09	53.36	45.25	46.55	41.21	37.28
$l_1s_2n_1$	30.17	38.83	46.16	56.19	47.22	48.49	43.46	31.43
$l_1s_2n_2$	31.66	39.63	49.26	58.66	50.76	52.60	46.31	39.52
$l_1s_3n_1$	24.63	35.60	44.41	53.10	42.45	44.63	39.44	35.16
$l_1s_3n_2$	28.20	38.64	45.56	55.54	50.46	51.00	46.00	38.09
$l_2s_1n_1$	25.50	31.83	33.89	41.43	37.68	35.61	27.40	24.16
$l_2s_1n_2$	29.18	35.88	48.25	57.27	44.58	40.82	37.35	29.46
$l_2s_2n_1$	31.50	35.28	45.99	54.67	47.62	46.57	35.32	29.96
$l_2s_2n_2$	31.66	43.48	48.52	57.15	47.29	48.87	40.35	33.57
$l_2s_3n_1$	26.94	33.92	42.53	53.35	44.71	41.33	33.16	28.62
$l_2s_3n_2$	25.08	38.51	45.52	54.18	45.20	45.20	37.92	31.27
$l_3s_1n_1$	26.90	33.82	38.81	46.89	39.11	39.24	32.72	29.46
$l_3s_1n_2$	28.85	37.58	49.50	57.47	43.38	42.70	40.16	37.96
$l_3s_2n_1$	31.36	38.52	50.24	59.49	44.75	45.41	44.50	39.46
$l_3s_2n_2$	32.46	45.15	60.60	69.86	47.99	45.78	44.46	39.48
$l_3s_3n_1$	30.45	34.37	49.53	57.23	42.77	41.72	39.73	37.42
$l_3s_3n_2$	31.12	42.58	53.14	61.26	42.64	42.87	41.34	39.50
$l_4s_1n_1$	25.27	32.22	35.99	44.77	39.50	37.43	31.40	27.38
$l_4s_1n_2$	25.49	38.51	45.57	51.58	43.10	40.50	33.42	28.54
$l_4s_2n_1$	30.80	36.79	51.72	59.49	47.43	40.37	35.62	31.67
$l_4s_2n_2$	29.98	41.87	54.89	64.95	45.20	44.07	37.44	32.67
$l_4s_3n_1$	23.97	33.74	45.23	54.40	44.12	39.31	33.26	31.46
$l_4s_3n_2$	26.80	40.02	46.50	53.73	44.70	42.80	33.95	30.85
SEm±	0.945	0.945	1.148	1.036	1.076	1.123	1.061	0.785
CD (0.05)	NS	NS	3.249	2.932	3.045	NS	NS	2.222

NS- Not significant

compared to rice husk as soil conditioner (s_3) at all stages of crop growth except at harvest when it was on a par with rice husk.

Regarding the effect of nutrient management, organic nutrition (n_2) recorded taller plants at all growth stages compared to INM (n_1).

With regard to interaction effects during I year (Table 4b), the effect of L x S interaction was significant at all growth stages except at 3 MAP and 6 MAP. The treatment combination l_3s_2 recorded the tallest plants at 2 MAP when it was on a par with l_1s_2, l_2s_2, l_4s_2 and l_3s_3. At 4 MAP and 5 MAP, l_3s_2 produced the tallest plants but it was on a par with l_4s_2. At 7 MAP and 8 MAP, l_1s_2 recorded the tallest plants but it was on a par with $l_3s_2$at 8 MAP. At harvest, l_3s_2 and l_3s_3 were on a par but significantly superior to other treatment combinations. Considering L x N interaction, the effects were significant from 3 MAP onwards upto harvest. During initial stages (3 MAP, 4 MAP and 5 MAP), l_3n_2 produced the tallest plants while at 6 MAP, 7 MAP and 8 MAP, l_1n_2 produced the tallest plants. At harvest, l_3n_2 recorded the tallest plants but was on a par with l_1n_2. The effect of S x N interaction was significant at all stages from 4 MAP onwards upto harvest except at 7 MAP. The treatment combination s_2n_2 recorded the tallest plants at all stages.

The effect of L x S x N interaction (Table 4c) was significant at 4 MAP, 5 MAP, 6 MAP and harvest. The treatment combination $l_3s_2n_2$ produced significantly taller plants at 4 MAP, 5 MAP and 6 MAP. At 6 MAP, it was on a par with $l_1s_2n_2$ and $l_1s_3n_2$. At harvest, $l_1s_2n_2$ produced the tallest plants but was on a par with $l_1s_3n_2$, $l_3s_1n_2$, $l_3s_2n_1$, $l_3s_2n_2$, $l_3s_3n_1$ and $l_3s_3n_2$.Though not significant, $l_3s_2n_2$ produced the tallest plants at 2 MAP and 3 MAP and $l_1s_2n_2$ produced the tallest plants at 7 MAP and 8 MAP.

During the II year (Table 5a), deep tillage followed by pit system (l_3) recorded taller plants at all growth stages. But its effect was on a par with conventional tillage followed by pit system (l_1) during initial stages (at 2 MAP and 3 MAP) and with deep tillage followed by mound system (l_4) during later stages (7 MAP, 8 MAP and harvest). Deep tillage dominated over conventional 68 tillage at all stages except at 2 MAP. Pit system of planting was found advantageous at all stages except at 7 MAP.

Application of soil conditioner (s_2 and s_3) had significant effect on plant height at all growth stages compared to control (s_1). At all the stages of crop growth, coir pith as soil conditioner (s_2) produced the tallest plants.

The plants were significantly taller at all growth stages due to organic nutrition compared to integrated nutrient management.

Considering the interaction effects (Table 5b), the effect of L x S interaction was significant at all growth stages. At 2 MAP, the effects of tillage systems, l_1, l_2, l_3 and l_4 in combination with coir pith as soil conditioner (s_2) were on a par. The treatment combination l_3s_2 produced the tallest plants from 3 MAP onwards upto 6 MAP. During later stages (7 MAP, 8 MAP and harvest), it was on a par with l_4s_2. The interaction L x N had significant effect on plant height only from 4 MAP onwards. The treatment combination l_3n_2 produced the tallest plants at all stages and it was at par with l_4n_2 during later stages (7 MAP, 8 MAP and harvest). In the case of S x N interaction, s_2n_2 produced the tallest plants at all growth stages, but the effect was significant only at 5 MAP and 6 MAP.

The interaction L x S x N (Table 5c) was significant at all growth stages except at harvest. At 2 MAP and 3 MAP, the treatment combination $l_3s_2n_2$ produced significantly taller plants but was on a par with $l_3s_3n_2$, $l_3s_2n_1$, $l_2s_2n_1$, $l_2s_2n_2$, $l_1s_2n_2$ at 2 MAP and with $l_4s_2n_2$, $l_3s_3n_2$, $l_1s_2n_2$ at 3 MAP. At 4 MAP, 5 MAP, 6 MAP and 7 MAP, the treatment combination $l_3s_2n_2$ produced significantly taller plants but was on a par with $l_4s_2n_2$ at 7 MAP. At 8 MAP, $l_4s_2n_2$ produced the tallest plants. Though not significant, $l_4s_2n_2$ produced the tallest plants at harvest followed by $l_3s_2n_2$.

Table 5a. Effect of tillage systems, soil conditioners and nutrient management on plant height during II year, cm

Treatments	Plant height							
	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
Tillage systems (L)								
l_1- Conventional tillage- pit system	25.26	31.02	42.79	52.87	50.16	42.82	37.14	31.97
l_2- Conventional tillage-mound system	23.96	28.22	39.67	45.90	48.70	39.37	34.02	32.25
l_3- Deep tillage-pit system	25.90	31.68	45.53	57.22	66.54	58.28	57.00	55.45
l_4 - Deep tillage-mound system	23.31	30.31	43.37	52.11	60.32	59.74	56.84	53.60
SEm±	0.206	0.230	0.284	0.366	0.552	0.621	0.558	0.580
CD (0.05)	0.763	0.854	1.052	1.356	2.047	2.301	2.068	2.147
Contrast analysis- Conventional vs Deep tillage								
Conventional tillage	24.61	29.62	41.23	49.38	49.43	41.09	35.58	32.11
Deep tillage	24.60	30.99	44.45	54.66	63.43	59.00	56.92	54.53
F test	NS	S	S	S	S	S	S	S
Contrast analysis – Pit vs Mound system of planting								
Pit system	25.58	31.34	44.16	55.05	58.35	50.55	47.07	43.71
Mound system	23.63	29.26	41.52	49.00	54.51	49.55	45.43	42.93
F test	S	S	S	S	S	NS	S	S
Soil conditioners (S)								
s_1- Control	23.13	27.38	36.60	47.03	51.31	44.67	42.23	39.57
s_2- Coir pith	27.49	33.63	48.31	56.01	62.11	56.07	51.30	47.72
s_3- Rice husk	23.21	29.92	43.61	53.04	55.86	49.41	45.22	42.68
SEm±	0.264	0.224	0.246	0.298	0.275	0.329	0.327	0.387
CD (0.05)	0.746	0.632	0.695	0.844	0.779	0.931	0.925	1.096
Nutrient management (N)								
n_1- INM	24.05	27.15	38.85	47.62	52.36	45.91	43.96	40.50
n_2- Organic nutrition	25.17	33.46	46.82	56.43	60.50	54.19	48.54	46.14
SEm±	0.215	0.183	0.201	0.244	0.225	0.269	0.267	0.316
CD (0.05)	0.609	0.516	0.567	0.689	0.636	0.761	0.755	0.895

S- Significant NS- Not significant

Table 5b. Interaction effect of tillage systems, soil conditioners and nutrient management on plant height during II year, cm

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
L x S interaction								
l_1s_1	24.84	28.31	36.21	48.20	47.00	36.85	33.60	29.30
l_1s_2	27.62	34.53	47.12	54.55	56.50	49.90	40.90	36.00
l_1s_3	23.33	30.20	45.03	55.87	46.99	41.70	36.90	30.60
l_2s_1	23.27	25.66	34.92	42.16	43.15	33.60	30.85	27.05
l_2s_2	27.52	31.27	44.82	48.75	54.15	43.85	37.15	36.15
l_2s_3	21.08	27.75	39.26	46.79	48.81	40.65	34.05	33.55
l_3s_1	22.96	27.47	37.26	50.62	62.15	51.65	52.75	52.60
l_3s_2	28.14	35.91	51.70	64.30	70.75	64.98	62.00	59.15
l_3s_3	26.60	31.66	47.64	56.75	66.70	58.20	56.25	54.60
l_4s_1	21.43	28.06	38.00	47.15	52.95	56.55	51.70	49.30
l_4s_2	26.69	32.79	49.60	56.41	67.05	65.55	65.15	59.55
l_4s_3	21.81	30.07	42.51	52.75	60.95	57.10	53.65	51.95
SEm±	0.527	0.447	0.491	0.597	0.551	0.659	0.654	0.775
CD (0.05)	1.492	1.265	1.390	1.690	1.559	1.865	1.851	2.193
L x N interaction								
l_1n_1	24.42	28.21	40.68	49.45	44.02	37.10	32.90	27.00
l_1n_2	26.11	33.82	44.90	56.30	56.30	48.53	41.37	36.94
l_2n_1	23.58	24.90	34.40	40.94	46.41	36.27	32.74	29.80
l_2n_2	24.33	31.55	44.94	50.86	51.00	42.47	35.30	34.70
l_3n_1	25.18	28.52	40.87	52.81	61.94	53.34	54.87	53.64
l_3n_2	26.61	34.83	50.20	61.64	71.14	63.22	59.14	57.27
l_4n_1	23.01	26.97	39.47	47.28	57.07	56.94	55.34	51.57
l_4n_2	23.61	33.64	47.27	56.94	63.57	62.54	58.34	55.64
SEm±	0.453	0.365	0.401	0.487	0.449	0.538	0.534	0.632
CD (0.05)	NS	NS	1.140	1.378	1.271	1.523	1.511	1.789
S x N interaction								
s_1n_1	22.24	24.10	32.36	43.19	48.13	40.65	40.05	36.68
s_1n_2	24.01	30.65	40.83	50.88	54.50	48.68	44.40	42.45
s_2n_1	27.20	30.51	44.30	50.36	57.28	51.68	49.23	45.03
s_2n_2	27.78	36.74	52.31	61.65	66.95	60.46	53.38	50.40
s_3n_1	22.71	26.85	39.89	49.31	51.67	45.40	42.60	39.80
s_3n_2	23.71	32.99	47.33	56.77	60.05	53.43	47.83	45.55
SEm±	0.393	0.393	0.347	0.422	0.389	0.466	0.463	0.548
CD (0.05)	NS	NS	NS	1.194	1.101	NS	NS	NS

NS- Not significant

Table 5c. Effect of L x S x N interaction on plant height during II year, cm

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
$l_1s_1n_1$	23.85	23.13	38.26	47.20	42.70	32.11	27.90	24.00
$l_1s_1n_2$	25.83	33.50	34.17	49.20	51.30	41.60	39.30	34.60
$l_1s_2n_1$	26.81	32.46	43.18	48.51	51.10	43.21	37.71	31.00
$l_1s_2n_2$	28.43	36.60	51.05	60.60	61.90	56.60	44.10	41.00
$l_1s_3n_1$	22.60	29.03	40.59	52.64	38.27	36.00	33.10	26.00
$l_1s_3n_2$	24.07	31.37	49.48	59.10	55.70	47.40	40.70	35.20
$l_2s_1n_1$	21.30	22.77	27.20	36.41	41.20	32.30	30.60	24.21
$l_2s_1n_2$	25.24	28.55	42.65	47.91	45.10	34.90	31.10	29.90
$l_2s_2n_1$	27.90	27.22	41.10	43.40	50.00	39.50	35.10	33.10
$l_2s_2n_2$	27.13	35.32	48.53	54.10	58.30	48.20	39.20	39.20
$l_2s_3n_1$	21.53	24.72	34.90	43.00	48.01	37.00	32.50	32.11
$l_2s_3n_2$	20.63	30.78	43.63	50.57	49.60	44.30	35.60	35.00
$l_3s_1n_1$	22.47	25.66	32.00	46.03	57.10	44.30	51.50	51.90
$l_3s_1n_2$	23.45	29.28	42.52	55.20	67.20	59.00	54.00	53.30
$l_3s_2n_1$	27.20	33.47	45.04	58.90	65.50	60.30	60.30	57.90
$l_3s_2n_2$	29.08	38.35	58.36	69.71	76.00	69.65	63.71	60.40
$l_3s_3n_1$	25.88	26.44	45.58	53.50	63.20	55.40	52.80	51.10
$l_3s_3n_2$	27.32	36.87	49.70	60.00	70.21	61.00	59.70	58.10
$l_4s_1n_1$	21.33	24.84	32.00	43.10	51.50	53.90	50.20	46.60
$l_4s_1n_2$	21.54	31.28	44.00	51.20	54.40	59.20	53.21	52.00
$l_4s_2n_1$	26.88	28.90	47.90	50.62	62.50	63.70	63.80	58.10
$l_4s_2n_2$	26.49	36.69	51.30	62.20	71.60	67.40	66.50	61.00
$l_4s_3n_1$	20.82	27.19	38.51	48.10	57.20	53.20	52.00	50.01
$l_4s_3n_2$	22.81	32.94	46.51	57.40	64.70	61.00	55.30	53.90
SEm±	0.746	0.746	0.695	0.844	0.779	0.931	0.925	1.095
CD (0.05)	2.110	2.110	1.966	2.389	2.205	2.635	2.618	NS

NS- Not significant

4.1.2 Number of Leaves Plant^{-1}

The main effects and the interaction effects of treatments on number of leaves plant^{-1} during 2014-15 and 2015-16 are presented in Table 6a, 6b, 6c, 7a, 7b and 7c.

Number of leaves plant^{-1} increased upto 5 MAP after which it showed a declining trend upto harvest during both the years.

During I year, tillage system significantly influenced leaf number at all stages of crop growth (Table 6a) with the highest number being recorded by deep tillage followed by pit system (l_3). At harvest, l_3 was found to be on a par with l_4 (deep tillage followed by mound system). Contrast analysis indicated the superiority of deep tillage over conventional tillage in producing higher number of leaves at all growth stages. System of planting was found significant at all stages of growth except at harvest and pit system was found superior to mound system.

Application of soil conditioner (s_2 and s_3) produced significantly higher leaf number over control (s_1). Coir pith as soil conditioner (s_2) recorded significantly higher leaf number at all growth stages.

Significantly higher leaf number was produced under organic nutrition (n_2) at all stages except at harvest. Although the effect was not significant at harvest, higher number of leaves was produced under organic nutrition itself.

Regarding L x S interaction (Table 6b), the treatment combination l_3s_2 recorded the highest number of leaves at all growth stages but the effects were significant only at 3 MAP, 5 MAP and 6 MAP. With respect to L x N interaction, the treatment combination l_3n_2 recorded higher number of leaves at all stages but the effects were significant at 3 MAP, 4 MAP, 6 MAP and 7 MAP. The interaction S x N, failed to produce significant effect on leaf number at any stage of crop growth.

Table 6a. Effect of tillage systems, soil conditioners and nutrient management on leaf number plant^{-1} during I year

Treatments	Leaf number plant^{-1}							
	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
Tillage systems (L)								
l_1- Conventional tillage- pit system	2.14	3.50	3.98	4.52	3.06	2.63	2.20	1.90
l_2- Conventional tillage-mound system	1.79	2.41	3.27	4.13	2.90	2.23	1.95	1.72
l_3- Deep tillage-pit system	2.57	3.63	4.44	4.93	4.21	3.54	2.94	2.45
l_4 - Deep tillage-mound system	2.35	3.38	3.98	4.58	3.98	3.11	2.73	2.44
SEm±	0.473	0.029	0.043	0.030	0.017	0.091	0.046	0.044
CD (0.05)	0.175	0.108	0.158	0.112	0.062	0.337	0.170	0.165
Contrast analysis- Conventional vs Deep tillage								
Conventional tillage	1.96	2.95	3.63	4.32	2.98	2.43	2.07	1.81
Deep tillage	2.46	3.5	4.21	4.76	4.09	3.33	2.83	2.44
F test	S	S	S	S	S	S	S	S
Contrast analysis – Pit vs Mound system of planting								
Pit system	2.35	3.56	4.21	4.72	3.64	3.08	2.57	2.17
Mound system	2.07	2.89	3.63	4.35	3.44	2.67	2.34	2.08
F test	S	S	S	S	S	S	S	NS
Soil conditioners (S)								
s_1- Control	2.02	2.91	3.75	4.20	3.23	2.60	2.27	1.93
s_2- Coir pith	2.42	3.49	4.14	4.85	3.84	3.22	2.69	2.33
s_3- Rice husk	2.20	3.27	3.86	4.56	3.54	2.81	2.41	2.12
SEm±	0.042	0.035	0.034	0.038	0.032	0.049	0.065	0.049
CD (0.05)	0.118	0.099	0.096	0.108	0.089	0.139	0.184	0.139
Nutrient management (N)								
n_1- INM	2.12	3.10	3.71	4.42	3.28	2.62	2.35	2.07
n_2- Organic nutrition	2.31	3.35	4.12	4.66	3.79	3.14	2.55	2.18
SEm±	0.034	0.028	0.028	0.031	0.026	0.040	0.053	0.040
CD (0.05)	0.097	0.080	0.078	0.088	0.073	0.113	0.150	NS

S- Significant NS- Not significant

Table 6b. Interaction effect of tillage systems, soil conditioners and nutrient management on leaf number plant^{-1} during I year

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
L x S interaction								
l_1s_1	2.00	3.13	3.91	4.16	2.88	2.41	2.06	1.78
l_1s_2	2.31	3.91	4.09	4.81	3.28	2.88	2.38	2.06
l_1s_3	2.09	3.47	3.94	4.59	3.03	2.59	2.16	1.84
l_2s_1	1.59	2.22	3.09	3.94	2.72	1.97	1.84	1.50
l_2s_2	1.97	2.63	3.50	4.28	3.06	2.47	2.13	1.88
l_2s_3	1.81	2.38	3.22	4.16	2.91	2.25	1.88	1.78
l_3s_1	2.38	3.31	4.25	4.41	3.69	3.09	2.63	2.22
l_3s_2	2.81	3.91	4.78	5.47	4.66	4.06	3.28	2.69
l_3s_3	2.53	3.66	4.28	4.91	4.28	3.47	2.91	2.44
l_4s_1	2.13	3.00	3.75	4.31	3.66	2.94	2.53	2.22
l_4s_2	2.59	3.53	4.19	4.84	4.34	3.47	2.97	2.69
l_4s_3	2.34	3.59	4.00	4.59	3.94	2.94	2.69	2.41
SEm±	0.084	0.070	0.068	0.076	0.063	0.098	0.130	0.098
CD (0.05)	NS	0.197	NS	0.216	0.179	NS	NS	NS
L x N interaction								
l_1n_1	2.06	3.35	3.77	4.44	2.90	2.33	1.98	1.77
l_1n_2	2.21	3.65	4.19	4.60	3.23	2.92	2.42	2.02
l_2n_1	1.69	2.13	2.83	4.04	2.73	2.27	1.92	1.75
l_2n_2	1.90	2.69	3.71	4.21	3.06	2.19	1.98	1.69
l_3n_1	2.48	3.58	4.38	4.77	3.73	3.02	2.85	2.38
l_3n_2	2.67	3.67	4.50	5.08	4.69	4.06	3.02	2.52
l_4n_1	2.25	3.35	3.88	4.42	3.77	2.85	2.67	2.40
l_4n_2	2.46	3.40	4.08	4.75	4.19	3.38	2.79	2.48
SEm±	0.068	0.057	0.055	0.062	0.052	0.080	0.106	0.080
CD (0.05)	NS	0.161	0.156	NS	0.146	0.227	NS	NS
S x N interaction								
s_1n_1	1.95	2.78	3.53	4.06	2.97	2.39	2.19	1.84
s_1n_2	2.09	3.05	3.97	4.34	3.50	2.81	2.34	2.02
s_2n_1	2.30	3.39	3.95	4.75	3.58	2.94	2.53	2.27
s_2n_2	2.55	3.59	4.33	4.95	4.09	3.50	2.84	2.39
s_3n_1	2.11	3.14	3.66	4.44	3.30	2.53	2.34	2.11
s_3n_2	2.28	3.41	4.06	4.69	3.78	3.09	2.47	2.13
SEm±	0.059	0.049	0.048	0.054	0.045	0.069	0.092	0.069
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS- Not significant

Table 6c. Effect of L x S x N interaction on leaf number plant^{-1} during I year

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
$l_1s_1n_1$	1.94	3.06	3.75	4.06	2.69	2.13	1.94	1.69
$l_1s_1n_2$	2.06	3.19	4.06	4.25	3.06	2.69	2.19	1.88
$l_1s_2n_1$	2.25	3.75	3.88	4.75	3.13	2.56	2.06	1.94
$l_1s_2n_2$	2.38	4.06	4.31	4.88	3.44	3.19	2.69	2.19
$l_1s_3n_1$	2.00	3.25	3.69	4.50	2.88	2.31	1.94	1.69
$l_1s_3n_2$	2.19	3.69	4.19	4.69	3.19	2.88	2.38	2.00
$l_2s_1n_1$	1.44	1.94	2.63	3.81	2.63	2.00	1.81	1.50
$l_2s_1n_2$	1.75	2.50	3.56	4.06	2.81	1.94	1.88	1.50
$l_2s_2n_1$	1.88	2.38	3.13	4.19	2.88	2.50	2.06	1.75
$l_2s_2n_2$	2.06	2.88	3.88	4.38	3.25	2.44	2.19	2.00
$l_2s_3n_1$	1.75	2.06	2.75	4.13	2.69	2.31	1.88	2.00
$l_2s_3n_2$	1.88	2.69	3.69	4.19	3.13	2.19	1.88	1.56
$l_3s_1n_1$	2.38	3.19	4.13	4.25	3.13	2.69	2.50	2.06
$l_3s_1n_2$	2.38	3.44	4.38	4.56	4.25	3.50	2.75	2.38
$l_3s_2n_1$	2.56	3.94	4.69	5.38	4.19	3.50	3.13	2.69
$l_3s_2n_2$	3.06	3.88	4.88	5.56	5.13	4.63	3.44	2.69
$l_3s_3n_1$	2.50	3.63	4.31	4.69	3.88	2.88	2.94	2.38
$l_3s_3n_2$	2.56	3.69	4.25	5.13	4.69	4.06	2.88	2.50
$l_4s_1n_1$	2.06	2.94	3.63	4.13	3.44	2.75	2.50	2.13
$l_4s_1n_2$	2.19	3.06	3.88	4.50	3.88	3.13	2.56	2.31
$l_4s_2n_1$	2.50	3.50	4.13	4.69	4.13	3.19	2.88	2.69
$l_4s_2n_2$	2.69	3.56	4.25	5.00	4.56	3.75	3.06	2.69
$l_4s_3n_1$	2.19	3.63	3.88	4.44	3.75	2.63	2.63	2.38
$l_4s_3n_2$	2.50	3.56	4.13	4.75	4.13	3.25	2.75	2.44
SEm±	0.118	0.098	0.095	0.108	0.089	0.139	0.184	0.139
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS- Not significant

The interaction, L x S x N (Table 6c) had no significant effect on leaf number at any growth stage. But $l_3s_2n_2$ produced more number of leaves at all stages compared to other treatment combinations.

During II year, the main effects of treatments were significant at all growth stages (Table 7a). Among tillage systems, deep tillage followed by pit system (l_3) produced the highest number of leaves plant^{-1} at all growth stages. But it was found on a par with deep tillage followed by mound system (l_4) at 2 MAP and with conventional tillage followed by pit system (l_1) at 4 MAP and 5 MAP. Contrast analysis indicated the significance of deep tillage in producing higher number of leaves at all stages except at 5 MAP. Pit system of planting was found superior to mound system.

Coir pith as soil conditioner (s_2) registered the highest leaf number at all growth stages but was on a par with rice husk as soil conditioner (s_3) at harvest.

Organic nutrition was found superior to INM at all growth stages for producing higher leaf number plant^{-1}.

Regarding the effect of L x S interaction during II year (Table 7b), the highest leaf number was produced by the treatment combination l_3s_2 at any stage of crop growth although the effects were significant only at 2 MAP, 3 MAP, 7 MAP and 8 MAP. The effect of L x N interaction was significant at all growth stages except at 2 MAP and l_3n_2 produced the highest number of leaves. Significant effect of S x N interaction was observed on leaf number at all growth stages except at 5 MAP. The treatment combination s_2n_2 registered the highest leaf number at all growth stages, but it was on a par with s_2n_1 and s_3n_2 at 2 MAP and 6 MAP.

The interaction L x S x N (Table 7c) had significant effects on leaf number at 4 MAP, 5 MAP, 6 MAP and 8 MAP. At 4 MAP, the highest leaf number was produced by $l_4s_2n_2$ but was on a par with $l_3s_3n_2$, $l_3s_2n_2$ and $l_1s_2n_2$. At 5 MAP, the treatment combinations, $l_4s_2n_2$, $l_3s_2n_2$ and $l_1s_2n_2$ produced the same number of leaves and were on a par with $l_1s_3n_2$, $l_2s_3n_2$, $l_3s_3n_2$ and $l_2s_2n_2$. At 6 MAP, $l_3s_3n_2$

Table 7a. Effect of tillage systems, soil conditioners and nutrient management on leaf number plant^{-1} during II year

Treatments	Leaf number							
	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
Tillage systems (L)								
l_1- Conventional tillage- pit system	1.92	3.14	3.89	4.43	2.29	2.29	2.21	1.71
l_2- Conventional tillage-mound system	1.72	2.94	3.58	4.01	2.09	2.09	1.83	1.61
l_3- Deep tillage-pit system	2.29	3.50	4.08	4.49	3.26	2.66	2.90	2.38
l_4 - Deep tillage-mound system	2.30	3.14	3.78	4.05	2.99	2.47	2.25	2.06
SEm±	0.033	0.057	0.058	0.054	0.031	0.036	0.039	0.037
CD (0.05)	0.122	0.213	0.215	0.201	0.116	0.133	0.144	0.139
Contrast analysis- Conventional vs Deep tillage								
Conventional tillage	1.82	3.04	3.73	4.22	2.19	2.19	2.02	1.66
Deep tillage	2.3	3.32	3.93	4.27	3.13	2.56	2.57	2.22
F test	S	S	S	NS	S	S	S	S
Contrast analysis – Pit vs Mound system of planting								
Pit system	2.1	3.32	3.98	4.46	2.78	2.47	2.55	2.04
Mound system	2.01	3.04	3.68	4.03	2.54	2.28	2.04	1.84
F test	S	S	S	S	S	S	S	S
Soil conditioners (S)								
s_1- Control	1.77	2.73	3.34	3.63	2.38	2.05	1.90	1.74
s_2- Coir pith	2.38	3.59	4.30	4.72	2.90	2.62	2.70	2.05
s_3- Rice husk	2.02	3.21	3.86	4.39	2.70	2.46	2.30	2.02
SEm±	0.045	0.051	0.052	0.048	0.048	0.041	0.045	0.049
CD (0.05)	0.127	0.145	0.147	0.135	0.135	0.116	0.128	0.140
Nutrient management (N)								
n_1- INM	1.87	2.77	3.42	3.92	2.42	2.16	2.06	1.83
n_2- Organic nutrition	2.24	3.58	4.25	4.57	2.90	2.60	2.53	2.05
SEm±	0.037	0.042	0.042	0.039	0.039	0.033	0.037	0.040
CD (0.05)	0.104	0.118	0.120	0.110	0.110	0.095	0.104	0.114

S- Significant NS- Not significant

Table 7b. Interaction effect of tillage systems, soil conditioners and nutrient management on leaf number plant^{-1} during II year

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
L x S interaction								
l_1s_1	1.78	2.75	3.34	3.75	2.03	2.00	1.84	1.53
l_1s_2	2.06	3.56	4.34	4.88	2.66	2.56	2.75	1.84
l_1s_3	1.91	3.09	3.97	4.66	2.19	2.31	2.03	1.75
l_2s_1	1.34	2.44	3.03	3.44	1.84	1.88	1.25	1.38
l_2s_2	2.19	3.44	4.00	4.47	2.22	2.34	2.34	1.66
l_2s_3	1.63	2.94	3.72	4.13	2.22	2.06	1.91	1.81
l_3s_1	2.09	2.97	3.56	3.88	2.84	2.34	2.59	2.16
l_3s_2	2.47	3.84	4.56	4.97	3.56	2.75	3.22	2.47
l_3s_3	2.31	3.69	4.13	4.63	3.38	2.88	2.88	2.50
l_4s_1	1.88	2.75	3.41	3.44	2.81	2.00	1.91	1.91
l_4s_2	2.78	3.53	4.31	4.56	3.16	2.81	2.47	2.25
l_4s_3	2.25	3.13	3.63	4.16	3.00	2.59	2.38	2.03
SEm±	0.284	0.102	0.104	0.096	0.095	0.082	0.090	0.099
CD (0.05)	0.803	0.289	NS	NS	NS	0.232	0.255	NS
L x N interaction								
l_1n_1	1.81	2.96	3.63	4.19	2.21	2.13	1.98	1.81
l_1n_2	2.02	3.31	4.15	4.67	2.38	2.46	2.44	1.60
l_2n_1	1.58	2.65	2.94	3.46	1.98	1.94	1.54	1.54
l_2n_2	1.85	3.23	4.23	4.56	2.21	2.25	2.13	1.69
l_3n_1	2.00	2.90	3.71	4.21	2.88	2.50	2.79	2.08
l_3n_2	2.58	4.10	4.46	4.77	3.65	2.81	3.00	2.67
l_4n_1	2.08	2.58	3.40	3.81	2.63	2.06	1.94	1.88
l_4n_2	2.52	3.69	4.17	4.29	3.35	2.88	2.56	2.25
SEm±	0.232	0.084	0.085	0.078	0.078	0.067	0.074	0.081
CD (0.05)	NS	0.236	0.240	0.221	0.220	0.189	0.208	0.218
S x N interaction								
s_1n_1	1.53	2.41	3.13	3.34	2.03	1.80	1.84	1.61
s_1n_2	2.02	3.05	3.55	3.91	2.73	2.31	1.95	1.88
s_2n_1	2.14	3.08	3.75	4.31	2.81	2.34	2.28	1.84
s_2n_2	2.61	4.11	4.86	5.13	2.98	2.89	3.11	2.27
s_3n_1	1.94	2.83	3.38	4.09	2.42	2.33	2.06	2.03
s_3n_2	2.11	3.59	4.34	4.69	2.97	2.59	2.53	2.02
SEm±	0.201	0.072	0.073	0.068	0.067	0.058	0.064	0.070
CD (0.05)	0.568	0.205	0.208	NS	0.190	0.164	0.180	0.197

NS- Not significant

Table 7c. Effect of L x S x N interaction on leaf number plant^{-1} during II year

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
$l_1s_1n_1$	1.63	2.44	3.44	3.75	2.00	1.81	1.63	1.56
$l_1s_1n_2$	1.94	3.06	3.25	3.75	2.06	2.19	2.06	1.50
$l_1s_2n_1$	2.00	3.38	3.75	4.56	2.50	2.38	2.50	1.88
$l_1s_2n_2$	2.13	3.75	4.94	5.19	2.81	2.75	3.00	1.81
$l_1s_3n_1$	1.81	3.06	3.69	4.25	2.13	2.19	1.81	2.00
$l_1s_3n_2$	2.00	3.13	4.25	5.06	2.25	2.44	2.25	1.50
$l_2s_1n_1$	1.13	2.19	2.50	3.06	1.50	1.69	1.31	1.25
$l_2s_1n_2$	1.56	2.69	3.56	3.81	2.19	2.06	1.19	1.50
$l_2s_2n_1$	2.06	3.06	3.38	4.00	2.38	2.19	1.69	1.56
$l_2s_2n_2$	2.31	3.81	4.63	4.94	2.06	2.50	3.00	1.75
$l_2s_3n_1$	1.56	2.69	2.94	3.31	2.06	1.94	1.63	1.81
$l_2s_3n_2$	1.69	3.19	4.50	4.94	2.38	2.19	2.19	1.81
$l_3s_1n_1$	1.88	2.63	3.38	3.44	2.50	2.13	2.56	1.81
$l_3s_1n_2$	2.31	3.31	3.75	4.31	3.19	2.56	2.63	2.50
$l_3s_2n_1$	1.94	3.06	4.31	4.75	3.38	2.50	3.00	2.00
$l_3s_2n_2$	3.00	4.63	4.81	5.19	3.75	3.00	3.44	2.94
$l_3s_3n_1$	2.19	3.00	3.44	4.44	2.75	2.88	2.81	2.44
$l_3s_3n_2$	2.44	4.38	4.81	4.81	4.00	2.88	2.94	2.56
$l_4s_1n_1$	1.50	2.38	3.19	3.13	2.13	1.56	1.88	1.81
$l_4s_1n_2$	2.25	3.13	3.63	3.75	3.50	2.44	1.94	2.00
$l_4s_2n_1$	2.56	2.81	3.56	3.94	3.00	2.31	1.94	1.94
$l_4s_2n_2$	3.00	4.25	5.06	5.19	3.31	3.31	3.00	2.56
$l_4s_3n_1$	2.19	2.56	3.44	4.38	2.75	2.31	2.00	1.88
$l_4s_3n_2$	2.31	3.69	3.81	3.94	3.25	2.88	2.75	2.19
SEm±	0.402	0.145	0.147	0.135	0.135	0.116	0.128	0.140
CD (0.05)	NS	NS	0.416	0.382	0.381	NS	0.361	NS

NS- Not significant

produced significantly higher number of leaves while at 8 MAP $l_3s_2n_2$ produced the highest number of leaves. Though not significant, $l_3s_2n_2$ produced more number of leaves at 2 MAP, 3 MAP and harvest, while $l_4s_2n_2$ dominated at 7 MAP.

4.1.3 Leaf Area Index

The data on the main effects of treatments on leaf area index during 2014-15 and 2015-16 are presented in Table 8a and 9a respectively and the interaction effects in Table 8b, 8c, 9b and 9c respectively.

As in the case of leaf number plant^{-1}, LAI also showed an increasing trend upto 5 MAP after which it showed a declining trend upto harvest during both the years.

The main effects of treatments were significant at all growth stages during both the years. Among tillage systems during I year (Table 8a), deep tillage followed by pit system (l_3) registered the highest LAI at all stages, but it was on a par with deep tillage followed by mound system (l_4) at 2 MAP, 8 MAP and harvest. Contrast analysis revealed the superiority of deep tillage over conventional tillage in recording higher LAI at all stages. System of planting significantly influenced LAI at all stages except at 2 MAP and harvest and pit system was found superior.

Similar to leaf number, application of soil conditioner (s_2 and s_3) recorded significantly higher LAI compared to control (s_1). Coir pith as soil conditioner (s_2) was found superior in registering higher LAI at all growth stages.

Significantly higher LAI has been observed under organic nutrition (n_2) than under INM (n_1) at all growth stages.

Considering the interaction effects (Table 8b), L x S interaction had significant effect at all growth stages except 2 MAP and 5 MAP. The treatment combination l_3s_2 registered the highest LAI at each growth stage though the effect was not significant at 2 MAP and 5 MAP. At harvest, it was on a par with l_4s_2.

Table 8a. Effect of tillage systems, soil conditioners and nutrient management on leaf area index during I year

Treatments	Leaf area index							
	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
Tillage systems (L)								
l_1- Conventional tillage- pit system	0.16	0.37	0.60	0.84	0.43	0.35	0.21	0.14
l_2- Conventional tillage-mound system	0.13	0.25	0.44	0.68	0.37	0.24	0.18	0.13
l_3- Deep tillage-pit system	0.27	0.50	0.73	1.13	0.94	0.57	0.40	0.30
l_4 - Deep tillage-mound system	0.27	0.44	0.59	0.93	0.75	0.47	0.37	0.29
SEm±	0.007	0.010	0.012	0.016	0.015	0.014	0.009	0.006
CD (0.05)	0.024	0.036	0.046	0.060	0.056	0.050	0.035	0.024
Contrast analysis- Conventional vs Deep tillage								
Conventional tillage	0.15	0.31	0.52	0.76	0.40	0.30	0.19	0.14
Deep tillage	0.27	0.47	0.66	1.03	0.85	0.52	0.39	0.29
F test	S	S	S	S	S	S	S	S
Contrast analysis – Pit vs Mound system of planting								
Pit system	0.22	0.44	0.66	0.98	0.69	0.46	0.3	0.22
Mound system	0.2	0.34	0.51	0.8	0.56	0.36	0.27	0.21
F test	NS	S	S	S	S	S	S	NS
Soil conditioners (S)								
s_1- Control	0.17	0.30	0.49	0.73	0.49	0.33	0.24	0.18
s_2- Coir pith	0.25	0.47	0.69	1.07	0.76	0.51	0.35	0.26
s_3- Rice husk	0.20	0.40	0.58	0.88	0.62	0.39	0.27	0.21
SEm±	0.006	0.008	0.012	0.018	0.013	0.010	0.010	0.006
CD (0.05)	0.017	0.023	0.034	0.052	0.036	0.028	0.027	0.017
Nutrient management (N)								
n_1- INM	0.17	0.34	0.51	0.83	0.56	0.33	0.25	0.19
n_2- Organic nutrition	0.24	0.44	0.67	0.96	0.69	0.48	0.32	0.24
SEm±	0.005	0.007	0.010	0.015	0.011	0.008	0.008	0.005
CD (0.05)	0.014	0.019	0.028	0.042	0.030	0.022	0.022	0.014

S- Significant NS- Not significant

Table 8b. Interaction effect of tillage systems, soil conditioners and nutrient management on leaf area index during I year

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
L x S interaction								
l_1s_1	0.14	0.28	0.53	0.67	0.37	0.28	0.18	0.13
l_1s_2	0.20	0.43	0.68	1.02	0.51	0.42	0.25	0.17
l_1s_3	0.16	0.41	0.58	0.82	0.41	0.36	0.19	0.13
l_2s_1	0.10	0.20	0.38	0.57	0.30	0.18	0.16	0.11
l_2s_2	0.17	0.31	0.50	0.82	0.45	0.31	0.21	0.15
l_2s_3	0.13	0.24	0.45	0.64	0.38	0.24	0.17	0.13
l_3s_1	0.22	0.39	0.60	0.94	0.66	0.44	0.31	0.24
l_3s_2	0.32	0.62	0.89	1.34	1.19	0.73	0.51	0.37
l_3s_3	0.26	0.50	0.70	1.11	0.98	0.53	0.38	0.29
l_4s_1	0.22	0.34	0.47	0.76	0.63	0.41	0.31	0.24
l_4s_2	0.33	0.52	0.70	1.09	0.90	0.56	0.44	0.36
l_4s_3	0.25	0.45	0.59	0.95	0.73	0.43	0.36	0.28
SEm±	0.012	0.016	0.024	0.036	0.026	0.019	0.019	0.012
CD (0.05)	NS	0.046	0.068	NS	0.073	0.055	0.055	0.035
L x N interaction								
l_1n_1	0.13	0.35	0.54	0.80	0.40	0.27	0.16	0.13
l_1n_2	0.20	0.40	0.65	0.87	0.46	0.44	0.25	0.16
l_2n_1	0.10	0.18	0.34	0.66	0.34	0.24	0.17	0.13
l_2n_2	0.17	0.32	0.54	0.69	0.41	0.25	0.18	0.13
l_3n_1	0.23	0.44	0.63	1.01	0.77	0.44	0.35	0.26
l_3n_2	0.31	0.56	0.83	1.26	1.12	0.70	0.45	0.33
l_4n_1	0.24	0.41	0.53	0.84	0.72	0.38	0.33	0.26
l_4n_2	0.29	0.46	0.64	1.03	0.78	0.55	0.41	0.33
SEm±	0.010	0.013	0.020	0.030	0.021	0.016	0.016	0.010
CD (0.05)	NS	0.038	0.055	0.084	0.059	0.045	0.045	0.028
S x N interaction								
s_1n_1	0.14	0.26	0.44	0.69	0.45	0.28	0.21	0.15
s_1n_2	0.20	0.35	0.55	0.78	0.53	0.38	0.27	0.20
s_2n_1	0.21	0.41	0.60	0.99	0.67	0.41	0.30	0.24
s_2n_2	0.30	0.52	0.79	1.15	0.85	0.61	0.40	0.29
s_3n_1	0.17	0.36	0.49	0.80	0.55	0.31	0.25	0.19
s_3n_2	0.23	0.44	0.67	0.96	0.69	0.47	0.30	0.23
SEm±	0.008	0.012	0.017	0.026	0.018	0.014	0.014	0.009
CD (0.05)	NS	NS	NS	NS	0.051	0.039	NS	NS

NS- Not significant

Table 8c. Effect of L x S x N interaction on leaf area index during I year

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
$l_1s_1n_1$	0.11	0.25	0.49	0.63	0.34	0.22	0.16	0.12
$l_1s_1n_2$	0.17	0.31	0.58	0.71	0.40	0.34	0.21	0.14
$l_1s_2n_1$	0.16	0.39	0.63	0.99	0.47	0.33	0.20	0.16
$l_1s_2n_2$	0.24	0.47	0.73	1.05	0.55	0.52	0.29	0.19
$l_1s_3n_1$	0.12	0.40	0.52	0.79	0.38	0.26	0.14	0.11
$l_1s_3n_2$	0.20	0.42	0.65	0.86	0.43	0.46	0.24	0.16
$l_2s_1n_1$	0.08	0.13	0.30	0.58	0.29	0.19	0.15	0.10
$l_2s_1n_2$	0.13	0.27	0.46	0.56	0.31	0.18	0.17	0.11
$l_2s_2n_1$	0.13	0.22	0.39	0.77	0.40	0.30	0.20	0.13
$l_2s_2n_2$	0.20	0.40	0.62	0.86	0.50	0.33	0.22	0.16
$l_2s_3n_1$	0.10	0.18	0.33	0.64	0.34	0.23	0.17	0.15
$l_2s_3n_2$	0.17	0.31	0.56	0.65	0.41	0.24	0.17	0.11
$l_3s_1n_1$	0.19	0.33	0.53	0.85	0.54	0.36	0.25	0.19
$l_3s_1n_2$	0.25	0.44	0.67	1.04	0.78	0.52	0.38	0.28
$l_3s_2n_1$	0.25	0.54	0.74	1.21	0.95	0.56	0.45	0.33
$l_3s_2n_2$	0.39	0.69	1.05	1.47	1.42	0.91	0.58	0.40
$l_3s_3n_1$	0.24	0.44	0.63	0.96	0.81	0.39	0.36	0.27
$l_3s_3n_2$	0.29	0.56	0.77	1.26	1.15	0.68	0.40	0.31
$l_4s_1n_1$	0.19	0.31	0.44	0.71	0.62	0.35	0.29	0.21
$l_4s_1n_2$	0.24	0.36	0.50	0.80	0.64	0.48	0.33	0.27
$l_4s_2n_1$	0.31	0.50	0.65	0.98	0.87	0.45	0.37	0.32
$l_4s_2n_2$	0.36	0.54	0.75	1.21	0.93	0.68	0.50	0.40
$l_4s_3n_1$	0.22	0.42	0.50	0.83	0.68	0.35	0.33	0.24
$l_4s_3n_2$	0.28	0.49	0.68	1.07	0.78	0.51	0.39	0.32
SEm±	0.016	0.023	0.034	0.052	0.036	0.027	0.027	0.017
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS- Not significant

The interaction L x N was significant at all growth stages except at 2 MAP and the treatment combination l_3n_2 registered higher LAI at those stages. Although the effect was not significant, l_3n_2 registered the highest LAI during 2 MAP. At harvest, l_3n_2 was on a par with l_4n_2 also. The interaction S x N had significant effect on LAI only at 6 MAP and 7 MAP when the treatment combination s_2n_2 recorded the highest LAI at both stages.

The interaction L x S x N failed to produce significant effect on LAI at all growth stages (Table 8c) but the highest LAI at 2 MAP was produced by $l_4s_2n_2$ and by $l_3s_2n_2$ at other stages.

During II year, deep tillage followed by pit system (l_3) recorded the highest LAI at all growth stages (Table 9a). Contrast analysis revealed the superiority of deep tillage over conventional tillage and pit system over mound system at all stages in producing higher LAI.

Application of soil conditioner registered significantly higher LAI and coir pith (s_2) was found superior to rice husk (s_3).

Organic nutrition (n_2) resulted in the highest LAI at all growth stages compared to INM (n_1).

The data in Table 9b revealed that the interaction L x S had significant effect on LAI at all growth stages except at 4 MAP, 7 MAP and 8 MAP. At 2 MAP, the treatment combination l_3s_2 produced highest LAI but was on a par with l_3s_3 and l_4s_2. At 3 MAP, l_3s_2 was on a par with l_4s_2. At 5 MAP, 6 MAP and harvest, l_3s_2 recorded the highest value at each stage. The effect of L x N interaction was significant at all stages except 2 MAP when the treatment combination l_3n_2 registered the highest LAI but it was on a par with l_4n_2 at 3 MAP and 7 MAP. Regarding S x N interaction, the treatment combination s_2n_2 registered significantly higher LAI at all stages except 6 MAP when it failed to produce significant effect.

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Table 9a. Effect of tillage systems, soil conditioners and nutrient management on leaf area index during II year

Treatments	Leaf area index							
	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
Tillage systems (L)								
l_1- Conventional tillage- pit system	0.12	0.26	0.52	0.79	0.29	0.29	0.18	0.10
l_2- Conventional tillage-mound system	0.09	0.23	0.45	0.64	0.24	0.20	0.14	0.10
l_3- Deep tillage-pit system	0.17	0.34	0.60	0.96	0.68	0.37	0.36	0.26
l_4 - Deep tillage-mound system	0.15	0.33	0.51	0.76	0.51	0.34	0.28	0.22
SEm±	0.003	0.008	0.012	0.015	0.006	0.007	0.005	0.003
CD (0.05)	0.010	0.028	0.043	0.057	0.021	0.027	0.018	0.011
Contrast analysis- Conventional vs Deep tillage								
Conventional tillage	0.10	0.24	0.49	0.72	0.27	0.24	0.16	0.10
Deep tillage	0.16	0.33	0.56	0.86	0.59	0.36	0.32	0.24
F test	S	S	S	S	S	S	S	S
Contrast analysis – Pit vs Mound system of planting								
Pit system	0.14	0.30	0.56	0.88	0.49	0.33	0.27	0.18
Mound system	0.12	0.28	0.48	0.7	0.38	0.27	0.21	0.16
F test	S	S	S	S	S	S	S	S
Soil conditioners (S)								
s_1- Control	0.10	0.22	0.39	0.59	0.33	0.22	0.18	0.14
s_2- Coir pith	0.16	0.37	0.66	0.96	0.52	0.37	0.30	0.20
s_3- Rice husk	0.13	0.28	0.51	0.82	0.44	0.31	0.24	0.17
SEm±	0.003	0.006	0.010	0.015	0.010	0.008	0.007	0.005
CD (0.05)	0.010	0.016	0.029	0.042	0.027	0.023	0.020	0.015
Nutrient management (N)								
n_1- INM	0.11	0.21	0.42	0.67	0.37	0.25	0.20	0.14
n_2- Organic nutrition	0.15	0.37	0.62	0.91	0.49	0.35	0.28	0.20
SEm±	0.003	0.005	0.008	0.012	0.008	0.007	0.006	0.004
CD (0.05)	0.008	0.013	0.024	0.034	0.022	0.019	0.016	0.012

S- Significant

Table 9b. Interaction effect of tillage systems, soil conditioners and nutrient management on leaf area index during II year

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
L x S interaction								
l_1s_1	0.10	0.21	0.40	0.60	0.24	0.20	0.13	0.09
l_1s_2	0.13	0.34	0.65	0.95	0.38	0.35	0.24	0.13
l_1s_3	0.11	0.24	0.53	0.83	0.27	0.30	0.16	0.10
l_2s_1	0.07	0.17	0.33	0.49	0.18	0.15	0.08	0.08
l_2s_2	0.11	0.28	0.56	0.77	0.29	0.26	0.19	0.10
l_2s_3	0.08	0.23	0.47	0.67	0.26	0.20	0.15	0.11
l_3s_1	0.12	0.27	0.45	0.72	0.48	0.29	0.28	0.20
l_3s_2	0.20	0.41	0.77	1.14	0.84	0.45	0.45	0.30
l_3s_3	0.18	0.33	0.59	1.02	0.73	0.38	0.35	0.27
l_4s_1	0.12	0.25	0.39	0.54	0.44	0.25	0.22	0.18
l_4s_2	0.18	0.44	0.68	0.99	0.59	0.42	0.33	0.27
l_4s_3	0.14	0.30	0.47	0.74	0.50	0.34	0.28	0.21
SEm±	0.007	0.011	0.021	0.030	0.019	0.016	0.011	0.011
CD (0.05)	0.019	0.032	NS	0.084	0.054	NS	NS	0.030
L x N interaction								
l_1n_1	0.10	0.19	0.46	0.72	0.27	0.23	0.14	0.11
l_1n_2	0.13	0.34	0.59	0.87	0.32	0.34	0.21	0.10
l_2n_1	0.07	0.16	0.33	0.53	0.23	0.18	0.12	0.09
l_2n_2	0.11	0.29	0.57	0.76	0.26	0.23	0.16	0.11
l_3n_1	0.14	0.24	0.48	0.80	0.54	0.31	0.31	0.20
l_3n_2	0.19	0.44	0.72	1.12	0.82	0.44	0.41	0.31
l_4n_1	0.13	0.24	0.42	0.63	0.44	0.26	0.20	0.17
l_4n_2	0.16	0.42	0.61	0.88	0.58	0.41	0.35	0.27
SEm±	0.006	0.009	0.017	0.024	0.016	0.013	0.009	0.009
CD (0.05)	NS	0.026	0.048	0.069	0.044	0.037	0.024	0.024
S x N interaction								
s_1n_1	0.08	0.17	0.34	0.53	0.28	0.18	0.16	0.11
s_1n_2	0.12	0.28	0.44	0.65	0.38	0.26	0.20	0.16
s_2n_1	0.13	0.27	0.52	0.79	0.46	0.30	0.23	0.16
s_2n_2	0.19	0.47	0.81	1.13	0.58	0.44	0.37	0.24
s_3n_1	0.12	0.18	0.40	0.69	0.37	0.26	0.19	0.16
s_3n_2	0.14	0.37	0.62	0.95	0.51	0.36	0.28	0.19
SEm±	0.005	0.008	0.015	0.021	0.014	0.011	0.007	0.007
CD (0.05)	0.014	0.023	0.041	0.060	NS	0.032	0.021	0.021

NS- Not significant

Table 9c. Effect of L x S x N interaction on leaf area index during II year

Treatments	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	Harvest
$l_1s_1n_1$	0.08	0.15	0.39	0.58	0.23	0.18	0.11	0.09
$l_1s_1n_2$	0.12	0.27	0.41	0.63	0.24	0.23	0.16	0.08
$l_1s_2n_1$	0.11	0.24	0.54	0.85	0.33	0.30	0.20	0.13
$l_1s_2n_2$	0.16	0.43	0.75	1.04	0.43	0.41	0.28	0.13
$l_1s_3n_1$	0.10	0.17	0.45	0.72	0.26	0.23	0.13	0.11
$l_1s_3n_2$	0.13	0.31	0.60	0.95	0.28	0.37	0.19	0.09
$l_2s_1n_1$	0.06	0.12	0.25	0.45	0.15	0.14	0.09	0.07
$l_2s_1n_2$	0.08	0.21	0.41	0.54	0.22	0.16	0.08	0.10
$l_2s_2n_1$	0.09	0.21	0.42	0.64	0.29	0.22	0.14	0.10
$l_2s_2n_2$	0.14	0.36	0.71	0.90	0.28	0.29	0.25	0.11
$l_2s_3n_1$	0.06	0.15	0.33	0.52	0.24	0.18	0.13	0.12
$l_2s_3n_2$	0.10	0.31	0.61	0.83	0.28	0.23	0.17	0.11
$l_3s_1n_1$	0.10	0.22	0.40	0.62	0.42	0.24	0.24	0.16
$l_3s_1n_2$	0.14	0.31	0.50	0.82	0.54	0.33	0.33	0.25
$l_3s_2n_1$	0.16	0.29	0.62	0.94	0.69	0.36	0.37	0.21
$l_3s_2n_2$	0.24	0.54	0.93	1.34	0.99	0.55	0.52	0.39
$l_3s_3n_1$	0.17	0.21	0.44	0.84	0.53	0.34	0.33	0.25
$l_3s_3n_2$	0.20	0.46	0.74	1.20	0.93	0.43	0.37	0.29
$l_4s_1n_1$	0.10	0.19	0.34	0.49	0.34	0.18	0.20	0.14
$l_4s_1n_2$	0.14	0.31	0.44	0.60	0.53	0.32	0.24	0.21
$l_4s_2n_1$	0.16	0.35	0.52	0.74	0.54	0.32	0.23	0.21
$l_4s_2n_2$	0.21	0.54	0.84	1.24	0.64	0.52	0.44	0.34
$l_4s_3n_1$	0.14	0.20	0.39	0.67	0.44	0.29	0.18	0.15
$l_4s_3n_2$	0.15	0.40	0.54	0.81	0.56	0.40	0.38	0.27
SEm±	0.010	0.016	0.029	0.042	0.027	0.023	0.015	0.015
CD (0.05)	NS	NS	NS	0.119	0.077	NS	0.042	0.042

NS- Not significant

The interaction L x S x N (Table 9c) had significant effect on LAI at 5 MAP, 6 MAP, 8 MAP and harvest. At these stages, the treatment combination $l_3s_2n_2$ produced the highest LAI but it was on a par with $l_4s_2n_2$ at 5 MAP and $l_3s_3n_2$ at 6 MAP. Though not significant, $l_3s_2n_2$ recorded the highest LAI at 2 MAP, 3 MAP, 4 MAP and 7 MAP.

4.2 YIELD COMPONENTS

4.2.1 Number of Cormels Plant^{-1}

The data on number of cormels plant^{-1} during both the years are summarized in Table 10a, 10b and 10c.

The treatments had significant effect on cormel number plant^{-1} during both the years. Among the tillage systems, deep tillage followed by pit system (l_3) registered the highest number during both the years (4.7 during I year and 5.92 during II year) followed by deep tillage and mound system (l_4). The lowest number during both the years was produced by conventional tillage followed by mound (l_2). Planting in pit or mound under deep tillage produced more cormels plant^{-1} than under conventional tillage (l_3 and $l_4 > l_1$ and l_2). Pit system of planting tannia recorded higher cormel number compared to mound system under conventional and deep tillage systems ($l_1 > l_2$ and $l_3 > l_4$). The results were confirmed by contrast analysis.

Application of soil conditioners registered significantly higher cormel number and coir pith (s_2) was found superior (4.44 during I year and 5.38 during II year) to rice husk as soil conditioner (s_3) during both the years.

Organic nutrition (n_2) proved superior to INM (n_1) during both the years in producing higher cormel number plant^{-1}.

Considering interactions, the interactions L x S, L x N and S x N had significant effects on cormel number during II year only (Table 10b) when the treatment combinations l_3s_2 (on a par with l_3s_3), l_3n_2 and s_2n_2 recorded higher cormel number plant^{-1}. Although the interaction effects were not significant during I year, the same treatment combinations (l_3s_2, l_3n_2 and s_2n_2) recorded higher cormel number plant^{-1}.

The interaction L x S x N had significant effect on cormel number only during II year (Table 10c). The effects of the treatment combinations $l_3s_3n_2$, $l_3s_2n_2$and $l_4s_2n_2$ were on a par but superior to others. During I year, $l_3s_2n_1$, $l_3s_2n_2$ and $l_3s_3n_2$ and $l_4s_2n_2$ produced higher number of cormels (> 5) compared to other treatment combinations.

4.2.2 Mean Weight of Cormel

A perusal of the data in Table 10a indicated that variation in mean weight of cormel due to tillage systems was significant only during second year. Deep tillage and mound system (l_4) registered the highest value (60.6 g) followed by deep tillage and pit system (l_3). Contrast analysis also indicated the superiority of deep tillage over conventional tillage during II year. Planting in pit or mound system did not produce significant variation in cormel size during both the years.

The mean weight of cormel was significantly higher (59.6 g during I year and 61.49 g during II year) in plots which received no soil conditioner (s_1) during both the years. The effects of coir pith (s_2) and rice husk (s_3) as soil conditioner were on a par in producing bigger sized cormels.

The mean weight of cormel was higher under INM (n_1) than under organic nutrition (n_2) during both the years(54.94 and 59.17 g during I and II year respectively) though the variation was significant only during the II year.

Interaction effect furnished in Table 10b revealed significant effects of L x S, L x N and S x N interaction on mean weight of cormel only during II year. With regard toL x S interaction, the effect of treatment combinations, l_3s_1 and l_4s_1 were on a par but superior to other combinations. In the case of L x N interaction, $l_4n_1$produced significantly bigger sized cormels followed by l_1n_1 and l_3n_2. Regarding S x N interaction, the treatment combination $s_1n_1$produced heavier cormels but was on a par with s_1n_2.

Table 10a. Effect of tillage systems, soil conditioners and nutrient management on yield components

Treatments	Cormel number plant^{-1}		Mean cormel weight (g)	
	I year	II year	I year	II year
Tillage systems (L)				
l_1- Conventional tillage- pit system	3.58	4.78	55.80	55.68
l_2- Conventional tillage-mound system	3.30	4.23	53.68	53.36
l_3- Deep tillage-pit system	4.70	5.92	53.56	57.02
l_4 - Deep tillage-mound system	4.05	4.89	52.44	60.60
SEm±	0.067	0.039	0.876	0.503
CD (0.05)	0.249	0.146	NS	1.862
Contrast analysis- Conventional vs Deep tillage				
Conventional tillage	3.44	4.51	54.74	54.52
Deep tillage	4.38	5.40	53.00	58.81
F test	S	S	NS	S
Contrast analysis – Pit vs Mound system of planting				
Pit system	4.14	5.35	54.68	56.35
Mound system	3.68	4.56	53.06	56.98
F test	S	S	NS	NS
Soil conditioners (S)				
s_1- Control	3.18	4.37	59.60	61.49
s_2- Coir pith	4.44	5.38	51.05	53.79
s_3- Rice husk	4.11	5.12	50.96	54.72
SEm±	0.088	0.045	1.452	0.518
CD (0.05)	0.248	0.128	4.108	1.465
Nutrient management (N)				
n_1- INM	3.58	4.54	54.94	59.17
n_2- Organic nutrition	4.24	5.37	52.80	54.16
SEm±	0.072	0.037	1.186	0.423
CD (0.05)	0.203	0.104	NS	1.196

S- Significant NS- Not significant

Table 10b. Interaction effect of tillage systems, soil conditioners and nutrient management on yield components

Treatment	Cormel number plant^{-1}		Mean cormel weight (g)	
	I year	II year	I year	II year
L x S interaction				
l_1s_1	2.78	4.31	64.87	59.18
l_1s_2	4.19	5.22	49.71	52.49
l_1s_3	3.78	4.81	52.82	55.38
l_2s_1	2.94	3.88	55.40	56.00
l_2s_2	3.63	4.44	54.23	52.72
l_2s_3	3.34	4.38	51.40	51.34
l_3s_1	3.66	5.00	61.88	64.44
l_3s_2	5.41	6.38	49.08	54.17
l_3s_3	5.03	6.38	49.73	52.44
l_4s_1	3.34	4.28	56.24	66.36
l_4s_2	4.53	5.47	51.18	55.76
l_4s_3	4.28	4.91	49.89	59.69
SEm±	0.176	0.090	2.905	1.036
CD (0.05)	NS	0.255	NS	2.930
L x N interaction				
l_1n_1	3.23	4.27	57.71	59.43
l_1n_2	3.94	5.29	53.88	51.94
l_2n_1	3.00	3.85	57.00	55.59
l_2n_2	3.60	4.60	50.35	51.12
l_3n_1	4.54	5.73	50.63	55.66
l_3n_2	4.85	6.10	56.50	58.37
l_4n_1	3.54	4.29	54.40	66.01
l_4n_2	4.56	5.48	50.47	55.20
SEm±	0.143	0.074	2.372	0.846
CD (0.05)	NS	0.208	NS	2.392
S x N interaction				
s_1n_1	2.81	4.14	62.18	61.60
s_1n_2	3.55	4.59	57.01	61.39
s_2n_1	4.14	4.84	51.24	57.71
s_2n_2	4.73	5.91	50.86	49.86
s_3n_1	3.78	4.63	51.39	58.21
s_3n_2	4.44	5.61	50.53	51.22
SEm±	0.124	0.064	2.054	0.732
CD (0.05)	NS	0.180	NS	2.072

NS- Not significant

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Table 10c. Effect of L x S x N interaction on yield components

Treatment	Cormel number plant^{-1}		Mean cormel weight (g)	
	I year	II year	I year	II year
$l_1s_1n_1$	2.50	3.88	66.95	61.67
$l_1s_1n_2$	3.06	4.75	62.78	56.68
$l_1s_2n_1$	3.69	4.75	53.45	55.99
$l_1s_2n_2$	4.69	5.69	45.96	48.99
$l_1s_3n_1$	3.50	4.19	52.73	60.62
$l_1s_3n_2$	4.06	5.44	52.91	50.15
$l_2s_1n_1$	2.38	3.75	63.24	54.69
$l_2s_1n_2$	3.50	4.00	47.56	57.32
$l_2s_2n_1$	3.44	3.94	53.81	57.14
$l_2s_2n_2$	3.81	4.94	54.65	48.31
$l_2s_3n_1$	3.19	3.88	53.95	54.95
$l_2s_3n_2$	3.50	4.88	48.85	47.73
$l_3s_1n_1$	3.31	4.88	62.21	62.27
$l_3s_1n_2$	4.00	5.13	61.54	66.61
$l_3s_2n_1$	5.50	6.19	43.20	53.18
$l_3s_2n_2$	5.31	6.56	54.97	55.15
$l_3s_3n_1$	4.81	6.13	46.47	51.53
$l_3s_3n_2$	5.25	6.63	53.00	53.36
$l_4s_1n_1$	3.06	4.06	56.32	67.76
$l_4s_1n_2$	3.63	4.50	56.15	64.95
$l_4s_2n_1$	3.94	4.50	54.48	64.53
$l_4s_2n_2$	5.13	6.44	47.88	46.99
$l_4s_3n_1$	3.63	4.31	52.41	65.73
$l_4s_3n_2$	4.94	5.50	47.37	53.66
SEm±	0.248	0.127	4.108	1.465
CD (0.05)	NS	0.361	NS	4.143

NS- Not significant

The effect of L x S x N interaction furnished in Table 10c revealed its significant effect only during II year and the effects of the treatment combinations $l_4s_1n_1$, $l_3s_1n_2$, $l_4s_3n_1$,$l_4s_1n_2$and$l_4s_2n_1$ were on a par but superior to others.

4.2.3 Cormel Yield Plant^{-1}

The data in table 11a revealed the significant effects of treatments on cormel yield plant^{-1} during both the years.

Deep tillage with pit system (l_3) recorded significantly higher cormel yield plant^{-1} during both the years (244.99 and 333.66 g during I and II year respectively) followed by deep tillage with mound system (l_4). The lowest cormel yield plant^{-1} was produced by conventional tillage followed by mound system (l_2). Significantly higher cormel yield plant^{-1} was registered by deep tillage followed by pit or mound system compared to conventional tillage followed by pit or mound system (l_3 and l_4> l_1 and l_2). Pit system under both tillage produced significantly higher cormel yield plant^{-1} compared to mound system under both tillage (l_3> l_4 and l_1> l_2). Contrast analysis also revealed the superiority of deep tillage over conventional tillage and pit system over mound system during both the years.

Application of soil conditioner significantly increased cormel yield plant^{-1} and the highest yield (221.98 g during I year and 285.53 g during II year) was produced by coir pith as soil conditioner (s_2) than rice husk (s_3).

Significantly higher cormel yield plant^{-1} (219.17 g and 288.45 g during I and II year respectively) was registered by organic nutrition (n_2) compared to INM (n_1) during both the years.

Considering the interaction effects (Tale 11b), only L x N interaction had significant effect on cormel yield plant^{-1} during I year. The treatment combination l_3n_2 recorded highest cormel yield plant^{-1}. During II year, L x S, L x N and S x N interaction had significant effects on cormel yield plant^{-1}. The treatment combinations l_3s_2, l_3n_2 and s_2n_2 recorded significantly higher cormel yield plant^{-1} compared to other respective treatment combinations.

The effect of L x S x N interaction (Table 11c) was significant only during II year and the treatment combination $l_3s_2n_2$ was found superior. Though not significant, the same treatment combination registered the highest cormel yield plant^{-1} during I year also.

4.2.4 Corm Yield Plant^{-1}

As depicted in Table 11a, corm yield plant^{-1} was significantly influenced by tillage systems, soil conditioners and nutrient management.

Similar to cormel yield plant^{-1}, the highest corm yield plant^{-1} during both the years (391.36 g during I year and 478.39 g during II year) was registered by deep tillage followed by pit system (l_3) and the lowest by conventional tillage followed by mound system (l_2). Deep tillage followed by pit or mound system (l_3 and l_4 respectively) registered significantly higher corm yield plant^{-1} than conventional tillage followed by pit or mound system (l_1 and l_2 respectively). Pit system under both the tillage registered significantly higher corm yield plant^{-1} compared to mound system under both tillage systems ($l_1 > l_2$ and $l_3 > l_4$) during both the years. Contrast analysis also indicated the superiority of deep tillage over conventional tillage and pit system over mound system during both the years.

Coir pith as soil conditioner (s_2) recorded significantly higher corm yield plant^{-1} during both the years (355.22 g during I year and 432 g during II year) over control (s_1) and rice husk as soil conditioner (s_3).

As in the case of cormel yield plant^{-1}, organic nutrition (n_2) proved superior to INM (n_1) with respect to corm yield plant^{-1} during both the years (357.74 g during I year and 437.97 g during II year respectively).

Interaction effects shown in Table 11b revealed the significant effects of L x S, L x N and S x N interaction on corm yield plant^{-1} during both the years. In the case of L x S interaction, significantly higher corm yield plant^{-1} were obtained 95 from plots given l_3s_1, l_3s_2 and l_3s_3 which were on a par during I year. During II year, significantly higher corm yield plant^{-1} was obtained from l_3s_3 and l_3s_1 which were on a par. During both the years, the treatment combination l_3n_2, among L x N interactions, recorded significantly higher corm yield plant^{-1}. In the case of S x N interaction s_2n_2 recorded the highest corm yield plant^{-1} during both the years. During II year, the effects of s_3n_2 and $s_2n_2$were on a par.

In the case of L x S x N interaction (Table 11c), the effects of $l_3s_2n_2$ and $l_3s_3n_2$ were on a par during I year and during II year, $l_3s_3n_2$ proved its superiority.

4.2.5 Cormel: Corm Ratio

Table 11a depicts the significant effects of treatments on cormel : corm ratio during both the years.

During I year, significantly higher cormel: corm ratio (0.62) was registered by deep tillage followed by pit system (l_3) but it was on a par with deep tillage followed by mound system (l_4). During II year, l_3 registered superior cormel : corm ratio (0.70). The lowest ratio was recorded by conventional tillage followed by mound system (l_2) during both the years. No significant variation in cormel: corm ratio was observed from contrast analysis of deep versus conventional tillage and pit versus mound system of planting during I year. But significance was observed during II year when deep tillage was found superior to conventional tillage and pit system was found superior to mound system.

Coir pith as soil conditioner recorded significantly higher cormel : corm ratio (0.62 during I year and 0.66 during II year) compared to control (s_1) and rice husk as soil conditioner (s_3).

Organic nutrition (n_2) was found superior in producing higher cormel : corm ratio (0.61 during I year and 0.66 during II year) than INM (n_1).

The data presented in the Table 11b revealed significant effects of L x S, L x N and S x N interactions on cormel : corm ratio only during II year. The treatment combinations l_3s_2 among L x S interaction and l_3n_2 among 96

Table 11a. Effect of tillage systems, soil conditioners and nutrient management on yield components (continued)

Treatments	Cormel yield plant^{-1} (g)		Corm yield plant^{-1} (g)		Cormel:Corm ratio	
	I year	II year	I year	II year	I year	II year
Tillage systems (L)						
l_1- Conventional tillage- pit system	190.92	262.90	325.88	407.67	0.58	0.65
l_2- Conventional tillage-mound system	173.39	223.36	312.87	399.52	0.55	0.56
l_3- Deep tillage-pit system	244.99	333.66	391.36	478.39	0.62	0.70
l_4 - Deep tillage-mound system	208.43	288.86	344.37	418.22	0.60	0.69
SEm±	1.662	0.933	1.106	1.543	0.006	0.003
CD (0.05)	6.159	3.458	4.099	5.718	0.022	0.009
Contrast analysis- Conventional vs Deep tillage						
Conventional tillage	182.16	243.13	319.37	403.59	0.57	0.60
Deep tillage	226.71	311.26	367.86	448.3	0.61	0.70
F test	S	S	S	S	NS	S
Contrast analysis – Pit vs Mound system of planting						
Pit system	217.96	298.28	358.62	443.03	0.6	0.67
Mound system	190.91	256.11	328.62	408.87	0.58	0.63
F test	S	S	S	S	NS	S
Soil conditioners (S)						
s_1- Control	185.38	268.91	334.90	420.91	0.55	0.64
s_2- Coir pith	221.98	285.53	355.22	432.00	0.62	0.66
s_3- Rice husk	205.95	277.14	340.74	424.94	0.60	0.65
SEm±	2.041	0.470	1.085	1.394	0.006	0.003
CD (0.05)	5.772	1.330	3.068	3.942	0.016	0.007
Nutrient management (N)						
n_1- INM	189.70	265.94	329.50	413.93	0.57	0.64
n_2- Organic nutrition	219.17	288.45	357.74	437.97	0.61	0.66
SEm±	1.667	0.384	0.886	1.138	0.004	0.002
CD (0.05)	4.712	1.086	2.505	3.219	0.013	0.006

S- Significant NS- Not significant

Table 11b. Interaction effect of tillage systems, soil conditioners and nutrient management on yield components (continued)

Treatment	Cormel yield plant^{-1} (g)		Corm yield plant^{-1} (g)		Cormel:corm ratio	
	I year	II year	I year	II year	I year	II year
L x S interaction						
l_1s_1	173.18	254.00	317.82	391.78	0.55	0.65
l_1s_2	204.05	271.56	331.31	425.88	0.61	0.64
l_1s_3	195.54	263.13	328.50	405.35	0.59	0.65
l_2s_1	157.50	216.71	299.88	377.72	0.53	0.57
l_2s_2	194.42	231.11	337.85	433.48	0.58	0.54
l_2s_3	168.26	222.26	300.87	387.35	0.56	0.57
l_3s_1	223.95	322.05	388.69	489.59	0.57	0.66
l_3s_2	261.99	344.80	393.89	452.04	0.66	0.77
l_3s_3	249.05	334.13	391.50	493.53	0.63	0.68
l_4s_1	186.89	282.86	333.21	424.55	0.56	0.67
l_4s_2	227.46	294.66	357.82	416.60	0.63	0.71
l_4s_3	210.94	289.04	342.07	413.51	0.61	0.70
SEm±	4.080	0.940	2.169	2.787	0.011	0.005
CD (0.05)	NS	2.660	6.136	7.883	NS	0.015
L x N interaction						
l_1n_1	180.14	252.43	316.03	389.39	0.57	0.65
l_1n_2	201.71	273.36	335.72	425.96	0.60	0.64
l_2n_1	166.50	214.05	313.69	390.52	0.53	0.55
l_2n_2	180.28	232.68	312.05	408.52	0.58	0.57
l_3n_1	221.11	315.64	363.10	466.22	0.61	0.68
l_3n_2	268.88	351.69	419.63	490.55	0.64	0.72
l_4n_1	191.06	281.65	325.17	409.60	0.58	0.69
l_4n_2	225.80	296.07	363.56	426.85	0.62	0.70
SEm±	3.332	0.768	1.771	2.276	0.009	0.004
CD (0.05)	9.423	2.172	5.010	6.436	NS	0.012
S x N interaction						
s_1n_1	172.34	255.06	326.11	413.30	0.53	0.62
s_1n_2	198.42	282.76	343.69	428.52	0.58	0.66
s_2n_1	207.07	276.51	340.17	420.82	0.61	0.66
s_2n_2	236.88	294.56	370.27	443.18	0.64	0.66
s_3n_1	189.70	266.26	322.21	407.67	0.59	0.65
s_3n_2	222.19	288.03	359.26	442.20	0.62	0.65
SEm±	2.885	0.665	1.534	1.971	0.008	0.004
CD (0.05)	NS	1.881	4.339	5.574	NS	0.011

NS- Not significant

Table 11c. Effect of L x S x N interaction on yield components (continued)

Treatment	Cormel yield plant^{-1} (g)		Corm yield plant^{-1} (g)		Cormel:corm ratio	
	I year	II year	I year	II year	I year	II year
$l_1s_1n_1$	165.52	238.76	318.38	385.74	0.52	0.62
$l_1s_1n_2$	180.85	269.24	317.25	397.83	0.57	0.68
$l_1s_2n_1$	195.19	264.89	324.85	400.78	0.60	0.66
$l_1s_2n_2$	212.91	278.23	337.78	450.99	0.63	0.62
$l_1s_3n_1$	179.72	253.65	304.88	381.66	0.59	0.67
$l_1s_3n_2$	211.36	272.62	352.13	429.05	0.60	0.64
$l_2s_1n_1$	149.49	204.64	299.11	359.02	0.50	0.57
$l_2s_1n_2$	165.52	228.79	300.66	396.42	0.55	0.58
$l_2s_2n_1$	183.10	224.86	332.86	440.58	0.55	0.51
$l_2s_2n_2$	205.74	237.36	342.85	426.38	0.60	0.56
$l_2s_3n_1$	166.92	212.64	309.10	371.96	0.54	0.57
$l_2s_3n_2$	169.60	231.88	292.64	402.75	0.58	0.58
$l_3s_1n_1$	203.77	303.37	370.69	482.35	0.55	0.63
$l_3s_1n_2$	244.13	340.73	406.69	496.83	0.60	0.69
$l_3s_2n_1$	236.67	328.09	359.02	439.31	0.66	0.75
$l_3s_2n_2$	287.30	361.52	428.77	464.77	0.67	0.78
$l_3s_3n_1$	222.89	315.45	359.58	477.01	0.62	0.66
$l_3s_3n_2$	275.20	352.81	423.43	510.05	0.65	0.70
$l_4s_1n_1$	170.58	273.46	316.27	426.10	0.54	0.64
$l_4s_1n_2$	203.21	292.27	350.16	423.00	0.58	0.69
$l_4s_2n_1$	213.33	288.20	343.97	402.61	0.62	0.72
$l_4s_2n_2$	241.60	301.13	371.67	430.60	0.65	0.70
$l_4s_3n_1$	189.28	283.29	315.28	400.08	0.60	0.71
$l_4s_3n_2$	232.60	294.80	368.86	426.94	0.63	0.69
SEm±	5.771	1.330	3.068	3.941	0.016	0.007
CD (0.05)	NS	3.762	8.678	11.148	NS	0.021

NS- Not significant

L x N interaction recorded superior cormel : corm ratios. In the case of S x N interaction, the effects of all treatment combinations were on a par except s_1n_1.

Considering L x S x N interaction (Table 11c), the treatment combination $l_3s_2n_2$ recorded the highest cormel : corm ratio of 0.67 during I year and 0.78 during II year, though the effect was significant only during II year.

4.3 TUBER YIELD

4.3.1 Cormel Yield ha^{-1}

It is evident from Table 12a that tillage systems, soil conditioners and nutrient management had significant effects on cormel yield during both the years.

Cormel yield was the highest for deep tillage followed by pit system (l_3) during both the years (4.36 t ha^{-1} during 2014-15 and 5.94 t ha^{-1} during 2015-16). Conventional tillage followed by mound system (l_2) registered the lowest cormel yield during both the years. Pooled data also indicated the same trend. With pit or mound system deep tillage resulted in significantly higher cormel yield ha^{-1} (l_3 and l_4> l_1 and l_2). Pit system registered significantly higher cormel yield compared to mound system under conventional or deep tillage (l_1> l_2 and l_3> l_4). Contrast analysis also revealed the superiority of deep tillage over conventional tillage and pit system over mound system of planting during both the years and also in the pooled analysis.

Cormel yield during both the years and also the pooled mean significantly increased over the control (s_1) due to application of soil conditioner. Coir pith (s_2) was found superior (pooled mean of 4.51 t ha^{-1}) to rice husk (s_3 - pooled mean of 4.30 t ha^{-1}) as soil conditioner.

During both the years, significantly higher cormel yield was obtained under organic nutrition (n_2) than under INM (n_1). Pooled analysis revealed the same trend recording 4.52 t ha^{-1} due to n_2 and 4.05 t ha^{-1} due to n_1.

Interaction effects are furnished in Table 12b. Similar to cormel yield plant^{-1}, only L x N interaction had significant effect on cormel yield ha^{-1} during I year and the treatment combination l_3n_2 registered the highest cormel yield ha^{-1}. During II year, the interactions L x S, L x N and S x N had significant effects on cormel yield. The treatment combination l_3s_2 among L x S interaction, l_3n_2 among L x N interaction and s_2n_2 among S x N interaction registered superior cormel yield ha^{-1} than other treatment combinations. Pooled analysis indicated the significance of L x S and L x N interactions only. The treatment combinations l_3s_2 (5.4 t ha^{-1}) and l_3n_2 (5.52t ha^{-1}) recorded significantly higher cormel yield than other respective treatment combinations.

Among L x S x N interaction (Table 12c), the treatment combination $l_3s_2n_2$ produced the highest cormel yield ha^{-1} during both the years (5.11 and 6.44 t ha^{-1} during I and II year respectively) followed by $l_3s_3n_2$, but the effects were significant only during II year.Although the effect of L x S x N interaction was not significant in the pooled analysis, the treatment combination, $l_3s_2n_2$ recorded the highest cormel yield of 5.77 t ha^{-1} followed by $l_3s_3n_2$ (5.59 t ha^{-1}).

4.3.2 Corm Yield ha^{-1}

A clear scrutiny of the data in Table 12a indicated the significant effects of treatments on corm yield ha^{-1} during both the years and in the pooled analysis.

As in the case of cormel yield, deep tillage followed by pit system (l_3) recorded significantly higher corm yield ha^{-1} during both the years (6.96 and 8.5 t ha^{-1} during I and II year respectively) and in the pooled analysis (pooled mean of 7.73 tha^{-1}). The lowest corm yield was registered by conventional tillage followed by mound system (l_2) during both the years (pooled mean of 6.33 t ha^{-1}). Deep tillage followed by pit or mound system (l_3 and l_4) recorded significantly higher corm yield over conventional tillage followed by pit or mound system (l_1 and l_2). Similarly, pit system under conventional or deep tillage produced significantly higher corm yield over mound system under both tillage ($l_3 > l_4$ and

$l_1 > l_2$). The superiority of deep tillage over conventional tillage and pit system over mound system was also evident from contrast analysis (Table 12a).

During both the years, significantly higher corm yield (pooled mean of 6.99 t ha^{-1}) was obtained from plots given coir pith (s_2) as soil conditioner. The lowest corm yield (pooled mean of 6.71 t ha^{-1}) was obtained for plots without soil conditioner.

Organic nutrition (n_2) proved superior during both the years in registering higher corm yield (pooled mean of 7.07 t ha^{-1}) than INM (n_1) with pooled mean of 6.61t ha^{-1}.

Significant effects of L x S, L x N and S x N interactions during both the years and in the pooled analysis were evident from Table 12b. Considering L x S interaction, deep tillage followed by pit system with or without soil conditioner (l_3s_2, l_3s_3 and l_3s_1) were on a par with each other but superior to other combinations during I year. During the II year, significantly higher corm yield was recorded by l_3s_3 but was on a par with l_3s_1 and the same trend was observed in the pooled analysis. In the case of L x N interaction, plots which received deep tillage followed by pit system with organic nutrition (l_3n_2) registered significantly higher corm yield during both the years and in the pooled analysis. With regard to S x N interaction, coir pith as soil conditioner with organic nutrition (s_2n_2) recorded the highest corm yield during both the years. But it was on a par with s_3n_2 during II year. Pooled analysis indicated the superiority of s_2n_2 producing 7.23 t ha^{-1} of corm.

The data on L x S x N interaction (given in Table 12c) indicated significant effects during both the years. The treatment combination $l_3s_2n_2$ produced the highest yield of corm (7.62 t ha^{-1}), but was on a par with $l_3s_3n_2$ (7.53 t ha^{-1}) during I year. During II year, the treatment combination $l_3s_3n_2$ produced superior yield of corm (9.07 t ha^{-1}) than other treatments combinations. The pooled analysis revealed the superiority of $l_3s_3n_2$ in producing higher corm yield (8.30 t ha^{-1}).

Table 12a. Effect of tillage systems, soil conditioners and nutrient management on tuber yield, t ha^{-1}

Treatments	Cormel yield			Corm yield		
	I year	II year	Pooled mean	I year	II year	Pooled mean
Tillage systems (L)						
l_1- Conventional tillage- pit system	3.39	4.68	4.04	5.79	7.25	6.52
l_2- Conventional tillage-mound system	3.08	3.98	3.53	5.56	7.10	6.33
l_3- Deep tillage-pit system	4.36	5.94	5.15	6.96	8.50	7.73
l_4 - Deep tillage-mound system	3.71	5.14	4.42	6.12	7.44	6.78
SEm±	0.030	0.017	0.022	0.020	0.027	0.018
CD (0.05)	0.110	0.062	0.103	0.073	0.102	0.083
Contrast analysis- Conventional vs Deep tillage						
Conventional tillage	3.24	4.33	3.78	5.68	7.18	6.43
Deep tillage	4.03	5.54	4.79	6.54	7.97	7.26
F test	S	S	S	S	S	S
Contrast analysis – Pit vs Mound system of planting						
Pit system	3.87	5.31	4.59	6.38	7.88	7.13
Mound system	3.39	4.56	3.98	5.84	7.27	6.56
F test	S	S	S	S	S	S
Soil conditioners (S)						
s_1- Control	3.30	4.79	4.04	5.95	7.48	6.71
s_2- Coir pith	3.95	5.08	4.51	6.32	7.68	6.99
s_3- Rice husk	3.66	4.93	4.30	6.06	7.55	6.81
SEm±	0.036	0.008	0.020	0.019	0.025	0.016
CD (0.05)	0.103	0.024	0.073	0.055	0.070	0.058
Nutrient management (N)						
n_1- INM	3.37	4.73	4.05	5.86	7.36	6.61
n_2- Organic nutrition	3.90	5.13	4.52	6.36	7.79	7.07
SEm±	0.030	0.007	0.039	0.016	0.020	0.013
CD (0.05)	0.084	0.019	0.147	0.045	0.057	0.047

S- Significant NS- Not significant

Table 12b. Interaction effect of tillage systems, soil conditioners and management on tuber yield, t ha^{-1}

Treatment	Cormel yield			Corm yield		
	I year	II year	Pooled mean	I year	II year	Pooled mean
L x S interaction						
l_1s_1	3.08	4.52	3.80	5.65	6.97	6.31
l_1s_2	3.63	4.83	4.23	5.89	7.57	6.73
l_1s_3	3.48	4.68	4.08	5.84	7.21	6.52
l_2s_1	2.80	3.86	3.32	5.33	6.72	6.02
l_2s_2	3.46	4.11	3.79	6.01	7.71	6.86
l_2s_3	2.99	3.96	3.47	5.35	6.89	6.12
l_3s_1	3.98	5.73	4.86	6.91	8.70	7.81
l_3s_2	4.66	6.14	5.40	7.00	8.04	7.52
l_3s_3	4.43	5.95	5.19	6.96	8.77	7.87
l_4s_1	3.32	5.04	4.18	5.92	7.55	6.74
l_4s_2	4.04	5.25	4.64	6.36	7.41	6.89
l_4s_3	3.75	5.15	4.45	6.08	7.35	6.72
SEm±	0.073	0.017	0.039	0.039	0.050	0.031
CD (0.05)	NS	0.047	0.147	0.109	0.140	0.116
L x N interaction						
l_1n_1	3.20	4.49	3.85	5.62	6.92	6.27
l_1n_2	3.59	4.87	4.23	5.97	7.57	6.77
l_2n_1	2.96	3.81	3.39	5.58	6.94	6.26
l_2n_2	3.21	4.14	3.67	5.55	7.26	6.41
l_3n_1	3.93	5.62	4.78	6.46	8.29	7.37
l_3n_2	4.78	6.26	5.52	7.46	8.72	8.09
l_4n_1	3.40	5.01	4.21	5.78	7.28	6.53
l_4n_2	4.01	5.27	4.64	6.46	7.59	7.03
SEm±	0.059	0.014	0.032	0.031	0.040	0.025
CD (0.05)	0.168	0.039	0.120	0.089	0.114	0.095
S x N interaction						
s_1n_1	3.06	4.54	3.80	5.80	7.35	6.57
s_1n_2	3.53	5.03	4.28	6.11	7.62	6.86
s_2n_1	3.68	4.92	4.30	6.05	7.48	6.76
s_2n_2	4.21	5.24	4.73	6.58	7.88	7.23
s_3n_1	3.37	4.74	4.06	5.73	7.25	6.49
s_3n_2	3.95	5.13	4.54	6.39	7.86	7.12
SEm±	0.051	0.012	0.028	0.027	0.035	0.020
CD (0.05)	NS	0.033	NS	0.077	0.099	0.082

NS- Not significant

Table 12 c. Effect of L x S x N interaction on tuber yield, t ha^{-1}

Treatment	Cormel yield			Corm yield		
	I year	II year	Pooled mean	I year	II year	Pooled mean
$l_1s_1n_1$	2.94	4.25	3.60	5.66	6.86	6.26
$l_1s_1n_2$	3.22	4.79	4.00	5.64	7.07	6.36
$l_1s_2n_1$	3.47	4.72	4.09	5.78	7.13	3.45
$l_1s_2n_2$	3.79	4.95	4.37	6.01	8.02	7.01
$l_1s_3n_1$	3.20	4.52	3.86	5.42	6.79	6.10
$l_1s_3n_2$	3.76	4.85	4.31	6.26	7.63	6.94
$l_2s_1n_1$	2.66	3.64	3.15	5.32	6.38	5.85
$l_2s_1n_2$	2.94	4.07	3.51	5.35	7.05	6.20
$l_2s_2n_1$	3.26	4.00	3.63	5.92	7.83	6.88
$l_2s_2n_2$	3.66	4.23	3.94	6.10	7.58	6.84
$l_2s_3n_1$	2.97	3.79	3.38	5.50	6.61	6.05
$l_2s_3n_2$	3.02	4.13	3.57	5.20	7.16	6.18
$l_3s_1n_1$	3.62	5.40	4.51	6.59	8.58	7.58
$l_3s_1n_2$	4.34	6.07	5.20	7.23	8.83	8.03
$l_3s_2n_1$	4.21	5.84	5.02	6.38	7.81	7.10
$l_3s_2n_2$	5.11	6.44	5.77	7.62	8.26	7.94
$l_3s_3n_1$	3.96	5.62	4.79	6.39	8.48	7.44
$l_3s_3n_2$	4.89	6.28	5.59	7.53	9.07	8.30
$l_4s_1n_1$	3.03	4.87	3.95	5.62	7.58	6.60
$l_4s_1n_2$	3.61	5.20	4.41	6.23	7.52	6.89
$l_4s_2n_1$	3.79	5.13	4.46	6.12	7.16	6.64
$l_4s_2n_2$	4.30	5.36	4.83	6.61	7.66	7.13
$l_4s_3n_1$	3.37	5.04	4.20	5.61	7.11	6.36
$l_4s_3n_2$	4.14	5.25	4.69	6.56	7.59	7.07
SEm±	0.103	0.024	0.014	0.055	0.070	0.044
CD (0.05)	NS	0.067	NS	0.154	0.198	0.164

NS- Not significant

4.4 DRY MATTER PRODUCTION

4.4.1 Total Dry Matter Production

The main effects and interaction effects of treatments on TDMP are furnished in Table 13a, 13b and 13c.

A perusal of the data on Table 13a revealed significant effects of treatments on TDMP during both the years. Among tillage systems, deep tillage and pit system (l_3) registered significantly higher dry matter production (4.36 and 5.94 t ha^{-1} during I and II year respectively) followed by deep tillage and mound system (l_4) during both the years. Deep tillage registered significantly higher TDMP over conventional tillage. Pit system registered superior TDMP over mound system as revealed from contrast analysis.

Application of soil conditioner recorded significantly higher TDMP over control (s_1) during both the years. Coir pith (s_2) was superior (5.08 t ha^{-1}) to rice husk (s_3) as soil conditioner.

During both the years, organic nutrition (n_2) proved its superiority in its effect on TDMP (5.13 t ha^{-1}) over INM (n_1).

Among the interactions L x S, L x N and S x N (Table 13b) only L x N and S x N had significant effects on TDMP that too only during I year. The treatment combinations l_3n_2 and s_2n_2 were found superior.

L x S x N interaction was significant only during I year when the effects of the treatment combinations $l_3s_2n_2$ and $l_3s_3n_2$ were on a par but superior to others (Table 13c). Although the interaction effects were not significant during II year, the treatment combination $l_3s_3n_2$ recorded the highest TDMP followed by $l_3s_2n_2$.

4.4.2 Harvest Index

The data in Table 13a revealed the significant effects of treatments on harvest index during both the years.

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Table 13a. Effect of tillage systems, soil conditioners and nutrient management on total dry matter production (TDMP) and harvest index

Treatments	TDMP ($t\ ha^{-1}$)		Harvest index	
	I year	II year	I year	II year
Tillage systems (L)				
l_1- Conventional tillage- pit system	3.39	4.68	0.31	0.34
l_2- Conventional tillage-mound system	3.08	3.98	0.29	0.29
l_3- Deep tillage-pit system	4.36	5.94	0.32	0.38
l_4 - Deep tillage-mound system	3.71	5.14	0.31	0.36
SEm±	0.030	0.017	0.005	0.002
CD (0.05)	0.110	0.062	0.018	0.008
Contrast analysis- Conventional vs Deep tillage				
Conventional tillage	3.24	4.33	0.30	0.32
Deep tillage	4.04	5.54	0.32	0.37
F test	S	S	S	S
Contrast analysis – Pit vs Mound system of planting				
Pit system	3.87	5.31	0.32	0.36
Mound system	3.40	4.56	0.30	0.33
F test	S	S	S	S
Soil conditioners (S)				
s_1- Control	3.30	4.79	0.30	0.33
s_2- Coir pith	3.95	5.08	0.32	0.35
s_3- Rice husk	3.66	4.93	0.31	0.35
SEm±	0.036	0.008	0.004	0.003
CD (0.05)	0.103	0.024	0.011	0.008
Nutrient management (N)				
n_1- INM	3.37	4.73	0.29	0.33
n_2- Organic nutrition	3.90	5.13	0.32	0.35
SEm±	0.030	0.007	0.003	0.002
CD (0.05)	0.084	0.019	0.009	0.006

S- Significant

Table 13b. Interaction effect of tillage systems, soil conditioners and nutrient management on total dry matter production (TDMP) and harvest index

Treatments	TDMP (t ha^{-1})		Harvest index	
	I year	II year	I year	II year
L x S interaction				
l_1s_1	2.94	3.64	0.30	0.33
l_1s_2	3.54	3.99	0.32	0.34
l_1s_3	3.35	3.85	0.31	0.34
l_2s_1	2.65	3.40	0.28	0.29
l_2s_2	3.37	3.77	0.31	0.29
l_2s_3	2.94	3.56	0.29	0.29
l_3s_1	3.93	4.46	0.32	0.37
l_3s_2	4.54	4.77	0.33	0.40
l_3s_3	4.38	4.86	0.32	0.38
l_4s_1	3.26	3.96	0.30	0.35
l_4s_2	3.97	4.23	0.33	0.37
l_4s_3	3.68	4.09	0.30	0.37
SEm±	0.049	0.055	0.007	0.005
CD (0.05)	NS	NS	NS	0.015
L x N interaction				
l_1n_1	3.03	3.57	0.29	0.33
l_1n_2	3.53	4.08	0.33	0.34
l_2n_1	2.80	3.39	0.27	0.28
l_2n_2	3.17	3.77	0.31	0.30
l_3n_1	3.84	4.45	0.31	0.37
l_3n_2	4.72	4.95	0.34	0.39
l_4n_1	3.33	3.92	0.30	0.36
l_4n_2	3.94	4.27	0.32	0.37
SEm±	0.040	0.044	0.006	0.004
CD (0.05)	0.113	NS	NS	NS
S x N interaction				
s_1n_1	2.96	3.70	0.28	0.33
s_1n_2	3.43	4.03	0.31	0.34
s_2n_1	3.53	3.95	0.31	0.34
s_2n_2	4.17	4.43	0.34	0.36
s_3n_1	3.26	3.84	0.29	0.33
s_3n_2	3.91	4.34	0.32	0.36
SEm±	0.034	0.038	0.005	0.004
CD (0.05)	0.098	NS	NS	NS

NS- Not significant

Table 13c. Effect of L x S x N interaction on total dry matter production (TDMP) and harvest index

Treatments	TDMP (t ha^{-1})		Harvest index	
	I year	II year	I year	II year
$l_1s_1n_1$	2.80	3.41	0.28	0.32
$l_1s_1n_2$	3.10	3.86	0.31	0.33
$l_1s_2n_1$	3.29	3.72	0.31	0.34
$l_1s_2n_2$	3.80	4.25	0.34	0.35
$l_1s_3n_1$	3.05	3.58	0.29	0.33
$l_1s_3n_2$	3.69	4.12	0.33	0.35
$l_2s_1n_1$	2.47	3.21	0.25	0.29
$l_2s_1n_2$	2.84	3.60	0.30	0.29
$l_2s_2n_1$	3.10	3.62	0.29	0.28
$l_2s_2n_2$	3.63	3.92	0.33	0.30
$l_2s_3n_1$	2.85	3.34	0.27	0.28
$l_2s_3n_2$	3.03	3.78	0.31	0.30
$l_3s_1n_1$	3.61	4.33	0.30	0.35
$l_3s_1n_2$	4.25	4.60	0.34	0.38
$l_3s_2n_1$	4.05	4.46	0.32	0.39
$l_3s_2n_2$	5.02	5.07	0.35	0.41
$l_3s_3n_1$	3.86	4.56	0.31	0.36
$l_3s_3n_2$	4.88	5.16	0.34	0.39
$l_4s_1n_1$	2.97	3.87	0.28	0.35
$l_4s_1n_2$	3.53	4.05	0.31	0.36
$l_4s_2n_1$	3.69	4.04	0.32	0.37
$l_4s_2n_2$	4.24	4.46	0.34	0.37
$l_4s_3n_1$	3.32	3.89	0.29	0.37
$l_4s_3n_2$	4.03	4.28	0.32	0.38
SEm±	0.069	0.077	0.010	0.008
CD (0.05)	0.197	NS	NS	NS

NS- Not significant

During I year, tillage systems except conventional tillage followed by mound system (l_2) were found on a par in their effects on harvest index. During II year, deep tillage followed by pit system (l_3) registered the highest harvest index (0.38) and l_2 registered the lowest index (0.29). During both the years, application of soil conditioner significantly increased the harvest index and the effects of coir pith (s_2) and rice husk (s_3) were found on a par. Organic nutrition (n_2) registered the higher harvest index during both the years compared to INM (n_1).

Among the interactions (Table 13b), only L x S had significant effect on harvest index that too only during II year. The treatment combination l_3s_2 was found superior in its effect on harvest index.

Although the effect of L x S x N interaction (Table 13c) was not significant, the treatment combination $l_3s_2n_2$ registered the highest harvest index during both the years (0.35 during I year and 0.41 during II year).

4.5 QUALITY CHARACTERS OF CORMEL

The data on quality characters of cormel are furnished in Table 14a, 14b and 14c.

4.5.1 Dry Matter Content

Various tillage systems, soil conditioners and nutrient management had significant influence on dry matter content of cormel (Table 14a).

Deep tillage and pit system (l_3) registered significantly higher (31.9 and 29.83 per cent during I and II year respectively) dry matter content of cormel followed by deep tillage and mound system (l_4). The superiority of deep tillage over conventional tillage and pit over mound system of planting was revealed from contrast analysis. Application of soil conditioner resulted in significantly higher content of dry matter in cormel and coir pith (s_2) was found superior (31.55 and 29.3 per cent during I and II year respectively) to rice husk (s_3) as soil conditioner during both the years. Organic nutrition (n_2) resulted in significantly higher dry matter content (31.91 and 29.35 per cent during I and II year respectively) of cormel than INM (n_1) during both the years.

Interaction effects presented in Table 14b indicates that L x S interaction was not significant during both the years. Regarding L x N interaction, the treatment combination l_3n_2 produced the highest dry matter content during both the years, although its effect was not significant during II year. Among S x N interaction, the treatment combination s_2n_2 registered the highest dry matter content of cormel but its effect was significant only during II year. It was on a par with s_3n_2 also.

The effect of L x S x N interaction was not significant during both the years (Table 14c).

4.5.2 Starch Content

The main effects of treatments were significant during both the years (Table 14a).

During I year, deep tillage followed by pit system (l_3) registered the highest content of starch (66.05 per cent) in cormel but was on a par with deep tillage followed by mound system (l_4). During II year, l_3 registered significantly higher starch content. Contrast analysis indicated the superiority of deep tillage over conventional tillage and pit system of planting over mound system. Coir pith as soil conditioner (s_2) registered significantly higher starch content (64.04 and 69.76 per cent during I year and II year respectively) than control (s_1) and rice husk as soil conditioner (s_3) during both the years. Organic nutrition (n_2) recorded significantly higher starch content (63.39 and 69.04 per cent during I and II year respectively) during both the years.

Considering the effect of L x S interaction (Table 14b), the treatment combination l_3s_2 recorded the highest content of starch in cormel but its effect was significant only during II year. Regarding L x N interaction, the treatment combination l_3n_2 registered the highest content of starch but it was on a par with l_4n_2 during I year when its effect was significant. Among S x N interaction, the treatment combination, s_2n_2 produced the highest content of starch but its effect was significant only during I year.

The interaction L x S x N (Table 14c) failed to produce any significant effect of starch content during both the years.

4.5.3 Protein Content

As presented in Table 14a, the main effects of treatments on protein content of cormel were significant during both the years.

During I year, deep tillage followed by pit system (l_3) produced significantly higher protein content (14 per cent) but during II year, it was on a par with deep tillage followed by mound system (l_4). Contrast analysis revealed the superiority of deep tillage over conventional tillage and pit system over mound system of planting. Coir pith (s_2) was superior to rice husk (s_3) as soil conditioner and control (s_1) in its effect on protein content during both the years. As in the case of dry matter and starch contents, organic nutrition (n_2) resulted in significantly higher content of protein in the cormel during both the years (13.71 and 14.59 per cent during I year and II year respectively) compared to INM (n_1).

As shown in Table 14b, L x S interaction had significant effects on protein content during both the years. The treatment combinations, l_3s_2, l_3s_3, l_4s_2 and l_1s_3 were on a par during both the years. Although L x N interaction was not significant during both the years, the treatment combination l_3n_2 recorded the highest content of protein. The significant effects of S x N interaction were observed during both the years. The effects of the treatment combinations s_2n_2 and s_3n_2 were on a par but superior to others.

The interaction L x S x N had no significant effect on protein content during both the years (Table 14c).

Table 14a. Effect of tillage systems, soil conditioners and nutrient management on quality characters of cormel, %

Treatments	Dry matter content		Starch content		Protein content	
	I year	II year	I year	II year	I year	II year
Tillage systems (L)						
l_1- Conventional tillage- pit system	29.68	27.48	61.32	64.98	6.86	7.33
l_2- Conventional tillage-mound system	28.25	26.57	57.78	62.08	6.53	6.78
l_3- Deep tillage-pit system	31.90	29.83	66.05	75.08	7.26	7.66
l_4 - Deep tillage-mound system	30.22	28.61	65.57	71.10	7.00	7.40
SEm±	0.272	0.302	0.136	0.134	0.043	0.070
CD (0.05)	1.007	1.118	0.503	0.496	0.160	0.259
Contrast analysis- Conventional vs Deep tillage						
Conventional tillage	28.96	27.03	59.55	63.53	6.70	7.06
Deep tillage	31.06	29.22	65.81	73.09	7.13	7.53
F test	S	S	S	S	S	S
Contrast analysis – Pit vs Mound system of planting						
Pit system	30.79	28.66	63.68	70.03	7.06	7.50
Mound system	29.24	27.59	61.68	66.59	6.77	7.09
F test	S	S	S	S	S	S
Soil conditioners (S)						
s_1- Control	28.56	26.55	61.44	66.96	6.48	6.92
s_2- Coir pith	31.55	29.30	64.04	69.76	7.14	7.55
s_3- Rice husk	29.92	28.53	62.56	68.21	7.11	7.41
SEm±	0.246	0.237	0.117	0.155	0.065	0.070
CD (0.05)	0.695	0.671	0.331	0.439	0.184	0.198
Nutrient management (N)						
n_1- INM	28.11	26.89	61.97	67.59	6.73	7.09
n_2- Organic nutrition	31.91	29.35	63.39	69.04	7.09	7.50
SEm±	0.201	0.194	0.095	0.127	0.053	0.057
CD (0.05)	0.568	0.548	0.270	0.358	0.150	0.162

S- Significant

Table 14b. Interaction effect of tillage systems, soil conditioners and nutrient management on quality characters of cormel, %

Treatments	Dry matter content		Starch content		Protein content	
	I year	II year	I year	II year	I year	II year
L x S interaction						
l_1s_1	28.09	26.07	60.18	63.22	6.35	6.78
l_1s_2	31.51	28.51	62.62	66.60	6.89	7.44
l_1s_3	29.43	27.87	61.15	65.13	7.33	7.77
l_2s_1	26.10	25.29	56.26	61.15	6.13	6.35
l_2s_2	30.28	27.55	59.53	62.77	6.78	7.11
l_2s_3	28.38	26.88	57.55	62.33	6.67	6.89
l_3s_1	31.14	27.99	65.04	74.03	6.89	7.55
l_3s_2	32.56	31.18	67.39	77.07	7.44	7.88
l_3s_3	32.01	30.32	65.71	74.15	7.44	7.55
l_4s_1	28.92	26.84	64.29	69.46	6.57	7.00
l_4s_2	31.86	29.95	66.61	72.62	7.44	7.77
l_4s_3	29.88	29.03	65.82	71.23	7.00	7.44
SEm±	0.492	0.475	0.234	0.310	0.130	0.140
CD (0.05)	NS	NS	NS	0.878	NS	0.396
L x N interaction						
l_1n_1	27.51	25.86	60.34	64.20	6.71	7.07
l_1n_2	31.85	29.11	62.30	65.77	7.00	7.59
l_2n_1	25.81	25.46	57.44	61.66	6.42	6.71
l_2n_2	30.70	27.69	58.12	62.51	6.64	6.86
l_3n_1	30.23	28.81	65.42	74.45	6.93	7.37
l_3n_2	33.57	30.85	66.67	75.71	7.59	7.95
l_4n_1	28.90	27.45	64.67	70.05	6.86	7.22
l_4n_2	31.55	29.77	66.48	72.16	7.15	7.59
SEm±	0.401	0.388	0.191	0.253	0.106	0.114
CD (0.05)	1.135	NS	0.540	NS	NS	NS
S x N interaction						
s_1n_1	26.69	26.10	60.88	66.16	6.35	6.78
s_1n_2	30.43	26.99	62.01	67.77	6.62	7.06
s_2n_1	29.58	27.72	63.03	68.85	7.00	7.39
s_2n_2	33.52	30.88	65.04	70.68	7.28	7.71
s_3n_1	28.06	26.86	61.99	67.75	6.84	7.11
s_3n_2	31.79	30.19	63.12	68.67	7.39	7.71
SEm±	0.348	0.336	0.165	0.219	0.092	0.099
CD (0.05)	NS	0.949	0.467	NS	NS	NS

NS- Not significant

Table 14c. Effect of L x S x N interaction on quality characters of cormel, %

Treatments	Dry matter content		Starch content		Protein content	
	I year	II year	I year	II year	I year	II year
$l_1s_1n_1$	26.17	25.32	59.21	62.52	6.35	6.78
$l_1s_1n_2$	30.01	26.82	61.14	63.93	6.35	6.78
$l_1s_2n_1$	29.09	26.35	61.31	65.42	6.78	7.22
$l_1s_2n_2$	33.94	30.67	63.93	67.78	7.00	7.66
$l_1s_3n_1$	27.26	25.90	60.49	64.66	7.00	7.22
$l_1s_3n_2$	31.60	29.85	61.82	65.61	7.66	8.32
$l_2s_1n_1$	23.61	24.96	55.70	60.48	6.13	6.35
$l_2s_1n_2$	28.58	25.63	56.82	61.82	6.13	6.35
$l_2s_2n_1$	27.75	26.03	59.21	62.50	6.78	7.00
$l_2s_2n_2$	32.82	29.06	59.84	63.03	6.78	7.22
$l_2s_3n_1$	26.07	25.40	57.40	61.99	6.35	6.78
$l_2s_3n_2$	30.69	28.37	57.70	62.68	7.00	7.00
$l_3s_1n_1$	29.67	27.59	64.66	73.05	6.57	7.22
$l_3s_1n_2$	32.60	28.40	65.42	75.01	7.22	7.88
$l_3s_2n_1$	31.01	29.88	66.18	76.28	7.22	7.66
$l_3s_2n_2$	34.10	32.48	68.60	77.87	7.66	8.10
$l_3s_3n_1$	30.02	28.97	65.42	74.03	7.00	7.22
$l_3s_3n_2$	34.00	31.68	65.99	74.27	7.88	7.88
$l_4s_1n_1$	27.31	26.55	63.93	68.60	6.35	6.78
$l_4s_1n_2$	30.53	27.13	64.66	70.32	6.78	7.22
$l_4s_2n_1$	30.49	28.61	65.42	71.20	7.22	7.66
$l_4s_2n_2$	33.24	31.30	67.81	74.05	7.66	7.88
$l_4s_3n_1$	28.89	27.20	64.66	70.34	7.00	7.22
$l_4s_3n_2$	30.87	30.87	66.98	72.12	7.00	7.66
SEm±	0.695	0.671	0.330	0.439	0.184	0.198
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- Not significant

4.5.4 Shelf Life

When cormels were arranged over news paper spread on floor under ambient conditions, no decay of cormel was observed upto 45 days of storage. Sprouting of cormels started from 32^{nd} day. About 50 per cent sprouting was observed on 46^{th} day when observations on shelf life were concluded.

The data on physiological loss in weight of cormel after 45 days of storage is given in Table 15a, 15b and 15c. Tillage systems differed significantly in registering PLW of cormel during storage (Table 15a). During both the years, PLW was minimum (12.71 per cent and 14.47 per cent during I and II year respectively) after 45 days of storage with deep tillage followed by pit system of planting (l_3) and maximum with conventional tillage followed by mound system (l_2). The superiority of deep tillage over conventional tillage and pit system over mound system of planting was evident from contrast analysis also.

The cormels from plots without soil conditioner (s_1) recorded minimum (14.09 per cent) PLW after 45 days of storage during I year (Table 15a) while it recorded maximum loss (16.19 per cent) during II year. During II year, the effects of coir pith (s_2) and rice husk (s_3) were on a par in this respect but superior to control.

The plots with organic nutrition (n_2) produced cormels which recorded lower values of PLW after 45 days of storage compared to INM (n_1) during both the years.

Regarding interaction effects (Table 15b and 15c), only L x S and L x N interaction effects were significant, that too only during II year. In the case of L x S interaction, the effects of the treatment combinations l_3s_1, l_3s_2 and l_3s_3 were on a par, but superior to others. With regard to L x N interaction, l_3n_1 and l_3n_2 were on a par but superior to others.

Table 15a. Effect of tillage systems, soil conditioners and nutrient management on physiological loss in weight of cormel after 45 days of storage, %

Treatments	Physiological loss in weight	
	I year	II year
Tillage systems (L)		
l_1- Conventional tillage- pit system	15.31	15.91
l_2- Conventional tillage-mound system	16.16	17.77
l_3- Deep tillage-pit system	12.71	14.47
l_4 - Deep tillage-mound system	13.41	15.76
SEm±	0.035	0.043
CD (0.05)	0.130	0.161
Contrast analysis- Conventional vs Deep tillage		
Conventional tillage	15.74	16.84
Deep tillage	13.06	15.11
F test	S	S
Contrast analysis – Pit vs Mound system of planting		
Pit system	14.01	15.19
Mound system	14.78	16.76
F test	S	S
Soil conditioners (S)		
s_1- Control	14.09	16.19
s_2- Coir pith	14.63	15.88
s_3- Rice husk	14.47	15.87
SEm±	0.037	0.033
CD (0.05)	0.104	0.094
Nutrient management (N)		
n_1- INM	14.59	16.12
n_2- Organic nutrition	14.21	15.83
SEm±	0.030	0.027
CD (0.05)	0.085	0.077

S- Significant

Table 15b. Interaction effect of tillage systems, soil conditioners and nutrient management on physiological loss in weight of cormel after 45 days of storage, %

Treatments	Physiological loss in weight	
	I year	II year
L x S interaction		
l_1s_1	14.96	16.10
l_1s_2	15.58	15.79
l_1s_3	15.39	15.84
l_2s_1	16.01	17.99
l_2s_2	16.28	17.60
l_2s_3	16.20	17.71
l_3s_1	12.36	14.56
l_3s_2	12.99	14.41
l_3s_3	12.77	14.43
l_4s_1	13.03	16.09
l_4s_2	13.67	15.70
l_4s_3	13.52	15.48
SEm±	0.074	0.066
CD (0.05)	NS	0.187
L x N interaction		
l_1n_1	15.59	16.05
l_1n_2	15.03	15.77
l_2n_1	16.30	17.89
l_2n_2	16.02	17.65
l_3n_1	12.86	14.53
l_3n_2	12.55	14.41
l_4n_1	13.60	16.02
l_4n_2	13.22	15.50
SEm±	0.060	0.054
CD (0.05)	NS	0.153
S x N interaction		
s_1n_1	14.27	16.33
s_1n_2	13.91	16.05
s_2n_1	14.82	16.02
s_2n_2	14.44	15.74
s_3n_1	14.67	16.02
s_3n_2	14.27	15.71
SEm±	0.052	0.047
CD (0.05)	NS	NS

NS- Not significant

Table 15c. Effect of L x S x N interaction on physiological loss in weight of cormel after 45 days of storage, %

Treatments	Physiological loss in weight	
	I year	II year
$l_1s_1n_1$	16.23	18.15
$l_1s_1n_2$	15.79	17.84
$l_1s_2n_1$	16.38	17.66
$l_1s_2n_2$	16.18	17.54
$l_1s_3n_1$	16.30	17.86
$l_1s_3n_2$	16.10	17.56
$l_2s_1n_1$	15.14	16.24
$l_2s_1n_2$	14.79	15.96
$l_2s_2n_1$	15.89	16.01
$l_2s_2n_2$	15.28	15.58
$l_2s_3n_1$	15.74	15.91
$l_2s_3n_2$	15.04	15.78
$l_3s_1n_1$	13.14	16.30
$l_3s_1n_2$	12.93	15.89
$l_3s_2n_1$	13.89	15.94
$l_3s_2n_2$	13.45	15.46
$l_3s_3n_1$	13.76	15.81
$l_3s_3n_2$	13.28	15.14
$l_4s_1n_1$	12.58	14.63
$l_4s_1n_2$	12.14	14.50
$l_4s_2n_1$	13.14	14.45
$l_4s_2n_2$	12.85	14.38
$l_4s_3n_1$	12.86	14.50
$l_4s_3n_2$	12.68	14.36
SEm±	0.104	0.094
CD (0.05)	NS	NS

NS- Not significant

4.6 UPTAKE OF NUTRIENTS

The main effects and interaction effects of treatments during both the years are presented in Table 16a, 16b and 16c respectively.

4.6.1 N Uptake

Perusal of the data in Table 16a clearly indicates that uptake of N was significantly influenced by the main effects of treatments.

Among tillage systems, deep tillage followed by pit system (l_3) registered significantly higher uptake of N (68.64 and 73.17 kg ha^{-1} during I and II year respectively) followed by deep tillage and mound system (l_4) during both the years. Contrast analysis indicated the superiority of deep tillage over conventional tillage and pit system over mound system of planting during both the years.

Coir pith as soil conditioner (s_2) recorded significantly higher uptake of N during both the years (62.01 and 67.77 kg ha^{-1}) proving its superiority over control (s_1) and rice husk (s_3).

Uptake of N was significantly higher under organic nutrition (n_2) during both the years (60.66 and 67.40 kgha^{-1} during I and II year respectively) than under INM (n_1).

As shown in Table 16b, the interactions L x N and S x N had significant effects on the uptake of N during both the years. Considering L x N interaction, the treatment combination l_3n_2 registered significantly higher uptake of N during both the years (77.02 and 78.49 kgha^{-1}during I and II year respectively) which was followed by l_4n_2.The significant effect of S x N interaction was evident during both the years and the treatment combination s_2n_2 registered significantly higher uptake of N (67.67 and 72.49 kgha^{-1}during I and II year respectively) followed by s_3n_2.

The data presented in Table 16c indicated no significant effect of L x S x N interaction on N uptake but the highest uptake of N during both the years was recorded by $l_3s_2n_2$ followed by $l_3s_3n_2$.

4.6.2 P uptake

The data in Table 16a revealed the significant effects of tillage systems, soil conditioners and nutrient management on the uptake of P during both the years. Deep tillage followed by pit system (l_3) registered significantly higher uptake of P during both the years (13.77 and 15.54 kgha^{-1}during I and II year respectively) followed by deep tillage and mound system (l_4). The results of contrast analysis also indicated the superiority of deep tillage over conventional tillage and pit system over mound system.

Coir pith (s_2) as soil conditioner resulted in significantly higher uptake of P during both the years (11.61 and 13.03 kg ha^{-1}during I and II year respectively) closely followed by rice husk (s_3).

Organic nutrition registered significantly higher uptake of P during both the years (11.61 and 13.29 kg ha^{-1}during I and II year respectively).

Among interactions (Table 16b), the interactions L x N and S x N had significant effects on P uptake only during I year. The treatment combination l_3n_2 resulted in significantly higher uptake of P during both the years. Similarly the treatment combination s_2n_2 registered significantly higher uptake of P during both the years.

No significant variation in P uptake was noticed due to L x S x N interaction (Table 16c) during both the years. However, the treatment combination $l_3s_2n_2$ registered the highest uptake of P during both the years followed by $l_3s_3n_2$.

4.6.3 K Uptake

The significant effect of treatments on K uptake is evident from Table 16a. As in the case of uptake of N and P, deep tillage followed by pit system (l_3)

Table 16a. Effect of tillage systems, soil conditioners and nutrient management on nutrient uptake, kg ha^{-1}

Treatments	N uptake		P uptake		K uptake	
	I year	II year	I year	II year	I year	II year
Tillage systems (L)						
l_1- Conventional tillage- pit system	51.30	61.36	9.16	11.05	87.11	126.80
l_2- Conventional tillage-mound system	44.05	55.93	8.00	10.04	76.67	120.77
l_3- Deep tillage-pit system	68.64	73.17	13.77	15.54	138.99	173.94
l_4 - Deep tillage-mound system	57.57	63.10	10.89	12.67	110.26	143.78
SEm±	0.359	0.427	0.107	0.135	0.688	1.248
CD (0.05)	1.329	1.582	0.397	0.500	2.549	4.624
Contrast analysis- Conventional vs Deep tillage						
Conventional tillage	47.68	58.65	8.58	10.55	81.89	123.78
Deep tillage	63.11	68.14	12.33	14.1	124.63	158.86
F test	S	S	S	S	S	S
Contrast analysis – Pit vs Mound system of planting						
Pit system	59.97	67.27	11.47	13.29	113.05	150.37
Mound system	50.81	59.52	9.45	11.36	93.47	132.28
F test	S	S	S	S	S	S
Soil conditioners (S)						
s_1- Control	47.70	57.93	9.14	11.45	90.49	133.89
s_2- Coir pith	62.01	67.77	11.61	13.03	115.10	147.45
s_3- Rice husk	56.46	64.47	10.62	12.49	104.19	142.63
SEm±	0.515	0.582	0.120	0.141	0.980	1.331
CD (0.05)	1.457	1.647	0.340	0.398	2.771	3.764
Nutrient management (N)						
n_1- INM	50.12	59.37	9.30	11.36	93.63	133.27
n_2- Organic nutrition	60.66	67.40	11.61	13.29	112.89	149.38
SEm±	0.421	0.475	0.098	0.115	0.800	1.086
CD (0.05)	1.190	1.345	0.278	0.325	2.263	3.073

S- Significant NS- Not significant

Table 16b. Interaction effect of tillage systems, soil conditioners and nutrient management on nutrient uptake, kg ha^{-1}

Treatments	N uptake		P uptake		K uptake	
	I year	II year	I year	II year	I year	II year
L x S interaction						
l_1s_1	43.19	55.32	7.93	10.23	75.53	120.05
l_1s_2	56.60	65.14	10.21	11.84	97.15	132.51
l_1s_3	54.12	63.61	9.33	11.08	88.65	127.84
l_2s_1	37.10	50.60	6.84	9.32	66.39	115.73
l_2s_2	51.38	61.58	9.25	10.77	87.42	126.37
l_2s_3	43.66	55.60	7.93	10.05	76.20	120.21
l_3s_1	61.09	67.56	12.29	14.34	123.73	161.88
l_3s_2	74.86	76.27	14.92	16.09	152.83	181.05
l_3s_3	69.98	75.68	14.11	16.18	140.41	178.88
l_4s_1	49.44	58.22	9.51	11.93	96.30	137.90
l_4s_2	65.22	68.07	12.05	13.42	122.98	149.87
l_4s_3	58.06	63.00	11.12	12.67	111.51	143.58
SEm±	1.030	1.164	0.241	0.281	1.959	2.661
CD (0.05)	NS	NS	NS	NS	NS	NS
L x N interaction						
l_1n_1	46.64	56.34	8.23	10.05	79.18	119.78
l_1n_2	55.96	66.38	10.09	12.05	95.03	133.82
l_2n_1	41.57	54.03	7.32	9.29	71.01	113.33
l_2n_2	46.53	57.83	8.69	10.79	82.33	128.21
l_3n_1	60.26	67.85	11.96	14.29	123.91	162.87
l_3n_2	77.02	78.49	15.58	16.78	154.07	185.00
l_4n_1	52.00	59.27	9.69	11.80	100.41	137.09
l_4n_2	63.15	66.92	12.10	13.53	120.11	150.47
SEm±	0.841	0.951	0.196	0.230	1.600	2.173
CD (0.05)	2.379	2.689	0.555	NS	4.525	NS
S x N interaction						
s_1n_1	43.73	55.36	8.22	10.69	82.50	128.25
s_1n_2	51.68	60.49	10.06	12.22	98.47	139.53
s_2n_1	56.35	63.04	10.24	11.88	104.09	138.18
s_2n_2	67.67	72.49	12.97	14.17	126.11	156.71
s_3n_1	50.27	59.71	9.43	11.51	94.31	133.37
s_3n_2	62.64	69.23	11.81	13.48	114.08	151.88
SEm±	0.728	0.823	0.170	0.199	1.385	1.882
CD (0.05)	2.060	2.328	0.481	NS	NS	NS

NS- Not significant

Table 16c. Effect of L x S x N interaction on nutrient uptake, kg ha^{-1}

Treatments	N uptake		P uptake		K uptake	
	I year	II year	I year	II year	I year	II year
$l_1s_1n_1$	41.05	52.28	7.26	9.30	69.38	114.64
$l_1s_1n_2$	45.33	58.36	8.61	11.15	81.68	125.46
$l_1s_2n_1$	51.68	59.22	9.16	10.74	88.40	125.18
$l_1s_2n_2$	61.51	71.07	11.27	12.94	105.90	139.83
$l_1s_3n_1$	47.20	57.51	8.27	10.11	79.77	119.51
$l_1s_3n_2$	61.04	69.71	10.39	12.06	97.53	136.16
$l_2s_1n_1$	34.96	49.20	6.19	8.58	60.82	109.05
$l_2s_1n_2$	39.23	52.01	7.49	10.06	71.96	122.41
$l_2s_2n_1$	47.91	59.60	8.19	10.04	79.88	119.77
$l_2s_2n_2$	54.85	63.56	10.30	11.50	94.97	132.98
$l_2s_3n_1$	41.83	53.28	7.57	9.27	72.34	111.19
$l_2s_3n_2$	45.50	57.91	8.28	10.83	80.07	129.24
$l_3s_1n_1$	54.96	64.65	11.01	13.54	112.70	156.30
$l_3s_1n_2$	67.23	70.47	13.58	15.15	134.76	167.47
$l_3s_2n_1$	65.69	69.49	12.79	14.49	134.63	165.98
$l_3s_2n_2$	84.03	83.04	17.05	17.68	171.03	196.11
$l_3s_3n_1$	60.14	69.41	12.09	14.85	124.41	166.32
$l_3s_3n_2$	79.82	81.96	16.12	17.52	156.42	191.43
$l_4s_1n_1$	43.96	55.31	8.44	11.34	87.09	133.02
$l_4s_1n_2$	54.92	61.14	10.57	12.52	105.51	142.78
$l_4s_2n_1$	60.13	63.85	10.81	12.25	113.44	141.80
$l_4s_2n_2$	70.31	72.29	13.28	14.58	132.52	157.94
$l_4s_3n_1$	51.91	58.66	9.80	11.83	100.71	136.46
$l_4s_3n_2$	64.21	67.34	12.44	13.50	122.31	150.71
SEm±	1.457	1.646	0.340	0.398	2.771	3.763
CD (0.05)	NS	NS	NS	NS	NS	NS

NS- Not significant

registered significantly higher uptake of K (138.99 and 173.94 kgha^{-1}during I and II year respectively) followed by l_4. Deep tillage followed by pit or mound system resulted in higher K uptake than conventional tillage followed by pit or mound system. Contrast analysis also indicated the superiority of deep tillage and pit system of planting.

Application of soil conditioner profoundly influenced K uptake and coir pith (s_2) was found superior to rice husk (s_3) during both the years (115.1 and 147.45 kgha^{-1}during I and II year respectively).

Organic nutrition (n_2) showed its superiority in enhancing K uptake (from 93.63 under INM to 112.89 kg ha^{-1}during I year and from 133.27 under INM to 149.38 kgha^{-1}during II year) by the crop compared to INM (n_1) during both the years.

As shown in Table 16b, only the interaction L x N had significant effect on K uptake that too only during I year. The treatment combination l_3n_2 recorded significantly higher uptake of K (154.07 kg ha^{-1}) and it recorded the highest uptake of K during II year though the effect was not significant.

The interaction L x S x N had no significant effect on K uptake during both the years but the treatment combination $l_3s_2n_2$ recorded the highest uptake of K during both the years followed by $l_3s_3n_2$ (Table 16c).

4.7 SOIL ANALYSIS AFTER EXPERIMENT

4.7.1 Physical Properties of Soil

The data on the main effects and interaction effects of treatments on physical properties of the soil from 0 to15 cm and 15 to 30 cm depth after the experiment during both the years are presented in Table 17a, 17b and 17c respectively.

4.7.1.1 Bulk Density

Tillage systems, soil conditioners and nutrient management significantly influenced bulk density (Table 17a).

It is clear from Table 1 and Table 17a that bulk density in both depths of the soil was lowered after the experiment due to any tillage system than the value before the experiment. Significantly lower values of bulk density were recorded in both depths of soil after the experiment due to deep tillage followed by pit or mound system (l_3 and l_4) which were on a par during I year. During II year, l_3 recorded the lowest bulk density in 0 to15 cm depth of soil and in 15 to 30 cm depth of soil l_4, recorded the lowest value, but on a par with l_3. Significantly higher bulk density after the experiment was registered in conventionally tilled plots followed by mound system in both depths of soil.

After the experiment, significantly lower bulk density in both depths of soil was observed due to application of rice husk as soil conditioner (s_3) during both the years. Plots without soil conditioner (s_1) registered significantly higher bulk density in both depths of soil.

The bulk density was significantly lower in both depths of soil due to organic nutrition (n_2) compared to INM (n_1) during both the years.

Interaction effects given in Table 17c indicated the significant effect of L x N interaction on bulk density of soil in 0 to 15 cm depth only during both the years. It can be seen that bulk density was reduced when any tillage system was combined with organic nutrition (n_2) than with INM (n_1). Significantly lower values of bulk density were registered by deep tillage combined with organic nutrition (l_3n_2 and l_4n_2) than conventional tillage combined with organic nutrition (l_1n_2 and l_2n_2).

The interaction L x S x N (Table 17d) was significant only during I year in 0 to 15 cm depth of soil and the lowest bulk density was recorded by the treatment combination $l_3s_3n_2$.

4.7.1.2 Porosity

The data in Table 17a revealed the significant main effects of treatments on porosity of the soil in 0 to 15 cm and 15 to 30 cm depth.

Deep tillage followed by pit or mound system (l_3 and l_4) registered significantly higher porosity of the soil after the experiment than conventional tillage followed by pit or mound system (l_1 and l_2). In general, soil porosity improved due to tillage systems than the initial value and exhibited significant effects in 0 to 15 cm and 15 to 30 cm depth during both the years (Table 1 and 17a).

Porosity of soil in 0 to 15 cm depth of soil significantly increased due to application of soil conditioner and rice husk (s_3) was found superior during I year and during II year, the effects of coir pith and rice husk were on a par. No significant variation on porosity of the soil in 15 to 30 cm depth of soil was noticed during both the years.

Organic nutrition significantly increased porosity in 0 to 15 cm depth of soil during I year and 15 to 30 cm depth of soil during the II year. The effect of nutrient management was not significant in 15 to 30 cm depth of soil during I year and 0 to 15 cm depth of soil during II year.

The interaction effects presented in Table 17b and 17c indicated the significant effects of L x S and L x N interactions in 0 to 15 cm depths of soil during I year only. In the case of L x S interaction, deep tillage followed by pit or mound system supplied with rice husk as soil conditioner (l_3s_3 and l_4s_3) resulted in significantly higher porosity than other combinations. With respect to L x N interaction, deep tillage followed by pit or mound system under organic nutrition (l_3n_2 and l_4n_2) resulted in significantly higher porosity of soil. During II year, only L x N interaction had significant effect on porosity in 0 to 15 cm depth of soil.

The effects of treatment combinations l_3n_1 and l_3n_2 were on a par but superior to other combinations.

The data in Table 17d indicated no significant effect of L x S x N interaction on soil porosity.

4.7.1.3 Water Holding Capacity

Water holding capacity in both depths of soil during both the years improved after the experiment compared to initial values (Table 1 and 17d).

It is clear from Table 17a that tillage systems, soil conditioners and nutrient management had significant effects on water holding capacity of the soil in 0 to 15 cm and 15 to 30 cm depth.

In 0 to 15 cm depth of soil, water holding capacity was significantly higher in l_4 plots (deep tillage followed by mound system) during both the years but it was on a par with l_3 plots (deep tillage followed by pit system) during II year.In 15 to 30 cm depth of soil, it was significantly higher in l_3 plots (deep tillage followed by pit system).

In both depths of soil, water holding capacity significantly increased due to application of soil conditioner and coir pith (s_2) applied plots registered significantly higher values during both the years.

Similar to the effect on porosity, organic nutrition (n_2) significantly increased the water holding capacity of the soil in both depths during both the years.

The data in Table 17b and 17c clearly indicated the significant effects of L x S, L x N and S x N interactions on water holding capacity in both depths of soil during I year. In the case of L x S interaction, the treatment combination l_4s_2 and l_4s_3, the effects of which were on a par registered significantly higher water holding capacity in 0 to 15 cm depth of soil while in 15 to 30 cm depth of soil, significantly higher water holding capacity was registered by l_3s_2. Regarding 128

Table 17a. Effect of tillage systems, soil conditioners and nutrient management on soil physical properties after the experiment

Treatments	Bulk density (Mg m^{-3})				Porosity (%)				Water holding capacity (%)			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
Tillage systems (L)												
l_1- Conventional tillage- pit system	1.47	1.62	1.50	1.70	36.42	34.28	36.39	31.12	26.94	23.45	27.05	22.30
l_2- Conventional tillage-mound system	1.49	1.67	1.52	1.69	36.28	32.86	36.17	31.64	27.14	22.57	27.30	23.93
l_3- Deep tillage-pit system	1.40	1.55	1.44	1.56	37.54	34.63	37.24	36.12	27.67	25.62	29.91	25.54
l_4 - Deep tillage-mound system	1.41	1.55	1.46	1.55	37.58	35.21	36.89	36.34	27.96	24.34	30.12	24.45
SEm±	0.003	0.005	0.004	0.003	0.092	0.255	0.155	0.150	0.066	0.047	0.101	0.075
CD (0.05)	0.012	0.017	0.014	0.013	0.341	0.946	0.574	0.556	0.243	0.175	0.375	0.277
Soil conditioners (S)												
s_1- Control	1.46	1.61	1.49	1.64	36.33	34.00	36.48	33.60	27.16	23.33	28.06	23.48
s_2- Coir pith	1.44	1.60	1.48	1.63	37.02	34.20	36.67	33.92	27.73	24.56	29.10	24.65
s_3- Rice husk	1.42	1.59	1.47	1.62	37.51	34.54	36.86	33.90	27.39	24.09	28.63	24.04
SEm±	0.001	0.004	0.001	0.003	0.059	0.188	0.054	0.143	0.020	0.045	0.063	0.076
CD (0.05)	0.004	0.012	0.003	0.009	0.168	NS	0.153	NS	0.056	0.126	0.180	0.214
Nutrient management (N)												
n_1- INM	1.45	1.61	1.49	1.63	36.67	34.03	36.63	33.61	27.25	23.74	27.95	23.81
n_2- Organic nutrition	1.43	1.59	1.48	1.62	37.23	34.46	36.72	34.01	27.60	24.25	29.24	24.30
SEm±	0.001	0.003	0.001	0.003	0.049	0.154	0.044	0.117	0.016	0.036	0.052	0.062
CD (0.05)	0.003	0.010	0.003	0.007	0.137	NS	NS	0.331	0.046	0.103	0.147	0.175

NS- Not significant

Table 17b. Interaction effect of tillage systems, soil conditioners and nutrient management on soil physical properties after the experiment

Treatments	Bulk density (Mg m^{-3})				Porosity (%)				Water holding capacity (%)			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
L x S interaction												
l_1s_1	1.50	1.63	1.51	1.71	35.77	33.93	36.18	30.87	26.73	22.50	26.50	21.71
l_1s_2	1.47	1.63	1.50	1.70	36.56	34.21	36.44	31.35	27.42	24.21	27.58	22.89
l_1s_3	1.45	1.62	1.49	1.70	36.94	34.71	36.54	31.14	26.68	23.65	27.06	22.31
l_2s_1	1.51	1.68	1.53	1.70	35.57	32.63	36.04	31.57	26.85	21.96	26.82	23.36
l_2s_2	1.48	1.67	1.52	1.70	36.61	32.41	36.13	31.58	27.46	23.11	27.79	24.44
l_2s_3	1.47	1.65	1.51	1.68	36.65	33.53	36.35	31.78	27.12	22.64	27.30	24.01
l_3s_1	1.42	1.57	1.45	1.57	36.88	34.43	36.97	35.80	27.44	25.05	29.35	25.03
l_3s_2	1.40	1.56	1.44	1.55	37.49	34.50	37.25	36.32	27.87	26.13	30.42	25.99
l_3s_3	1.37	1.54	1.43	1.55	38.26	34.95	37.50	36.25	27.71	25.67	29.98	25.60
l_4s_1	1.43	1.56	1.48	1.56	37.09	34.99	36.73	36.17	27.64	23.83	29.59	23.81
l_4s_2	1.41	1.54	1.46	1.55	37.44	35.69	36.87	36.41	28.17	24.78	30.60	25.29
l_4s_3	1.39	1.55	1.45	1.54	38.21	34.96	37.07	36.45	28.06	24.42	30.17	24.26
SEm±	0.003	0.008	0.002	0.006	0.119	0.376	0.108	0.287	0.040	0.089	0.127	0.151
CD (0.05)	NS	NS	NS	NS	0.336	NS	NS	NS	0.112	0.253	NS	NS

NS- Not significant

Table 17c. Interaction effect of tillage system, soil conditioner and nutrient management on soil physical properties after the experiment (continued)

Treatments	Bulk density (Mg m^{-3})				Porosity (%)				Water holding capacity (%)			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
L x N interaction												
l_1n_1	1.49	1.64	1.51	1.71	35.97	33.85	36.21	30.93	26.61	23.56	26.47	22.06
l_1n_2	1.45	1.61	1.49	1.70	36.87	34.72	36.57	31.31	27.28	23.34	27.62	22.54
l_2n_1	1.50	1.67	1.53	1.70	36.02	32.76	36.11	31.51	26.85	22.07	26.70	23.81
l_2n_2	1.47	1.66	1.52	1.69	36.53	32.95	36.24	31.78	27.44	23.07	27.90	24.05
l_3n_1	1.41	1.57	1.44	1.57	37.35	34.44	37.35	35.93	27.64	25.17	29.22	25.40
l_3n_2	1.39	1.54	1.44	1.55	37.74	34.81	37.13	36.32	27.70	26.06	30.61	25.67
l_4n_1	1.42	1.56	1.46	1.56	37.36	35.06	36.85	36.07	27.92	24.14	29.43	23.96
l_4n_2	1.40	1.54	1.46	1.54	37.80	35.37	36.93	36.62	28.00	24.55	30.81	24.95
SEm±	0.002	0.007	0.002	0.005	0.097	0.307	0.088	0.234	0.032	0.073	0.104	0.124
CD (0.05)	0.006	NS	0.005	NS	0.275	NS	0.249	NS	0.092	0.206	NS	0.349
S x N interaction												
s_1n_1	1.47	1.62	1.50	1.64	36.16	33.85	36.44	33.46	26.99	23.18	27.43	23.28
s_1n_2	1.45	1.60	1.49	1.63	36.49	34.14	36.52	33.74	27.34	23.48	28.69	23.67
s_2n_1	1.45	1.61	1.48	1.63	36.65	33.89	36.63	33.76	27.50	24.26	28.44	24.42
s_2n_2	1.43	1.59	1.47	1.62	37.40	34.51	36.72	34.08	27.97	24.85	29.76	24.89
s_3n_1	1.43	1.60	1.47	1.63	37.22	34.35	36.81	33.61	27.28	23.77	28.00	23.73
s_3n_2	1.41	1.58	1.47	1.61	37.81	34.73	36.92	34.20	27.50	24.42	29.26	24.35
SEm±	0.002	0.006	0.002	0.004	0.084	0.266	0.076	0.203	0.028	0.063	0.090	0.107
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.079	0.179	NS	NS

NS- Not significant

Table 17d. Effect of L x S x N interaction on soil physical properties after the experiment (continued)

Treatments	Bulk density (Mg m^{-3})				Porosity (%)				Water holding capacity (%)			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
$l_1s_1n_1$	1.51	1.65	1.52	1.72	35.61	33.42	35.96	30.78	26.34	22.83	25.94	21.48
$l_1s_1n_2$	1.49	1.62	1.50	1.71	35.92	34.44	36.40	30.97	27.12	22.17	27.05	21.94
$l_1s_2n_1$	1.49	1.65	1.51	1.71	35.91	33.60	36.25	31.29	26.98	24.19	26.98	22.75
$l_1s_2n_2$	1.45	1.61	1.49	1.70	37.20	34.82	36.63	31.41	27.87	24.23	28.18	23.04
$l_1s_3n_1$	1.47	1.63	1.50	1.71	36.39	34.53	36.41	30.73	26.51	23.68	26.48	21.96
$l_1s_3n_2$	1.43	1.61	1.49	1.69	37.49	34.89	36.67	31.55	26.85	23.62	27.64	22.65
$l_2s_1n_1$	1.52	1.69	1.54	1.71	35.55	32.67	36.00	31.53	26.68	21.51	26.21	23.24
$l_2s_1n_2$	1.50	1.68	1.53	1.70	35.59	32.59	36.09	31.62	27.02	22.42	27.42	23.48
$l_2s_2n_1$	1.50	1.68	1.53	1.70	36.13	32.19	36.06	31.52	27.02	22.58	27.24	24.32
$l_2s_2n_2$	1.46	1.67	1.52	1.69	37.10	32.63	36.21	31.65	27.91	23.64	28.34	24.56
$l_2s_3n_1$	1.48	1.65	1.52	1.69	36.37	33.43	36.27	31.48	26.85	22.13	26.65	23.89
$l_2s_3n_2$	1.45	1.64	1.51	1.67	36.92	33.64	36.43	32.08	27.39	23.15	27.95	24.12
$l_3s_1n_1$	1.43	1.58	1.45	1.58	36.67	34.44	37.19	35.91	27.36	24.71	28.65	24.94
$l_3s_1n_2$	1.41	1.56	1.46	1.57	37.10	34.42	36.74	35.68	27.53	25.38	30.05	25.12
$l_3s_2n_1$	1.41	1.57	1.44	1.57	37.28	34.37	37.39	35.98	27.87	25.63	29.70	25.85
$l_3s_2n_2$	1.39	1.55	1.44	1.54	37.71	34.63	37.11	36.66	27.87	26.62	31.14	26.12
$l_3s_3n_1$	1.39	1.56	1.44	1.56	38.10	34.52	37.47	35.89	27.70	25.17	29.32	25.42
$l_3s_3n_2$	1.36	1.52	1.43	1.55	38.42	35.38	37.53	36.61	27.71	26.18	30.63	25.78
$l_4s_1n_1$	1.44	1.57	1.48	1.58	36.80	34.88	36.62	35.64	27.58	23.69	28.92	23.48
$l_4s_1n_2$	1.42	1.55	1.47	1.55	37.37	35.11	36.84	36.71	27.70	23.97	30.25	24.15
$l_4s_2n_1$	1.42	1.56	1.46	1.56	37.28	35.41	36.83	36.23	28.12	24.64	29.84	24.75
$l_4s_2n_2$	1.40	1.53	1.45	1.54	37.60	35.97	36.92	36.59	28.23	24.92	31.37	25.84
$l_4s_3n_1$	1.40	1.55	1.45	1.55	38.00	34.90	37.09	36.35	28.05	24.09	29.54	23.65
$l_4s_3n_2$	1.38	1.54	1.45	1.53	38.42	35.02	37.04	36.55	28.06	24.75	30.81	24.86
SEm±	0.004	0.012	0.003	0.009	0.168	0.532	0.152	0.406	0.056	0.126	0.179	0.214
CD (0.05)	0.011	NS	NS	NS	NS	NS	NS	NS	0.159	NS	NS	NS

NS- Not significant

L x N interaction, the treatment combinations l_4n_2 and l_4n_1, the effects of which were on a par, produced significantly higher water holding capacity of soil in 0 to 15 cm depth and in 15 to 30 cm depth, the treatment combination l_3n_2 registered significantly higher water holding capacity. With respect to S x N interaction, the treatment combination s_2n_2 recorded significantly higher water holding capacity in both depths of soil. During II year, only L x N interaction was significant on water holding capacity in 15 to 30 cm depth of soil and the treatment combination l_3n_2 resulted in significantly higher water holding capacity.

The effect of L x S x N interaction (Table 17d) on water holding capacity was significant in 0 to 15 cm depth of soil during I year only and the effect of treatment combinations $l_4s_2n_2$ and $l_4s_2n_1$ were on a par but superior to others.

4.7.2 Soil Reaction

As shown in Table 18a, soil pH was higher in 0 to 15 cm depth of soil than in 15 to 30 cm depth of soil. Various treatments significantly influenced soil pH in 0 to 15 and 15 to 30 cm depths during both the years.

Conventional tillage followed by mound system (l_2) registered significantly higher pH in both depths of soil during both the years. In both depths of soil, deep tillage followed by pit or mound system registered lower values than conventional tillage followed by pit or mound system.

Application of soil conditioner (s_2 or s_3) significantly increased the pH over control (s_1) in both depths during both the years. Coir pith (s_2) as soil conditioner registered significantly higher pH values in both depths during both the years.

Organic nutrition (n_2) significantly increased soil pH in both depths during both the years.

It is evident from Table 18b, that the soil pH in 0 to 15 cm depth of soil was significantly influenced by L x S, L x N and S x N interaction during both the years. Considering L x S interaction in 0 to 15 cm depth of soil, conventional

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tillage followed by pit or mound system and coir pith (s_2) as soil conditioner (l_1s_2 and l_2s_2) significantly increased the soil pH during I year and l_2s_2 recorded the highest soil pH during II year. Regarding L x N interaction, the effects of conventional tillage followed by pit or mound system under organic nutrition (l_1n_2 and l_2n_2) were on a par but superior to other combinations during both the years. In the case of S x N interaction, the treatment combination s_2n_2 registered significantly higher soil pH during both the years. In 15 to 30 cm depth of soil, L x S interaction was significant during both the years and the treatment combination l_2s_2 recorded the highest soil pH. The effect of L x N interaction was significant only during I yearand the treatment combination l_2n_2 recorded the highest pH. The interaction S x N failed to produce significant effect during both the years.

L x S x N interaction had significant effect on pH in 0 to 15 cm depth of soil only during I year. The pH was significantly higher in plots which received $l_1s_2n_2$ and $l_2s_2n_2$, the effects of which were on a par. Though not significant during II year, $l_2s_2n_2$ registered the highest pH in 0 to 15 cm depth of soil. The effect of L x S x N interaction on pH in 15 to 30 cm depth of the soil was significant during both the years and the treatment combination $l_2s_2n_2$ resulted in the highest pH.

4.7.3 Soil Nutrient Status

4.7.3.1 Organic Carbon

The data on main effects of treatments on organic carbon status of the soil after the experiment is given in Table 18a and the interaction effects in Table 18b and 18c. Organic carbon status of the surface soil (0 to 15 cm depth) was higher than in subsoil (15 to 30 cm depth). Organic carbon status of the surface soil increased after the experiment whereas it declined in the subsoil (Table 1 and 17d).

During I year, conventional tillage followed by pit system (l_1) resulted in significantly higher content of organic carbon in 0 to 15cm depth of soil but was on a par with conventional tillage followed by mound system (l_2). But, l_2 was

Table 18a. Effect of tillage systems, soil conditioners and nutrient management on soil chemical properties after the experiment

Treatments	pH				Organic carbon (%)			
	I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Tillage systems (L)								
l_1- Conventional tillage- pit system	5.78	5.37	5.31	5.13	1.25	0.85	1.43	1.10
l_2- Conventional tillage-mound system	5.81	5.46	5.35	5.18	1.23	0.86	1.42	1.08
l_3- Deep tillage-pit system	5.61	5.25	5.16	4.91	1.22	0.85	1.46	1.08
l_4 - Deep tillage-mound system	5.64	5.37	5.23	5.03	1.20	0.84	1.41	1.10
SEm±	0.010	0.005	0.007	0.003	0.007	0.003	0.008	0.005
CD (0.05)	0.037	0.018	0.027	0.010	0.025	NS	0.029	NS
Soil conditioners (S)								
s_1- Control	5.62	5.24	5.16	4.92	1.20	0.85	1.40	1.07
s_2- Coir pith	5.86	5.52	5.39	5.21	1.25	0.87	1.46	1.10
s_3- Rice husk	5.65	5.32	5.24	5.06	1.22	0.85	1.42	1.08
SEm±	0.009	0.008	0.009	0.007	0.006	0.002	0.009	0.007
CD (0.05)	0.025	0.022	0.025	0.019	0.018	0.007	0.026	0.018
Nutrient management (N)								
n_1- INM	5.61	5.27	5.21	4.99	1.19	0.84	1.42	1.07
n_2- Organic nutrition	5.81	5.45	5.32	5.13	1.26	0.87	1.44	1.10
SEm±	0.007	0.006	0.007	0.006	0.005	0.002	0.007	0.005
CD (0.05)	0.020	0.018	0.020	0.016	0.014	0.005	0.021	0.015

NS- Not significant

Table 18b. Interaction effect of tillage systems, soil conditioners and nutrient management on soil chemical properties after the experiment

Treatments	pH				Organic carbon (%)			
	I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
L x S interaction								
l_1s_1	5.71	5.21	5.21	5.02	1.22	0.84	1.42	1.07
l_1s_2	5.96	5.58	5.46	5.27	1.27	0.86	1.46	1.13
l_1s_3	5.67	5.31	5.28	5.11	1.25	0.85	1.43	1.10
l_2s_1	5.73	5.33	5.23	5.05	1.20	0.86	1.39	1.08
l_2s_2	5.93	5.65	5.52	5.33	1.26	0.88	1.43	1.10
l_2s_3	5.79	5.41	5.29	5.17	1.24	0.86	1.43	1.05
l_3s_1	5.48	5.15	5.08	4.78	1.20	0.84	1.41	1.07
l_3s_2	5.81	5.37	5.26	5.06	1.26	0.86	1.54	1.09
l_3s_3	5.54	5.21	5.15	4.88	1.21	0.84	1.43	1.07
l_4s_1	5.55	5.29	5.12	4.82	1.17	0.84	1.39	1.07
l_4s_2	5.76	5.49	5.33	5.20	1.22	0.86	1.42	1.10
l_4s_3	5.60	5.33	5.24	5.08	1.20	0.86	1.41	1.11
SEm±	0.017	0.015	0.018	0.014	0.012	0.005	0.018	0.013
CD (0.05)	0.049	0.043	0.050	0.038	NS	NS	0.051	NS
L x N interaction								
l_1n_1	5.64	5.24	5.24	5.05	1.20	0.84	1.41	1.08
l_1n_2	5.91	5.49	5.39	5.21	1.29	0.86	1.45	1.12
l_2n_1	5.68	5.33	5.27	5.11	1.20	0.86	1.40	1.06
l_2n_2	5.94	5.60	5.43	5.25	1.27	0.88	1.43	1.09
l_3n_1	5.52	5.18	5.14	4.85	1.18	0.83	1.48	1.05
l_3n_2	5.70	5.31	5.19	4.97	1.26	0.87	1.45	1.10
l_4n_1	5.58	5.33	5.19	4.95	1.16	0.82	1.37	1.08
l_4n_2	5.69	5.41	5.27	5.11	1.24	0.89	1.44	1.11
SEm±	0.014	0.012	0.014	0.011	0.010	0.004	0.015	0.011
CD (0.05)	0.040	0.035	0.041	NS	NS	0.011	0.042	NS
S x N interaction								
s_1n_1	5.50	5.16	5.12	4.84	1.16	0.83	1.39	1.06
s_1n_2	5.73	5.33	5.20	4.99	1.24	0.86	1.42	1.09
s_2n_1	5.75	5.42	5.30	5.15	1.21	0.85	1.47	1.09
s_2n_2	5.98	5.63	5.48	5.28	1.29	0.88	1.46	1.12
s_3n_1	5.57	5.23	5.20	4.99	1.18	0.84	1.40	1.07
s_3n_2	5.73	5.41	5.28	5.13	1.26	0.87	1.45	1.10
SEm±	0.012	0.011	0.012	0.010	0.009	0.003	0.013	0.009
CD (0.05)	0.035	NS	0.035	NS	NS	NS	NS	NS

NS- Not significant

Table 18c. Effect of L x S x N interaction on soil chemical properties after the experiment

Treatments	pH				Organic carbon (%)			
	I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
$l_1s_1n_1$	5.50	5.10	5.14	4.89	1.17	0.82	1.41	1.06
$l_1s_1n_2$	5.92	5.32	5.28	5.15	1.27	0.85	1.43	1.08
$l_1s_2n_1$	5.82	5.42	5.35	5.25	1.24	0.85	1.44	1.11
$l_1s_2n_2$	6.10	5.74	5.57	5.30	1.31	0.87	1.47	1.14
$l_1s_3n_1$	5.62	5.20	5.23	5.02	1.20	0.85	1.40	1.06
$l_1s_3n_2$	5.72	5.41	5.33	5.20	1.30	0.86	1.46	1.13
$l_2s_1n_1$	5.60	5.23	5.19	4.95	1.16	0.85	1.39	1.06
$l_2s_1n_2$	5.85	5.42	5.28	5.16	1.25	0.87	1.38	1.11
$l_2s_2n_1$	5.78	5.49	5.38	5.28	1.23	0.86	1.42	1.09
$l_2s_2n_2$	6.07	5.82	5.67	5.38	1.29	0.88	1.44	1.12
$l_2s_3n_1$	5.68	5.28	5.24	5.12	1.20	0.86	1.40	1.05
$l_2s_3n_2$	5.90	5.55	5.33	5.22	1.27	0.87	1.47	1.05
$l_3s_1n_1$	5.40	5.08	5.07	4.76	1.16	0.82	1.39	1.05
$l_3s_1n_2$	5.57	5.23	5.09	4.81	1.23	0.87	1.44	1.09
$l_3s_2n_1$	5.72	5.32	5.21	4.95	1.21	0.84	1.42	1.06
$l_3s_2n_2$	5.89	5.42	5.32	5.18	1.30	0.88	1.47	1.11
$l_3s_3n_1$	5.43	5.14	5.13	4.85	1.17	0.82	1.42	1.05
$l_3s_3n_2$	5.64	5.28	5.18	4.92	1.24	0.85	1.45	1.10
$l_4s_1n_1$	5.52	5.24	5.09	4.77	1.15	0.82	1.36	1.06
$l_4s_1n_2$	5.58	5.34	5.14	4.87	1.20	0.87	1.42	1.09
$l_4s_2n_1$	5.68	5.46	5.28	5.13	1.17	0.83	1.39	1.08
$l_4s_2n_2$	5.85	5.52	5.38	5.27	1.27	0.90	1.45	1.13
$l_4s_3n_1$	5.56	5.28	5.21	4.97	1.16	0.82	1.38	1.11
$l_4s_3n_2$	5.65	5.38	5.28	5.19	1.24	0.89	1.44	1.11
SEm±	0.025	0.021	0.025	0.019	0.018	0.007	0.026	0.018
CD (0.05)	0.070	0.061	NS	0.054	NS	NS	0.073	NS

NS- Not significant

found to be on a par with l_3 (deep tillage followed by pit system). During the II year, l_3 registered significantly higher organic carbon content followed by l_1. In 15 to 30 cm depth of soil, tillage systems failed to register any significant effects during both the years.

Application of soil conditioner improved the organic carbon status in soil during both the years. Coir pith (s_2) as soil conditioner recorded significantly higher organic carbon status in both depths of soil during both the years.

Organic nutrition (n_2) significantly improved the organic carbon status of soil in both depths of soil during both the years compared to INM.

Interaction effects presented in Table 18b, indicated the significant effect of L x S interaction only in 0 to 15 cm depth of soil during II year and the treatment combination l_3s_2 resulted in significantly higher content of organic carbon. The effect of L x N interaction was significant in 15 to 30 cm depth during I year and 0 to 15 cm depth during II year. The treatment combinations l_4n_2 and l_2n_2 registered significantly higher content of organic carbon in 15 to 30 cm depth , the effects of which were on a par, but superior to others during I year. During II year, the treatment combination l_3n_1 registered the highest content of organic carbon in 0 to 15 cm depth of soil but was on a par with l_1n_2, l_3n_2 and l_4n_2. S x N interaction failed to register any significant effect on organic carbon at both depths of soil during both the years.

L x S x N interaction (Table 18c) failed to produce any significant effect on organic carbon status in both depths of soil during I year. During II year, significant effect was observed in 0 to 15 cm depth of soil and all the treatment combinations except $l_2s_1n_1$, $l_2s_1n_2$, $l_3s_1n_1$, $l_4s_1n_1$ and $l_4s_3n_1$ were on a par.

4.7.3.2 Available Nitrogen

As presented in Table 19a, the main effects of treatments on available N status in both depths of the soil were significant during both the years.

Conventional tillage followed by mound system (l_2), registered the highest status of available N in both depths of soil, but was on a par with conventional tillage followed by pit system (l_1) in 0 to 15 cm depth of soil during both the years. The lowest values in both depths of soil during both the years were recorded by deep tillage followed by pit system (l_3). Conventional tillage followed by pit or mound system (l_1 and l_2) resulted in higher status of available N in both depths of soil compared to deep tillage followed by pit or mound system (l_3 and l_4). In general, available N status in 15 to 30 cm depth of soil was higher than in 0 to 15 cm depth of soil.

Available N status was significantly higher in plots without soil conditioner in both depths of soil during both the years. Coir pith applied plots registered significantly lower status of available N in both depths of soil during both the years.

Organic nutrition (n_2) was found superior to INM (n_1) in registering higher content of available N in both depths of soil during both the years.

Considering interaction effects in Table 19b and 19c, it can be seen that L x S and L x N interactions had significant effect on available N status in both depths of soil during I year. With respect to L x S interaction, the treatment combination l_2s_1 recorded significantly higher status of available N in both depths of soil, but was on a par with l_1s_1 in 0 to 15 cm depth of soil. In the case of L x N interaction, the treatment combinations l_2n_2 recorded significantly higher status of available N in both depths of soil, but was on a par with l_1n_2 in 0 to 15 cm depth during the I year. S x N interaction had significant effect on available N status at 15 to 30 cm depth only and the treatment combination s_1n_2 recorded significantly higher status of available N. During II year, only L x S interaction had significant effect on available N in 0 to 15 cm depth of soil. Significantly higher N status was registered by the treatment combination l_2s_1.

L x S x N interaction presented in Table 19d revealed the significant effect in 15 to 30 cm depth of soil that too during I year only. The treatment 139 combination $l_2s_1n_2$ registered the highest status of available N in 15 to 30 cm depth of soil.

4.7.3.3 Available Phosphorus

The data on main effects of treatments on available P status after the experiment are presented in Table 19a. The main effects were significant in both depths of soil during both the years.

Significantly higher status of available P in 0 to 15 cm depth of soil was recorded by conventional tillage followed by pit (l_1) and by deep tillage followed by mound system (l_4) in 15 to 30 cm depth of soil during both the years. Conventional tillage followed by pit or mound system (l_1 and l_2) recorded significantly higher status of available P in 0 to 15 cm depth of soil while deep tillage followed by pit or mound system (l_3 and l_4) registered higher status of available P in 15 to 30 cm depth of soil.

Plots without soil conditioner (s_1) recorded higher status of available P in both depths of soil during both the years. It was on a par with rice husk (s_3) as soil conditioner in 15 to 30 cm depth of soil during the I year only. The lowest status of available P in both depths of soil during both the years was recorded by coir pith as soil conditioner (s_2).

During both the years in both depths of soil, available P status significantly improved due to organic nutrition (n_2) compared to INM (n_1).

The interaction effects presented in Table 19b and 19c revealed no significant effect of the interactions on available P status in 0 to 15 cm depth of soil during both the years. In 15 to 30 cm depth of soil, L x S interaction had significant effect on available P status during both the years and the treatment combination l_4s_1 registered significantly higher available P. L x N interaction had significant effect only during I year and l_4n_2 registered the highest content of available P in 15 to 30 cm depth. The effect of S x N interaction was significant during both the years. During I year, the treatment combination s_3n_2 registered significantly higher available P status whereas during the II year, s_1n_2 recorded significantly higher available P than the other combinations.

L x S x N interaction (Table 19d) failed to register significant effects on available P status in 0 to 15 cm depth of soil during both the years. But in 15 to 30 cm depth of soil, the treatment combination $l_4s_3n_2$ registered significantly higher available P status during both the years, but was found on a par with $l_4s_1n_1$ during I year and $l_4s_1n_2$ during II year.

4.7.3.4 Available Potassium

As shown in Table 19a, the main effects of treatments on available K status in both depths of soil were significant during both the years. Available K status was higher in 0 to15 cm depth of soil than in 15 to 30 cm depth.

Among tillage systems, conventional tillage followed by mound system (l_2) recorded significantly higher status of available K in both depths of soil except in 15 to 30 cm during II year when conventional tillage followed by pit system (l_1) recorded significantly higher status of available K.

During both the years, application of coir pith as soil conditioner (s_2) recorded higher status of available K in both depths of soil compared to control (s_1) and rice husk as soil conditioner (s_3). The lowest status of available K in both depths of soil was recorded by control plots during both the years.

As in the case of available N and P, available K status of soil significantly improved in both depths of soil due to organic nutrition (n_2) during both the years.

Regarding interaction effects (Table 19b and 19c), the effect of L x S interaction on available K status in both depths of soil were significant during both the years. The treatment combination l_2s_2 recorded the highest status of available K except in 15 to 30 cm depth during II year when l_1s_2 recorded the highest K status. In the case of L x N interaction, the treatment combination l_2n_2 recorded significantly higher status of available K in both depths of soil during I year. Though not significant, l_2n_2 recorded the highest K status in 0 to 15 cm

Table 19a. Effect of tillage systems, soil conditioners and nutrient management on soil nutrient status after the experiment, kg ha^{-1}

Treatments	Available N				Available P				Available K			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
Tillage systems (L)												
l_1- Conventional tillage- pit system	182.93	190.25	205.93	219.52	157.47	160.28	218.48	202.41	301.17	109.48	373.62	321.90
l_2- Conventional tillage-mound system	187.12	234.16	217.43	227.88	148.04	170.17	191.25	181.58	325.17	126.20	399.76	296.39
l_3- Deep tillage-pit system	178.23	165.16	169.32	194.43	142.46	183.95	176.15	250.43	180.88	107.54	246.90	265.03
l_4 - Deep tillage-mound system	180.32	177.71	184.50	206.98	127.58	209.80	168.19	306.48	253.12	105.46	312.79	249.34
SEm±	3.072	1.474	4.062	0.371	1.064	1.077	1.917	2.617	0.958	1.037	1.594	1.716
CD (0.05)	11.381	5.462	15.050	1.374	3.944	3.992	7.104	9.696	3.550	3.844	5.908	6.357
Soil conditioners (S)												
s_1- Control	199.92	211.68	207.74	225.79	156.28	183.73	204.39	255.85	255.85	97.07	319.87	249.61
s_2- Coir pith	164.64	174.05	185.02	200.70	131.49	175.66	172.32	213.20	274.91	128.22	346.16	314.51
s_3- Rice husk	181.89	189.73	190.12	210.11	143.89	183.76	188.83	236.63	264.49	111.22	333.77	285.37
SEm±	1.201	0.935	0.969	2.091	1.571	0.964	1.879	1.567	1.099	0.333	1.501	1.513
CD (0.05)	3.396	2.645	2.742	5.914	4.443	2.726	5.316	4.433	3.110	0.943	4.245	4.279
Nutrient management (N)												
n_1- INM	172.48	178.75	187.38	204.89	136.85	173.83	182.16	221.30	259.96	105.27	327.20	255.77
n_2- Organic nutrition	191.82	204.89	201.21	219.52	150.92	188.27	194.88	249.15	270.21	119.07	339.34	310.56
SEm±	0.980	0.763	0.792	1.707	1.283	0.787	1.534	1.280	0.898	0.272	1.225	1.235
CD (0.05)	2.773	2.160	2.239	4.829	3.628	2.226	4.340	3.619	2.539	0.770	3.466	3.494

Table 19b. Interaction effect of tillage systems, soil conditioners and nutrient management on soil nutrient status after the experiment, kg ha^{-1}

Treatments	Available N				Available P				Available K			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
L x S interaction												
l_1s_1	205.41	206.98	219.52	232.07	168.64	145.42	234.54	218.29	296.04	103.52	363.01	286.91
l_1s_2	159.94	175.62	191.30	206.98	145.04	167.75	201.23	192.73	307.07	116.83	382.11	366.62
l_1s_3	183.46	188.16	206.98	219.52	158.72	167.67	219.68	196.21	300.40	108.09	375.76	312.17
l_2s_1	205.41	263.42	230.50	244.61	160.37	157.16	212.85	209.23	320.04	103.60	388.60	259.72
l_2s_2	167.78	206.98	217.95	219.52	135.39	164.55	171.03	154.80	331.07	150.87	410.35	323.44
l_2s_3	188.16	232.07	203.84	219.52	148.34	188.78	189.86	180.71	324.40	124.14	400.33	306.02
l_3s_1	192.86	181.89	181.81	206.98	159.10	209.66	187.36	252.61	168.27	85.72	234.70	234.95
l_3s_2	164.64	150.53	159.94	181.89	127.52	177.04	163.76	238.23	194.47	128.35	259.51	305.82
l_3s_3	177.18	163.07	166.21	194.43	140.77	165.16	177.31	260.45	179.88	108.55	246.48	254.31
l_4s_1	196.00	194.43	199.14	219.52	137.02	222.66	182.83	343.26	239.07	95.46	293.18	216.87
l_4s_2	166.21	163.07	170.91	194.43	118.02	193.31	153.26	267.04	267.01	116.83	332.69	262.17
l_4s_3	178.75	175.62	183.46	206.98	127.71	213.42	168.48	309.15	253.30	104.09	312.50	268.99
SEm±	2.401	1.870	1.939	4.181	3.141	1.927	3.758	3.134	2.199	0.667	3.001	3.025
CD (0.05)	6.791	5.289	5.483	NS	NS	5.452	NS	8.864	6.218	1.886	8.488	8.557

NS- Not significant

Table 19c. Interaction effect of tillage systems, soil conditioners and nutrient management on soil nutrient status after the experiment, kg ha^{-1} (contd.)

Treatments	Available N				Available P				Available K			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
L x N interaction												
l_1n_1	166.21	179.80	199.66	213.25	152.09	160.81	212.82	190.36	297.95	106.09	368.91	269.02
l_1n_2	199.66	200.70	212.20	225.79	162.84	159.75	224.14	214.46	304.39	112.88	378.34	374.78
l_2n_1	179.80	213.25	210.11	217.43	139.90	152.32	184.17	170.28	321.95	122.78	392.87	279.82
l_2n_2	194.43	255.06	224.75	238.34	156.17	188.01	198.32	192.88	328.39	129.62	406.65	312.96
l_3n_1	170.39	154.71	163.07	188.16	133.74	177.83	172.03	235.80	173.57	92.91	239.28	243.59
l_3n_2	186.07	175.62	175.56	200.70	151.18	190.08	180.26	265.06	188.18	122.17	254.52	286.46
l_4n_1	173.53	167.25	176.66	200.70	121.66	204.36	159.60	288.78	246.36	99.30	307.73	230.63
l_4n_2	187.12	188.16	192.34	213.25	133.50	215.24	176.77	324.18	259.88	111.62	317.85	268.06
SEm±	1.960	1.527	1.583	3.414	2.565	1.574	3.068	2.559	1.795	0.544	2.450	2.470
CD (0.05)	5.545	4.318	NS	NS	NS	4.451	NS	NS	5.077	1.540	NS	6.987
S x N interaction												
s_1n_1	190.51	203.84	201.49	219.52	148.36	192.65	196.99	232.80	250.39	92.62	312.47	212.97
s_1n_2	209.33	219.52	213.99	232.06	164.20	174.80	211.80	278.90	261.32	101.52	327.27	286.25
s_2n_1	156.02	159.94	176.40	194.43	125.09	175.32	165.73	207.97	270.29	120.28	340.96	294.52
s_2n_2	173.27	188.16	193.65	206.98	137.90	176.01	178.91	218.42	279.53	136.16	351.36	334.50
s_3n_1	170.91	172.48	184.24	200.70	137.10	153.51	183.75	223.14	259.19	102.91	328.16	259.81
s_3n_2	192.86	206.98	196.00	219.52	150.67	214.00	193.91	250.12	269.79	119.53	339.38	310.94
SEm±	1.698	1.322	1.371	2.957	2.221	1.363	2.657	2.216	1.555	0.471	2.122	2.139
CD (0.05)	NS	3.740	NS	NS	NS	3.855	NS	6.268	NS	1.333	NS	6.051

NS- Not significant

Table 19d. Effect of L x S x N interaction on soil nutrient status after the experiment, kg ha^{-1}

Treatments	Available N				Available P				Available K			
	I year		II year		I year		II year		I year		II year	
	Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil		Depth of soil	
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
$l_1s_1n_1$	191.30	200.71	213.25	225.80	161.97	150.45	227.09	192.09	293.54	101.54	358.16	217.90
$l_1s_1n_2$	219.52	213.25	225.80	238.34	175.30	140.39	241.98	244.50	298.54	105.50	367.85	355.92
$l_1s_2n_1$	147.39	163.08	185.03	200.71	137.88	184.93	195.99	188.22	302.87	112.22	377.92	331.87
$l_1s_2n_2$	172.48	188.16	197.57	213.25	152.21	150.57	206.48	197.23	311.28	121.45	386.29	401.36
$l_1s_3n_1$	159.94	175.62	200.71	213.25	156.43	147.04	215.40	190.77	297.43	104.50	370.64	257.30
$l_1s_3n_2$	206.98	200.71	213.25	225.80	161.02	188.30	223.97	201.65	303.36	111.68	380.87	367.05
$l_2s_1n_1$	197.57	250.88	225.79	238.34	152.18	167.29	202.92	191.35	317.54	105.65	380.47	233.98
$l_2s_1n_2$	213.25	275.97	235.20	250.88	168.56	147.04	222.79	227.11	322.54	101.54	396.74	285.47
$l_2s_2n_1$	159.94	188.16	206.98	213.25	127.67	152.57	165.60	149.32	326.87	146.87	405.56	313.32
$l_2s_2n_2$	175.62	225.80	228.93	225.80	143.12	176.54	176.45	160.28	335.28	154.87	415.14	333.56
$l_2s_3n_1$	181.89	200.71	197.57	200.71	139.85	137.11	184.01	170.17	321.43	115.82	392.60	292.18
$l_2s_3n_2$	194.43	263.43	210.11	238.34	156.84	240.45	195.71	191.26	327.36	132.45	408.07	319.86
$l_3s_1n_1$	185.02	175.62	175.62	200.71	149.92	200.68	181.93	213.02	158.21	73.25	226.01	209.52
$l_3s_1n_2$	200.70	188.16	188.00	213.25	168.28	218.65	192.79	292.21	178.34	98.19	243.40	260.38
$l_3s_2n_1$	156.80	137.99	150.53	175.62	119.87	177.54	157.72	236.92	189.97	109.82	252.18	292.51
$l_3s_2n_2$	172.48	163.08	169.35	188.16	135.17	176.54	169.81	239.55	198.98	146.87	266.84	319.13
$l_3s_3n_1$	169.35	150.53	163.07	188.16	131.44	155.27	176.43	257.46	172.53	95.65	239.65	228.75
$l_3s_3n_2$	185.02	175.62	169.35	200.71	150.10	175.04	178.19	263.44	187.24	121.45	253.32	279.87
$l_4s_1n_1$	188.16	188.16	191.30	213.25	129.37	252.20	176.01	334.73	232.28	90.05	285.26	190.50
$l_4s_1n_2$	203.84	200.71	206.98	225.80	144.67	193.12	189.65	351.79	245.85	100.87	301.11	243.25
$l_4s_2n_1$	159.94	150.53	163.07	188.16	114.93	186.24	143.62	257.44	261.43	112.22	328.21	240.39
$l_4s_2n_2$	172.48	175.62	178.76	200.71	121.11	200.39	162.90	276.64	272.58	121.45	337.17	283.94
$l_4s_3n_1$	172.48	163.08	175.62	200.71	120.69	174.64	159.18	274.17	245.38	95.65	309.74	261.01
$l_4s_3n_2$	185.03	188.16	191.30	213.25	134.74	252.20	177.78	344.13	261.22	112.54	315.27	276.98
SEm±	3.395	2.644	2.742	5.913	4.443	2.726	5.315	4.432	3.109	0.943	4.244	4.278
CD (0.05)	NS	7.480	NS	NS	NS	7.710	NS	12.536	NS	2.667	NS	12.101

NS- Not significant

depth of soil and l_1n_2 recorded significantly higher K status in 15 to 30 cm depth of soil during II year. The interaction S x N had significant effect on available K status in 15 to 30 cm depth only during both the years when s_2n_2 registered significantly higher available K status.

L x S x N interaction effects presented in Table 19d indicated no significant effect on available K status in 0 to 15 cm depth of soil during both the years. In 15 to 30 cm depth of soil, the treatment combination $l_2s_2n_2$ resulted in significantly higher K status during I year and $l_1s_2n_2$ during II year.

4.8 INCIDENCE OF PEST AND DISEASES

No incidence of any pest or disease was noticed in the crop during two years of experimentation.

4.9 ECONOMICS OF CULTIVATION

The economics of cultivation was worked out in terms of net income and BCR considering the cost of inputs and price of produce during the cropping periods as given in Appendix II. The effect of treatments on net income and BCR are presented in Tables 20a, 20b and 20c.

4.9.1 Net Income

Net income varied significantly due to tillage systems, soil conditioners and nutrient management (Table 20a).

Deep tillage followed by pit system (l_3) registered the highest income during both the years and in pooled analysis (pooled mean of ₹ 1,21,605 ha^{-1}). It was followed by deep tillage and mound system (l_4 - pooled mean of ₹ 92,130 ha^{-1}). The lowest net income (pooled mean of ₹ 54,893 ha^{-1}) was recorded by conventional tillage followed by mound system (l_2). The data indicated the superiority of deep tillage over conventional system and pit system over mound system of planting as evident from significant variation in their effects on net income ($l_3 > l_4 > l_1 > l_2$).

During I year, the highest net income of ₹ 56,403 ha^{-1} was obtained from coir pith applied plots (s_2) but was a on a par with control (s_1) but superior to rice husk (s_3) as soil conditioner. During II year, significantly higher net income of ₹ 12,8693 ha^{-1} was obtained from control plots (s_1). Pooled analysis indicated that significantly higher net income of ₹ 91,230 ha^{-1} was obtained without soil conditioner (s_1). Among soil conditioners, coir pith (s_2) was found superior to rice husk (s_3).

Organic nutrition (n_2) resulted in significantly higher net income during both the years and also in pooled analysis (pooled mean of ₹ 94,142 ha^{-1}) over INM (n_1).

The effects of L x S interaction (Table 20b) was not significant during I year but the treatment combination, l_3s_2 registered the highest net income followed by l_3s_1. During II year and in the pooled analysis, the effects were significant and l_3s_1 registered the highest net income (pooled mean of ₹ 1,28,747 ha^{-1}). L x N interaction effects were significant during both the years and in the pooled analysis. The treatment combination l_3n_2 was found superior to others which registered mean net income of ₹ 1,38,506 ha^{-1}. In the case of S x N interaction, the effects were significant during II year only when the treatment combination s_1n_2 registered the highest net income of ₹ 1,38,306 ha^{-1}. The same treatment combination registered the highest net income of ₹ 1,00,653 ha^{-1} in the pooled analysis although the effect was not significant.

The effects of L x S x N interaction were significant during both the years (Table 20c). During I year, the treatment combination $l_3s_2n_2$ registered the highest net income (₹ 1,08,325 ha^{-1}) but was on a par with $l_3s_1n_2$ and $l_3s_3n_2$. During II year, $l_3s_1n_2$ recorded significantly higher net income of ₹ 1,85,725 ha^{-1}closely followed by $l_3s_3n_2$ and $l_3s_2n_2$. Though the effect was not significant, the treatment combination $l_3s_1n_2$ registered the highest net income of ₹ 1,43,213 ha^{-1} in the pooled analysis closely followed by $l_3s_2n_2$ and $l_3s_3n_2$.

4.9.2 Benefit Cost Ratio

Significant variation in benefit cost ratio due to treatments was evident from Table 20a.

During both the years, deep tillage followed by pit system (l_3) registered significantly higher BCR of 1.51 during I year and 2.01 during II year. The lowest ratios of 1.2 during I year and 1.5 during II year were recorded by conventional tillage followed by mound system (l_2) but was on a par with conventional tillage followed by pit system (l_1) during I year only. Pooled analysis also indicated that l_3 registered significantly higher BCR of 1.76 and l_2 registered the lowest BCR of 1.37.

With respect to soil conditioner, the control plots (s_1) registered significantly higher BCR during both the years and the pooled analysis (pooled mean of 1.66). Among soil conditioners, coir pith (s_2) registered significantly higher BCR over rice husk (s_3).

Organic nutrition (n_2) recorded significantly higher BCR during both the years and in the pooled analysis with a mean BCR of 1.6 compared to INM (n_1).

Considering L x S interaction (Table 20b), the treatment combination l_3s_1 registered the highest BCR during both the years and in the pooled data (1.9) though the effect was not significant during I year. The effect of L x N interaction was significant during both the years and in the pooled analysis and the treatment combination l_3n_2 recorded the highest BCR (pooled mean of 1.86). In the case of S x N interaction, although the treatment combination s_1n_2 recorded the highest BCR (pooled mean of 1.72), the effects were significant only during II year.

The effect of L x S x N interaction was significant only during II year and the treatment combination $l_3s_1n_2$ registered significantly higher BCR of 2.28. Although the effects were not significant, the same treatment combination registered the highest BCR of 1.69 during I year and the pooled mean of 1.99. It was followed by $l_3s_2n_2$ (1.63) and $l_3s_3n_2$ (1.57) during I year; $l_3s_1n_1$ (2.13) and

Table 20a. Effect of tillage systems, soil conditioners and nutrient management on economics of cultivation

Treatments	Net income, ₹ ha^{-1}			Benefit : cost ratio		
	I year	II year	Pooled mean	I year	II year	Pooled mean
Tillage systems (L)						
l_1- Conventional tillage- pit system	35103	101061	68082	1.22	1.65	1.43
l_2- Conventional tillage-mound system	29324	80461	54893	1.20	1.55	1.37
l_3- Deep tillage-pit system	82195	161016	121605	1.51	2.01	1.76
l_4 - Deep tillage-mound system	56841	127420	92130	1.38	1.85	1.61
SEm±	1160	782	926	0.008	0.005	0.006
CD (0.05)	4300	2899	4258	0.029	0.018	0.028
Soil conditioners (S)						
s_1- Control	53766	128693	91230	1.39	1.93	1.66
s_2- Coir pith	56403	115503	85953	1.34	1.70	1.52
s_3- Rice husk	42428	108271	75350	1.25	1.65	1.45
SEm±	1458	408	786	0.009	0.003	0.005
CD (0.05)	4124	1155	2956	0.027	0.007	0.019
Nutrient management (N)						
n_1- INM	39483	108943	74213	1.26	1.71	1.49
n_2- Organic nutrition	62248	126035	94142	1.40	1.81	1.60
SEm±	1190	333	641	0.008	0.002	0.004
CD (0.05)	3367	943	2413	0.022	0.006	0.015

Table 20b. Interaction effect of tillage systems, soil conditioners and nutrient management on economics of cultivation

Treatments	Net income, ₹ ha^{-1}			Benefit : cost ratio		
	I year	II year	Pooled mean	I year	II year	Pooled mean
L x S interaction						
l_1s_1	39053	109903	74478	1.28	1.78	1.53
l_1s_2	36403	101466	68934	1.22	1.61	1.41
l_1s_3	29853	91816	60834	1.18	1.55	1.36
l_2s_1	33716	89853	61784	1.25	1.68	1.47
l_2s_2	39716	83016	61366	1.25	1.52	1.39
l_2s_3	14541	68516	41528	1.09	1.43	1.26
l_3s_1	84753	172741	128747	1.59	2.20	1.90
l_3s_2	85728	155266	120497	1.50	1.91	1.71
l_3s_3	76103	155041	115572	1.45	1.91	1.68
l_4s_1	57541	142278	99909	1.43	2.06	1.74
l_4s_2	63766	122266	93016	1.39	1.76	1.57
l_4s_3	49216	117716	83466	1.31	1.73	1.52
SEm±	2916	817	1571	0.019	0.005	0.010
CD (0.05)	NS	2310	5911	NS	0.015	0.038
L x N interaction						
l_1n_1	27289	91964	59627	1.18	1.59	1.39
l_1n_2	42917	110158	76538	1.27	1.70	1.48
l_2n_1	26173	73831	50002	1.18	1.50	1.34
l_2n_2	32475	87092	59783	1.22	1.59	1.40
l_3n_1	61789	147623	104706	1.39	1.93	1.66
l_3n_2	102600	174408	138504	1.63	2.08	1.86
l_4n_1	42681	122356	82519	1.29	1.82	1.56
l_4n_2	71000	132483	101742	1.46	1.87	1.67
SEm±	2381	667	1283	0.015	0.004	0.008
CD (0.05)	6735	1887	4826	0.044	0.012	0.031
S x N interaction						
s_1n_1	44531	119081	81806	1.32	1.87	1.60
s_1n_2	63000	138306	100653	1.45	1.99	1.72
s_2n_1	44731	108694	76712	1.27	1.67	1.47
s_2n_2	68075	122313	95194	1.41	1.73	1.57
s_3n_1	29187	99056	64122	1.18	1.60	1.39
s_3n_2	55669	117488	86578	1.33	1.70	1.52
SEm±	2062	578	1111	0.013	0.004	0.007
CD (0.05)	NS	1633.88	NS	NS	0.01	NS

NS- Not significant

Table 20c. Effect of L x S x N interaction on economics of cultivation

Treatments	Cost of cultivation, ₹ ha^{-1}	Net income, ₹ ha^{-1}			Benefit : cost ratio		
		I year	II year	Pooled mean	I year	II year	Pooled mean
$l_1s_1n_1$	138994	35306	99581	67444	1.25	1.72	1.49
$l_1s_1n_2$	142200	42800	120225	81513	1.30	1.85	1.57
$l_1s_2n_1$	165994	30556	93856	62206	1.19	1.57	1.38
$l_1s_2n_2$	169200	42250	109075	75663	1.25	1.65	1.45
$l_1s_3n_1$	165994	16006	82456	49231	1.09	1.50	1.30
$l_1s_3n_2$	169200	43700	101175	72438	1.26	1.60	1.43
$l_2s_1n_1$	129994	29481	79531	54506	1.23	1.61	1.42
$l_2s_1n_2$	133200	37950	100175	69063	1.28	1.75	1.52
$l_2s_2n_1$	156994	32381	81431	56906	1.21	1.52	1.36
$l_2s_2n_2$	160200	47050	84600	65825	1.29	1.53	1.41
$l_2s_3n_1$	156994	16656	60531	38594	1.11	1.39	1.25
$l_2s_3n_2$	160200	12425	76500	44463	1.08	1.48	1.28
$l_3s_1n_1$	141994	68806	159756	114281	1.48	2.13	1.80
$l_3s_1n_2$	145200	100700	185725	143213	1.69	2.28	1.99
$l_3s_2n_1$	168994	63131	142706	102919	1.37	1.85	1.61
$l_3s_2n_2$	172200	108325	167825	138075	1.63	1.98	1.80
$l_3s_3n_1$	168994	53431	140406	96919	1.32	1.83	1.57
$l_3s_3n_2$	172200	98775	169675	134225	1.57	1.99	1.78
$l_4s_1n_1$	132994	44531	137456	90994	1.34	2.04	1.69
$l_4s_1n_2$	136200	70550	147100	108825	1.52	2.08	1.80
$l_4s_2n_1$	159994	52856	116781	84819	1.33	1.73	1.53
$l_4s_2n_2$	163200	74675	127750	101213	1.46	1.78	1.62
$l_4s_3n_1$	159994	30656	112831	71744	1.20	1.71	1.45
$l_4s_3n_2$	163200	67775	122600	95188	1.42	1.75	1.58
SEm±	-	4124	1155	2222	0.027	0.007	0.014
CD (0.05)	-	11665	3268	NS	NS	0.021	NS

NS- Not significant

$l_4s_1n_2$ (2.08) during II year and $l_3s_1n_1$ (1.8), $l_3s_2n_2$ (1.8), $l_4s_1n_2$ (1.8), and $l_3s_3n_2$ (1.78) in the pooled data.

4.10 CORRELATION STUDIES

Correlation analysis of yield versus LAI, yield components and nutrient uptake, TDMP versus LAI, yield and nutrient uptake and yield versus soil physical properties were done and the correlation coefficients are given in Table 21a, 21b and 21c.

The correlation studies (Table 21a) indicated that cormel yield was significantly and positively correlated with LAI at 5 MAP, number of cormels plant^{-1}, cormel : corm ratio and N, P and K uptake during both the years. Mean cormel weight is significantly and negatively correlated with number of cormels plant^{-1} during both the years. Corm yield was also significantly and positively correlated with LAI at 5 MAP, and N, P and K uptake.

The results presented in Table 21b revealed that TDMP was significantly and positively correlated with LAI at 5 MAP, cormel and corm yields and N, P and K uptake during both the years.

Correlation coefficients presented in Table 21c showed that cormel as well as corm yields were significantly and negatively correlated with bulk density in 0 to 15 cm and 15 to 30 cm depth of soil during both the years. Cormel as well as corm yields were significantly and positively correlated with porosity and water holding capacity in both depths of the soil during both the years.

Table 21a. Correlation analysis of yield versus LAI, yield components and nutrient uptake

Variables correlated	Correlation coefficients (r)	
	I year	II year
Cormel yield x LAI at 5 MAP	0.956**	0.715**
Cormel yield x number of cormels plant^{-1}	0.885**	0.797**
Cormel yield x cormel:corm ratio	0.878**	0.829**
Corm yield x LAI at 5 MAP	0.855**	0.607**
Number of cormels per plant^{-1} x Mean cormel weight	-0.689**	-0.515**
Cormel yield x N uptake	0.992**	0.921**
Cormel yield x P uptake	0.992**	0.953**
Cormel yield x K uptake	0.978**	0.949**
Corm yield x N uptake	0.930**	0.823**
Corm yield x P uptake	0.946**	0.850**
Corm yield x K uptake	0.932**	0.843**

** Significant at 1% level
*Significant at 5% level

Table 21b. Correlation analysis of total dry matter production versus LAI, yield and nutrient uptake

Variables correlated	Correlation coefficients (r)	
	I year	II year
Total dry matter production x LAI at 5 MAP	0.944**	0.794**
Total dry matter production x Cormel yield	0.996**	0.943**
Total dry matter production x Corm yield	0.943**	0.875**
Total dry matter production x N uptake	0.995**	0.980**
Total dry matter production x P uptake	0.995**	0.995**
Total dry matter production x K uptake	0.979**	0.983**

** Significant at 1% level
*Significant at 5% level

Table 21c. Correlation analysis of tuber yield versus soil physical properties

Variables correlated	Correlation coefficients (r)	
	I year	II year
Cormel yield x bulk density (0-15cm depth)	-0.824**	-0.922**
Cormel yield x bulk density (15-30cm depth)	-0.746**	-0.791**
Cormel yield x porosity (0-15cm depth)	0.751**	0.866**
Cormel yield x porosity (15-30cm depth)	0.577**	0.786**
Cormel yield x water holding capacity (0-15cm depth)	0.637**	0.816**
Cormel yield x water holding capacity (15-30cm depth)	0.921**	0.643**
Corm yield x bulk density (0-15cm depth)	-0.755**	-0.705**
Corm yield x bulk density (15-30cm depth)	-0.701**	-0.563**
Corm yield x porosity (0-15cm depth)	0.650**	0.691**
Corm yield x porosity (15-30cm depth)	0.490*	0.575**
Corm yield x water holding capacity (0-15cm depth)	0.513*	0.635**
Corm yield x water holding capacity (15-30cm depth)	0.856**	0.657**

** Significant at 1% level
*Significant at 5% level

DISCUSSION

5. DISCUSSION

The results of the field experiments conducted to identify ideal tillage system, soil conditioner and nutrient management for productivity enhancement in tannia are discussed in this chapter.

5.1 GROWTH CHARACTERS

Growth characters like plant height, leaf number plant^{-1} and LAI were recorded from 2 MAP onwards at monthly interval. Tillage systems, soil conditioners and nutrient management profoundly influenced the growth characters at all growth stages during both the years. Whatever be the treatment, the plant height increased upto 5 MAP during I year (Fig.3a, 5a and 7a) and upto 6 MAP during II year (Fig. 4a, 6a and 8a) after which it showed a decreasing trend upto harvest. Leaf number plant^{-1} (Fig. 3b, 4b, 5b, 6b, 7b and 8b) and LAI (Fig. 3c, 4c, 5c, 6c, 7c and 8c) showed an increasing trend upto 5 MAP after which it showed a declining trend upto harvest during both the years. This clearly indicated that the rapid vegetative growth in tannia extends upto 5 or 6 MAP and during later stages of tuber development and bulking, the vegetative growth reduces. This is in agreement with the findings of Adiobo *et al*. (2011) who identified three distinct growth stages in tannia *viz.* crop establishment (from planting upto 2 MAP), period of rapid vegetative growth (from 2 MAP upto 5 MAP) and tuber development and maturation (after 5 or 6 MAP).

Among tillage systems, deep tillage followed by pit system produced taller plants during initial stages upto 5 MAP and at harvest during I year (Fig 3a). At other stages, conventional tillage followed by pit system produced the tallest plants. During II year, deep tillage followed by pit system produced taller plants but was on a par with conventional tillage followed by pit system during initial stages and deep tillage followed by mound system during later stages of crop growth (Fig 4a). The highest number of leaves plant^{-1} (Fig. 3b and 4b) and the highest LAI (Fig. 3c and 4c) were recorded by deep tillage followed by pit system at all growth stages during both the years. Contrast analysis indicated the superiority of deep tillage over conventional tillage in producing taller plants from 3 MAP onwards with more leaf number plant^{-1} and the highest LAI at all growth stages during both the years. Pit system of planting proved superior to mound system in increasing plant height, leaf number and LAI at all stages during both the years. This could be attributed to the variation in tillage depth which was 30 cm in deep tillage and only 15 cm in conventional tillage. Ramesh *et al*. (2007) also opined that ploughing to a depth of 20 to 40 cm could improve the growth of tannia. Corroboratory results have been reported by Kumar *et al*. (2015) in potato in which, plant height, number of branches and leaf number increased with increase in depth of tillage to 30cm.

At all stages of growth during both the years, application of soil conditioner improved the vegetative growth of tannia over control. Application of soil conditioner might have loosened the soil reducing soil compactness and improved the porosity and water holding capacity of the soil favouring crop growth (Gupta *et al*., 2000; Nedunchezhiyan *et al*., 2013). Coir pith performed better than rice husk as soil conditioner in producing taller plants with more leaf number plant^{-1} (Fig. 5b and 6b) and the highest LAI (Fig. 5c and 6c). After the harvest of the crop, no visible remnants of coir pith could be observed in the field in the present study. However, remnants of rice husk could be seen in the plots treated with rice husk. This is indicative of the fact that coir pith might have been completely decomposed during the long crop period (nine months) which might have supplied nutrients in addition to its effect on physical properties of the soil.

The vegetative characters like plant height, leaf number plant^{-1} and LAI were higher under organic nutrition compared to INM at all growth stages during both the years (Fig. 7a, 7b, 7c, 8a, 8b and 8c). This might be due to gradual availability of nutrients by decomposition of organic manures throughout the growth period and reduced loss of nutrients compared to readily available nutrients from fertilizers under INM. Suja *et al*. (2009) also opined that organic nutrition favoured plant height, leaf production and number of cormels plant^{-1} of tannia.

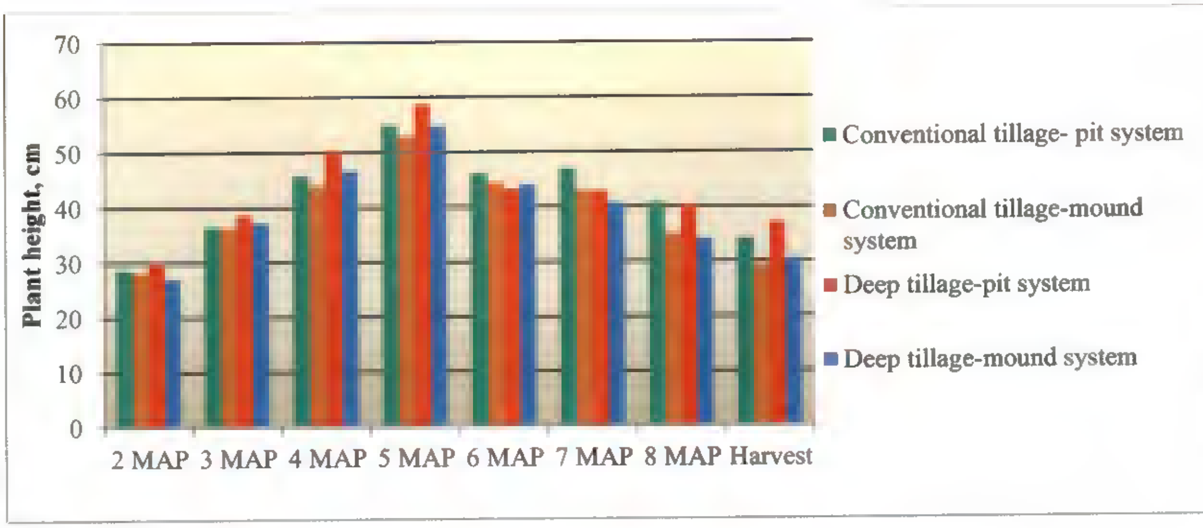

Fig. 3a Effect of tillage systems on plant height during I year, cm

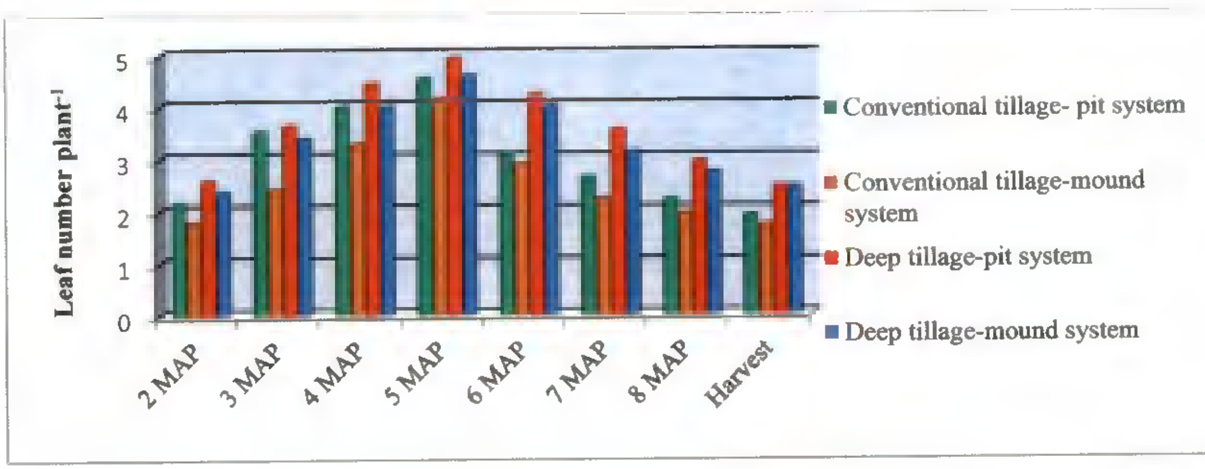

Fig. 3b Effect of tillage systems on leaf number during I year

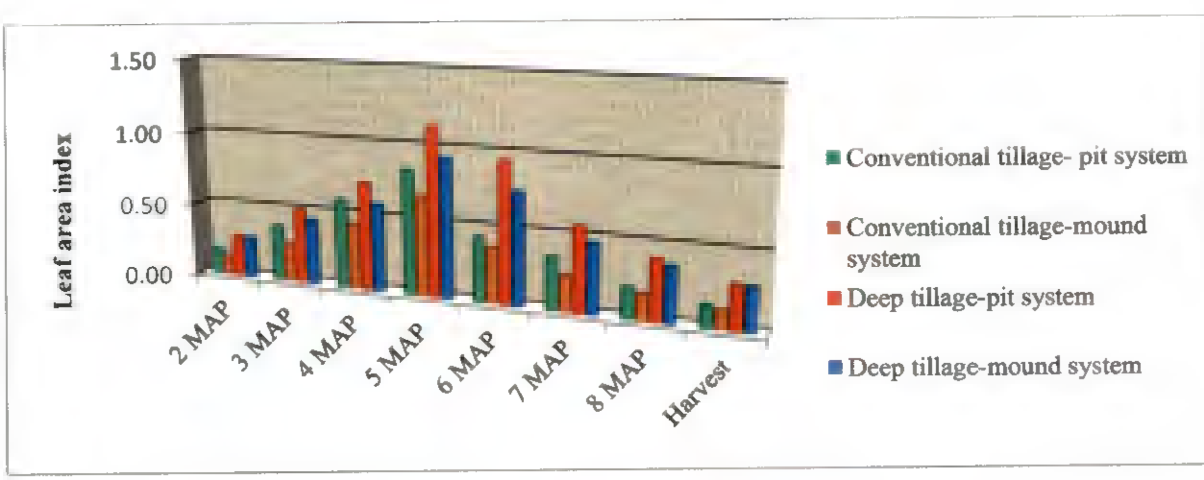

Fig. 3c Effect of tillage systems on leaf area index during I year

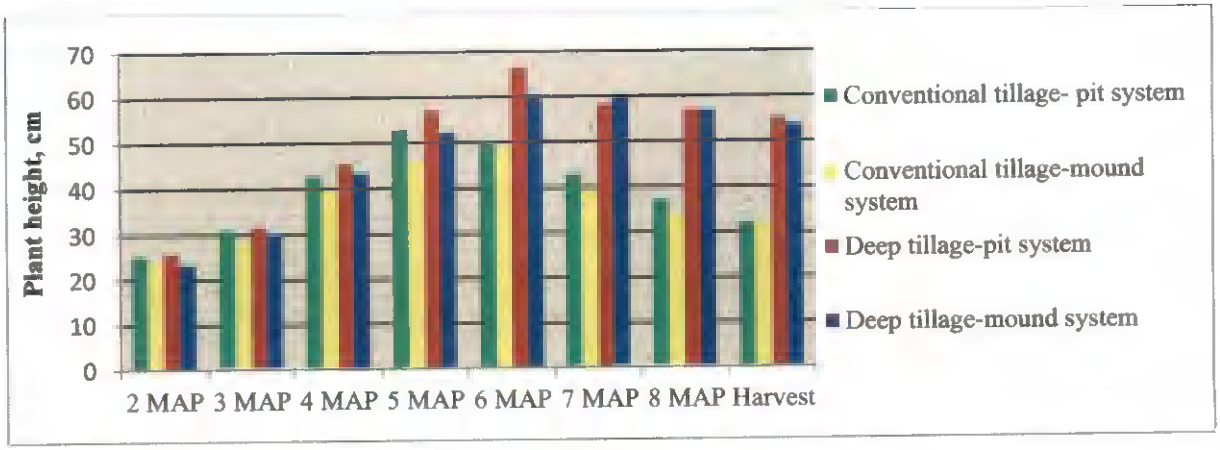

Fig. 4a Effect of tillage systems on plant height during II year, cm

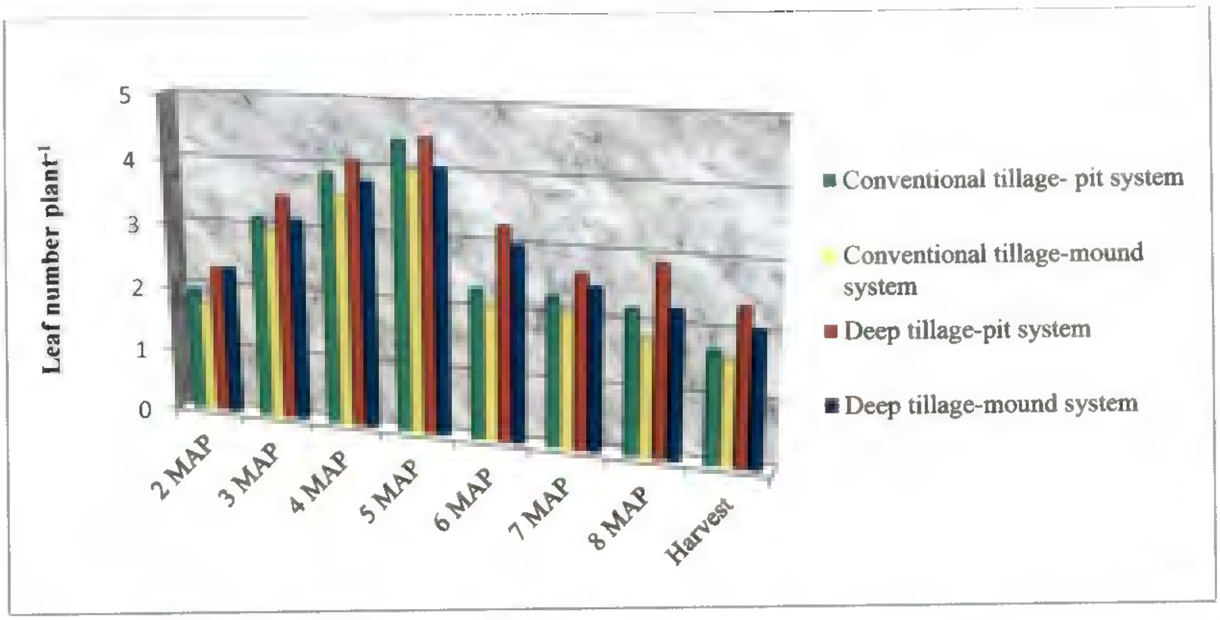

Fig. 4b Effect of tillage systems on leaf number during II year

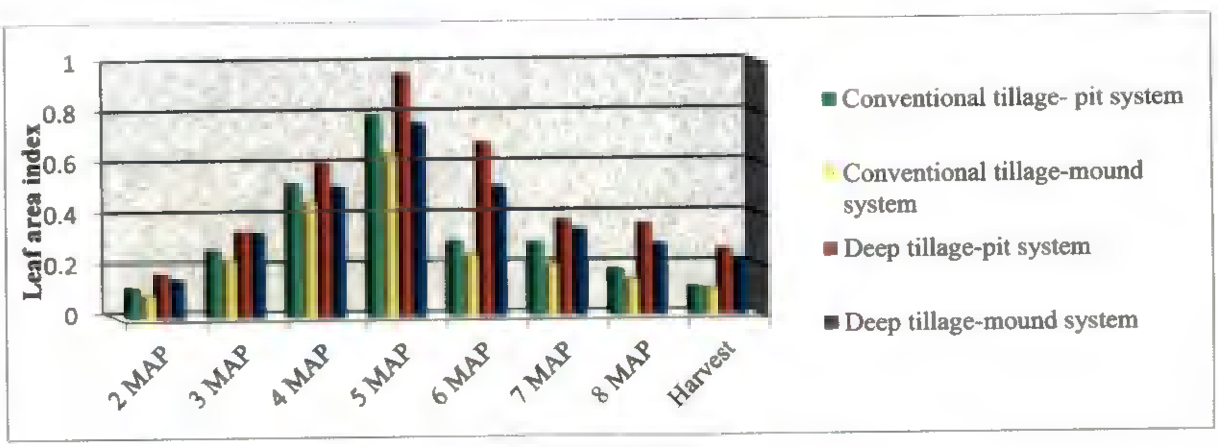

Fig. 4c Effect of tillage systems on leaf area index during II year

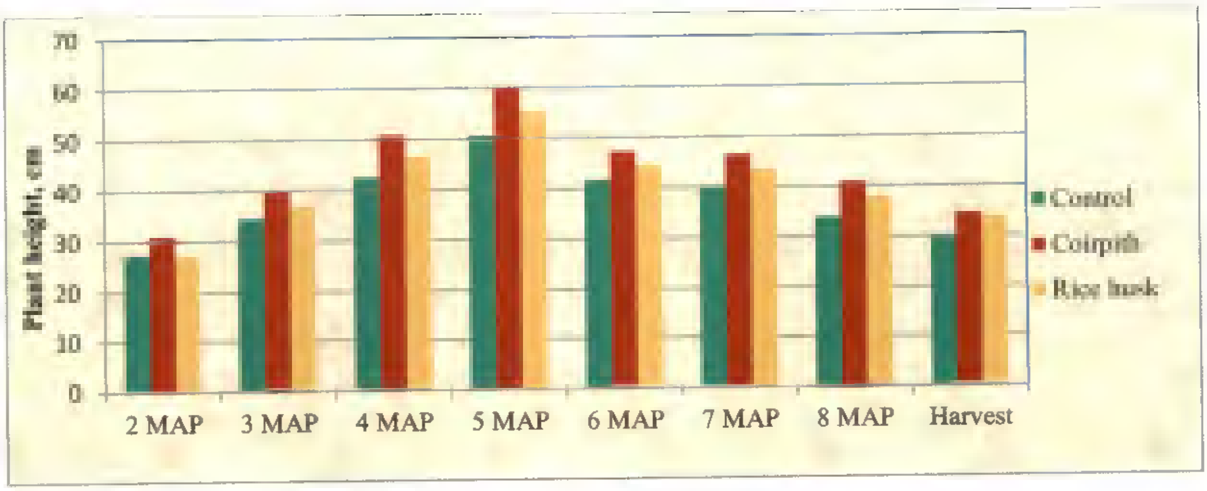

Fig. 5a Effect of soil conditioners on plant height during I year, cm

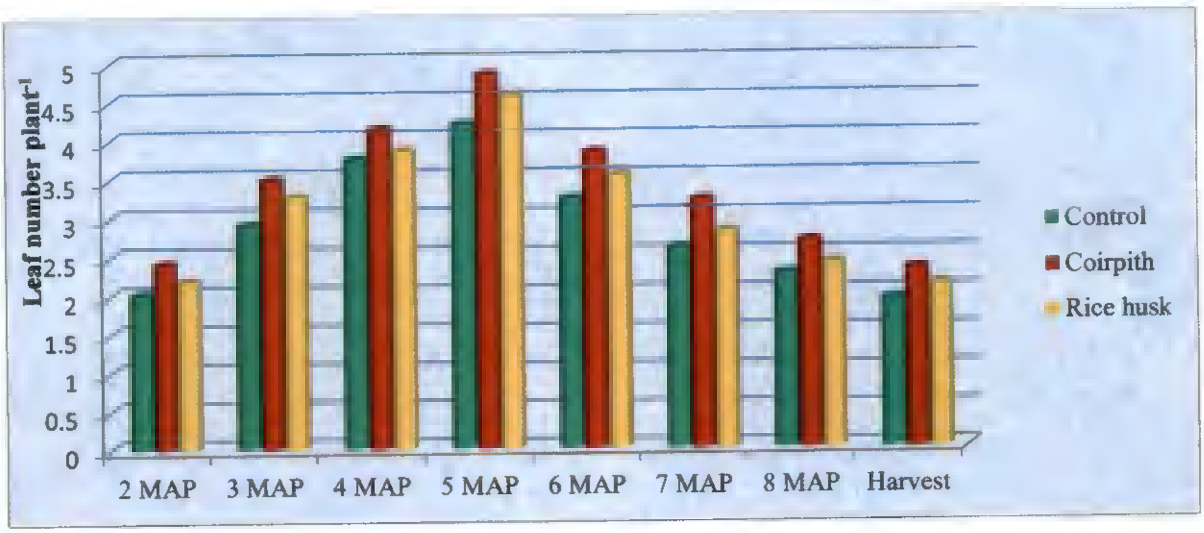

Fig. 5b Effect of soil conditioners on leaf number during I year

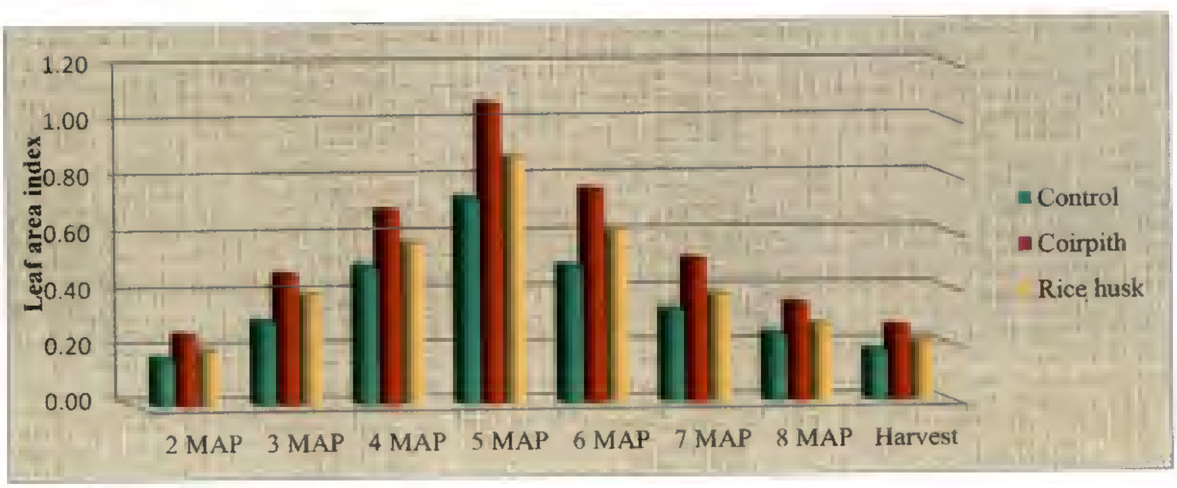

Fig. 5c Effect of soil conditioners on leaf area index during I year

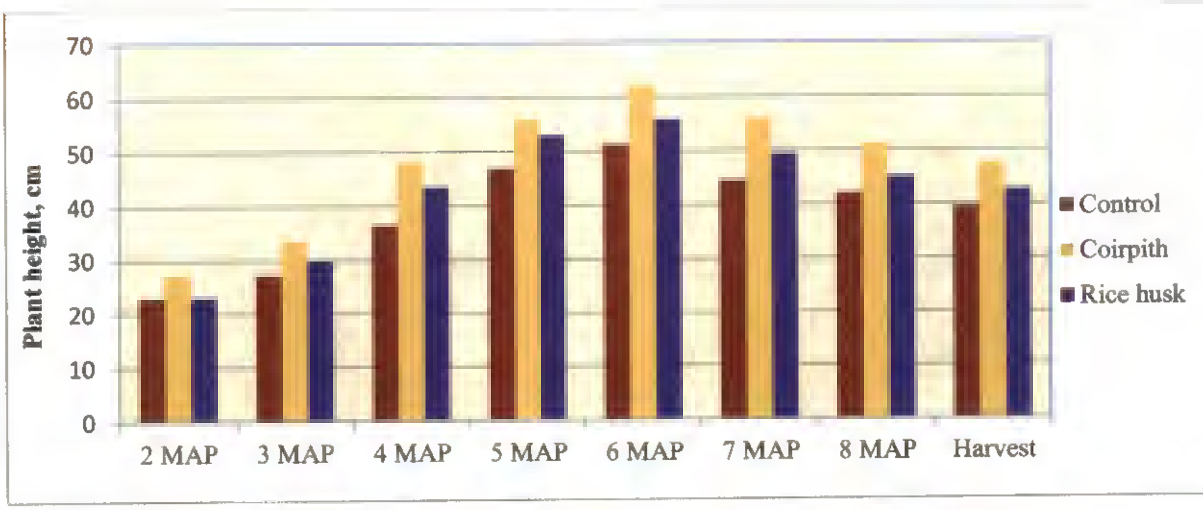

Fig. 6a Effect of soil conditioners on plant height during II year, cm

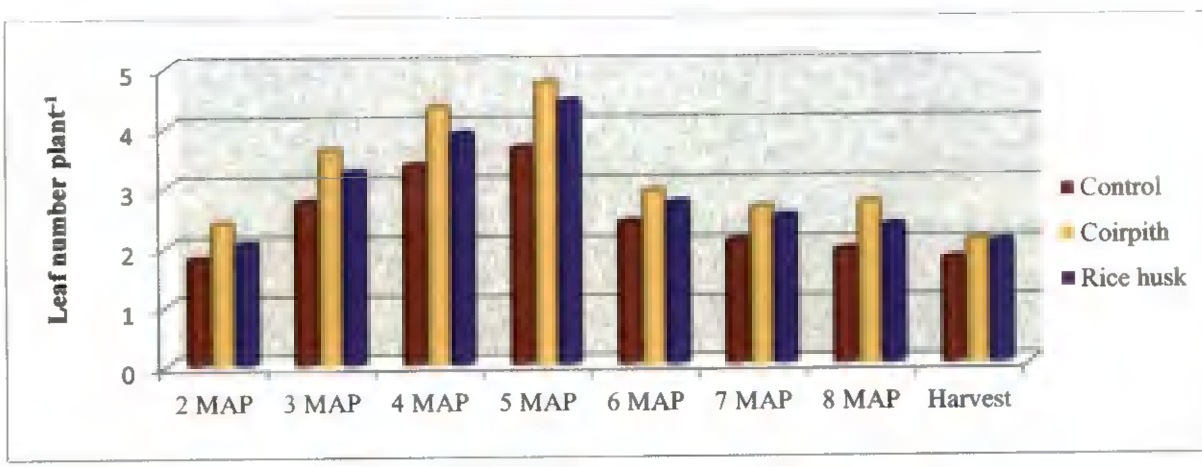

Fig. 6b Effect of soil conditioners on leaf number during II year

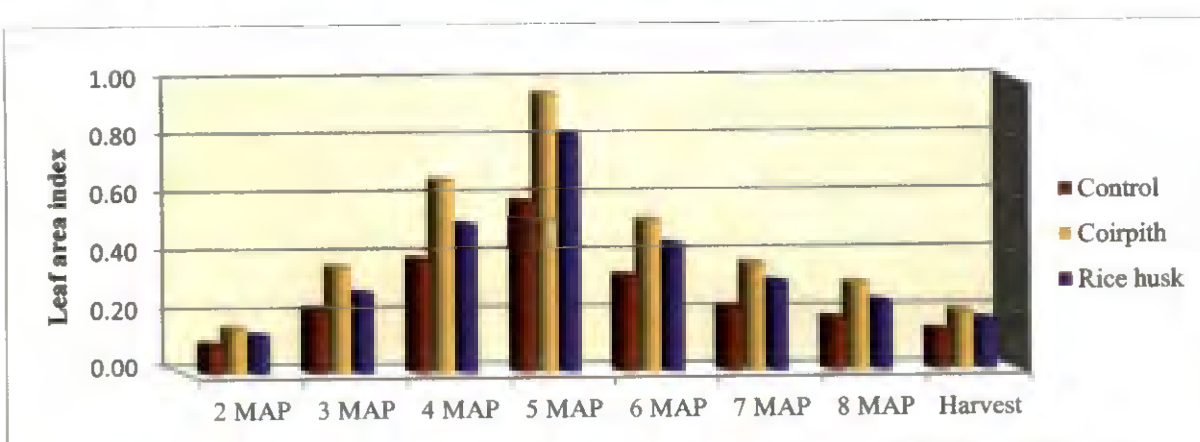

Fig. 6c Effect of soil conditioners on leaf area index during II year

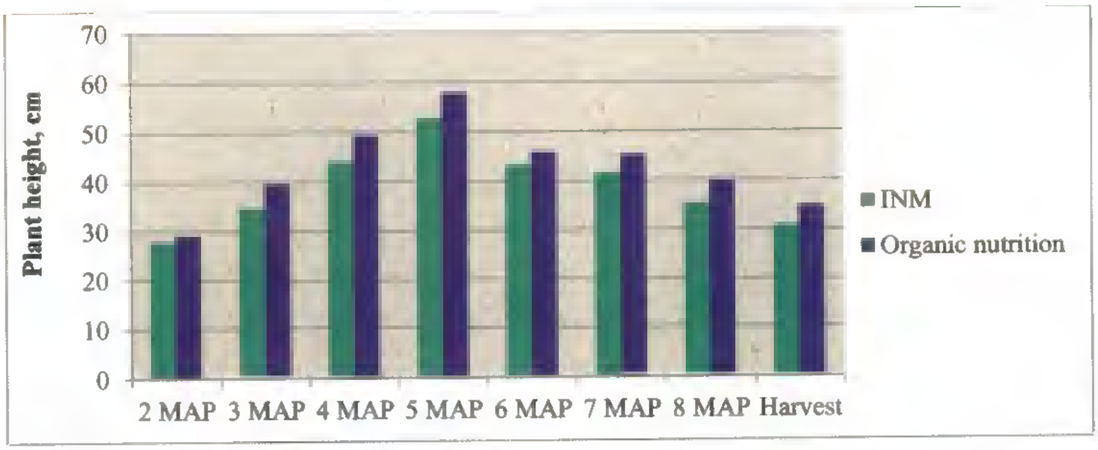

Fig. 7a Effect of nutrient management on plant height during I year, cm

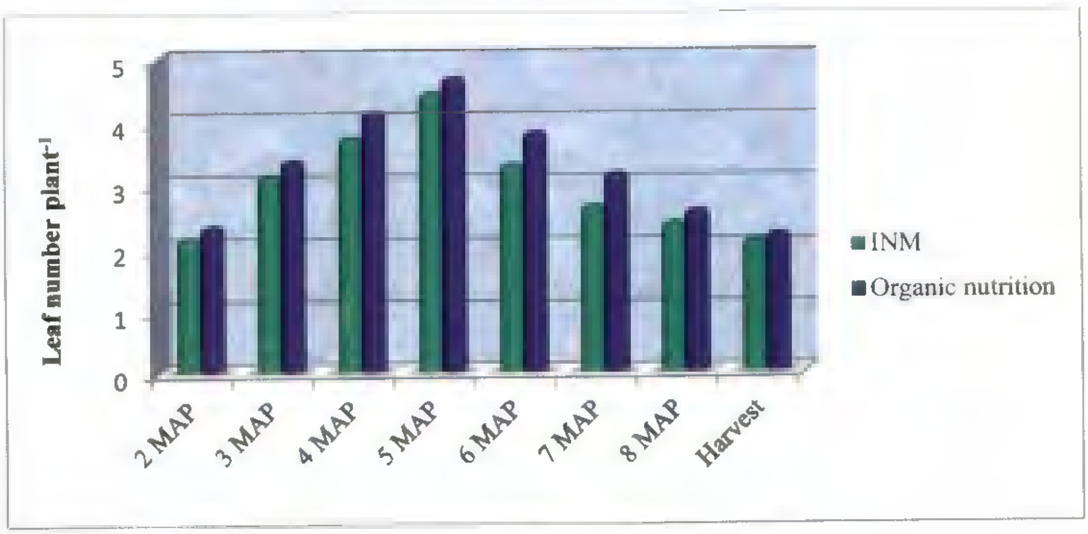

Fig. 7b Effect of nutrient management on leaf number during I year

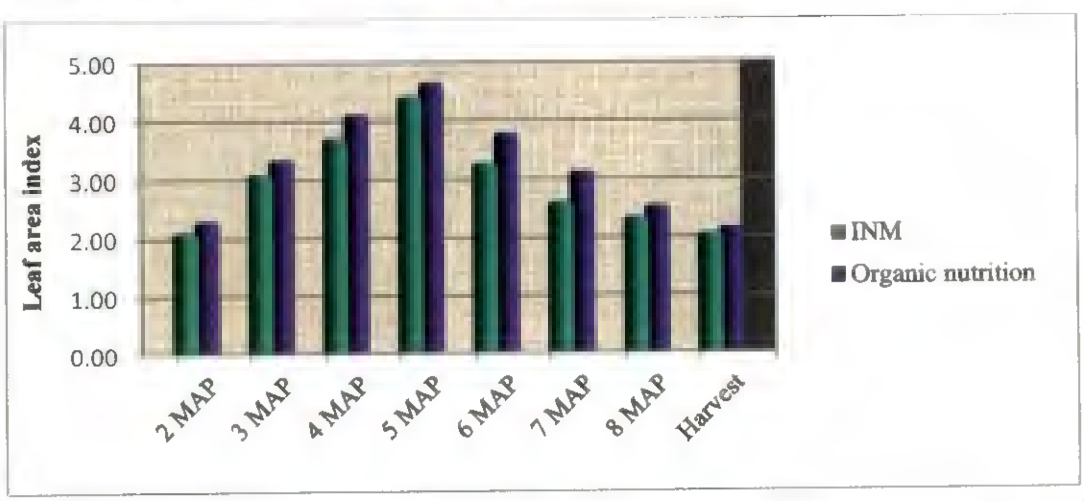

Fig. 7c Effect of nutrient management on leaf area index during I year

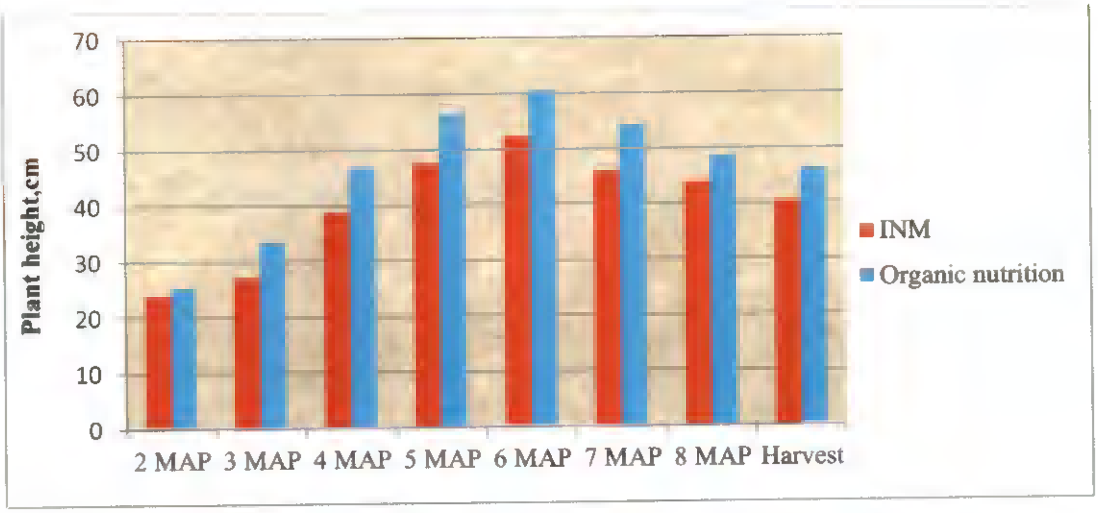

Fig. 8a Effect of nutrient management on plant height during II year, cm

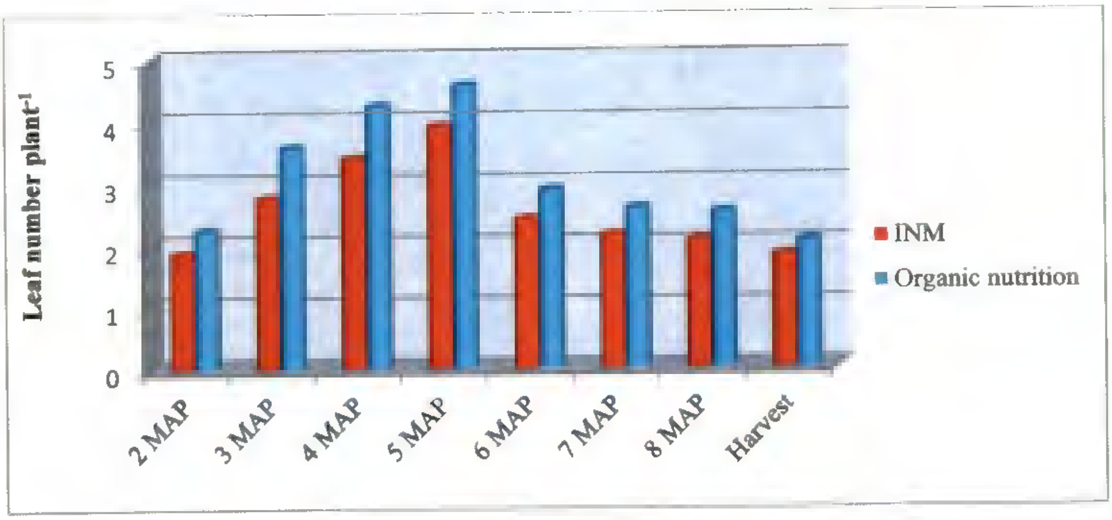

Fig. 8b Effect of nutrient management on leaf number during II year

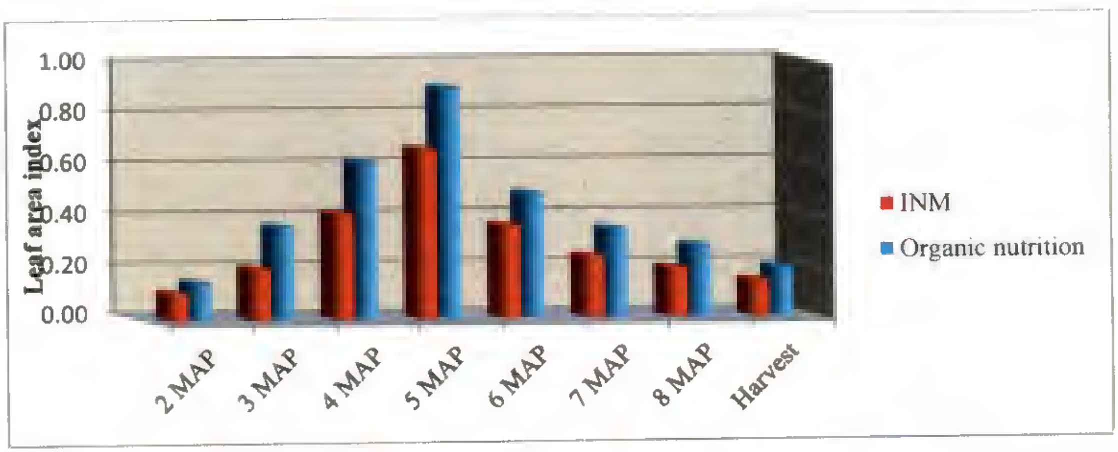

Fig. 8c Effect of nutrient management on leaf area index during II year

The interaction effects (L x S, L x N and N x S) followed the same trend as that of the main effects. Considering L x S x N interaction, deep tillage followed by pit system during initial stages upto 5 MAP and conventional tillage followed by pit system during later stages combined with coir pith as soil conditioner and organic nutrition ($l_3s_2n_2$ and $l_1s_2n_2$ respectively) produced taller plants during I year. During II year, deep tillage followed by pit system with coir pith as soil conditioner under organic nutrition ($l_3s_2n_2$) upto 7 MAP and deep tillage followed by mound system with coir pith as soil conditioner under organic nutrition ($l_4s_2n_2$) at later stages produced taller plants. In general, deep tillage followed by pit system with coir pith as soil conditioner under organic nutrition ($l_3s_2n_2$) registered the highest leaf number and LAI during both the years. The results pointed out the favourable influence of deep tillage and pit system of planting tannia, application of coir pith as soil conditioner and organic nutrition on vegetative growth of tannia.

5.2 YIELD COMPONENTS

The treatments varied in their influence on yield components like number of cormels plant^{-1}, mean cormel weight, cormel yield plant^{-1}, corm yield plant^{-1} and cormel : corm ratio during both the years (Table 10a, 10b, 10c, 11a, 11b and 11c).

Among tillage systems, deep tillage and pit system (l_3) registered the highest number of cormels plant^{-1} (4.7 during I year and 5.92 during II year) followed by deep tillage and mound system (l_4) while the effects were reversed with respect to mean weight of cormel during II year (57.02 g for l_3 and 60.6 g for l_4) and no significant effect was shown during I year (Fig. 9a and 9b). It was found that mean cormel weight was significantly and negatively correlated with number of cormels plant^{-1} during both the years. This indicated the inverse relationship between number and size of cormels as is usually the case with tuber crops. The highest cormel yield plant^{-1} (244.99 g during I year and 333.66 g during II year) as well as corm yield plant^{-1} (391.36 g during I year and 478.39 g during II year) and cormel : corm ratio (0.62 and 0.70 during I and II year respectively) were obtained with deep tillage followed by pit system (Fig. 9c, 9d and 9e). Conventional tillage followed by mound system (l_2) registered the lowest cormel number plant^{-1}, mean weight of cormel, cormel and corm yields plant^{-1} and cormel : corm ratio. Contrast analysis indicated the superiority of deep tillage over conventional tillage with respect to these yield components during both the years. Pit system of planting was found advantageous than mound system in improving the yield components except in the case of mean cormel weight in which no marked variation was observed.

Application of soil conditioner produced higher cormel number plant^{-1} but lower mean weight of cormel compared to control during both the years (Fig 9a and 9b). This again reflected the inverse relationship between number and size of cormel. Coir pith recorded more number of cormels (4.44 and 5.38 during I and II year respectively) compared to rice husk as soil conditioner, but both were equally effective in producing bigger sized cormels. Organic nutrition resulted in higher cormel number plant^{-1} (4.24 during I year and 5.37 during II year) while INM resulted in heavier individual cormels (54.94 g and 59.17 g during I and II year respectively). When number of cormels plant^{-1} increased, weight of individual cormels decreased as observed earlier. The highest cormel as well as corm yields plant^{-1} and cormel : corm ratio were obtained due to application of coir pith as soil conditioner and adoption of organic nutrition (Fig. 9c, 9d and 9e).

The interactions (L x S, L x N and S x N) had profound influence on cormel number and cormel size only during II year. Deep tillage followed by pit system combined with coir pith or rice husk as soil conditioner (l_3s_2 or l_3s_3) produced higher cormel number while deep tillage followed by pit or mound system without soil conditioner ($l_3s_1$or l_4s_1) produced bigger sized corms. Deep tillage followed by pit system under organic nutrition (l_3n_2) resulted in the highest number of cormels plant^{-1} while deep tillage followed by mound system under INM produced the heaviest individual cormel. All the tillage systems under organic nutrition produced marked increase in cormel number plant^{-1} than under

INM. But a reverse trend has been observed with respect to cormel size. Coirpith combined with organic nutrition (s_2n_2) registered higher cormel number and plots without soil conditioner, but with INM recorded the highest individual cormel weight pointing out the inverse relationship between the number and size of cormel.

Any tillage system combined with coir pith as soil conditioner (among L x S combinations) or under organic nutrition (among L x N combinations) registered higher cormel yield plant^{-1}. In both cases, the highest cormel yield during both the years was obtained due to deep tillage followed by pit system than INM. Cormel yield plant^{-1} markedly increased under organic nutrition with or without soil conditioner (among S x N combinations). With respect to corm yield plant^{-1}, deep tillage followed by pit system with or without soil conditioner (among L x S combinations) registered higher values. An increase in corm yield plant^{-1} was observed with any tillage system combined with organic nutrition than with INM (among L x N combinations). Higher corm yield plant^{-1} was obtained with organic nutrition than with INM in combination with or without soil conditioner (among S x N combinations). Deep tillage followed by pit system combined with coir pith as soil conditioner and deep tillage followed by pit system under organic nutrition resulted in superior cormel : corm ratio which exhibited the trend of the main effects. No marked variation in cormel : corm ratio has been observed in plots treated with or without soil conditioner and INM or organic nutrition under a particular tillage system. The treatments which produced higher cormel yield plant^{-1} had produced higher corm yield resulting in no marked variation in cormel: corm ratio.

The interaction L x S x N had profound influence on cormel number and size during II year only. Higher number of cormel plant^{-1} was recorded by deep tillage followed by pit or mound system with coir pith as soil conditioner under organic nutrition. Deep tillage followed by mound system with no soil conditioner or rice husk as soil conditioner mostly under INM produced bigger sized cormels.

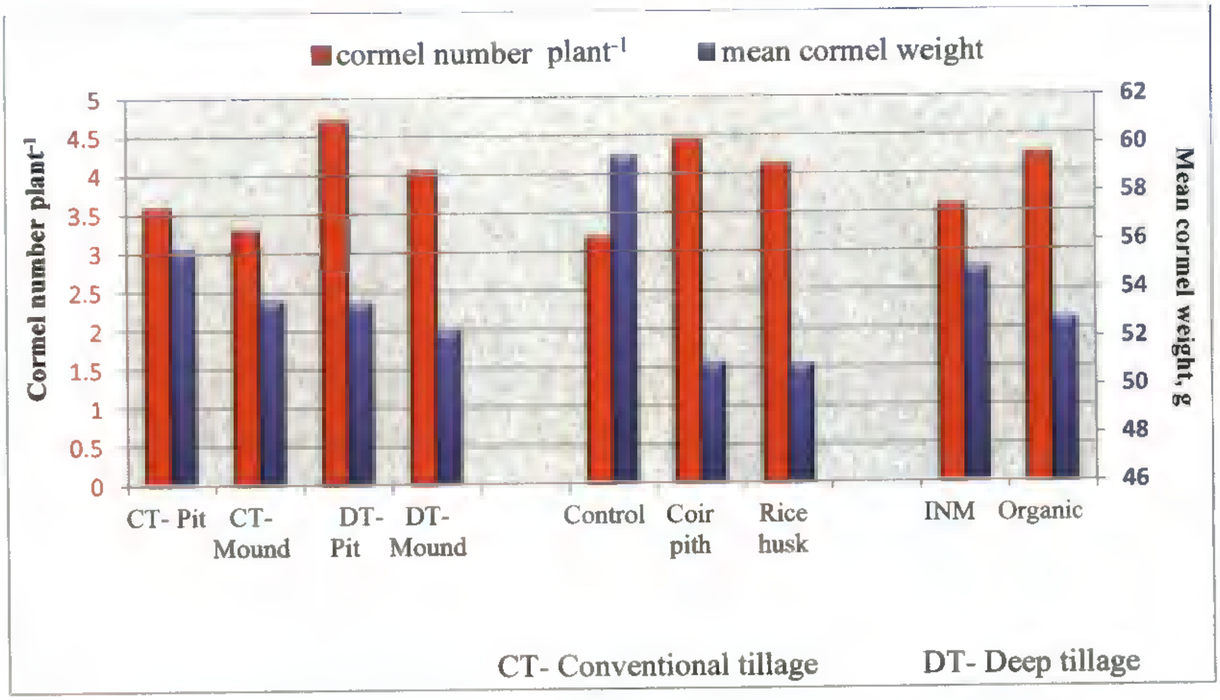

Fig. 9a Effect of tillage systems, soil conditioners and nutrient management on yield components during I year

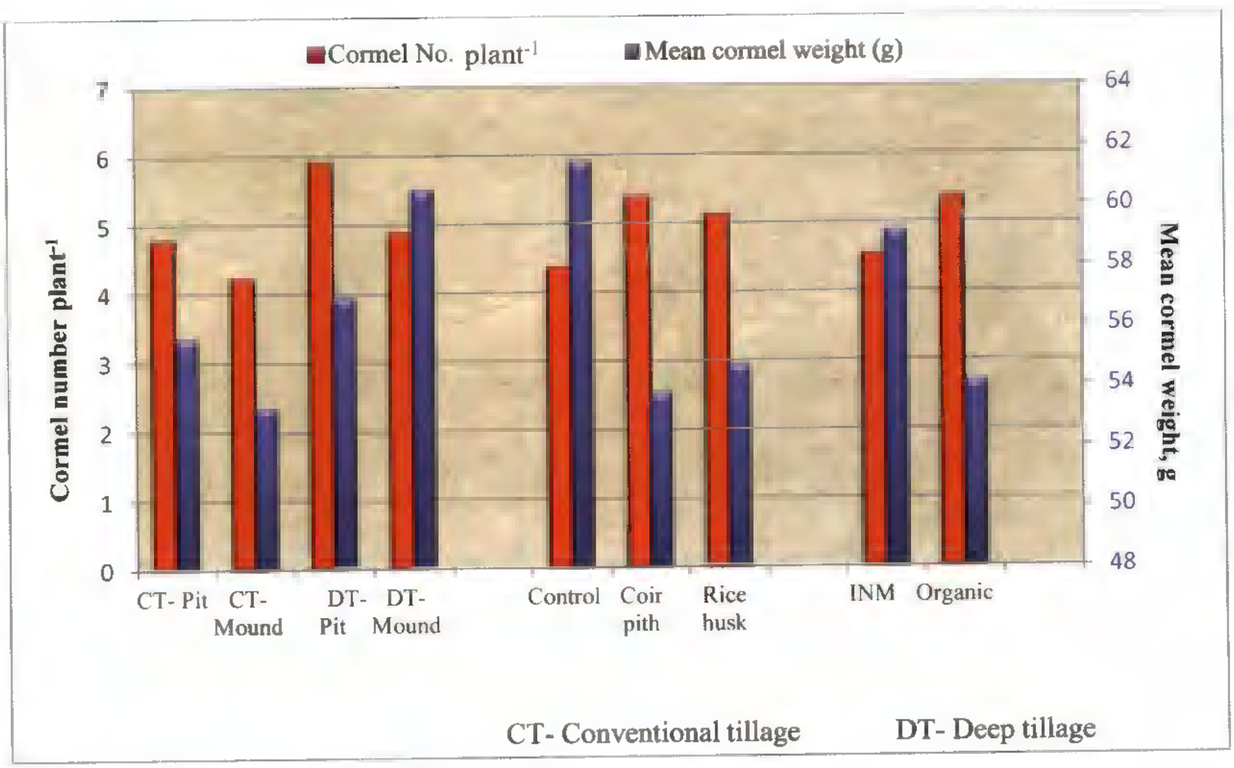

Fig. 9b Effect of tillage systems, soil conditioners and nutrient management on yield components during II year

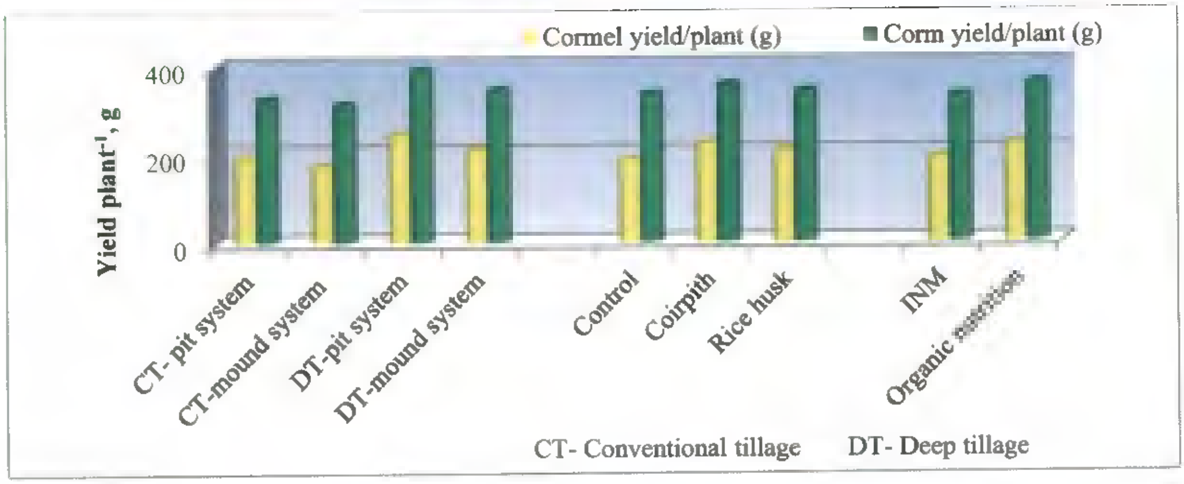

Fig. 9c Effect of tillage systems, soil conditioners and nutrient management on tuber yield plant^{-1} during I year, g

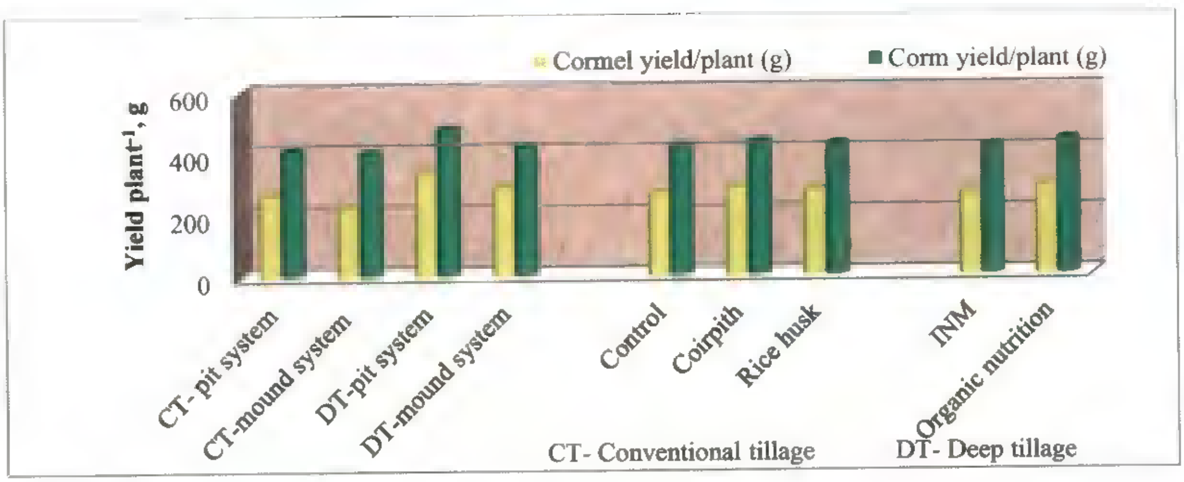

Fig. 9d Effect of tillage systems, soil conditioners and nutrient management on tuber yield plant^{-1}during II year, g

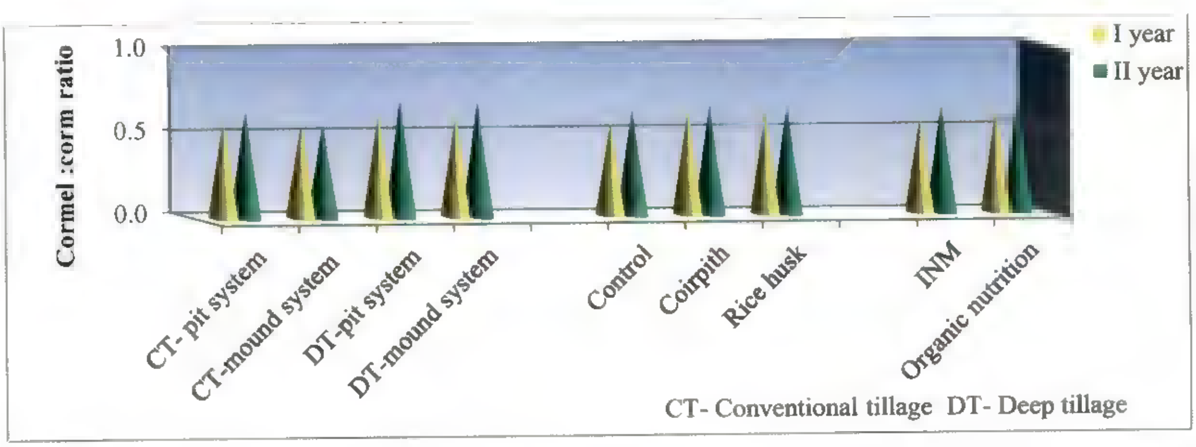

Fig. 9e Effect of tillage systems, soil conditioners and nutrient management oncormel: corm ratio

This indicated that deep tillage is necessary for tannia for producing not only higher number of cormels, but also bigger sized cormels.

Among the 24 treatment combinations tried (L x S x N interaction), the highest cormel yield plant^{-1} was produced by the deep tillage followed by pit system with coir pith as soil conditioner and organic nutrition. Deep tillage followed by pit system with any soil conditioner under organic nutrition ($l_3s_2n_2$ during I year and $l_3s_3n_2$ during II year) registered the highest corm yield plant^{-1}. Superior cormel:corm ratio was worked out for the treatment combination involving deep tillage followed by pit system with rice husk as soil conditioner under organic nutrition ($l_3s_3n_2$). The favourable influence of deep tillage followed by pit system, application of soil conditioner and organic nutrition on growth characters of tannia might have produced better results in terms of yield components.

5.3 TUBER YIELD

The tuber yield in terms of cormel and corm yield ha^{-1} exhibited marked variation during both the years (Table 12a, 12b and 12c). Higher cormel and corm yields ha^{-1} were obtained due to deep tillage followed by pit or mound system compared to conventional tillage followed by pit or mound system during both the years (Fig. 10a and 11a). Pooled analysis indicated that deep tillage followed by pit system produced the highest cormel yield (5.15 t ha^{-1}) and the highest corm yield (7.73 t ha^{-1}) as depicted in Fig. 10b and 11b. Conventional tillage followed by mound system registered the lowest cormel and corm yields during both the years. The superiority of deep tillage over conventional tillage for tannia as observed in the present study has also been reported by Ramesh *et al.* (2007). Increased yield of potato with increase in depth of tillage to 30 cm was also reported by Kumar *et al.* (2015). The superiority of pit system over mound system of planting has also been established from the present study. Deep tillage resulted in 24 per cent increase in yield over conventional tillage and pit system of planting produced 28 per cent increase in yield over mound system. Improvement in growth characters and yield components of tannia due to deep tillage and pit system of planting might have resulted in higher cormel as well as corm yields ha^{-1} under these treatments. Correlation analysis revealed significant and positive correlation of cormel as well as corm yields with LAI at 5 MAP during both the years (Table 21a). Positive and linear correlation between leaf area and cormel production has been established earlier by Karikari (1974). Significant and positive correlation was also observed between cormel yield and number of cormels plant^{-1}during both the years.

Coir pith as soil conditioner registered the highest cormel yield (pooled mean of 4.51 t ha^{-1})which is 11 per cent increase over control and the highest corm yield (pooled mean of 6.99 t ha^{-1}). The lowest cormel as well as corm yields were obtained from plots without soil conditioner (Fig. 10b and 11b). Ayyaswamy *et al*. (1996) also reported significant increase in tuber yield due to incorporation of coir waste @ 10 t ha^{-1} in cassava field. When soil was amended with coir pith, Mukherjee (2001) obtained significant increase in yield of sweet potato, taro and elephant foot yam over control. Ray *et al*. (2006) could get higher yield of elephant foot yam due to addition of paddy husk @ 1 kg plant^{-1} compared to the addition of karanj cake @ 500 g plant^{-1} or FYM @ 5 kg plant^{-1}. The favourable influence of coir pith might be due to its higher and longer moisture retention capacity as observed by Das (1992) and Savithri and Khan (1994) and slow release of nutrients on decomposition.

Organic nutrition resulted in higher cormel yield (pooled mean of 4.52 t ha^{-1}) and corm yield (pooled mean of 7.07 t ha^{-1}) than INM (Fig 10b and 11b). Organic nutrition could produce 12 per cent increase in cormel yield over INM. These findings are in agreement with that of Suja *et al*. (2009) in tannia, Suja *et al*. (2012b) in elephant foot yam and Radhakrishnan *et al*. (2013) in cassava.

During I year, interaction effect was noticed between tillage system and nutrient management (L x N) only, when deep tillage followed by pit system under organic nutrition resulted in the highest cormel yield ha^{-1} similar to cormel yield $plant^{-1}$. During II year, profound interactions were observed between treatments. Deep tillage followed by pit system combined with coir pith as soil conditioner (l_3s_2) produced the highest cormel yield ha^{-1} (pooled mean of 5.4 t ha^{-1}). With any tillage system, cormel yield ha^{-1} was higher with coir pith as soil conditioner than rice husk and control. Also, organic nutrition combined with any tillage system (L x N) resulted in higher cormel yield ha^{-1} compared to combinations of tillage systems and INM. Deep tillage followed by pit system under organic nutrition (l_3n_2) recorded the highest cormel yield ha^{-1} (pooled mean of 5.52 t ha^{-1}). The plots treated with or without soil conditioner produced higher cormel yield under organic nutrition, compared to INM in the case of S x N interaction.

Interaction was noticed for any tillage system combined with soil conditioner (L x S) and organic nutrition (L x N) for corm yield ha^{-1} during both years and in the pooled data. During I year, deep tillage followed by pit system combined with coir pith as soil conditioner produced the highest corm yield ha^{-1} while the same tillage system combined with rice husk as soil conditioner produced the highest corm yield ha^{-1} during II year and in the pooled data (7.87 t ha^{-1}). Any tillage system increased corm yield ha^{-1} under organic nutrition than under INM. The highest pooled mean of 8.09 t ha^{-1} was obtained from plots treated with deep tillage followed by pit system and organic nutrition. In the case of S x N interaction, significant increase in corm yield ha^{-1} has been observed under organic nutrition than under INM with or without soil conditioner. Coir pith as soil conditioner under organic nutrition produced the highest pooled mean of 7.23 t ha^{-1}.

The highest cormel yield ha^{-1} (pooled mean of 5.77 t ha^{-1}) was obtained by deep tillage followed by pit system combined with coir pith as soil conditioner and organic nutrition ($l_3s_2n_2$) followed by deep tillage and pit system with rice husk as soil conditioner and organic nutrition ($l_3s_3n_2$ -pooled mean of 5.59 t ha^{-1}). 171

These results followed the same trend as that of the main effects of treatments on

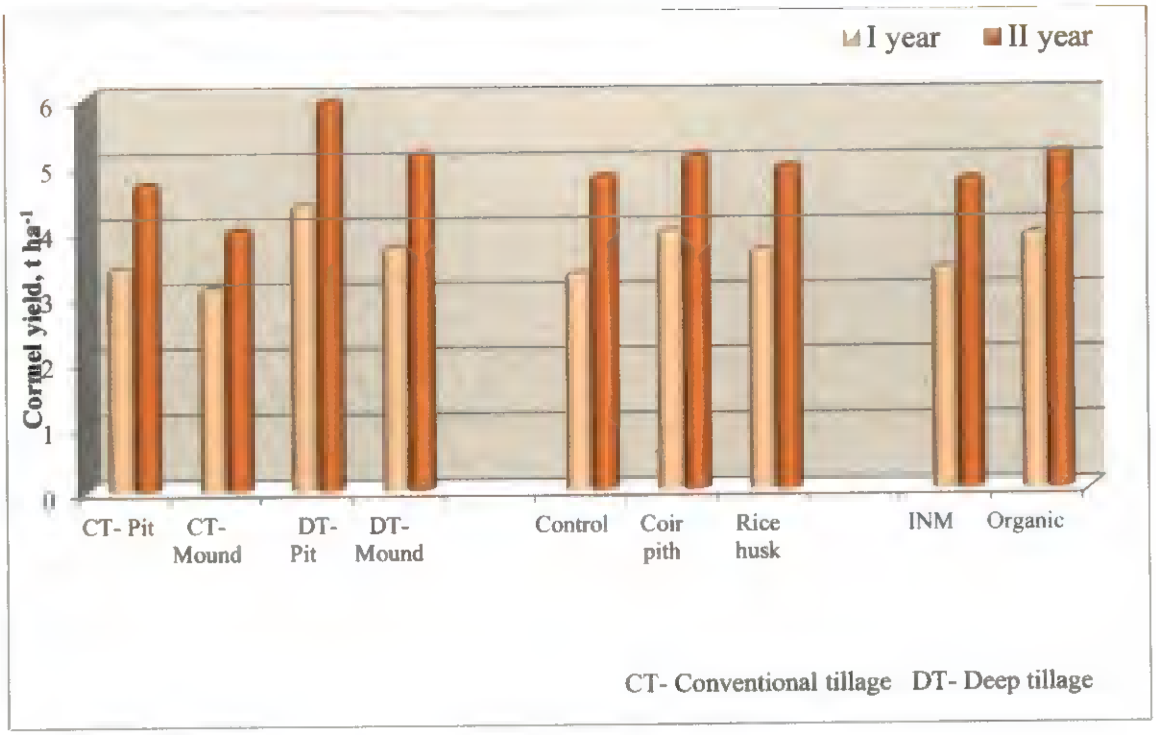

Fig. 10a Effect of tillage systems, soil conditioners and nutrient management on cormel yield, t ha^{-1}

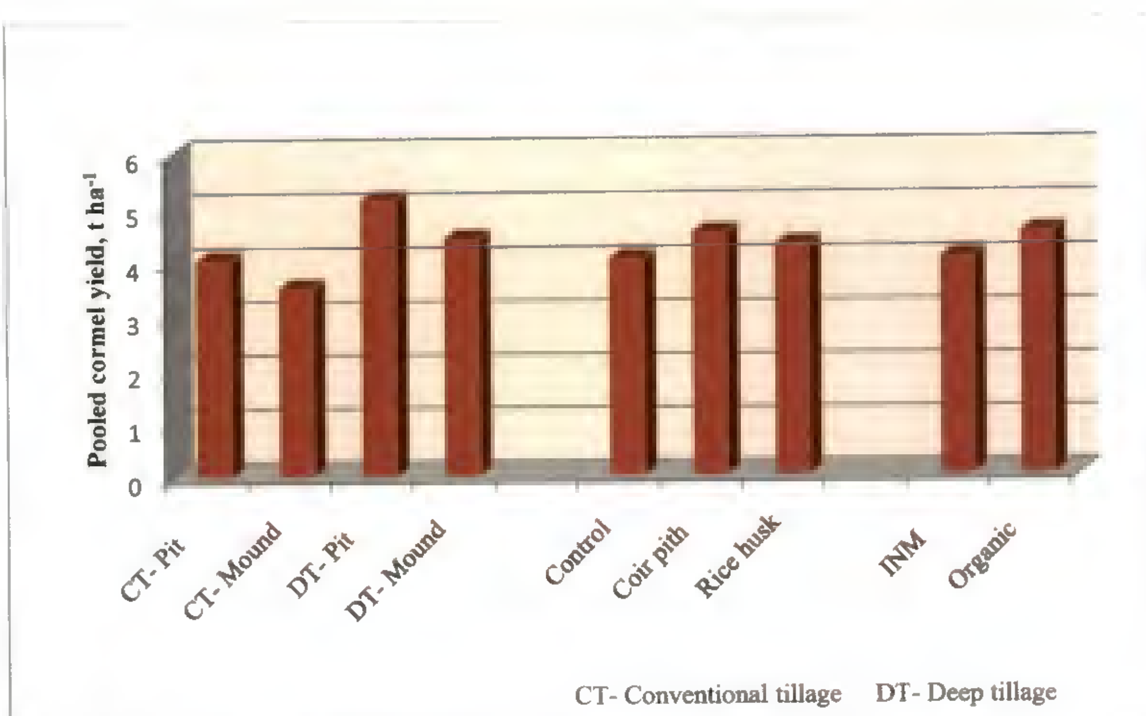

Fig. 10b Effect of tillage systems, soil conditioners and nutrient management on pooled cormel yield, t ha^{-1}

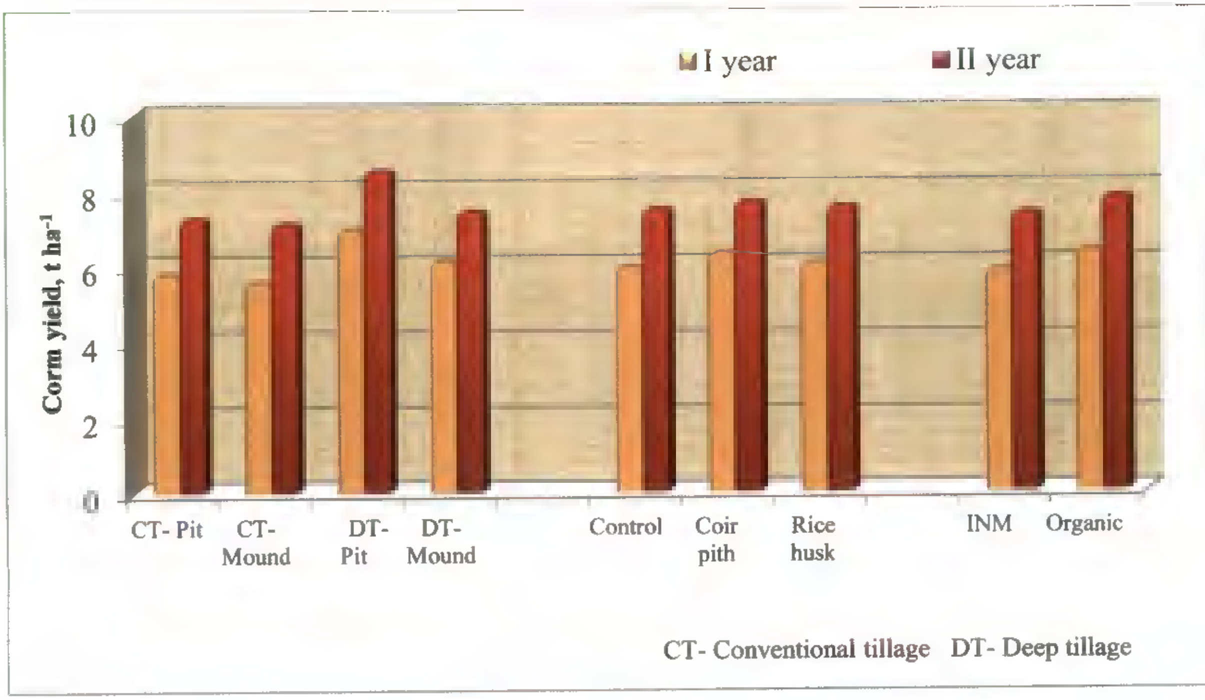

Fig. 11a Effect of tillage systems, soil conditioners and nutrient management on corm yield, t ha^{-1}

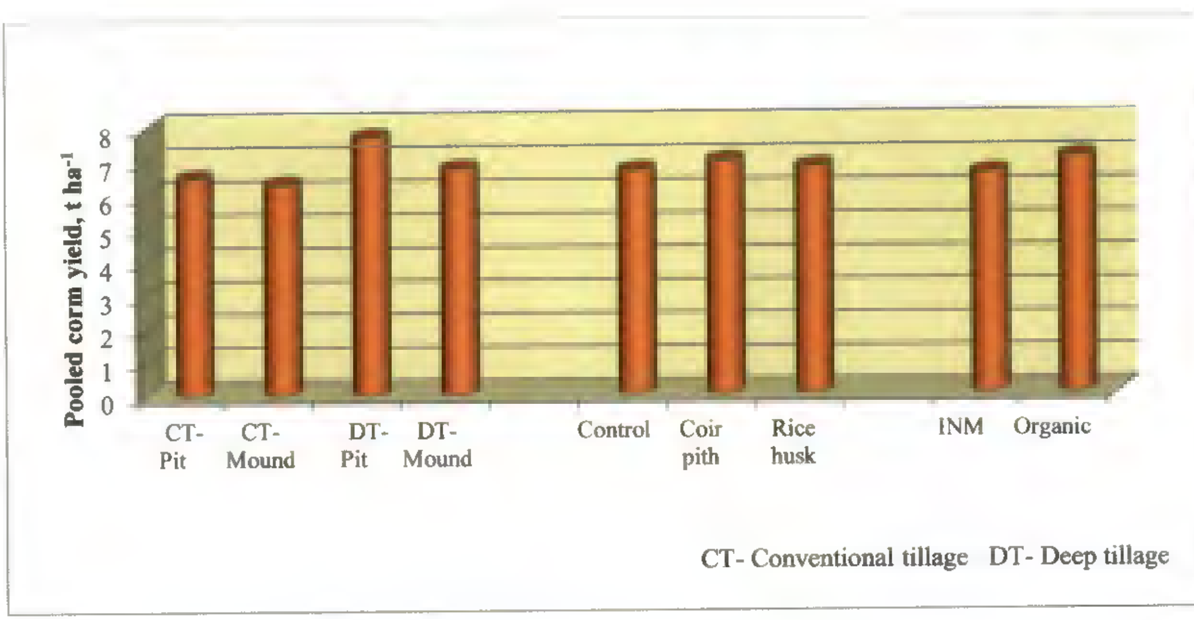

Fig. 11b Effect of tillage systems, soil conditioners and nutrient management on pooled corm yield, t ha^{-1}

cormel yield ha^{-1} and cormel yield $plant^{-1}$. Higher corm yield ha^{-1} was obtained with deep tillage followed by pit system combined with a soil conditioner (coir pith or rice husk during I year and rice husk during II year) under organic nutrition. But the pooled data showed the superiority of rice husk as soil conditioner in registering the highest corm yield of 8.3 t ha^{-1} along with deep tillage followed by pit system and organic nutrition ($l_3s_3n_2$).

Year wise scrutiny of the data on tuber yield revealed that higher yields were obtained during II year. The average cormel yields were 3.65 and 4.94 t ha^{-1} during I and II year respectively and corm yields were 6.11 and 7.57 t ha^{-1} during I and II year respectively. Higher quantity of rainfall (263.61 cm) and more number of rainy days (100) during the cropping period of II year (2015-16) compared to total rainfall of 138.49 cm and lesser number of rainy days (69) during the cropping period of I year (2014-15) might have contributed to higher yields during II year.

5.4 DRY MATTER PRODUCTION

The treatments exerted profound influence on TDMP during both the years (Table 13a, 13b and 13c). Deep tillage followed by pit system profoundly improved the TDMP and harvest index followed by deep tillage with mound system as shown in Fig. 12a and 12b. Deep tillage was found superior to conventional tillage and pit system dominated over mound system in their effects on TDMP and harvest index. Higher leaf area produced due to deep tillage followed by pit system might have led to improved production of assimilates resulting in higher dry matter production. Not only dry matter production, but its partitioning to the economic part, especially cormel was also favourably influenced by deep tillage and pit system of planting. Coir pith as soil conditioner produced marked increase in dry matter production over rice husk and control while both coir pith and rice husk as soil conditioner increased harvest index over control. Organic nutrition proved its superiority over INM in its effect on TDMP and harvest index. The impact of these treatments on growth and yield of tannia 174

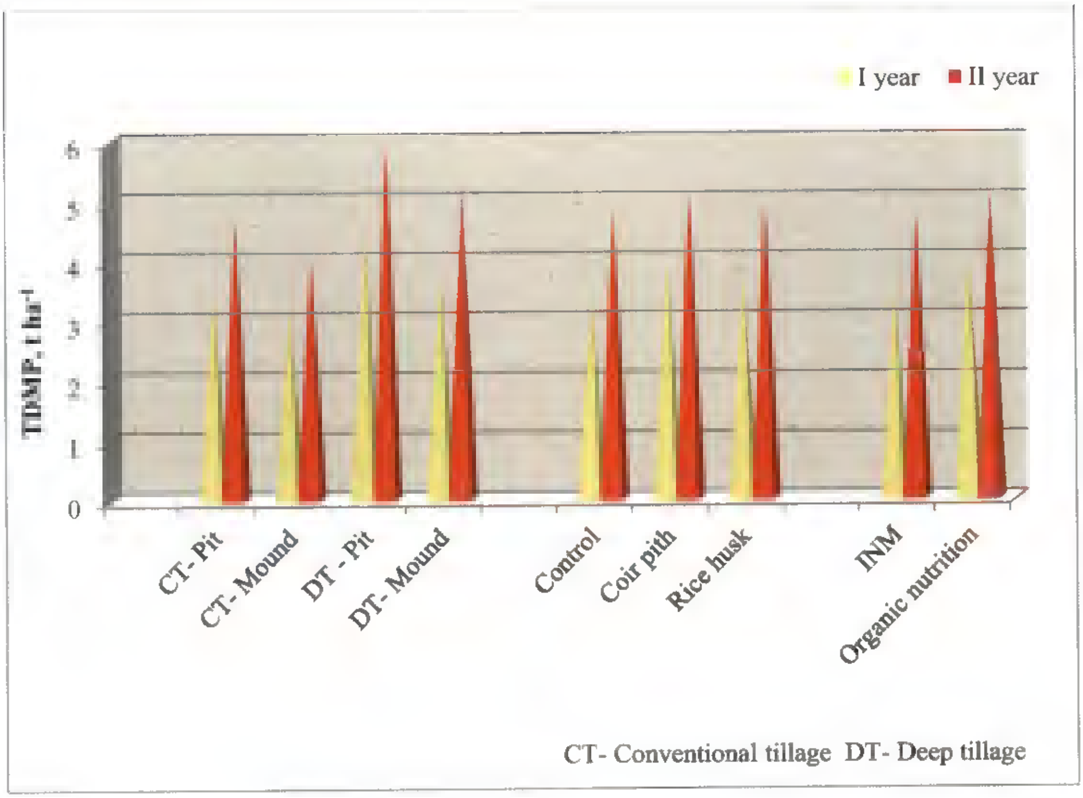

Fig. 12a Effect of tillage systems, soil conditioners and nutrient management on total dry matter production, t ha^{-1}

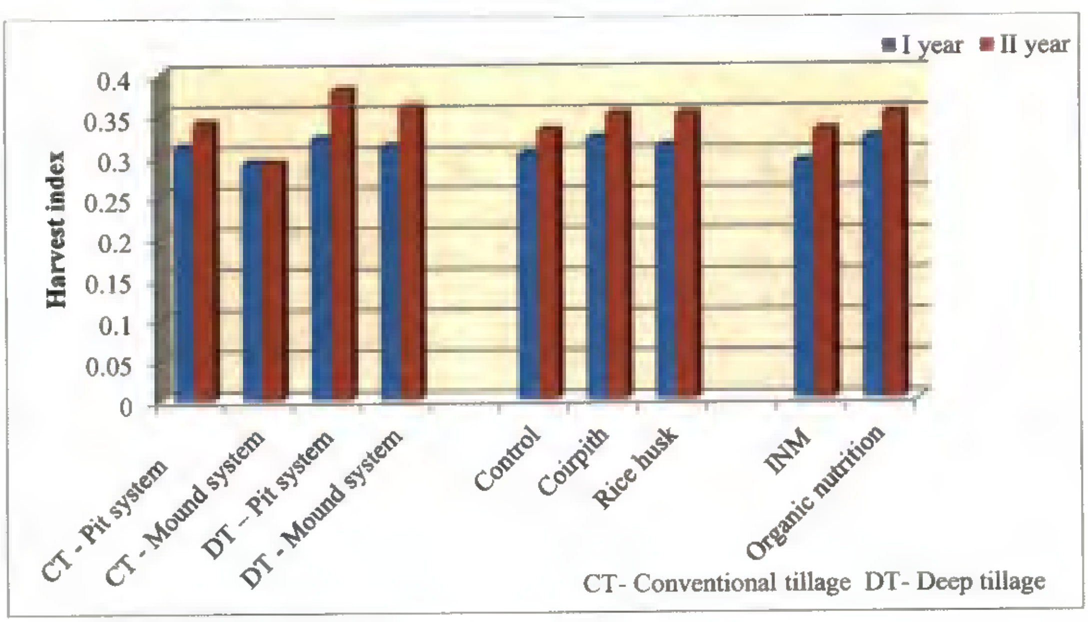

Fig. 12b Effect of tillage systems, soil conditioners and nutrient management on harvest index

might have resulted in higher dry matter production and efficient dry matter partitioning. Higher leaf area recorded by the treatments (coir pith as soil conditioner and organic nutrition) intercepted more light and produced more photosynthates resulting in higher dry matter production by the treatments. Suja *et al.* (2009) also reported that organic nutrition favoured effective partitioning of assimilates to cormels resulting in higher tuber yield of tannia. In the present study, TDMP was significantly and positively correlated with LAI at 5 MAP, cormel and corm yields and harvest index.

The interactions of tillage system and nutrient management (L x N) as well as soil conditioner and nutrient management (S x N) profoundly influenced TDMP only during I year. Any tillage system under organic nutrition enhanced TDMP among L x N combinations. Use of soil conditioner combined with organic nutrition also increased TDMP among S x N combinations. In the case of harvest index, only tillage system combined with soil conditioner (L x S) profoundly influenced harvest index during the II year and deep tillage followed by pit system combined with coir pith as soil conditioner recorded the highest harvest index (0.4).

With respect to L x S x N interaction, deep tillage followed by pit system combined with coir pith (5.02 and 5.07 t ha^{-1} during I and II year respectively) or rice husk (4.88 and 5.16 t ha^{-1}during I and II year respectively) as soil conditioner under organic nutrition produced higher dry matter production. Higher harvest index (0.35 during I year and 0.41during II year) was registered by deep tillage followed by pit system along with coir pith as soil conditioner and organic nutrition which reflected the main effects of the treatments.

5.5 QUALITY CHARACTERS

A perusal of the data given in Table 14a indicated that tillage systems, soil conditioners and nutrient management exerted significant influence on quality characters of cormel *viz.* dry matter, starch and protein contents. Deep tillage followed by pit system (l_3) registered the highest dry matter, starch and protein 176 contents of cormel during both years (Fig. 13a and 13b). It is inferred from contrast analysis that deep tillage compared to conventional tillage and pit system compared to mound system of planting improved the quality characters of cormel. Application of soil conditioner also enhanced the quality characters and coir pith was found superior to rice husk. Quality characters were improved by organic nutrition than INM during both the years. Improvement in tuber quality of elephant foot yam due to organic nutrition has been reported by Suja *et al.* (2010; 2012a; 2012b), Suja (2013) and Kolambe *et al.* (2013). Similar results were reported in yams by Suja (2013) and Kaswala *et al.* (2013).

Regarding shelf life of cormel, no decay due to microbial attack was observed upto 45 days of storage under ambient conditions. Sprouting of cormel started from 32nd day and 50 per cent sprouting was observed on 46th day. In coleus, Archana (2001) reported 50 per cent sprouting of tubers in the stored samples of coleus within 30 to 40 days of storage irrespective of the treatments. But no decay of the tubers was observed due to microbial attack even when the tubers were stored for more than two months (Archana, 2001; Jayapal *et al.*, 2015). Jayapal *et al.* (2015) also found that sprouting of coleus started after one month of storage and was completed by two months irrespective of treatments.

Physiological loss in weight of cormel during storage (Table 15a, 15b, 15c) varied with tillage systems, soil conditioners and nutrient management. PLW was minimum for tubers from plots given deep tillage and plants raised in pits. The highest loss in weight was noticed for cormels from plots with conventional tillage and mound system. Contrast analysis revealed the superiority of deep tillage over conventional tillage and pit system over mound system of planting. The plots which received no soil conditioner registered lower weight loss during I year while during the II year, the PLW was maximum for the same treatment. Higher loss in cormel weight during storage was observed in samples from INM plots compared to organic nutrition again indicating the superiority of organic nutrition for quality improvement in tannia. Kumar *et al.* (2011) also observed significant variation in PLW per cent in stored potato tubers due to nutrient

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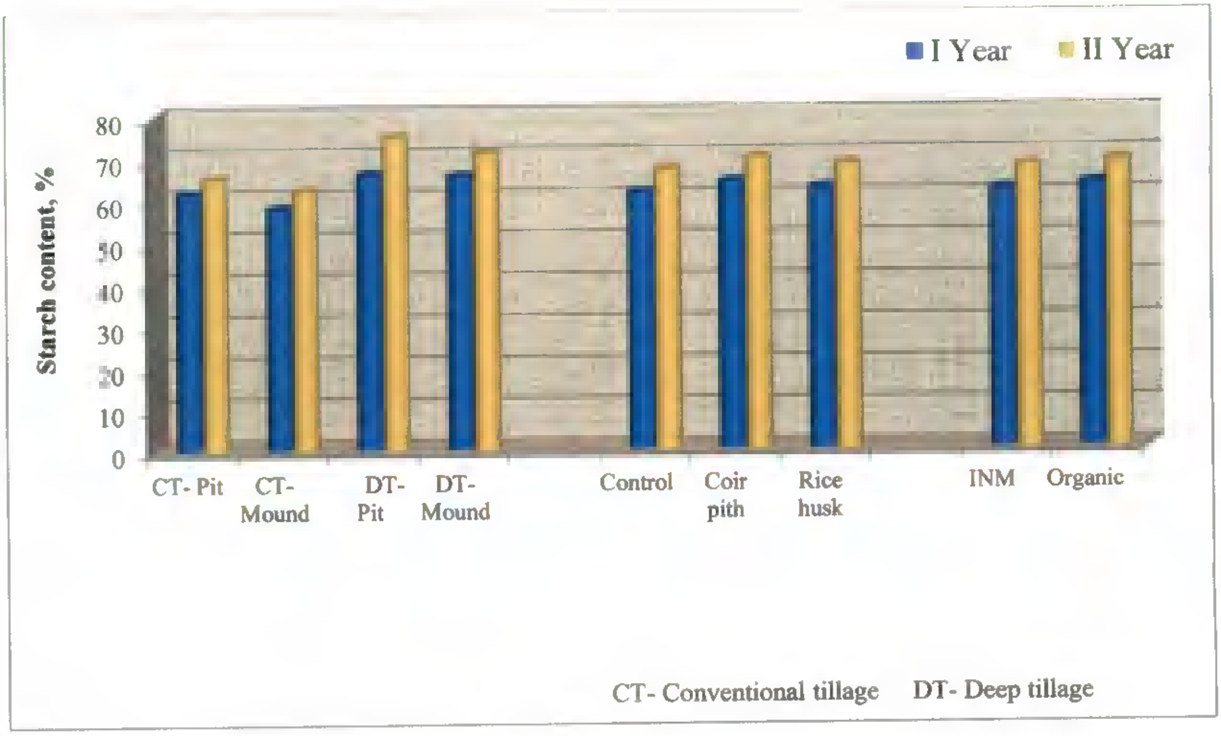

Fig. 13a Effect of tillage systems, soil conditioners and nutrient management on starch content of cormel, %

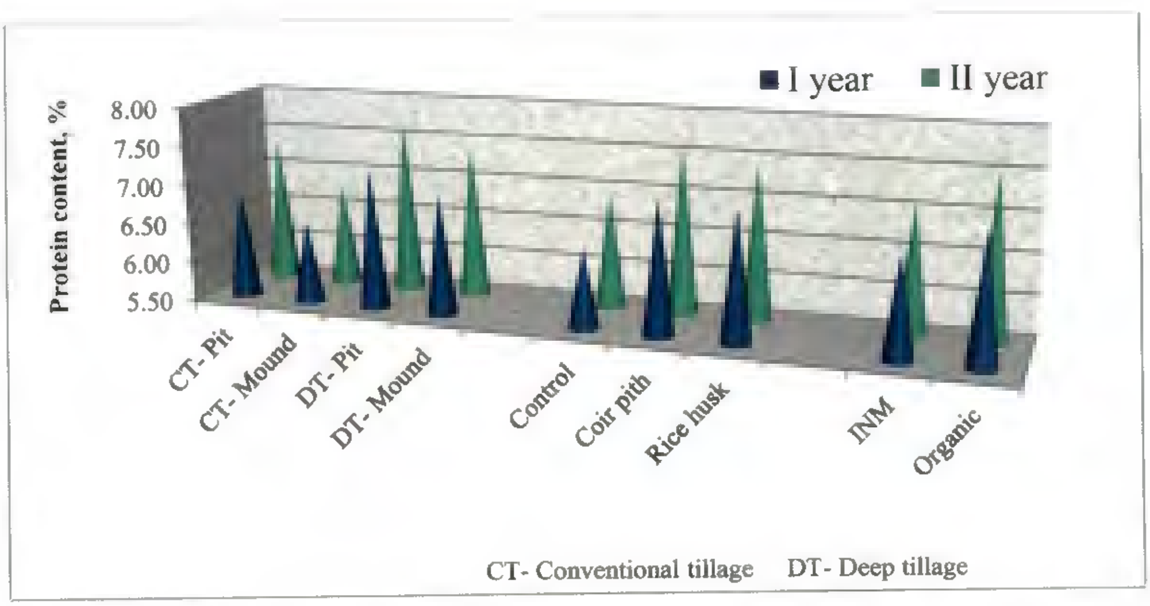

Fig. 13b Effect of tillage systems, soil conditioners and nutrient management on protein content of cormel, %

management. The highest percentage of PLW was obtained when the crop received inorganic fertilizers alone. The present study revealed that cormels of tannia could be stored for one month without any microbial decay, sprouting and appreciable PLW. This is in conformity with the findings of Jayapal *et al*. (2015) in coleus.

5.6 UPTAKE OF NUTRIENTS

A close scrutiny of the data in Table 16a indicated the significance of the main effects of treatments on uptake of N, P and K. Among tillage systems, deep tillage followed by pit system registered the highest uptake of N, P and K during both years followed by deep tillage and mound system. The lowest uptake of nutrients was recorded by conventional tillage followed by mound system (Fig.14a and 14b). The results of contrast analysis indicated the superiority of deep tillage over conventional tillage and pit system over mound system of planting. Application of soil conditioner markedly increased the nutrient uptake during both the years. Coir pith was found superior to rice husk as soil conditioner. Uptake of N, P and K were profoundly increased under organic nutrition than under INM during both the years. Since uptake is a function of nutrient content and dry matter production, the positive effects of these treatments on dry matter production had reflected in higher uptake of nutrients. Improvement in soil physical and chemical properties due to deep tillage, application of soil conditioner and organic manures might have culminated in higher uptake of nutrients owing to higher dry matter production and tuber yield. Correlation analysis also revealed significant and positive correlation of cormel and corm yields with N, P and K uptake (Table 21a). Higher uptake and efficient utilisation of nutrients might have led to higher cormel and corm yields. Total dry matter production was also significantly and positively correlated with N, P and K uptake (Table 21b).

Though the effect of the treatment combinations of tillage system, soil conditioner and nutrient management (L x S x N) did not appreciably influence

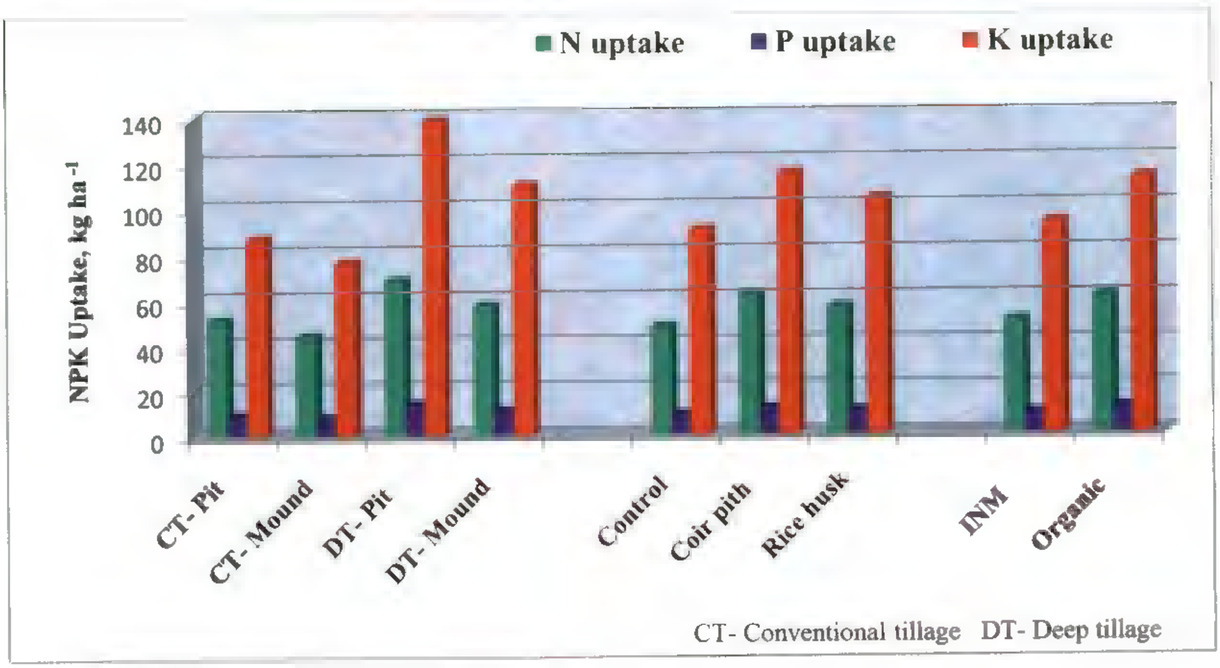

Fig. 14a Effect of tillage systems, soil conditioners and nutrient management on NPK uptake during I year, kg ha^{-1}

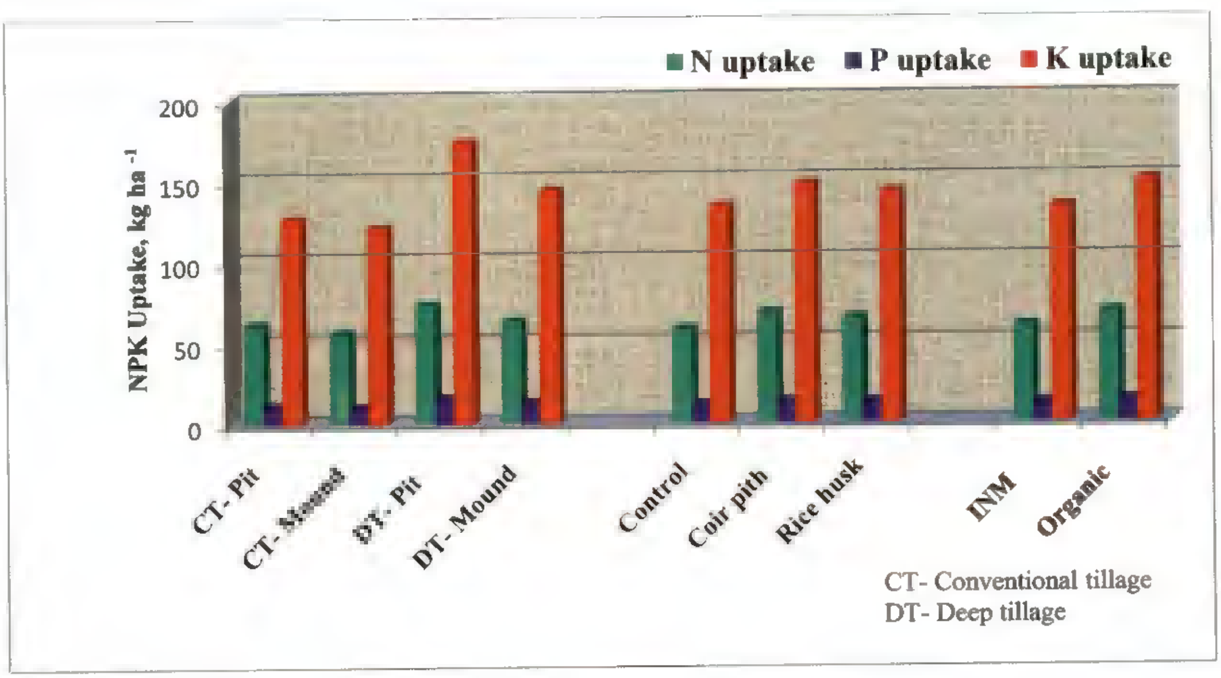

Fig. 14b Effect of tillage systems, soil conditioners and nutrient management on NPK uptake during II year, kg ha^{-1}

the nutrient uptake, the highest uptake of N, P and K were recorded by deep tillage and pit system with coir pith as soil conditioner under organic nutrition ($l_3s_2n_2$) followed by deep tillage with pit system, rice husk as soil conditioner and organic nutrition ($l_3s_3n_2$) during both years. Higher dry matter production was also registered by these treatment combinations.

5.7 SOIL ANALYSIS AFTER THE EXPERIMENT

5.7.1 Soil Physical Properties

After the experiment, soil samples were analysed for physical properties of soil *viz*. bulk density, porosity and water holding capacity. Prior to experiment, the bulk density was generally higher in lower soil layers (Table 1) which might be due to lower concentration of organic matter, lesser aggregation, lesser root penetration and compaction caused by the weight of overlying layers (Agbede, 2006). Compared to initial level, the bulk density values were lower after the experiment (Table 17d). This could be attributed to the effect of tillage on loosening the soil as reported by Agbede (2008). It can be seen from Table 1 that initially, the surface soil (0 to 15 cm depth) was more porous with high water holding capacity than subsoil (15 to 30 cm depth). After the experiment, porosity and water holding capacity of the soil increased over the respective initial values during both the years in 0 to 15 cm and 15 to 30 cm depth of soil (Table 17d).

The physical properties of the soil were greatly influenced by tillage systems, soil conditioners and nutrient management (Table 17a). Deep tillage followed by pit or mound system registered lower bulk density and higher porosity and water holding capacity in both soil depths during both the years than conventional tillage followed by pit or mound system (Fig. 15a, 15b, 16a, 16b, 17a and 17b). This might be due to the increased loosening effect of soil upto 30 cm depth in deep tillage and only upto 15 cm depth in conventional tillage. According to Burwell and Larson (1969), lowering of bulk density was found to increase soil water retention. Choudhary *et al.* (1985) also observed reduced 181

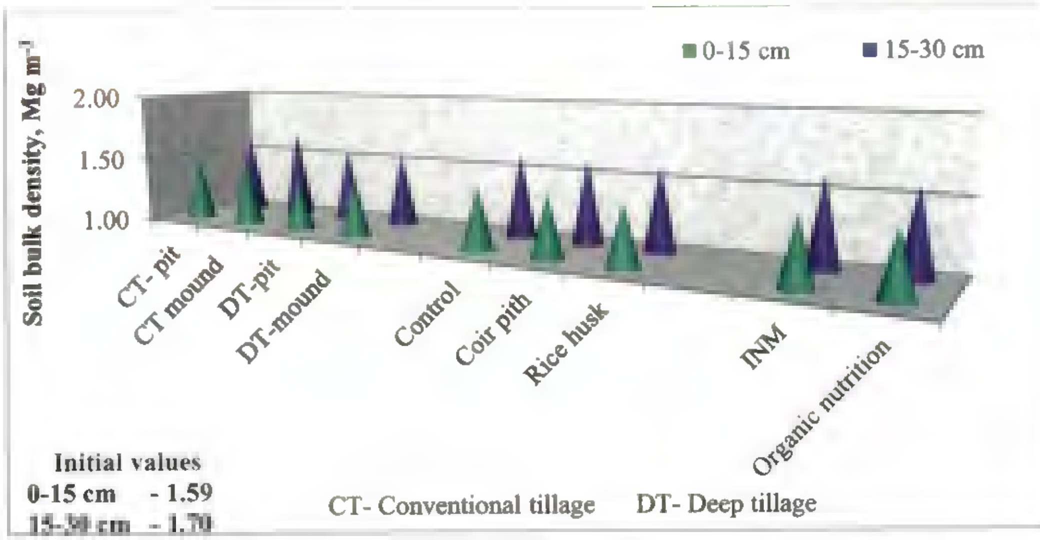

Fig. 15a Effect of tillage systems, soil conditioners and nutrient management on soil bulk density after the experiment during I year, Mg m^{-3}

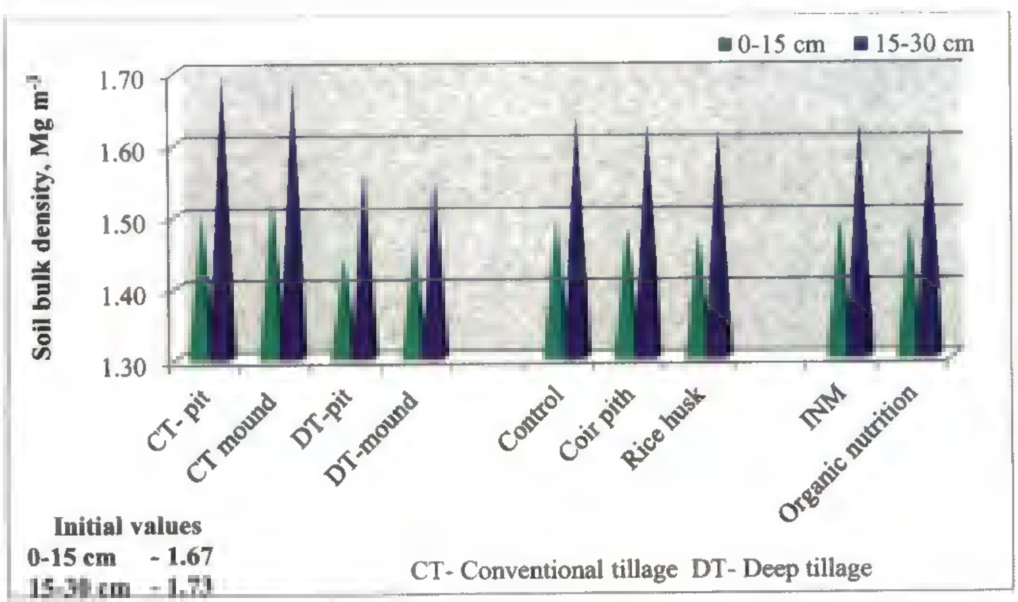

Fig. 15b Effect of tillage systems, soil conditioners and nutrient management on soil bulk density after the experiment during II year, Mg m^{-3}

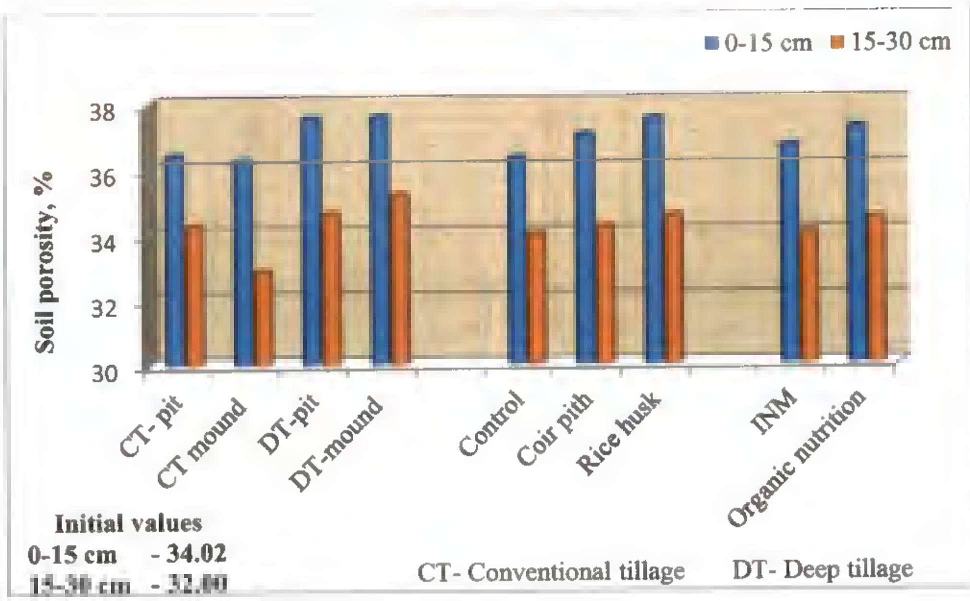

Fig. 16a Effect of tillage systems, soil conditioners and nutrient management on soil porosity after the experiment during I year, %

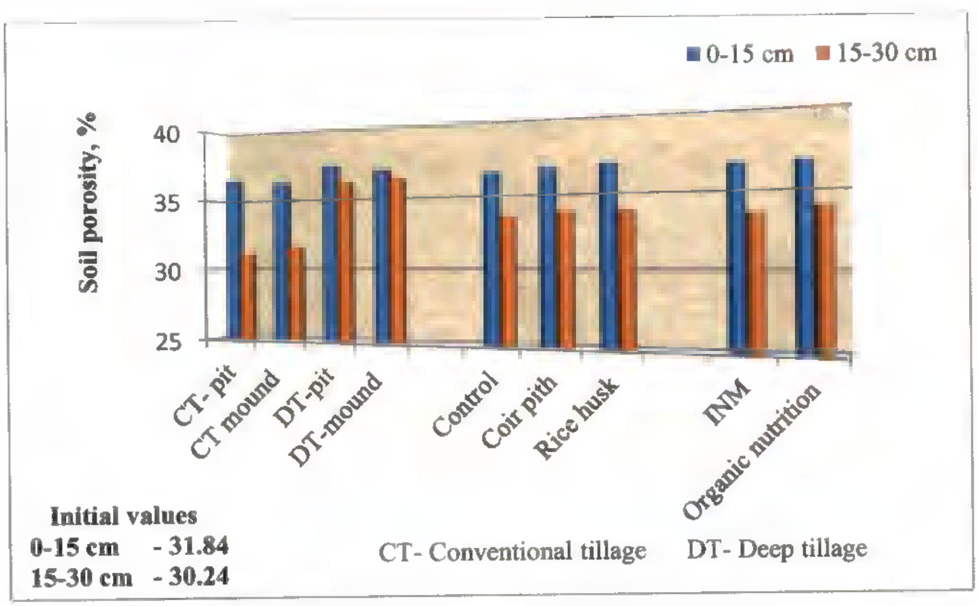

Fig. 16b Effect of tillage systems, soil conditioners and nutrient management on soil porosity after the experiment during II year, %

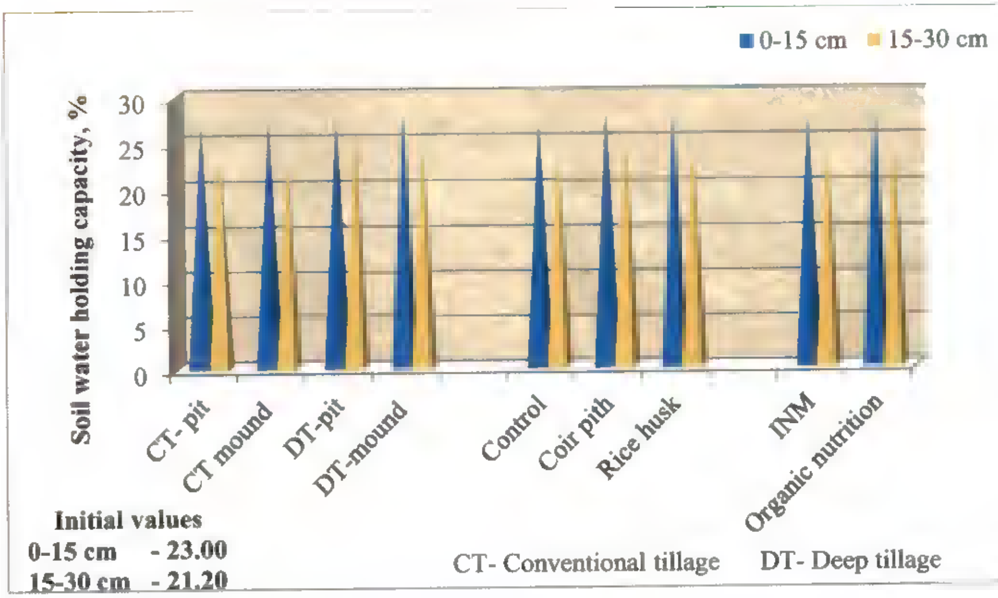

Fig. 17a Effect of tillage systems, soil conditioners and nutrient management on soil water holding capacity after the experiment during I year, %

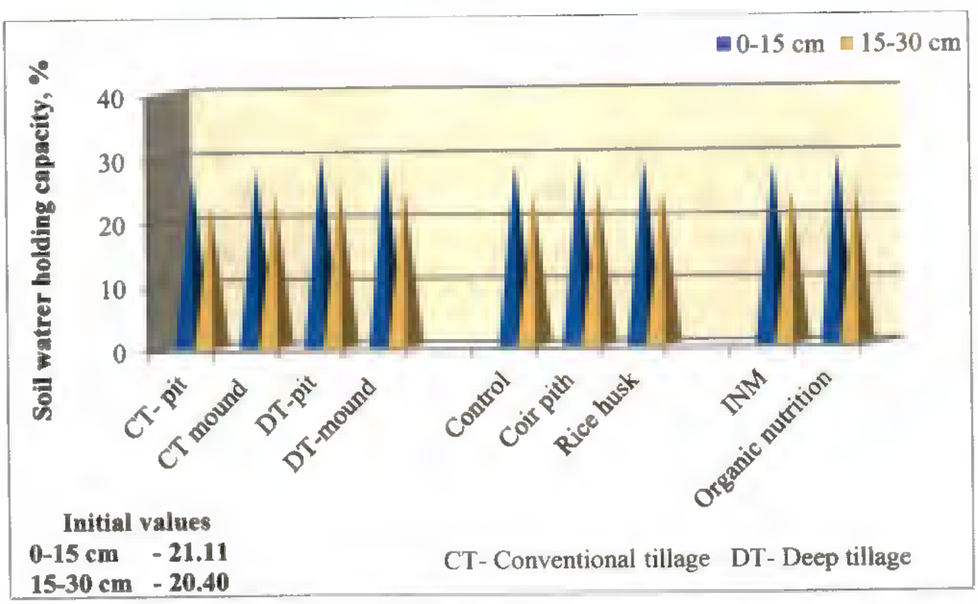

Fig. 17b Effect of tillage systems, soil conditioners and nutrient management on soil water holding capacity after the experiment during II year, %

bulk density in 10 to 30 cm soil depth by deep ploughing (45 cm) than conventional ploughing to 10 cm depth.

Application of soil conditioner showed favourable influence on soil physical properties during both the years. Rice husk as soil conditioner was superior to coir pith in lowering bulk density and increasing porosity while coir pith was found to increase water holding capacity of the soil. Increase in water holding capacity of the soil due to coir pith application has been reported by Bhowmic and Debnath (1985) and Cresswell (1992). According to Menon (1987), coir pith can absorb water about eight times its weight. The water holding capacity of coir pith has been reported to be above 500 per cent by Das (1992) and 400 to 600 per cent by Savithri and Khan (1994). Logmadevi (1997) also opined that application of coir pith reduced bulk density and increased water holding capacity of soil. Bulk density of the soil was lowered and porosity and water holding capacity of the soil increased due to organic nutrition compared to INM. The results are in agreement with the findings of Gerhardt (1997) and Kumar *et al.* (2015).

Another notable finding is that appreciable decrease in bulk density and increase in porosity and water holding capacity were found generally in 0 to 15 cm depth of soil after the experiment. This might be due to the fact that the soil conditioners and organic manures were applied and incorporated in the surface soil (0-15 cm depth). The study also revealed significant but negative correlation of corm yield with bulk density and positive correlation of yield with porosity and water holding capacity in both depths of soil during both the years (Table 21c). Agbede (2008) also obtained significant but negative correlation of yield of tannia with soil bulk density. Adekiya *et al.* (2011) also observed that differences in bulk density dictated the differences in the growth and yield of cocoyam.

5.7.2 Soil Reaction

The data presented in Table 1 revealed that the surface soil (0 to15 cm depth) was less acidic than subsoil (15 to 30 cm depth) before the start of the experiment. After the experiment also, the same trend has been observed (Table 18c). Higher soil pH in surface soil (0 to 15 cm depth) than in sub soil (15-30 cm depth) as observed in the present study has been earlier reported by Obatalu and Ibiremo (1999) and Agbede (2010). The reason might be higher concentration of organic matter in surface soil than in the subsoil.

After the experiment soil acidity increased or decreased from the initial status depending upon the treatments (Table 18a). In general, soil became more acidic after deep tillage and pit system of planting. This might be due to more porosity of the soil due to deep tillage which resulted in more leaching of bases. However, application of soil conditioners like coir pith and rice husk lowered the soil acidity in both depths of soil during both the years which might be due to improvement in physico-chemical properties of soil due to application of crop residues. By virtue of high cation exchange capacity, coir pith is able to retain large amounts of nutrients and the adsorption complex has high contents of exchangeable K, Na, Ca and Mg as reported by Verhagen and Papadopoulos (1997) and Prabhu and Thomas (2002). Due to alkaline nature of rice husk, pH increased over control in rice husk applied plots. Organic nutrition also lowered soil acidity than INM in both depths of soil in both the years as wood ash, which is alkaline in nature, was a component in organic nutrition.

The trend of main effects was reflected in the interaction effects (Table 18b and 18c). Conventional tillage with soil conditioners or organic nutrition raised soil pH than the combinations involving deep tillage. The treatment combinations involving coir pith (s_2) and rice husk (s_3) lowered soil acidity than that without soil conditioner (s_1). Similarly the treatment combinations involving organic nutrition (n_2) lowered soil acidity than those involving INM. The soil was found to be less acidic in both depths during both the years by conventional tillage followed by mound system with coir pith as soil conditioner and organic nutrition.

5.7.3 Soil Nutrient Status

5.7. 3.1 Organic Carbon

As shown in Table 1, initially, the surface soil had higher content of organic carbon (1.12 and 1.38 during I and II year respectively) than subsoil (0.99 and 1.2 during I and II year respectively). This might be due to high concentration of organic matter in the surface soil. The findings of Obatolu and Ibiremo (1999) and Agbede (2010) are in agreement with the result. Organic carbon status of the surface soil increased after the experiment whereas it declined in the sub soil (Table 18d). Even after crop removal, improvement of organic carbon in the surface soil might be due to application of organic manures and soil conditioners in the surface soil and addition of leaf litter of the crop. This is evident from the fact that even in the surface soil, the plots which were treated with soil conditioners and organic nutrition registered comparatively higher status of organic carbon than the plots which received no soil conditioners but organic nutrition (Table 18c).

Tillage system influenced the organic carbon status in the surface soil only, during both the years (Table 18a). Conventional tillage resulted in higher status of organic carbon than deep tillage. Due to more loosening of the soil under deep tillage, there might have been more oxidation of organic carbon resulting in lower content under deep tillage. Organic carbon status improved in both soil depths due to application of soil conditioners. Coir pith was found superior to rice husk in improving the organic carbon status which might be due to the rapid decomposition of coir pith compared to rice husk. At harvest, the remnants of rice husk could be seen in rice husk applied plots while coir pith has been completely decomposed and mixed with soil. Compared to INM, organic nutrition invariably improved the organic carbon status of the soil during both the years which might be due to higher carbon content of organic manures. The treatment combinations involving organic nutrition were able to improve organic carbon status in 0-15 cm depth of soil. Srivastava (1985), More (1994), Kaswala *et al.* (2013) and

Radhakrishnan *et al*. (2013) also observed increase in organic carbon status of soil due to organic nutrition.

5.7.3.2 Available N

Initially available N was higher in 0 to 15 cm depth of soil than in 15 to 30 cm depth (Table 1). In general, available N status after the experiment was higher in 15 to 30 cm depth of soil than in 0 to 15 cm depth of soil which might be due to crop removal and leaching loss of N from the surface layer. This is evident from the depletion of available N status in the surface soil and improvement in the sub soil than the initial status after the experiment (Table 19d).

Conventional tillage followed by pit/mound system (l_1 and l_2) resulted in higher status of available N in two soil depths compared to deep tillage followed by pit or mound system (l_3 and l_4) during both the years. Higher uptake of N by the crop raised by deep tillage might have resulted in lower status of available N after the experiment from such plots than conventionally tilled plots. Available N status was found to be higher in plots which did not receive any soil conditioner in both depths of soil compared to plots which received soil conditioner. In plots treated with soil conditioner, there was increased porosity and water holding capacity (Table 17a) and hence better root penetration which might have helped the plants to take up more of the available N. Organic nutrition was found superior to INM during both years in registering higher status of available N in the soil. Although higher uptake of N was also recorded (Table 16a) in organic nutrition, slow decomposition and slow release of nutrients from organic manures might have contributed to the higher status of available N in the soil. Corroboratory results have been reported by Srivastava (1985), More (1994) and Suja *et al*. (2012b).

5.7.3.3 Available P

There was build up of available P in both depths of soil after the experiment (Table 19d) especially in the sub soil (15 to 30 cm depth) compared to initial status (Table 1).

Higher status of available P in surface soil (0 to 15 cm depth) was recorded by conventional tillage followed by pit or mound system and by deep tillage followed by pit or mound system in sub soil (15 to 30 cm depth) during both the years. Plots without soil conditioner registered appreciably higher status of available P in both depths of soil in both years. Coir pith as soil conditioner recorded the lower status of available P compared to rice husk. Higher tuber yield and high uptake of P recorded in plots conditioned with coir pith might have led to lower status of available P in such plots compared to high P status in plots with no soil conditioner or rice husk as soil conditioner. Organic nutrition resulted in higher status of available P compared to INM which is in agreement with the findings of Srivastava (1985), More (1994) and Suja *et al.* (2012b). It is well known that organic matter reduce P fixation and enhance P availability. Also organic acids produced during the decomposition of organic matter might have increased the solubility of native P (Singh *et al.*, 2008).

5.7.3.4 Available K

After the experiment, build up of available K was noticed (Table 19d) compared to initial values (Table 1). Available K status was found to be higher in 0 to 15 cm depth than in 15 to 30 cm depth (Table 19d).

Conventional tillage followed by mound registered appreciably higher status of available K in both depths of soil except in 15 to 30 cm depth during II year when conventional tillage followed by pit system dominated other tillage systems. Higher uptake of K from deep tilled plots (Table 17a) might have resulted in lower status of available K after the experiment. A marked increase in available K status in both depths of soil during both the years was observed due to application of coir pith as soil conditioner compared to rice husk and control. Higher K content of coir pith and release of K in available form to the crop through its gradual decomposition might have increased the status of available K in the soil. Available K was appreciably higher in plots with organic nutrition. Slow decomposition of organic manures, reduction of K fixation and leaching loss, solubilisation and release of K might be the reasons for the higher status of available K in plots given organic nutrition. Similar findings have been earlier reported by Srivastava (1985), More (1994) and Suja *et al.* (2008).

5.8 ECONOMICS OF CULTIVATION

The economics of cultivation in terms of net income and BCR was worked out considering the cost of inputs and market price of produce during the cropping periods (Appendix II).

Perusal of the data given in Table 20a indicated that, among tillage systems, deep tillage followed by pit system registered higher net income and BCR during both the years (Fig. 18a and 18b). The highest pooled net income of ₹ 1,21,605 ha^{-1} as well as BCR of 1.76 were obtained from deep tillage followed by pit system. The lowest net income of ₹ 54,893 ha^{-1} in the pooled data was recorded by conventional tillage followed by mound system. Deep tillage followed by pit or mound system registered higher net income and BCR compared to conventional tillage followed by pit or mound system. Under conventional or deep tillage pit system recorded higher net income and BCR compared to mound system. The results revealed the superiority of deep tillage over conventional tillage and pit system over mound system of planting to realise economic yield from tannia. The same treatments have resulted in better growth and yield of the crop resulting in profitable tannia cultivation. Appreciably higher net income of ₹ 91,230 ha^{-1} (pooled mean) and BCR of 1.66 (pooled mean) could be obtained without soil conditioner than applying coir pith or rice husk as soil conditioner due to additional cost of the soil conditioner involved. Although cost of coir pith and rice husk were equal, application of coir pith resulted in higher yields than with rice husk (Table 12a) which was reflected in the economics. Higher net income and BCR could be obtained under organic nutrition than under INM. Comparatively higher dose of fertilizers (80:50:150 kg NPK ha^{-1}) included in INM along with the basal dose of organic manure and higher yield obtained under organic nutrition (Table 12a) might have increased the profitability of organic nutrition.

During I year, deep tillage and pit system of planting with coir pith as soil conditioner under organic nutrition ($l_3s_2n_2$) recorded the highest net income (₹ 1,08,325 ha^{-1}) followed by the same treatment combination but without soil conditioner ($l_3s_1n_2$- ₹ 1,00,700 ha^{-1}). Rice husk as soil conditioner in the above treatment combination ($l_3s_3n_2$) also resulted in higher net income of ₹ 98,775 ha^{-1}. During II year and in the pooled data, appreciably higher net income (₹ 1,85,725 and ₹ 1,43,213 ha^{-1} respectively) could be obtained due to deep tillage followed by pit system without soil conditioner under organic nutrition ($l_3s_1n_2$) which recorded the highest BCR during both the years (1.69 and 2.28 during I and II year respectively) and in the pooled data (1.99). Critical analysis of the results revealed that the same treatment combination ($l_3s_1n_2$) may be recommended for profitable tannia cultivation. Deep tillage followed by pit system with coir pith or rice husk as soil conditioner under organic nutrition could also register higher net income of ₹ 1,38,075 and ₹ 1,34,225 ha^{-1} respectively (pooled mean) and higher BCR of 1.8 and 1.78 (pooled mean) respectively compared to other treatment combinations. The results indicated that, wherever coir pith and rice husk are available in a cost effective manner, they can be applied as soil conditioner along with deep tillage followed by pit system and organic nutrition for higher economic yield of tannia. Choudhary *et al.* (2016) also opined that a suitable amount of crop residue can be applied in a cost effective manner to enhance crop productivity.

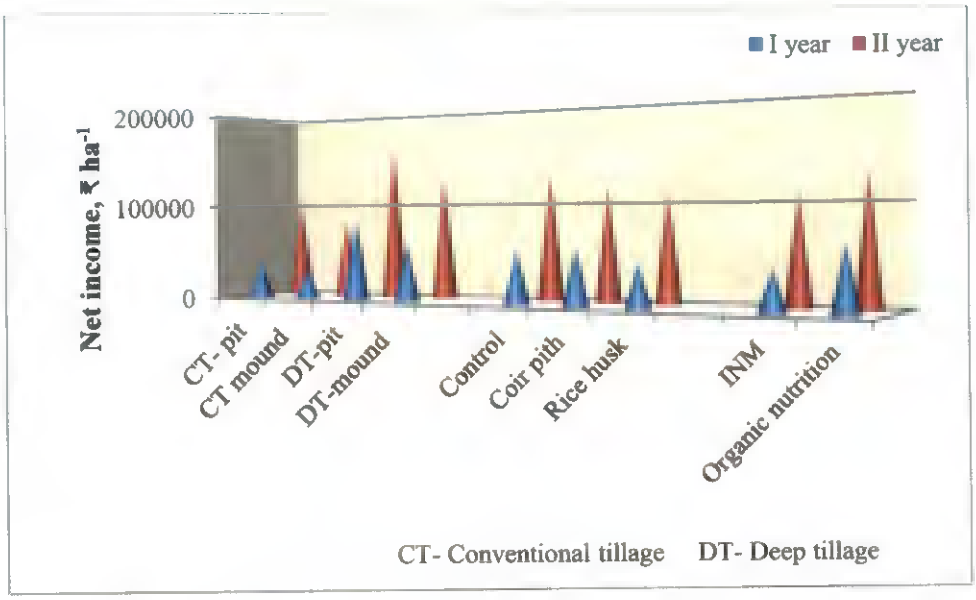

Fig. 18a Effect of tillage systems, soil conditioners and nutrient management on net income, ₹ ha^{-1}

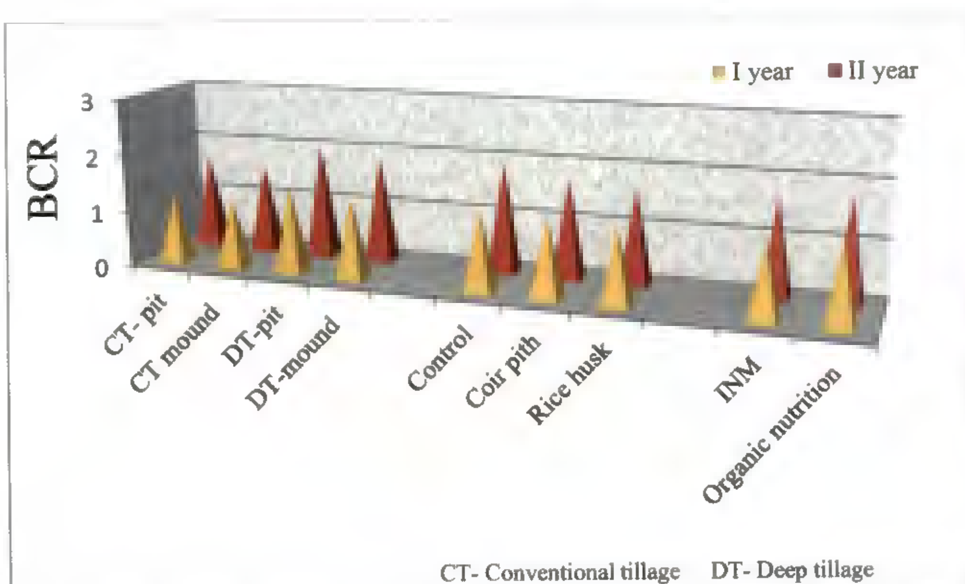

Fig. 18b Effect of tillage systems, soil conditioners and nutrient management on benefit : cost ratio

SUMMARY

6. SUMMARY

A field experiment entitled 'Tillage and nutrition for productivity enhancement in tannia (*Xanthosoma sagittifolium* (L.) Schott)' was undertaken in the Instructional Farm attached to College of Agriculture, Vellayani from August 2014 to May 2015 and repeated during May 2015 to February 2016. The objectives of the study were to identify ideal tillage system for productivity enhancement in tannia, to study the effect of soil conditioners and to compare the effects of integrated and organic nutrition on growth, yield and quality of tannia and to work out the economics of cultivation. The field experiment was laid out in split plot design with 24 treatment combinations and four replications. The main plot treatments consisted of four tillage systems (l_1- conventional tillage followed by pit system, l_2- conventional tillage followed by mound system, l_3- deep tillage followed by pit system and l_4- deep tillage followed by mound system) and sub plot treatments were combinations of two soil conditioners along with a control (s_1- control, s_2- coir pith @ 500 g plant^{-1} and s_3- rice husk @ 500 g plant^{-1}) and two nutrient management practices (n_1- integrated nutrient management (INM) – FYM @ 25 t ha^{-1} + 80:50:150 kg NPK ha^{-1} and n_2- organic nutrition- FYM @ 37.5 t ha^{-1} + wood ash @ 2 t ha^{-1}).In the case of INM, half the quantity of FYM and full P were applied as basal dose and remaining FYM and full N and K were applied in three equal splits each at two, four and six MAP along with interculture and earthing up. For organic nutrition, 2/3rd quantity of FYM was given as basal dose and remaining FYM and wood ash were given in three equal splits each at two, four and six MAP along with interculture and earthing up. Dolomite @ 1 t ha^{-1} was applied uniformly to all plots at land preparation.

Growth characters were recorded at monthly interval from 2 MAP upto harvest. In general, plant height increased upto 5 MAP during I year and upto 6 MAP during II year and then started to decline with the senescence of the crop. Among tillage systems, deep tillage followed by pit system of planting was advantageous in recording taller plants during both years. Deep tillage compared to conventional tillage and pit system compared to mound system was found to produce taller plants. Application of soil conditioner profoundly influenced plant height and coir pith produced taller plants. Organic nutrition was found superior to INM in producing taller plants.

Number of leaves plant^{-1} increased upto 5 MAP after which it showed a declining trend upto harvest during both the years.Deep tillage followed by pit system produced more number of leaves at all stages of growth. Application of soil conditioner had significant effect on leaf production and coir pith was found superior to rice husk. Compared to INM, organic nutrition produced significantly more leaves at all stages of growth.

Leaf area index also showed an increasing trend upto 5 MAP after which a declining trend was observed upto harvest during both the years. Among the treatments tried, deep tillage followed by pit system of planting, coir pith as soil conditioner and organic nutrition registered the highest LAI at all stages of growth, during both years.

During both the years of study, deep tillage followed by pit system of planting produced significantly higher cormel number plant^{-1} while deep tillage followed by mound system produced bigger sized cormels. Application of coir pith as soil conditioner recorded higher number of cormels plant^{-1} compared to rice husk and control. Mean weight of cormel was higher in plots with no soil conditioner. Organic nutrition favoured the production of more number of cormels plant^{-1} while INM favoured the production of bigger sized cormels. Correlation analysis revealed significant and negative correlation of mean cormel weight with number of cormel plant^{-1} during both the years.

The yield components such as cormel and corm yields plant^{-1} and cormel : corm ratio were significantly higher with deep tillage followed by pit system of planting, with coir pith as soil conditioner and with organic nutrition. The interaction effects followed the same trend of main effects.

Deep tillage followed by pit system produced the highest cormel yield (pooled mean of 5.15 t ha^{-1}).Conventional tillage followed by mound system registered the lowest value during both years. Contrast analysis indicated the superiority of deep tillage over conventional tillage and pit system over mound system of planting. Deep tillage resulted in 24 per cent increase in yield over conventional tillage and pit system of planting produced 28 per cent increase in yield over mound system. Coir pith as soil conditioner recorded the highest cormel yield (pooled mean of 4.3 t ha^{-1}) which was 11 per cent increase over control. Compared to INM, organic nutrition resulted in 12 per cent higher cormel yield (4.3 t ha^{-1}). The effect of treatments on corm yield ha^{-1} followed the same trend as that of cormel yield ha^{-1}. Pooled analysis indicated the superiority of deep tillage followed by pit system combined with coir pith as soil conditioner and organic nutrition in producing the highest cormel yield ha^{-1} (pooled mean of 5.77 t ha^{-1}). The highest corm yield ha^{-1}(pooled mean of 8.3 t ha^{-1}) could be obtained by the treatment combination involving deep tillage followed by pit system, rice husk as soil conditioner and organic nutrition.

The correlation studies indicated that cormel yield was significantly and positively correlated with LAI at 5 MAP, number of cormel $plant^{-1}$ and cormel:corm ratio. Corm yield ha^{-1} was also significantly and positively correlated with LAI at 5 MAP.

Deep tillage followed by pit system profoundly improved the TDMP and harvest index. Coir pith as soil conditioner produced marked increase in TDMP over rice husk and control. Coir pith or rice husk as soil conditioner increased harvest index over control. Organic nutrition dominated over INM in its effects on TDMP and harvest index. Deep tillage followed by pit system combined with coir pith or rice husk as soil conditioner under organic nutrition resulted in higher dry matter production and harvest index.

During both the years, quality characters like dry matter, starch and protein contents of cormel were improved by deep tillage followed by pit system. Application of soil conditioner improved the quality characters and coir pith was found superior to rice husk. Organic nutrition was found superior to INM in influencing quality characters.

When cormels were stored under ambient conditions, no decay due to microbial attack was observed upto 45 days of storage. Sprouting of cormel started from 32nd day and 50 per cent sprouting was observed on 46th day. Physiological loss in weight was minimum in cormels obtained from plots which received deep tillage and planted in pits with organic nutrition. Hence cormels could be stored for one month without sprouting, microbial decay and appreciable physiological loss in weight.

During both the years, the highest uptake of N, P and K were recorded with deep tillage followed by pit system and the lowest with conventional tillage followed by mound system. Coir pith as soil conditioner considerably increased the uptake of nutrients compared to rice husk and control. Uptake of N, P and K were higher in plots which received organic nutrition. Significant and positive correlations of cormel and corm yields as well as TDMP with N, P and K uptake were observed.

The physical properties of the soil like bulk density, porosity and water holding capacity showed higher values in the surface soil (0 to 15 cm depth) compared to sub surface soil (15 to 30 cm depth) before and after the experiment. After the experiment, bulk density was lowered and porosity and water holding capacity of the soil improved over the initial status. Correlation study indicated that tuber yield was significantly and negatively correlated with bulk density while it was significantly and positively correlated with porosity and water holding capacity in both depths of soil during both years of experimentation. Deep tillage followed by pit or mound system registered lower bulk density and higher porosity and water holding capacity in both depths of soil during both years. Rice husk as soil conditioner was superior to coir pith in lowering bulk density and increasing porosity while coir pith was found to increase water holding capacity of the soil. Compared to INM, organic nutrition lowered bulk density and increased porosity and water holding capacity of the soil.

Initially, the surface soil (0 to 15 cm depth) was less acidic than sub soil (15 to 30 cm depth). The same trend has also been observed after the experiment. The soil pH was lower or higher than the initial status depending upon the treatments after the cropping periods. In general, soil became more acidic after deep tillage and pit system of planting. Application of soil conditioners and organic nutrition lowered soil acidity in both depths of soil during both the years. Conventional tillage with soil conditioners or organic nutrition lowered soil acidity than the combinations involving deep tillage. During both the years, the combination involving conventional tillage followed by mound system, coir pith as soil conditioner and organic nutrition registered the highest pH in both depths of soil.

Prior to the experiment, the surface soil had higher content of organic carbon than sub soil. After the experiment, organic carbon status of the surface soil increased whereas it decreased in the sub soil. Tillage influenced the status of organic carbon in the surface soil only and conventional tillage favoured the build up of organic carbon. Application of soil conditioners improved the content of organic carbon in both depths of soil and coir pith was found superior to rice husk. Compared to INM, organic nutrition invariably improved the organic carbon status of the soil.

Available N was higher in the surface soil than in the sub surface soil initially and a reverse trend was observed after the experiment. Higher status of available N in both depths of soil was observed in plots which received conventional tillage followed by pit or mound system, no soil conditioner and organic nutrition.

Available P status improved in both depths of soil after the experiment. Conventional tillage followed by pit or mound system recorded higher status of available P in surface soil and deep tillage followed by pit or mound system in the sub soil. Higher status of available P was observed in plots without soil conditioner. Organic nutrition improved the status of available P in both depths of soil during both the years.

Available K was found to be higher in 0 to 15 cm depth of soil than in 15 to 30 cm depth. After the experiment, there was build up of available K compared to initial values. Conventional tillage registered higher status of available K in both depths. Available K status improved in both depths when coir pith was applied as soil conditioner. Organic nutrition resulted in higher status of available K in the soil.

No incidence of pest and disease was noticed during both years of cropping.

Among tillage systems, deep tillage followed by pit system registered higher net income (pooled mean of ₹ 1,21,605 ha^{-1}) and BCR (pooled mean of 1.76). Higher net income of ₹ 91,230 ha^{-1} (pooled mean) and BCR of 1.66 (pooled mean) could be obtained without soil conditioner. Organic nutrition resulted in higher net income (pooled mean of ₹ 94,142 ha^{-1}) and BCR (pooled mean of 1.6) compared to INM. Considering interaction effects, deep tillage followed by pit system under organic nutrition without soil conditioner ($l_3s_1n_2$) recorded the highest net income of ₹ 1,43,213 ha^{-1} (pooled mean) and pooled BCR of 1.99. The same treatment combination but with coir pith or rice husk as soil conditioner ($l_3s_2n_2$ or $l_3s_3n_2$) could also register higher net income of ₹ 1,38,075 ha^{-1} and ₹ 1,34,225 ha^{-1} (pooled mean) respectively with pooled BCR of 1.8 and 1.78 respectively.

The results clearly indicated that deep tillage to a depth of 30 cm followed by pit system of planting is ideal for productivity enhancement in tannia. Application of coir pith as soil conditioner and organic nutrition improved the growth, yield and quality of tannia.Deep tillage followed by pit system and organic nutrition (FYM @37.5 t ha^{-1} + wood ash @ 2 t ha^{-1}) can be recommended for economic production of tannia. Wherever coir pith or rice husk is available at a cheaper rate, it can be applied as soil conditioner @ 500 g $plant^{-1}$ for enhanced productivity of tannia.

FUTURE LINE OF WORK

- Since seasonal effect has been observed in the performance of tannia, it is necessary to fix the ideal time of planting for the crop.
- Performance of tannia under organic nutrition in different soil types may be studied.
- The feasibility of reducing the cost of organic nutrition through *in situ* green manuring and application of biofertilizers has to be explored.
- Intercropping tannia with Nendran banana being a common practice in our state, nutrient requirement and organic nutrient schedule for such a cropping system may be standardized

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APPENDICES

APPENDIX - I

Weather data during the cropping periods (August 2014 to February 2016)

Month and Year	Temperature (°C)		Average RH (%)	Total rainfall (cm)	Number of rainy days
	Maximum	Minimum			
August (2014)	29.55	23.74	86.00	53.57	16
September (2014)	30.21	24.19	84.88	21.90	10
October (2014)	30.53	23.82	84.68	22.92	12
November (2014)	30.18	23.38	85.35	13.73	11
December (2014)	30.22	23.29	83.52	1.34	5
January (2015)	30.6	21.6	79.44	0.80	2
February (2015)	31.6	22.3	78.25	0.00	0
March (2015)	32.4	23.7	78.53	5.61	4
April (2015)	32.7	24.5	81.98	18.62	9
May (2015)	32.1	25.3	87.00	40.60	8
June (2015)	31.4	24.5	86.83	34.69	19
July (2015)	31.3	24.6	84.55	5.35	5
August (2015)	31.7	24.6	82.97	8.02	4
September (2015)	31.4	24.4	87.58	28.98	15
October (2015)	31.3	24.0	86.50	39.91	19
November (2015)	31.6	23.8	86.13	25.41	18
December (2015)	31.6	23.8	89.20	25.93	11
January (2016)	32.34	22.64	82.18	0.04	0
February (2016)	32.94	23.17	82.88	5.47	1

Appendix - II

AVERAGE COST OF INPUTS AND MARKET PRICE OF PRODUCE

Inputs

a) Labour charge	- ₹ 600 day^{-1}
b) Cost of planting material (corm)	- ₹ 10kg^{-1}
c) Cost of dolomite	- ₹ 15000 t^{-1}
d) Cost of FYM	- ₹ 400t^{-1}
e) Cost of coir pith	- ₹ 3000t^{-1}
f) Cost of wood ash	- ₹ 3000t^{-1}
g) Cost of urea	- ₹ 6 kg^{-1}
h) Cost of rajphos	- ₹ 10 kg^{-1}
i) Cost of MOP	- ₹ 17 kg^{-1}
j) Hire charge of cultivator/rotavator	- ₹ 600 $hour^{-1}$

Output

a) Market price of cormel	- ₹ 40 kg^{-1}
b) Market price of corm	- ₹ 10 kg^{-1}

ABSTRACT

TILLAGE AND NUTRITION FOR PRODUCTIVITY ENHANCEMENT IN TANNIA
(*Xanthosoma sagittifolium* (L.) Schott)

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ABSTRACT

An investigation entitled 'Tillage and nutrition for productivity enhancement in tannia (*Xanthosoma sagittifolium* (L.) Schott)' was undertaken at College of Agriculture, Vellayani to identify ideal tillage system for productivity enhancement in tannia, to study the effect of soil conditioners and to compare the effects of integrated and organic nutrition on growth, yield and quality of tannia and to work out the economics of cultivation. The field experiments were conducted in the Instructional Farm attached to College of Agriculture, Vellayani from August 2014 to May 2015 and repeated during May 2015 to February 2016.

The field experiment was laid out in split plot design with 24 treatment combinations and four replications. The main plot treatments consisted of four tillage systems (l_1- conventional tillage followed by pit system, l_2- conventional tillage followed by mound system, l_3- deep tillage followed by pit system and l_4- deep tillage followed by mound system) and sub plot treatments were combinations of two soil conditioners along with a control (s_1- control, s_2- coir pith @ 500 g plant^{-1} and s_3- rice husk @ 500 g plant^{-1}) and two nutrient management practices (n_1- integrated nutrient management (INM) – FYM @ 25 t ha^{-1} + 80:50:150 kg NPK ha^{-1} and n_2- organic nutrition- FYM @ 37.5 t ha^{-1} + wood ash @ 2 t ha^{-1}).In the case of INM, half the quantity of FYM and full P were applied as basal dose and remaining FYM and full N and K were applied in three equal splits each at two, four and six months after planting along with interculture and earthing up. For organic nutrition, 2/3rd quantity of FYM was given as basal dose and remaining FYM and wood ash were given in three equal splits each at two, four and six months after planting along with interculture and earthing up. Dolomite @ 1 t ha^{-1} was applied uniformly to all plots at land preparation.

Growth characters like plant height, leaf number plant^{-1}and leaf area index were improved by deep tillage followed by pit system of planting. Application of coir pith as soil conditioner profoundly influenced growth characters. Organic nutrition was found superior to INM in improving growth characters.

Yield components like cormel number plant^{-1}, cormel and corm yield plant^{-1} and cormel: corm ratio were significantly higher due to deep tillage followed by pit system of planting. Application of coir pith as soil conditioner registered significantly higher values of yield components. Organic nutrition proved its superiority over INM in influencing the yield components.

Cormel yield was found to be significantly and positively correlated with leaf area index at five months after planting, cormel number plant^{-1} and

cormel : corm ratio. Significantly higher cormel yield (5.15 t ha^{-1}) and corm yield (7.73 t ha^{-1}) were obtained due to deep tillage followed by pit system. Deep tillage resulted in 24 per cent increase in yield over conventional tillage and pit system of planting registered 28 per cent increase in yield over mound system. Coirpith as soil conditioner resulted in higher cormel yield of 4.51 t ha^{-1} (11 per cent increase in yield over control) and corm yield of 6.99 t ha^{-1}. Organic nutrition significantly improved cormel yield (4.52 t ha^{-1} which was 12 per cent higher than due to INM) and corm yield (7.07 t ha^{-1}) compared to INM. Pooled analysis indicated that interaction of deep tillage followed by pit system with coir pith as soil conditioner and organic nutrition ($l_3s_2n_2$) recorded the highest cormel yield (5.77 t ha^{-1}) and the same treatment, but with rice husk as soil conditioner ($l_3s_3n_2$) recorded the highest corm yield (8.3 t ha^{-1}).

Deep tillage followed by pit system, application of coir pith as soil conditioner and organic nutrition compared to INM recorded significantly higher dry matter production and harvest index.

Quality characters of cormel like dry matter, starch and protein contents were improved due to deep tillage followed by pit system among tillage systems, application of coir pith as soil conditioner and organic nutrition compared to INM. In general, a shelf life of one month for cormel was observed without any microbial decay, sprouting and appreciable physiological loss in weight.

Higher uptake of N, P and K were noticed due to deep tillage followed by pit system. Coir pith as soil conditioner proved its superiority in enhancing nutrient uptake. Uptake of nutrients was significantly higher under organic nutrition than under INM.

Tillage systems, soil conditioners and organic nutrition profoundly influenced the physico-chemical properties of the soil after the experiment. Bulk density was lowered and porosity and water holding capacity were improved due to deep tillage, application of rice husk as soil conditioner and organic nutrition. Correlation study revealed significant and negative correlation of yield with bulk density and significant and positive correlation with porosity and water holding capacity of the soil. Organic nutrition resulted in significantly higher status of organic carbon and available N, P and K in the soil compared to INM.

Significantly higher net income and benefit cost ratio could be realized due to deep tillage followed by pit system among tillage systems, application of coir pith as soil conditioner and organic nutrition compared to INM. Considering interaction effects, deep tillage followed by pit system without soil conditioner under organic nutrition ($l_3s_1n_2$) registered higher net income and benefit cost ratio.

It is evident from the present study that deep tillage to a depth of 30 cm followed by pit system of planting is ideal for productivity enhancement in tannia. Application of coir pith as soil conditioner and organic nutrition improved the growth, yield and quality of tannia.Deep tillage followed by pit system and organic nutrition (FYM @37.5 t ha^{-1} + wood ash @ 2 t ha^{-1}) can be recommended for economic production of tannia. Wherever coir pith or rice husk is available at a cheaper rate, it can be applied as soil conditioner @ 500 g $plant^{-1}$ for enhanced productivity of tannia.

സംഗ്രഹം

'പാൽചേമ്പിന്റെ ഉത്പാദനക്ഷമത വർദ്ധിപ്പിക്കുവാൻ വേണ്ടിയുള്ള ഉഴവുരീതിയും സസ്യപോഷണവും' എന്ന ശീർഷകത്തിൽ ഒരു പഠനം വെള്ളായണി കാർഷികകോളേജിൽ നടത്തുകയുണ്ടായി. പാൽചേമ്പിന്റെ ഉത്പാദനക്ഷമത വർദ്ധിപ്പിക്കുവാൻ അനുയോജ്യമായ ഉഴവ് സമ്പ്രദായം കണ്ടെത്തുക, മൺഭൗതികഗുണപോഷകങ്ങളുടെ ഉപയോഗം കൊണ്ടുള്ള ഫലങ്ങൾ പഠിക്കുക, പാൽചേമ്പിന്റെ വളർച്ചയിലും വിളവിലും ഗുണത്തിലും സംയോജിതവളപ്രയോഗത്തിന്റെയും ജൈവവളപ്രയോഗത്തിന്റെയും സ്വാധീനം താരതമ്യപ്പെടുത്തുക, പാൽചേമ്പ് കൃഷിയുടെ സാമ്പത്തികവശം കണക്കാക്കുക എന്നിവ ആയിരുന്നു ഈ പഠനത്തിന്റെ ഉദ്ദേശ്യങ്ങൾ. ഇതിനുവേണ്ടി വെള്ളായണി കാർഷികകോളേജിലെ ഇൻസ്ട്രക്ഷണൽ ഫാമിൽ ഓഗസ്റ്റ് 2014 മുതൽ മെയ് 2015 വരെയും മെയ് 2015 മുതൽ ഫെബ്രുവരി 2016 വരെയും രണ്ടു പ്രാവശ്യം പാൽചേമ്പ് കൃഷി നടത്തുകയുണ്ടായി.

നാലു മുഖ്യപ്ലോട്ടുകളിൽ നാല് ഉഴവുസമ്പ്രദായങ്ങളും ആറു സബ്പ്ലോട്ടുകളിൽ മൺഭൗതികപോഷകങ്ങളും വളപ്രയോഗരീതികളും ചേർത്ത് 24 പ്ലോട്ടുകൾ നാല് പ്രാവശ്യം ആവർത്തിച്ച് മൊത്തം 96 പ്ലോട്ടുകളിലായി സ്പ്ലിറ്റ് പ്ലോട്ട് ഡിസൈൻ എന്ന പരീക്ഷണരീതി അവലംബിച്ച് വിളഭൂമിപരീക്ഷണം നടത്തുകയുണ്ടായി. സാധാരണ ഉഴവ് (15 സെന്റിമീറ്റർ ആഴത്തിൽ) നടത്തി കുഴിവെട്ടിയും കൂനകൂട്ടിയുമുള്ള നടീൽരീതികളും ആഴത്തിലുള്ള (30 സെന്റിമീറ്റർ) ഉഴവ് നടത്തി കുഴിവെട്ടിയും കൂനകൂട്ടിയുമുള്ള നടീൽരീതികളും നാല് മുഖ്യപ്ലോട്ടുകളിൽ പരീക്ഷിച്ചു. ഓരോ മുഖ്യപ്ലോട്ടുകളും ആറായി തിരിച്ചു മൺഭൗതികപോഷകങ്ങൾ ഇല്ലാതെയും, ചകിരിച്ചോറ്, ഉമി എന്നിവ ചെടിയൊന്നിന് 500 ഗ്രാം എന്ന തോതിൽ മൺഭൗതികപോഷകങ്ങളായി മണ്ണിൽ ചേർത്ത് സംയോജിതവളപ്രയോഗവും (ഹെക്ടറൊന്നിന് 25 ടൺ കാലിവളം + 80:50:50 കിലോഗ്രാം എൻ പി കെ രാസവളങ്ങളിലൂടെ) ജൈവവളപ്രയോഗവും (ഹെക്ടറൊന്നിന് 37.5 ടൺ കാലിവളം + രണ്ട് ടൺ ചാരം) ചെയ്തു പഠനം നടത്തി. ആദ്യ ഉഴവിനോടൊപ്പം ഒരു ടൺ ഡോളോമൈറ്റ് എല്ലാ പ്ലോട്ടുകളിലും ചേർത്ത് കൊടുത്തു. സംയോജിതവളപ്രയോഗരീതിയിൽ പകുതി അളവിൽ കാലിവളവും മുഴുവൻ ഭാവഹവും നടുന്നതിനു മുൻപ്

മണ്ണിൽ ചേർത്ത് കൊടുത്തു. ബാക്കി പകുതി കാലിവളവും, പാക്യജനകവും പൊട്ടാഷും മൂന്നു ഗഡുക്കളായി നട്ട് രണ്ട്, നാല്, ആറ് മാസങ്ങൾ കഴിഞ്ഞു ഇടയിളക്കി മണ്ണിൽ ചേർത്ത് മണ്ണണച്ചു കൊടുക്കുകയുണ്ടായി. ജൈവവളപ്രയോഗരീതിയിൽ രണ്ടിൽ മൂന്ന് ഭാഗം കാലിവളം നടുന്നതിനു മുൻപ് മണ്ണിൽ ചേർത്തു. ബാക്കി കാലിവളവും ചാരവും മൂന്ന് ഗഡുക്കളായി നട്ട് രണ്ട്, നാല്, ആറ് മാസങ്ങൾ കഴിഞ്ഞു ഇടയിളക്കി മണ്ണിൽ ചേർത്ത് മണ്ണണച്ചു കൊടുക്കുകയുണ്ടായി.

ആഴത്തിൽ ഉഴുതു കുഴിവെട്ടി നട്ടപ്പോൾ പാൽചേമ്പിനു മെച്ചപ്പെട്ട വളർച്ചയും വിളവും ഗുണമേന്മയും ലഭിക്കുകയുണ്ടായി. കൂടാതെ പാക്യജനകം, ഭാവഹം, പൊട്ടാഷ് എന്നീ സസ്യപോഷകങ്ങൾ താരതമ്യേന അധിക അളവിൽ ആഗിരണം ചെയ്യപ്പെടുകയും മെച്ചപ്പെട്ട വിളസൂചിക ലഭിക്കുകയും ചെയ്തു. മൺഭൗതികപോഷകമായി ചകിരിച്ചോർ ഉപയോഗിച്ചപ്പോൾ മെച്ചപ്പെട്ട വളർച്ചയും വിളവും ഗുണമേന്മയും ലഭിച്ചു. സംയോജിതവളപ്രയോഗത്തെക്കാൾ പാൽചേമ്പിനു അനുയോജ്യമായത് ജൈവവളപ്രയോഗമാണെന്നു പഠനം തെളിയിച്ചു. മേൽപറഞ്ഞ കൃഷിരീതികൾ സ്വീകരിച്ചപ്പോൾ അറ്റാദായത്തിലും വരവ് ചെലവ് അനുപാതത്തിലും വർദ്ധനവ് രേഖപ്പെടുത്തി. ആഴത്തിലുള്ള ഉഴവ് രീതി, മൺഭൗതികപോഷകങ്ങളുടെ ഉപയോഗം, ജൈവവളപ്രയോഗം എന്നിവ മണ്ണിന്റെ രാസഭൗതിക ഗുണങ്ങൾ മെച്ചപ്പെടുത്തുന്നതായും കണ്ടെത്തി.

പാൽചേമ്പ് ആദായകരമായി കൃഷി ചെയ്യുന്നതിന് 30 സെന്റിമീറ്റർ ആഴത്തിൽ ഉഴുത് കുഴിവെട്ടി നടുന്ന സമ്പ്രദായവും ജൈവവളപ്രയോഗവും (ഹെക്ടറൊന്നിന് 37.5 ടൺ കാലിവളം + രണ്ടു ടൺ ചാരം) ശുപാർശ ചെയ്യാവുന്നതാണ്. കൂടാതെ, മൺഭൗതികപോഷകങ്ങൾ ലാഭകരമായി ലഭിക്കുന്ന സ്ഥലങ്ങളിൽ ചകിരിച്ചോറോ ഉമിയോ മണ്ണിളക്കത്തിനായി ചെടിയൊന്നിന് 500 ഗ്രാം എന്ന തോതിൽ നൽകാവുന്നതാണ്.