ROLE OF TILLAGE/AGROCHEMICAL USE ON VAM IN COWPEA IN RICE FALLOW

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Department of Agronomy

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DECLARATION

I hereby declare that the thesis entitled **'Role of tillage/agrochemical use on VAM in cowpea in rice fallow'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that the thesis entitled **'Role of tillage/agrochemical use on VAM in cowpea in rice fallow'** is a record of research work done independently by **Ms.P.P. Duethi**, 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 her.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms.P.P.Duethi,** a candidate for the degree of **Master of Science in Agriculture** with major in **Agronomy,** agree that the thesis entitled **'Role of tillage/ agrochemical use on VAM in cowpea in rice fallow'** may be submitted by Ms.P.P.Duethi, in partial fulfilment of the requirement for the degree.

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Duethi, P.P.

To my parents

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Introduction

INTRODUCTION

Modern agriculture relies more on agrochemicals. Though the agrochemicals help to realise higher yields, their excessive use may often lead to environmental pollution and chronic health hazards. In this context ecofriendly management practices are to be developed for sustained production without adversely affecting the crop ecosystem where lot of beneficial flora and fauna exist. Reports reveal world wide occurrence of VAM colonies in the soil. They stimulate growth and biomass production of plants through enhanced availability of native nutrients and water. Such mycorrhizal colonisation is believed to be disturbed by normal tillage practices as well as use of agrochemicals. Hence the study aims at developing ecofriendly management practices to increase crop production with minimum disturbances to the mycorrhizal colonies in the soil so as to fully exploit their efficiency in enhancing the nutrient availability to the plants. Cowpea an ideal legume for summer rice fallows, is selected as the test crop.

Several reports reveal that activity of microorganisms especially vesicular arbuscular mycorrhizae is higher in poor soils. Mycorrhizal association enhances the availability of native nutrients and water. Exploitation of these soil microbes can lead to substantial saving in inorganic nutrition of the crop. Besides a number of studies reveal the adverse effects of intensive cultivation and use of agrochemicals on VAM population in soil. Hence an investigation was undertaken with the following objectives.

1. To assess the effect of tillage practices and herbicide use on VAM population.
2. To examine the possibility of saving inorganic fertilizer of the crop by the use of organics in conjunction with VAM.
3. To assess the effect of VAM on the nutrient uptake, biomass production and the yield of cowpea.

Review of Literature

REVIEW OF LITERATURE

Cowpea is an important leguminous crop which is highly suited for rice fallows in summer. It can thrive well in the residual fertility and moisture and can enrich the soil by fixing nitrogen and the addition of organic matter. Several reports reveal about the higher activity of microorganisms especially vesicular arbuscular mycorrhizae (VAM) in low fertility levels. Mycorrhizal association is found to increase the availability of native nutrients and water. So there is every possibility of saving fertilizer requirements by exploiting the efficiency of soil microorganisms especially VAM. A number of studies reveal the adverse effects of intensive cultivation practices as well as agrochemicals on VAM. Effects of soil management practices and agrochemicals on VAM, role of VAM on water stress, impact of VAM on performance of the crop, VAM and hyphal spread, effect of VAM on uptake of nutrients and interactions between rhizobium and VAM are reviewed here under.

Possible approaches to manipulate V-A-mycorrhizal association may be either by inoculation with selected VAM fungi, selection of plant genotypes, establishment of a soil environment that favours increased VAM number and activity by using suitable cropping pattern or by tillage activity through suitable cropping patterns and tillage practices (Lee *et al.*, 1991). More mycorrhizal propagules were present in soil cultivated with legumes than in those with cereals (Sreenivasa and Srihari, 1994).

The occurrence of endotrophic mycorrhizal association with roots of crop plants has been reported for a number of crop plants (Mosse, 1953; Nicolson, 1959; Dowding, 1959 and Gerdeman, 1968). Dense VAM infections are common in leguminosae as well as in gramineae (Rao, 1986).

Arbuscular fungi play a key role in natural and agricultural ecosystems through major functions in the enhancement of plant phosphorus, nitrogen nutrition, nutrient and soil conservation and the biological control of plant pathogens. They are essential for the sustainability of the systems and their importance in agricultural ecosystems is likely to increase as inputs are reduced and/or rationalised. In order to maximise their benefits it is essential to ensure that management practices include minimum tillage, timely use of fertilizer at the right quantity, appropriate crop rotations with minimal fallow and rationalized pesticide use (Hooker and Black, 1995).

1 Effect of soil management practices on VAM

Inoculation with *Glomus* sp. increased plant dry weight and seed yield in soybean established without tillage in rice field (Kuo and Huang, 1982). Colonisation decreased with increasing secondary tillage and depth within the soil profile (Mulligan *et al.*, 1985). Plant uptake of phosphorus was more efficient under no tillage than under conventional tillage (Sharp *et al.*, 1986). Tillage treatments affected the distribution of roots and extractable P in the top soil layer (Anderson *et al.*, 1987).

The number of fungal propagules per 100 g soil remained variable regarding tillage system or fertilization (Mc Allister et al., 1990). P absorption and shoot dry matter in a conventional tillage were less than that in hand planted no till plots but greater than that with severe soil disturbance (Mc Gonigle *et al.*, 1990). Gavito and Varela in 1990 reported that the most important factor influenced the abundance of these fungi was the soil management. They reported small number of propagules of VAM fungi in the fields of mechanised tillage and no rotation. VAM colonisation ratio was significantly higher in the ridged systems than in the mould board ploughed systems and markedly reduced the phosphorus fertilizer application in all cropping system (Vivekanandan and Fixen, 1991). Douds *et al.* (1993) reported that low input plots had higher soil populations of spores of VAM fungi than conventionally farmed plots. Bethlenfalvay and Barea (1994) related VAM to two biologically controlled aspect of sustainable agriculture - plant production and soil quality.

Soil compaction in presence of VAM decreased plant growth and yield but had no adverse effect on number and weight of nodules per plant (Buttery *et al.*, 1994). The results revealed favourable effect of mycorrhiza in promoting the yield of cowpea grown in pots. Tillage regime affected VAM populations and the effect varied with species (Douds *et al.*, 1995). Greater rates of P fertilizer were not required in reduced tillage systems compared with systems that cause a greater degree of soil disturbance (Miller *et al.*, 1995). Plants in no tillage treatments had higher root biomas and root biomass infected with mycorrhizas. The interaction effects of tillage and compaction from wheel traffic reduced root biomass and root biomass infected with mycorrhizas but did not affect plant nutrient and yield (Entry *et al.*, 1996). Slightly higher soil infectivity estimates were found under reduced tillage (Hamel *et al.*, 1996). Addition of organic amendments into soil increased VAM spore density, percentage infection and intensity of infection (Babi and Manibhushanrao, 1996).

2 Effect of agrochemicals on VAM

2.1 Effect of fertilizer application on VAM

Murdoch *et al.* (1967) observed a significant growth difference in maize plants with or without mycorrhizae grown in soil amended with rock phosphate when compared to unamended soil. However Menge *et al.* (1978) suggested that it was the phosphorus concentration of the root and not the amount of phosphorus applied to the soil which actually determined the extent of root colonisation by VAM. Waidyanatha *et al.* (1979) found that in mycorrhizal *Peuraria* and *Stylosanthes*, the application of rock phosphate greatly stimulated nodulation and nodule activity. Inoculation with *Glomus fasciculatum* along with superphosphate at the rate of 22 kg P/ha in a phosphorus deficient soil did not affect the percentage of root colonisation by VA-mycorrhiza in blackgram, green gram and chickpea (Manjunadh and Bagyaraj, 1986).

Hao *et al.* (1991) reported that phosphorus encouraged mycorrhizal infection in most of the soils deficient in available P but the optimum amount of P fertilisation was different for different soil types. Mycorrhizal association in the rock phosphate corn-soybean system appeared to provide a good environment for P nutrition during early vegetative growth (Vivekanandan and Fixen, 1991). Paulino *et al.* (1992) reported that in *Cajanus cajan* the best results were obtained with the combined VAM and rock phosphate treatment. FYM and P nutrition markedly increased shoot dry matter and reduced VAM infection of rice, compared with unfertilized control (Pasolan *et al.*, 1993). In mycorrhizae inoculated soil, shoot P uptake increased with upto 20 g/kg soil where as root P uptake increased upto 40 g P/kg soil applied through rock phosphate.

Heqqo and Barakah (1994) found that when phosphorus was added at low rates, the increase in dry matter yield with inoculation was four fold. Increased plant height as a result of VAM inoculation with rock phosphate was reported by Maksoud *et al.* (1994). According to Secilia and Bagyaraj (1994), application of phosphatic fertilizer to rice could be decreased by 50 per cent with no loss of yield when inoculated with *Glomus intraradices*. Chandrasekhara *et al.* (1995) found that the positive effect of mycorrhizae inoculation decreased with increasing P level above 16 kg P. The total mycorrhizal infection estimated by trypanblue staining was reduced by phosphate fertilization in P sufficient soils (Guillemin et al. 1995).

Miller et al.(1995) reported that higher rates of P fertilizer were not required in reduced tillage systems compared with systems that caused a greater degree of soil disturbance. The results of experiment by Santhi and Kothandaraman (1995) showed that plants inoculated with VAM and mussorie rock phosphate recorded maximum fertiliser recovery. Negative correlation between phosphorus levels and VAM spore population and colonisation was again established by Santhi and Sundarababu (1995). Plant phosphorus was highest on the VAM and phosphorus treatment in an experiment conducted in *Zeamays* L. (Klun, 1992). Geethakumari et al (1994) reported that mussorie rock phosphate in conjunction with mycorrhizae could very well be used as a source of phosphorus for cowpea and this saved 7.5 kg P_2O_5/ha.

2.2 Effect of agrochemicals other than fertlizer

The fungicides (Carbendazin and Captafol) and the herbicides (flan propisopropyl, metoxiuron, trifluralin) incorporated into soil had little or no effect on spore germination and hyphal growth of VAM fungus (Tommerup and Briggs, 1981). Highly fertile soils generally showed less VAM fungal population and pesticide treatments tended to decrease their number (Hayman, 1982). Siqueira *et al.* (1991) reported that mycorrhizal sorghum plants were less affected by herbicide toxicity than non mycorrhizal ones at low to moderate herbicide concentration. One or two applications of endosulfan and quinalphos at 5 and 10 kg/ha were toxic to plant growth and VAM fungal colonisation (Veeraswamy *et al.*, 1993). The fumigant and pesticides reduced VAM fungal colonisation and the number of spores. The effect of pesticides on VAM fungi varied with the associated host plant species (Udaiyan *et al.*, 1995). Sukarno *et al.*(1996) concluded that the fungicide application reduced overall contribution of the fungus to P nutrition.

3 Role of VAM on water stress

According to Levy and Krikun (1980) VAM association helped the citrus plant roots to overcome the water stress by stomatal regulation. Sanchez *et al.* (1990) reported that mycorrhizal plants maintained leaf area ratio constantly whereas in others the leaf area ratio decreased. The study also pinpointed that throughout, drought, nodule activity maintained significantly higher values in mycorrhizal ones. The capacity of the mycorrhizal hyphae to remain infective in undisturbed soil that had been allowed to dry, depended on the stage of life cycle reached at the time of the onset of drying (Jasper *et al.*, 1993). VAM inoculation enabled exploitation of a larger volume of soil water (Rao and Tarafdar, 1993).Inoculation increased relative water content in plant (Liu *et al.*, 1994). P fertilizer application in addition to mycorrhizal inocultion improved the drought tolerance of maize and sorghum plants (Osonubi, 1994). Greater water extraction in drought stressed mycorrhizal sorghum was also observed. Mycorrhizal activity in most plant species was at high levels throughout the summer (Green *et al.*, 1995).

Mycorrhizal roots showed high P concentration under drought stress. VAM contributed to the improved drought tolerance, higher assimilation and enhanced root conductance of flax (Reichenbach *et al.*, 1995). Fungal effects on drought tolerance, based on relative decrease in shoot dry weight, was decreased in order *G. deserticola, G. fasciculatum, G. mosseae, G. etunicatum, G. intraradices, G. calidonium* and *G. occulatum* (Lozano et al. 1995). Mycorrhizae significantly improved tolerance to moderate drought stress (Subramanian *et al.*, 1995).

4 Effect of VAM on performance of the crop

Association of mycorrhizae is known to improve the growth and general condition of crop plants (Mosse, 1957; Bayalis, 1959). VAM fungi played a significant role in improving plant growth and productivity through increased uptake of water, phosphorus and other minerals (Bagyaraj *et al.*, 1979). Carling *et al.* (1979) observed that the colonisation rate and growth response of soybean plants inoculated with VA-mycorrhizal fungi improved with an increasing quantity of *G. fasciculatus* inoculam. Hayman and Mosse (1979) also got improved growth in white clover under field conditions due to mycorrhizal inoculation.

Bagyaraj and Manjunadh (1980) got significant increase in root and shoot dry weights of cowpea inoculated with *Glomus fasciculatum*. The growth parameters were higher in plants inoculated with VA-mycorrhizae in combination with rockphosphate application. Islam and Ayanaba (1981) obtained higher yield in cowpea inoculated with G*lomus mossae*.

Inoculated cowpea had significantly higher plant height and higher yield than non mycorrhizal plant (Rosalus *et al.*, 1987). Combined inoculation with VAM and *Rhizobium* sp. produced better crop growth and seed yield (Hoque and Sattar, 1989). Jalid (1991) found that VAM inoculation with rockphosphate gave the highest total dry matter, root and shoot dry weight, root shoot ratio and nutrient uptake in corn. Increased growth by inoculation has been reported by Cabello (1992) in soybean plants.

Mane *et al.* (1993) reported that inoculation of plants either with VAM (*Glomus fasciculatum*) or rhizobium increased length and weight of roots, biomass production and seed yield. Dry matter production and seed yield were significantly improved by inoculation (Rao and Tarafdar, 1993). Shoot growth was increased by VAM inoculation (Heqqo and Barakah, 1994).

Mycorrhizal inoculation increased both dry weight and P uptake. Shoot dry weight increased with rate of P application where as root dry weight was highest with the lowest rate of P (Eranna and Parama, 1994). VAM caused a significant increase in plant growth and grain yield (Singh, 1994). Tarafdar and Marchner (1994) reported increased shoot dry weight due to mycorrhizal inoculation. VAM inoculation increased plant dry weight (Arafat *et al.*, 1995). Guillemin *et al.* (1995) reported that the level of mycorrhizal infection was not related to plant growth in the experiment. In *Leucaena leucocephala* mycorrhizal plants out performed their non mycorrhizal counter parts in all respects especially plant height, root length, nodulation and phosphorus uptake (Koffa *et al.*, 1995).

Mycorrhizal inoculation significantly increased shoot dry weight (Olsern and Habte, 1995). Significant increase in growth of soybean crop when inoculated with VAM was reported by Plinchette and Morel (1996). Grain yield of pigeon pea was significantly increased due to *Rhizobium sp.* and *Glomus fasciculatum* (Singh, 1996).

5 Effect of VAM on the uptake of nutrients

5.1 Effect of VAM on uptake of phosphorus

Increased surface area due to mycelial network was primarily responsible for the enhanced uptake of phosphorus (Sanders and Tinker, 1971). Mycorrhizal roots explored a greater volume of soil beyond the zone of phosphate depletion near the root surface, and lead to greater uptake of phosphorus by the root system (Hayman and Mosse, 1972).

A similar observation was also made by Hattingh *et al.* (1973). Cowpea was heavily dependent on VAM fungi when there was limited phosphorus supply (Mulligan *et al.*, 1985). Experiment with ^{32}P showed that VAM hyphae derived the extra phosphate from labile pool rather than dissolving the insoluble phosphate (Manoharachari, 1989).

Increased phosphorus absorption following the development of a mycorrhizal association with the roots was also reported by Ikombo *et al.* (1991). Mycorrhizal inoculation decreased the levels of phosphorus competition between maize and soybeans by increasing the availability of phosphorus (Hamel, 1992).

Mycorrhizal association increased phosphorus uptake (Klun, 1992; Eranna and Parama, 1994). Mycorrhizal inoculation significantly increased plant P concentration (Olsem and Habte, 1995). The total P uptake was significantly higher in inoculated plants than in uninoculated plants (Chandrasekhara *et al.*, 1995). The levels of root colonisation by VAM fungi were inversely related to the P concentration in these soils (Ibijbijen *et al.*, 1996). Nadian *et al.* (1996) found out that at low phosphorus application (15 mg/kg soil) P uptake was greater in mycorrhizal plants than those of non-mycorrhizal plants at similar levels of soil compaction. The mycorrhizal dependency of soybean was highly correlated with the P concentration in the soil solution (Plinchette and Morel, 1996).

5.2 Effect of VAM on the uptake of nutrients other than phosphorus

The importance of mycorrhiza in the absorption of other nutrient elements was first reported by Mosse (1957). Endomycorrhizal association in many plants greatly increased the uptake of P and Zn from a nutrient solution (Bowen and Mosse, 1969). VAM inoculation enhanced Zn uptake in peaches (Gilmore, 1971).

Sanni (1976) reported a positive correlation between VA-mycorrhizal infection and the amount of nitrogen in tissue of cowpea, tomato and maize. Cooper and Tinker (1978) investigated the uptake and translocation of ^{32}P, ^{65}Zn and ^{35}S supplied to white clover with mycorrhizal infection and observed that all the three were translocated through external hyphae to the host plant. Hamilton *et al.* (1993) showed a positive correlation of VAM with Zn, P and Cu uptake during early plant growth. VAM inoculation enabled the exploitation of a larger volume of soil water and nutrients (Rao and Tarafdar, 1993). Mycorrhizae improved K, Ca, Mg, Zn, Cu, Fe and Mn uptake (Urzua *et al.*, 1993). Shoot growth and composition of N, P, Zn, Fe, Mn and Cu increased with VAM inoculation (Heqqo and Barakah, 1994).

Mycorrhizae improved mineral nutrition by increasing absorptive surface area of the root system (Hernandez *et al.*, 1994). The results confirmed direct contribution of VAM hyphae to plant P, Cu and Zn nutrition (Tarafdar and Marchner, 1994).

Mycorrhizal fungal isolates played a pivotal role in removing Zn ions from solution (Denny and Ridge, 1995). VAM inoculated plants generally had higher S, K, Ca, Mg, Fe, Zn and Cu concentrations than uninoculated plants (Medeiros, et al. 1995). Diaz *et al.* (1996) reported that mycorrhizal plants showed equal or higher concentration of Zn compared with non mycorrhizal ones.

6 VAM hyphal spread and spore production

The intensity of root colonization and spore density varied not only with plant species but also within the same plant species (Muthukumar *et al.*, 1994). According to Chandrasekhara *et al.* (1995); at flowering and maturity, root colonization per cent and spore count were significantly higher in inoculated plants than uninoculated ones. Mycorrhizal hyphae grew to a distance of 300 mm in 180 days. VAM hyphal spread in soil was at the rate of 1.66 mm/day (Harinikumar and Bagyaraj 1995). The type of the crop and the harvest date greately influenced the size of the spore population and the extent of root colonization of *G. mossae* (Raddad, 1995).

7 VAM and *Rhizobium* interaction

Bagyaraj *et al.* (1979) reported that inoculation with *Glomus fasciculatus* greatly improved inoculation and nitrogen fixation in field grown soybean along with *Rhizobium japonicum*. Inoculation with rhizobium and mycorrhiza increased the growth, nodulation and phosphorus content of *Leucaena leucocephala*. Dual inoculation with rhizobium and vesicular arbuscular mycorrhizae enhanced the nodulation and nitrogen fixation in legumes (Sivaprasad *et al.*, 1983). Combined inoculation with rhizobium sp., phosphate dissolving microorganisms and VAM produced better nodulation and increased fixation of atmospheric nitrogen (Hoque and Sattar, 1989). The extent of mycorrhizal colonisation by native mycorrhizal fungi was significantly increased in the presence of rhizobium and led to increase the nodule number and dry weight and dry matter yields (Singh and Kapoor, 1990).

Interaction between the indigenous VAM fungus and *Bradyrhizobium. japonicum* increased the size and number of nodules compared with uninoculated plants (Cabello, 1992). Thiagarajan *et al.* (1992) suggested that dual inoculation of cowpea increased the pod yield, mycorrhizal infection nodule formation and shoot phosphorus and nitrogen content. Kumutha and Santhanakrishnan (1994) found that dual inoculation doubled N fixation compared with rhizobium alone. Enhanced nodulation associated with mycorrhizal inoculation was explained (Olsern and

Habte, 1995). Nodulation in pigeonpea was significant due to *Rhizobium* and *Glomus* interactions (Singh, 1996).

Various studies reviewed above throws light to the fact that there is every scope for improving the residual fertility and residual moisture conditions in fallows by exploiting the native microbes by providing a healthy environment, so this study was undertaken to know the impact of tillage and agrochemical on VAM in the test crop ie. cowpea in rice fallow.

Materials and Methods

MATERIALS AND METHODS

An investigation to study the effect of tillage practices and use of agrochemicals (herbicide) on the VAM population in rice fallow cowpea was undertaken at the Agricultural Research Station, Mannuthy during summer, 1997. The materials used and methods followed are presented below:

1 Experimental site

The experiment was conducted in the rice field of the Agricultural Research Station, Mannuthy, Kerala Agricultural University after the harvest of the 2nd crop of rice (rabi). It is located at 12° 32'N latitude and 72° 20'E longitude and at an altitude of 22.25 m above MSL.

1.1 Soil

Soil of the experimental site was sandy loam. The chemical properties of the soil are presented in Table 1.

2 Season

The experiment was conducted during the summer season (January - May) of 1997. The weather data is presented in Appendix-1.

3 Cropping history of the field

The area selected for the study was under rice crop during the previous two seasons.

Table 1. Physicochemical characteristics of the soil in the experimental field

Particulars	Value	Method employed
A. Physical properties		
Mechanical analysis		
Coarse sand	62.35%	Robinson's International Pipette method (Piper, 1942)
Fine sand	18.25%	
Silt	3.40%	
Clay	16.23%	
Field capacity	15.59%	Pressure Plate - Pressure memberane apparatus (Richards, 1949)
Permanent wilting point	7.06%	
Bulk density	1.32 g/c.c	Core method (Blake, 1965)
B. Chemical properties		
Available Nitrogen	165 kg ha^{-1}	Alkaline permanganate method (Jackson, 1958)
Available Phosphorus	16 kg ha^{-1}	Ascorbic acid blue colour method (Watanabe and Olson, 1965)
Available Potassium	175 kg ha^{-1}	Neutral normal ammonium acetate extract, Flame photometry (Jackson, 1958)
Organic carbon	0.4%	Walkley and Black mehtod (Jackson, 1958)
pH	5.1	1:2.5 soil-water suspension using a pH meter (Jackson, 1958)
C. Mycorrhizal observations		
Initial spore count of soil	68/100g soil	(Gerdeman, 1955)

4 MATERIALS

4.1 Variety

The variety chosen for the study was Kanakamony. It is a pureline selection, photo insensitive and slightly drought tolerant. This medium duration, moderately high yielding dual purpose variety is a bushy type which matures within 75-80 days during Kharif season and 65-70 days during summer. The average number of days taken for 50 per cent flowering is 48 days.

4.2 Seed material

Seeds of Kanakamony were obtained from seed production unit of Department of Olericulture, College of Horticulture, Vellanikkara.

4.3 Manures and fertilisers

Cattle manure analysing 0.5 per cent N, 0.3 per cent P_2O_5 and 0.2 per cent K_2O and chemical fertilizers, Urea, Rajphos and Muriate of potash analysing 46 per cent N, 22 per cent P_2O_5 and 60 per cent K_2O respectively were used for the experiment.

4.4 Vesicular Arbuscular Mycorrhizae

Mycorrhizal inoculum was obtained from the microbiological department of the Tamil Nadu Agricultural University, Coimbatore. The species used was *Glomus fasciculatum*. The inoculum was applied along with the seed @ 5 gm per pit.

4.5 Herbicide

Alachlor (Lasso-marketed by Monsanto Enterprises · Pvt. Ltd.) was applied as pre emergent spray in respective treatments at the rate of 2.5 kg ai/ha.

5 METHODS

5.1 Layout and design

The experiment was laid out in the strip plot design with three replications. (Plate 1)

5.1.1 Treatments

The treatments included two factors.

Factor A: Combination of tillage and herbicide.

T_0H_0 Minimum tillage without herbicide
T_0H_1 Minimum tillage with herbicide
T_1H_0 Normal tillage without herbicide
T_1H_1 Normal tillage with herbicide

Factor B: Nutrient application

F_0 Control (without fertilizer and organics)
F_1 Full recommended dose of fertilizer ie. inorganics and organics
F_2 Half the recommended dose of fertilizer ie. inorganics and organics
F_3 Half the recommended dose of fertilizer ie. inorganics and organics along with VAM @ 5 g/pit
F_4 Full recommended dose of inorganic fertilizer alone
F_5 Full recommended dose of organic manure alone

[Full recommended dose of fertilizer is fixed as per the Package of Practices ie. 20 t/ha FYM + 20-30-10 NPK kg/ha (KAU, 1993)].

Fig.1. PLAN OF LAYOUT

R_1 R_2 R_3 N

$T_1H_0F_0$	$T_1H_1F_1$	$T_0H_1F_5$	$T_0H_0F_0$	$T_0H_0F_5$	$T_1H_1F_4$	$T_1H_0F_2$	$T_0H_1F_1$	$T_1H_1F_4$	$T_0H_0F_5$	$T_0H_1F_3$	$T_1H_0F_4$
$T_1H_0F_5$	$T_1H_1F_5$	$T_0H_1F_0$	$T_0H_0F_5$	$T_0H_0F_4$	$T_1H_1F_5$	$T_1H_0F_5$	$T_0H_1F_0$	$T_1H_1F_2$	$T_0H_0F_3$	$T_0H_1F_2$	$T_1H_0F_1$
$T_1H_0F_4$	$T_1H_1F_3$	$T_0H_1F_4$	$T_0H_0F_4$	$T_0H_0F_1$	$T_1H_1F_0$	$T_1H_0F_3$	$T_0H_1F_5$	$T_1H_1F_1$	$T_0H_0F_1$	$T_0H_1F_0$	$T_1H_0F_5$
$T_1H_0F_1$	$T_1H_1F_2$	$T_0H_1F_3$	$T_0H_0F_2$	$T_0H_0F_0$	$T_1H_1F_1$	$T_1H_0F_0$	$T_0H_1F_2$	$T_1H_1F_0$	$T_0H_0F_0$	$T_0H_1F_4$	$T_1H_0F_3$
$T_1H_0F_3$	$T_1H_1F_0$	$T_0H_1F_1$	$T_0H_0F_3$	$T_0H_0F_2$	$T_1H_1F_3$	$T_1H_0F_1$	$T_0H_1F_4$	$T_1H_1F_5$	$T_0H_0F_2$	$T_0H_1F_1$	$T_0H_0F_0$
$T_1H_0F_2$	$T_1H_1F_4$	$T_0H_1F_2$	$T_0H_0F_1$	$T_0H_0F_3$	$T_1H_1F_2$	$T_1H_0F_4$	$T_0H_1F_3$	$T_1H_1F_3$	$T_0H_0F_4$	$T_0H_1F_5$	$T_1H_0F_2$

T_0 } Tillage
T_1 }

H_0 } Herbicide
H_1 } level

F_0 }
F_1 }
F_2 } Fertilizer
F_3 } levels
F_4 }
F_5 }

Plate 1. Overall view of the field

Gross plots size : 4 m x 3 m

Net plot size : 3 m x 2.4 m

The plan of layout is given in Fig.1.

5.2 Field culture

A single ploughing was given uniformly using tractor. Then the field was laid out into 3 blocks. The treatment combinations were allotted strip wise both horrizontally and vertically. Each block contained 24 plots of specified dimension. Irrigation channels and bunds were also made. To prevent seepage of water from the irrigation channels each plot was separated by bunds of 30 cm width and channels of 25 cm width around the plot. In the plots specified for minimum tillage only levelling of the field was done. In other plots the land was thoroughly digged and levelled. Fertilizer levels were allotted in horizontal strips along N-S direction and tillage and herbicidal combinations were allotted in vertical strips along E-W direction.

5.3 Irrigation

One pre-sowing irrigation was given uniformly to all plots one day before sowing. One more irrigation was given uniformly to all plots one month after sowing.

5.4 Fertilizer application

FYM, Urea, Rajphos and MOP were applied as per treatments. The different levels of fertilizers were applied in horrizontal strips.

5.5 Sowing

Sowing was done on 1st January 1997. Seeds were dibbled in the plots at a depth of 3-4 cm and at a spacing of 25 cm x 15 cm. Gap filling was done at 5 DAS to ensure uniform crop stand.

5.6 Herbicide application

The herbicide `alachlor' was sprayed as pre emergent application in specified plots at 2.5 kg ai/ha at 2 DAS.

5.7 Plant protection

Aphid population observed was above the critical level and it was controlled by spraying organic insecticide `econeem' 50 EC @ .05 per cent a.i. Other pests noticed were leaf eating caterpillars and plant hoppers, which were not serious.

5.8 Harvesting

First picking was carried out at 62 days after sowing and a second and final harvesting on 69 days after sowing. Plants from each plot were uprooted, dried in the sun, weighed and recorded.

5.9 Observations

5.9.1 Growth characters

Observations on growth characters were taken from 10 random plants in each plot at 30 DAS, 60 DAS and at harvest.

(i) Height of plants

Height was measured, from the scar of the first cotyledonous leaf of plant to the top growing point of the plant and the mean value for plant height was expressed in cm.

(ii) Number of branches per plant

Number of branches in each plant was counted and the average value was recorded.

(iii) Leaf area

Leaf area was determined by multiplying the product of leaf length and maximum width by a constant 0.704 (Puttaswamy *et al.*, 1976). Leaf area per plant = Length x Breadth x 0.704 x number of leaflets/plant. Leaf area index was calculated using the formula

$$\text{LAI} = \frac{\text{Leaf area per plant}}{\text{Land area occupied per plant}}$$

(iv) Drymatter production per plant

From each plot, 3 plants were collected from the row left for destructive sampling. Their roots were washed well and the plants were dried at 80°C to a constant weight and the average weight was recorded in grams.

5.9.2 Nodulation

(i) Number and dry weight of root nodules

Observation on nodules were taken at 60 DAS. Three plants were collected from the row left for destructive sampling. Roots were washed well and nodules were removed and counted. Nodules were dried in an oven at 80°C to a constant weight and the mean weight of nodules per plant was recorded.

5.9.3 Yield and yield attributes

Observations on yield and yield attributes were taken at the time of harvest. These observations were taken from the same plants selected earlier.

(i) Days to 50 per cent flowering

After commencement of flowering, the crop was observed daily and the number of days taken for 50 per cent flowering was recorded.

(ii) Number of pods/plant

Number of mature pods present in the plants were counted and average value of the observations was worked out.

(iii) Weight of pods per plant

Pods of the observation plants were dried in the sun and weighed. The mean weight was computed.

(iv) Weight of grains/plant

Grains of all pods of observation plants were dried and weighed. The mean weight was worked out.

(v) Number of seeds/pod

Ten pods were taken from each observation plant and number of seeds in each pod were counted and the average value was worked out.

(vi) Weight of 100 seeds

Samples of 100 seeds taken at random from each plot were sun dried and weight recorded.

(vii) Pod yield ha^{-1}

Pods obtained from each plot were dried in the sun, weighed and pod yield ha^{-1} was worked out.

(viii) Grain yield ha^{-1}

Grains obtained from each plot were collected, weighed and grain yield ha^{-1} was calculated.

(ix) Stover yield ha^{-1}

After harvesting all plants from each plot were uprooted, sun dried, weighed and stover yield ha^{-1} was computed.

5.9.4 Quality factors

Protein content of grain

Protein content of grain was worked out by multiplying nitrogen content of grain with the constant 6.25 (Simpson *et al*., 1965).

5.9.5 Uptake studies

Plant samples were dried in hot air oven at 70°C and the dry weight recorded. The samples were powdered and composite samples were stored for analysis.

Total nitrogen content of the samples was determined by Kjeldhal digestion and distillation method (Jackson, 1958). For the estimation of total phosphorus and potassium the plant samples were digested using diacid mixture (HNO_3 and $HClO_4$ in the ratio of 2:1) and the contents were made upto 50 ml. Phosphorus was determined by Vanadomolybdo phosphoric yellow colour method (Jackson, 1958) in Spectronic 20 spectrophotometer. Potassium was determined using EEL flamephotometer (Jackson, 1958). Nitrogen, phosphorus and potassium uptake by the crop at different intervals was computed from their respective chemical concentration and drymatter production.

5.9.6 Mycorrhizal observations

(i) Spore count

Number of spores in 25 g soil were counted under stereo microscope and expressed in percentage.

Isolation of *Glomus* sp.

The spores of the local culture of VA-mycorrhiza, *Glomus* sp., were isolated by the modified wet sieving and decanting method of Gerdemann (1955). For this, 250 g of cowpea rhisosphere soil was initially suspended in 1000 ml of tap water in a measuring cylinder and after the heavier particles had settled, the supernatant liquid was passed through a set of sieves of B.S.S. No. 60 (250 microns), 150 (150 microns) and 350 (45 microns). The residue left behind in the measuring cylinder was resuspended in 1000 ml of fresh tap water and passed through the same set of sieves. This procedure was repeated three to four times in order to collect maximum number of spores from the soil. Finally, the material present on each sieve was transferred to 100 ml beakers in small volume of water and filtered through Whatman No.1 filter paper. The contents of each filter paper were carefully examined under a stereomicroscope for the typical spores of VA-mycorrhiza.

(ii) Infection percentage

Root bits were stained with 0.05 per cent trypan blue in lactophenol (Philips and Hayman, 1970) and viewed under ordinary microscope.

The method of Phillips and Hayman (1970) was used for observing VA-mycorrhizal infection in various root samples. One hundred root bits of approximately 1 cm length were examined, segment-wise, for this purpose. The root bits were initially washed in tap water and softened by simmering in 10 per cent KOH at 90°C for 1 hour. After cooling, the excess of alkali was removed by repeated rinsing in tap water and then acidified with 2 per cent HCl before staining with 0.05 per cent trypan blue in lactophenol at 90°C for three minutes.

Preparation of trypan blue

Trypan blue (Romali)	50 mg
Lactophenol	100 ml

Preparation of lactophenol

Lactic acid	10 ml
Phenol	10 ml
Glycerol	20 ml
Water	20 ml

The excess stain from the root tissue was removed by clearing overnight in fresh lactophenol. Ten root bits were examined at a time for the typical VA-mycorrhizal infection under a light microscope. Each root bit was divided into four equal segments for recording the presence or absence of VA-mycorrhiza and based on this, different grades from 0 to 4 were given depending on the extent of mycorrhizal infection. The average value thus obtained for 100 root bits examined was taken as the mycorrhizal index.

5.9.7 Soil studies

The soil samples were air dried, powdered and passed through a 2 mm sieve.

a) Organic carbon

Soil organic carbon was determined by Walkley and Black method (Jackson, 1958).

b) Available nitrogen

Alkaline permanganate method (Subbiah and Asija, 1956).

c) Available Phosphorus

Available phosphorus in soil was extracted by Bray I extract and P content was determined by ascorbic acid - blue colour method in spectronic 20 spectrophotometer (Watanabe and Olsen, 1965).

d) Available Potassium

Available Potassium was extracted by neutral normal ammonium acetate and was read in EEL flame photometer (Jackson, 1958).

e) Available Sulphur

The procedure given by Massoumi and Cornfield (1963) was followed.

f) Available Zn

Available Zn was extracted by DTPA and was read in Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978).

5.9.8 Statistical analysis

Data generated on the various parameters of the experiment were analysed statistically by using the analysis of variance. In case the effects were found to be significant Dunckans Multiple Range Test was done for making logical comparisons between treatment means (Panse and Sukhatme, 1985).

Results and Discussion

RESULTS AND DISCUSSION

The observations recorded were analysed statistically and the results obtained are presented and discussed in the chapter. The duration of the crop was 69 days.

1 Growth characters

All the growth characters are given in Table 2. All the interaction effects on growth characters are given in Table 3, 4 and 5. (Plates 2, 3, 4 and 5)

1.1 Plant height

Though tillage had no significant effect on plant height at the initial stage of observation, taller plants were noticed in tilled plots. However at the later stages of observation taller plants were observed in minimum tilled plots. At 30 DAS plant height was slightly higher in the treatments without herbicide application. But at 60 DAS plant height was higher in treatment with herbicide application. However no significant difference was observed between the treatments.

Fertilizer levels had significant effect on plant height. At 30 DAS taller plants were observed in plots where half the recommended doze of fertilizer along with VAM was applied. This was followed by the treatment where full doze of organics alone was given. But at 60 DAS taller plants were observed in plots applied with full organics alone and was comparable with half the recommended doze of fertilizer along with VAM.

Interaction effects were not significant.

Plate 2. Treatment combination of minimum tillage, with herbicide and full dose of inorganics alone

Plate 3. Treatment combination of normal tillage, no herbicide and half the recommended doze of fertilizer along with bioinoculant

Plate 4. Treatment combination of minimum tillage, no herbicide and half the recommended doze of fertilizer along with bioinoculant

Plate 5. Treatment combination of minimum tillage, no herbicide and full doze of organics alone

Table 2. Growth characters as influenced by tillage, herbicide and fertilizer levels

Variables	Plant height at 30 DAS (cm)	Plant height at 60 DAS (cm)	Leaf area index at 60 DAS	Dry matter production at 30 DAS (g)	Dry matter production at 60 DAS (g)	Dry matter production at harvest (g)	Nodule number	Nodule dry weight (g)
<u>Tillage</u>								
T_0	19.46	27.09	1.74	1.99	2.31	3.82	1.74	0.008
T1	19.83	26.47	1.79	1.75	2.08	3.15	1.34	0.009
<u>Herbicide</u>								
H0	19.96	26.43	1.71	1.89	2.27	3.52	1.27	0.006
H1	19.33	27.13	1.82	1.85	2.12	3.45	1.53	0.010
<u>Fertilizer</u>								
F0	18.48	25.48^{c}	1.73^{b}	1.78	2.02^{b}	3.77^{a}	1.10	0.006
F1	19.03	26.93^{b}	2.04^{a}	1.95	2.24^{ab}	3.91^{a}	1.43	0.006
F2	20.82	25.48^{c}	1.45^{c}	1.67	1.82^{b}	2.45^{b}	1.08	0.007
F3	19.92	28.30^{a}	1.80^{b}	1.72	2.28^{ab}	3.81^{a}	1.81	0.014
F4	18.92	25.32^{c}	1.51^{c}	1.97	2.19^{ab}	2.84^{b}	1.24	0.006
F5	20.70	29.17^{a}	2.06^{a}	2.14	2.61^{a}	4.15^{a}	1.72	0.010
		S	S		S	S		

T - Tillage level; H - Herbicide level; F - Fertilizer level; S - Significant

The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

Table 3. Interaction effects between fertilizer and tillage treatments for growth characters

F/T	Plant height at 30 DAS (cm)		Plant height at 60 DAS (cm)		Leaf area index at 60 DAS		Dry matter production at 30 DAS (g)		Dry matter production at 60 DAS (g)		Dry matter production at harvest (g)		Nodule number		Nodule dry weight (g)	
	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1
F_0	17.75	19.22	26.13	24.83	1.81	1.66	1.92	1.64	2.22	1.82	4.13	3.40	1.00	1.19	0.003	0.008
F1	18.17	19.88	26.75	27.12	1.97	2.10	2.00	1.89	2.35	2.12	4.50	3.31	1.50	1.37	0.009	0.005
F2	21.05	20.58	26.23	24.73	1.45	1.45	1.77	1.57	1.93	1.71	2.95	1.94	1.37	0.8	0.005	0.002
F3	20.07	19.77	27.78	28.82	1.64	2.00	1.94	1.50	2.32	2.25	4.21	3.40	1.80	1.81	0.009	0.016
F4	18.92	18.85	26.10	24.53	1.44	1.57	2.01	1.93	2.30	2.08	2.71	2.97	1.29	1.22	0.007	0.010
F5	20.73	20.67	29.55	28.78	2.14	1.98	2.32	1.97	2.74	2.49	4.42	3.89	1.77	1.68	0.014	0.010
	NS		NS		NS		NS		NS		NS		NS		NS	

F - Fertilizer; T - Tillage levels; NS - Non significant

Table 4. Interaction effects between herbicides and fertilizer treatments for growth characters

F/T	Plant height at 30 DAS (cm)		Plant height at 60 DAS (cm)		Leaf area index at 60 DAS		Dry matter production at 30 DAS (g)		Dry matter production at 60 DAS (g)		Dry matter production at harvest (g)		Nodule number		Nodule dry weight (g)	
	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1
F_0	17.77	19.20	24.55	26.42	1.71	2.12	1.74	1.82	1.92	2.19	3.63	3.90	0.69	1.50	0.002	0.010
F1	19.60	18.45	26.05	27.82	1.95	1.45	2.01	1.88	2.39	2.09	4.14	3.67	1.41	1.46	0.007	0.007
F2	20.77	23.82	25.15	26.08	1.45	2.08	1.56	1.78	1.76	1.88	2.51	2.39	0.90	1.26	0.002	0.005
F3	20.32	19.52	27.48	29.12	1.52	1.75	1.74	1.71	2.34	2.22	3.53	4.08	1.77	1.85	0.008	0.017
F4	20.23	17.60	25.65	24.98	2.09	2.12	1.93	2.01	2.30	2.07	3.19	2.49	1.11	1.38	0.007	0.011
F5	20.98	20.42	29.05	29.28	1.75	1.45	2.36	1.93	2.91	2.32	4.14	4.17	1.72	1.73	0.012	0.012
	NS		NS		NS		NS		NS		NS		NS		NS	

F - Fertilizer; T - Tillage levels; NS - Non significant

Table 5. Interaction effects between tillage and herbicides for growth parameters

F/T	Plant height at 30 DAS (cm)		Plant height at 60 DAS (cm)		Leaf area index at 60 DAS		Dry matter production at 30 DAS (g)		Dry matter production at 60 DAS (g)		Dry matter production at harvest (g)		Nodule number		Nodule dry weight (g)	
	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1
T_0	19.61	19.31	26.89	27.29	1.65	1.83	1.94	2.05	2.31	2.31	3.87	3.77	1.48	1.43	0.006	0.006
T1	20.32	19.34	25.98	26.96	1.76	1.81	1.84	1.66	2.23	1.92	3.17	3.13	1.65	1.63	0.007	0.014
	NS		NS		NS		NS		NS		NS		NS		NS	

H - Herbicide; T - Tillage; NS - Non significant

Lack of significance between tillage treatments indicates that the loosening of soil by way of tillage need not necessarily enhance the nutrient availability to the plant. However, the trend in the increase of plant height at the later stage in minimum tilled plots. pinpoints to the fact that minimum soil disturbance is desirable in summer. This confirms the finding of Entry *et al.* (1996).

The absence of significance between the herbicide treatments might be because the crop chosen for the study, cowpea by itself have the ability to smother weeds to a certain extent. Further the high temperature during the crop period enhances the photodecomposition of the chemical.

Among the fertilizer levels half the recommended doze of fertilizer along with the bioinoculant, VAM fared comparatively better than all other treatments barring full organics alone. This might be because of the prolonged supply of the nutrients through the application of organics and inorganics in the right proportion. The reduced quantity of organics in the treatment may be compensated by the inoculation of VAM. In terms of economics this treatment is preferred. High cost together with the scarcity of organics limits the use of organic materials alone for crop nutrition.

1.2 Number of branches per plant

In general poor branching was observed and hence the data were exempted from statistical analysis.

The comparatively poor shoot growth in terms of lower number of branches might be due to the enhanced root development. Any crop in summer or adverse weather conditions have a built in mechanism to tide over the situation by reducing vegetative growth. The extensive root system as against the shoot growth observed in general with the crop substantiate the above results.

1.3 Leaf area index at 60 DAS

Tillage and herbicide levels had no significant influence on leaf area index. Significant difference was observed in the case of fertilizer levels. The lack of significant difference between tillage and herbicide treatments indicates that for summer cropping, soil loosening through tillage and herbicide use for weed control are not essential especially in cowpea.

Among the fertilizer levels full organics alone gave the highest value which was on par with full recommended dose and half the recommended doze plus VAM inoculation. The nutrient assimilating ability of VAM especially with respect to phosphorus, zinc and also water in water stress environments is well documented (Bowen and Mosse, 1969; Klun, 1992 and Liu *et al.*, 1994).

1.4 Dry matter production

With respect to dry matter production tillage treatments had no significant effect at all the stages of observations. However higher values were recorded in minimum tilled plots at all the stages. Though no significant difference was observed between herbicide treatment higher values were noticed in plots without herbicide application at all the stages.

Among the fertilizer levels significant difference was observed only at the later stages of observations. At all the stages organics alone gave the highest dry matter production which was comparable with full recommended doze and half the recommended doze along with VAM inoculation.

Interaction effects were not significant.

The results on DMP shows that the crop performance was unaltered by tillage and herbicide application. This might be because the loosening of soil through tillage leads to loss of residual moisture which is more important than the nutrient availability for a summer crop. The tilling operation normally favours potassium nutrition in the crop and also increases the availability of other nutrients by reducing the toxic effect mostly of iron in acidic laterite soils. The result indicates that water is more crucial in deciding the dry matter production of the crop in summer where the mean day temperature is very high with higher evaporative loss of water. The nutrient and water requirement of the crop was achieved with the use of a proper mix of organics and inorganics along with the bioinoculant.

High drymatter production observed in the plots which received full quantity of organics alone indicates the prolonged supply of nutrients throughout the growth period. This might be because of the direct and indirect beneficial effects of organics. Directly it acts as the source of plant nutrients and indirectly it influences the physical and chemical properties of the soil basically due to its qualitatively higher net negative charges which has more relevance in summer cropping. But cost wise half the recommended doze of fertilizer along with the bioinoculant is more economic bringing a saving of Rs.3800/ha and Rs.4320/ha comparing to full organics alone and full recommended dose of fertilizer respectively. At the same time this treatment showed comparable results. High expenditure incurred under fertilizer application is due to the high cost of FYM component i.e., Rs.8519/ha. Though supply of organics alone ensures prolonged availability of nutrients to the crop the immediate requirements of the crop has to be met through the readily available inorganics as a starter doze. Hence a proper mix of inorganics and organics along with the bioinoculant is always desirable for meeting the nutrient as well as water requirements of the crop.

1.5 Number and dry weight of nodules per plant

Tillage, herbicide and fertilizer treatments had no significant effect on nodule number and nodule dry weight. Dry weight of nodules were more in tilled and herbicide applied plots.

Among the fertilizer levels half the recommended doze together with VAM inoculation gave the highest value in terms of number and dry weight of nodules. The same was followed by full doze of organics alone and full recommended doze of fertilizer.

The interactions were not significant.

Results reveal that tillage and herbicide application had no adverse effect on the nodule forming microbes in the soil. The higher values for nodule weight in herbicide applied plots, indicate that the soil microbes are least disturbed by the herbicide application.

Though the fertilizer levels had no significant difference, the highest nodule number and nodule weight associated with half the recommended doze of fertilizer together with VAM inoculation. This pinpoints the favourable effect of VAM on rhizobia. Sinergestic interactions of VAM and rhizobia was reported earlier by Singh and Kapoor in 1990.

2 Yield and yield attributes

All the observations on yield attributing characters are given in Table 6. Various interaction effects were given in Table 6, 7, 8 and 9.

2.1 Days to fifty per cent flowering

Tillage had significant effect on flowering. Earlier flowering was observed in minimum tilled plots. No significant difference was noticed with herbicide and fertilizer effects. There was no significant difference in the case of interactions.

Generally higher growth rate of the crop in the minimum tilled plots might have helped to initiate the flowering earlier.

2.2 Total number of pods per plant

Number of pods was more in minimum tilled plots though the difference was not significant. The same trend was observed in the case of herbicide application. Plots without herbicide application recorded the highest pod number.

Fertiliser levels had significant effect on number of pods per plant. Pods were more in plots which received the full recommended doze of fertilizer. It was similar to application of full doze of organics alone which was followed by half the recommended doze of fertilizer along with VAM.

Interaction effects were not significant.

2.3 Weight of pods per plant

Weight of pods per plant followed the same trend as in the case of number of pods with respect to tillage and herbicide. Higher values of pod weight were obtained with minimum tillage and no herbicide treatments.

Though fertiliser levels had no significant effect on pod weight highest value was recorded in plots treated with full recommended doze of fertilizer. This was followed by application of full organics alone and half the recommended doze of fertilizer together with VAM.

The interactions were not found significant.

From the above results the crop performance was found to be benefitted by VAM inoculation in terms of weight of pods. This might be because the same treatment had better vegetative growth with higher plant height, drymatter production and leaf area.

2.4 Weight of grains per plant

No significant difference was observed among tillage, herbicide and fertiliser treatments. However tilled plots and those without herbicide application recorded more weight of grains per plant.

Among the fertilizer levels, full recommended doze of fertiliser recorded the highest grain weight per plant followed by full organics alone and those with half the recommended doze of fertilizer along with VAM.

Interaction effects were not significant.

Table 6. Yield attributing characters as influenced by tillage, herbicide and fertilizer levels

Variables	Days to 50% flowering	No. of pods per plant	Weight of pods/plant (g)	Weight of grain per plant (g)	No. of seeds per plant	100 seed weight (g)	Pod yield ha^{-1} (t ha^{-1})	Grain yield ha^{-1} (t ha^{-1})	Slover yield ha^{-1} (t ha^{-1})
<u>Tillage</u>									
T0	55.00	2.60	6.69	5.19	8.51	11.12	0.13	0.10	0.69
T1	56.22	2.56	6.67	6.67	8.96	10.86	0.13	0.10	0.64
<u>Herbicide</u>									
H0	55.58	2.91	7.09	5.45	9.19	9.19	0.13	0.11	0.69
H1	55.64	2.25	6.27	4.78	8.27	8.27	0.11	0.09	0.63
<u>Fertilizer</u>									
F0	56.67	1.81[c]	5.55	3.88	8.13	8.13	0.09	0.07	0.66
F1	54.50	3.53[a]	7.82	5.87	9.03	9.03	0.15	0.12	0.66
F2	55.33	2.43[b]	6.28	4.93	8.78	8.78	0.13	0.10	0.58
F3	55.33	2.43[b]	7.10	5.41	9.80	9.80	0.14	0.11	0.67
F4	56.83	2.08[bc]	5.94	4.84	8.52	8.52	0.12	0.10	0.65
F5	55.00	3.21[a]	7.38	5.75	8.13	8.13	0.12	0.10	0.76
		S							

T - Tillage level; H - Herbicide level; F - Fertilizer level; S - Significant

The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

Table 7. Interaction effects between fertilizer and tillage treatments for yield and yield attributes

F/T	Days to 50% flowering		No. of pods per plant		Weight of pods/plant		Weight of grain per plant (g)		No. of seeds per plant		100 seed weight (g)		Pod yield ha^{-1} (t ha^{-1})		Grain yield ha^{-1} (t ha^{-1})		Stover yield ha^{-1} (t ha^{-1})	
	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1
F_0	55.83	57.50	1.80	1.82	5.79	5.31	4.20	3.56	7.73	8.53	11.10	10.38	0.09	0.09	0.07	0.08	0.67	0.065
F1	53.83	55.17	3.23	3.83	7.92	7.71	5.99	5.75	9.27	8.80	11.26	10.99	0.14	0.15	0.12	0.12	0.69	0.64
F2	54.50	56.17	2.60	2.27	6.35	6.21	4.89	4.97	8.80	8.77	10.72	10.92	0.13	0.12	0.11	0.09	0.60	0.56
F3	55.33	55.33	2.85	2.50	6.73	7.47	5.02	5.81	9.13	10.47	11.47	11.18	0.14	0.14	0.11	0.11	0.71	0.62
F4	55.67	58.00	1.70	2.45	5.54	6.34	4.75	4.93	8.20	8.83	10.93	10.79	0.11	0.13	0.09	0.11	0.66	0.63
F5	54.83	55.17	3.90	2.52	6.78	7.00	6.26	5.24	7.90	8.37	11.23	10.88	0.14	0.11	0.11	0.08	0.79	0.73
	NS		NS		NS		NS		NS		NS		NS		NS		NS	

F - Fertilizer; T - Tillage level; NS - Non significant

Table 8. Interaction effects between herbicide and fertilizer treatments for yield and yield attributes

F/T	Days to 50% flowering		No. of pods per plant		Weight of pods/plant		Weight of grain per plant (gm)		No. of seeds per plant		100 seed weight (gm)		Pod yield ha^{-1}(t ha^{-1})		Grain yield ha^{-1}(t ha^{-1})		Stover yield ha^{-1} (t ha^{-1})	
	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1
F_0	57.50	55.83	1.98	1.63	6.19	4.91	4.53	3.23	9.63	6.63	10.51	10.97	0.089	0.085	0.077	0.072	0.660	0.661
F1	54.50	54.50	4.00	3.07	8.03	7.60	5.61	6.12	8.83	9.23	11.16	11.09	0.170	0.126	0.137	0.102	0.685	0.643
F2	54.00	56.67	2.57	2.30	5.92	6.64	5.01	4.85	8.53	9.03	10.66	10.98	0.136	0.115	0.105	0.095	0.550	0.608
F3	55.50	55.17	2.45	2.40	6.79	7.41	5.44	5.39	10.33	9.27	11.41	11.25	0.156	0.125	0.127	0.096	0.678	0.657
F4	57.00	56.67	2.70	1.45	6.81	5.07	5.48	4.20	8.97	8.07	10.90	10.82	0.125	0.118	0.103	0.098	0.738	0.556
F5	55.00	55.00	3.78	2.63	8.78	5.98	6.63	4.87	8.87	7.40	11.14	10.97	0.131	0.115	0.100	0.092	0.831	0.682
	NS		NS		NS		NS		NS		NS		NS		NS		NS	

F - Fertilizer; H - herbicide; NS - Non significant

Table 9. Interaction effects between tillage and herbicides for yield and yield attributes

F/T	Days to 50% flowering		No. of pods per plant		Weight of pods/plant		Weight of grain per plant (g)		No. of seeds per plant		100 seed weight (g)		Pod yield (t ha^{-1})		Grain yield (t ha^{-1})		Stover yield (t ha^{-1})	
	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1
T_0	55.17	54.83	2.71	2.49	6.76	5.30	5.30	5.07	8.92	8.09	10.98	11.25	0.13	0.12	0.11	0.10	0.69	0.68
T1	56.00	56.44	3.12	2.01	5.93	5.60	5.60	4.48	9.47	8.46	10.94	10.78	0.14	0.11	0.11	0.09	0.69	0.59
	NS		NS		NS		NS		NS		NS		NS		NS		NS	

F - Fertilizer; T - Tillage level; NS - Non significant

2.5 Number of seeds per pod

With respect to number of seeds per pod no significant difference was observed between tillage, herbicide and fertilizer levels. However tilled plots recorded more number of seeds per pod. Plots without herbicide gave relatively more number of seeds per pod.

Among the fertilizer levels half the recommended doze of fertilizer plus VAM inoculated plots registered higher value for seed number. It was closely followed by full recommended doze of fertilizer.

Interaction effects were not significant.

Though results reveal no significant difference between the fertilizer levels, VAM inoculated plots gave the highest number of seeds per pod. Better vegetative growth of the crop in the above treatment resulted from the supply of organics, inorganics and bioinoculant in the right proportion might have contributed to this.

2.6 Test weight/weight of 100 seeds

Test weight of seeds was higher in minimum tilled plots though the difference was not significant. In the case of herbicide also no significant difference was observed, but the herbicide treated plots recorded a higher value for test weight.

With respect to test weight fertilizer levels were not significant. Highest test weight was observed in plots treated with half the recommended doze of fertiliser along with VAM inoculation. This was comparable with application of full recommended doze of fertilizer and full of organics alone. The lowest value was observed in the control plot that is without fertilizer and organics.

Interaction effect was not significant.

Better vegetative growth and proper translocation of the assimilates from the vegetative parts to the sink might be the reason for the higher test weight in treatments which received half the recommended doze of fertilizer together with the bio-inoculant, VAM.

2.7 Pod yield ha^{-1}.

Regarding yield of pods per ha, tillage, herbicide and fertilizer had no significance. Same yield was observed in tilled and minimum tilled plots but in the case of herbicide, plots without herbicide application had a slight increase in pod yield.

In the case of fertilizer full doze of fertilizer gave the highest value closely followed by half the recommended doze along with VAM. Lowest yield was noticed in the control plot that is without fertilizer and organics.

There was no significant effect on various interactions.

2.8 Grain yield ha^{-1}

In general grain yield was poor and followed the very same trend as that of pod yield. Both tillage treatments had the same value while the plots without herbicide application registered a slightly higher yield.

Among the fertilizer treatments full recommended doze recorded more grain yield closely followed by half the recommended doze of fertiliser together with VAM. The lowest grain yield was observed in plots without either fertilizer or organics.

No significant difference was observed between different interactions.

Apparently low grain yield may look contrary to the performance of growth and yield attributes which was due to the unexpected population damage caused by the wild rabbits from the hide outs in the farm. Though the same value of grain yield was obtained in both the tillage treatments all the growth and yield attributes were found to be favourably influenced by minimum tillage. This might be because loosening of soil by way of tillage need not necessarily enhance the nutrient availability to the crop. Especially in summer with high atmospheric temperature and soil moisture stress, loosening may adversely affect the crop through the loss of residual moisture. This is substantiated by the fact that though no significant difference was noticed between treatments, most of the growth and yield attributes were higher in minimum tilled plots. The higher value in the stover yield in the minimum tilled plots (Table 6) again supports this fact.

In the case of herbicide application lack of significant difference between treatments indicates that in summer herbicide application can be avoided due to two reasons. The crop cowpea by itself possesses weed smothering ability to a certain extent. Further the high atmospheric temperature together with soil moisture stress induces metabolic stress which makes it more sensitive to the chemical. This is supported by the higher values of DMP, most of the yield attributing characters and grain yield in plots without herbicide application. These values indicate the possibility of reducing the herbicide dosage in summer because whenever a selective herbicide is applied to a crop some energy has to be utilised for metabolically detoxifying it in the crop plants. Moreover, avoiding herbicide application can lead to a saving of Rs.1150/ha in the cultivation expense.

Higher values for grain yield in plots receiving recommended doze of fertilizer and half recommended doze along with VAM might be due to the better photosynthetic efficiency through vegetative growth and proper translocation of assimilates to the sink as indicated by the higher value of drymatter production and yield attributes in the above treatments. At the initial stages of growth the crop needs readily available forms of nutrients and this is met from the inorganics. Prolonged supply of nutrients during the rest of the growth period is met through the organics in the plots where full recommended doze was applied. In case of VAM inoculated plots though the quantity of readily available form of the nutrient is reduced, the organics added along with VAM resulted in a prolonged supply during the rest of the growth period. Further applied organics directly acts as the source of nutrients and indirectly influences physico chemical properties of soil. The humic substances produced during its decomposition penetrates the inter lamellar spaces of clay minerals and influence the interaction of clays with other soil constituents. Moreover, it enhances the water retention capacity of soil due to its qualitatively higher net negative charges. This is of great importance in summer cropping where water is a crucial factor. The structural changes brought about by organics through the change in pore size both within and between the soil aggregates has more relevance in summer. Apart from all these the organics applied, enhance, CEC and buffering capacity of the soil, which contribute to more nutrient availability. As only less than 30 to 40 per cent of major nutrients are available from the organics applied in the season, the advantage of organic matter application is spreaded over a longer period. In the case of VAM the hyphae explore deeper soil layers than the plant roots and make available more nutrients and water to the plant roots. Thus the benefits derived both from the use of bioinoculant and organics along with the readily available inorganics leads to better performance of the crop. Cost wise also combination of VAM, organics and inorganics enables a cut in the fertilizer bill by 50 per cent and cultivation expense by 46 per cent. This again can be further reduced if the farmer can meet the demand of organics from the domestic supply.

Increase in grain yield with the inoculation of VAM in cowpea was reported earlier (Islam and Ayanaba, 1981).

2.9 Stover yield ha^{-1}

Tillage, herbicide and fertilizer treatments showed no significant effect on stover yield of the crop. However stover yield was higher in minimum tilled plots without herbicide application.

Among the fertilizer levels highest stover yield was observed in plots which received full doze of organics alone. This was followed by half the recommended doze of fertilizer along with VAM, or full recommended doze of fertilizer.

Various interactions had no significant difference.

From the results the higher values obtained for stover yield in minimum tilled plots and in plots without herbicide application might be due to the high dry matter production in the respective treatments. It indicates the better photosynthetic efficiency of the plants in this treatment. The reasons are explained elsewhere. Among the fertilizer levels highest stover yield obtained in plots supplied with full organics alone might be because of the continuous supply of nutrients facilitating vegetative growth. However, the comparable value for stover yield given by half the recommended doze of fertilizer along with VAM inoculation indicates the possibility of partial substitution of organics with inorganics and bioinoculant which is better in terms of monitory benefits. The same treatment could bring about a cut in the cultivation expense by 46 per cent. If the organic requirements can be met from indigenous source/domestic source this amount could be further reduced. Inoculation of VAM in summer cowpea makes available not only nutrient elements but water also which is a very crucial factor in deciding the ultimate performance of the crop.

Weather accelerated soil moisture depletion in summer is caused mainly through low relative humidity which stimulates evaporative losses of water from the plant and the soil leading to induced metabolic stress in plant. In the context the ability of the fungal hyphae to explore deeper soil layers for water and nutrients are to be tapped for efficient crop production. Any amount of organic matter added to soil especially in summer is of greater significance as it improves the organic carbon status of the soil. Mere exposure of land to solar radiation can cause serious drain in the organic carbon status of the soil. This problem is more serious in tropical climate where the paddy lands are kept fallow. So by making use of the advantage of bioinoculant VAM a crop can be raised with the dual benefits of restoring the inherent fertility of the soil and adding organic matter to the soil.

3 Quality factors

3.1 Protein content of grain

It is given in Table 10. Interaction effects are shown in Table 11, 12 and 13. Though no significant difference was observed between tillage treatments protein content was highest in properly tilled plots. Application of herbicide favoured the protein content of grain. However the difference was not significant.

Fertilizer treatments showed significant effect on the protein content of the crop. Highest value was observed in the plots where half the recommended doze of fertilizer along with VAM inoculation. Moreover this was superior to full recommended doze of fertilizer.

Among the interactions fertilizer x tillage interaction was significant. VAM inoculated treatment gave higher protein value both in minimum tilled and normally tilled plots. Slightly higher value for protein content in VAM treated plots which was normally tilled indicate that tillage operation had no adverse impact on the fungal hyphae.

4 Uptake studies

All the characters are given in Table 10. Interaction effects are shown in Table 11, 12 and 13.

4.1 NPK uptake of the crop

4.1.1 Content and uptake of Nitrogen in the crop [Fig. 2]

Cellular content of nitrogen in the plants was not affected significantly by the tillage treatments. The higher value was noticed in plots where minimum tillage was practiced.

In the case of herbicides also no significant difference was observed between treatments in nitrogen content.

Table 10. Protein content and uptake of nutrients as influenced by tillage, herbicide and fertilizer levels

Variable	Protein content of grain (%)	Percentage of nitrogen	Uptake of nitrogen (kg ha^{-1})	Percentage of phosphorus	Uptake of phosphorus (kg ha^{-1})	Percentage of potassium	Uptake of potassium (kg ha^{-1})
Tillages							
T0	23.85	1.82	18.53	0.52	5.22	1.41	13.65
T1	24.42	1.67	14.16	0.51	4.84	1.54	13.32
Herbicide							
H0	23.79	1.72	16.02	0.51	5.04	1.50	14.08
H1	24.47	1.77	16.68	0.51	5.01	1.44	12.89
Fertilizer							
F0	23.09^{b}	1.43^{b}	14.35^{b}	0.52^{a}	5.19^{ab}	1.53^{ab}	14.54^{ab}
F1	22.24^{b}	1.96^{a}	21.11^{a}	0.49^{b}	5.19^{ab}	1.58^{ab}	14.47^{ab}
F2	23.41^{b}	1.79^{ab}	12.64^{b}	0.52^{a}	4.51^{b}	1.60^{a}	11.18^{ab}
F3	25.78^{a}	1.75^{ab}	18.15^{ab}	0.52^{a}	5.23^{ab}	1.43^{ab}	14.90^{ab}
F4	25.31^{a}	1.94^{a}	14.59^{b}	0.51^{a}	4.62^{b}	1.23^{b}	9.62^{b}
F5	24.96^{a}	1.60^{ab}	17.24^{ab}	0.51^{a}	5.40^{a}	1.44^{ab}	16.09^{a}
	S	S	S	S	S	S	S

T - Tillage level; H - Herbicide level; F - Fertilizer level; S - Significant

The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

Table 11. Interaction effects between fertilizer and tillage treatments for content and uptake of nutrients and protein content of grains

F/T	Percentage of nitrogen		Uptake of nitrogen (kg ha^{-1})		Percentage of phosphorus		Uptake of phosphorus (kg ha^{-1})		Percentage of potassium		Uptake of potassium (kg ha^{-1})		Protein content of grain (%)	
	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1
F0	1.61^{ab}	1.24^{b}	17.66	11.04	0.52	0.52	5.42	4.96	1.32	1.75	12.75	16.32	25.04^{a}	21.15^{b}
F1	1.80^{ab}	2.11^{a}	23.45	18.78	0.50	0.49	5.44	4.94	1.57	1.60	14.91	14.23	20.85^{b}	23.63^{a}
F2	2.02^{a}	1.56^{ab}	15.34	9.95	0.52	0.52	4.75	4.27	1.59	1.62	12.85	9.52	21.22^{b}	25.59^{a}
F3	1.78^{ab}	1.72^{ab}	20.58	15.72	0.52	0.52	5.45	5.02	1.27	1.59	14.36	15.44	25.52^{a}	26.05^{a}
F4	1.77^{ab}	2.11^{a}	12.46	16.72	0.52	0.50	4.60	4.64	1.08	1.38	8.01	11.23	24.87^{a}	25.74^{a}
F5	1.94^{a}	1.26^{b}	21.71	12.78	0.52	0.50	5.61	5.18	1.60	1.28	19.01	13.16	25.58^{a}	24.34^{a}
	S		NS		NS		NS		NS		NS		S	

F - Fertilizer; T - Tillage level
NS - Non significant; S - Significant
The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

Table 12. Interaction effects between herbicide and fertilizer treatments for content and uptake of nutrients and for protein content of grains

F/T	Percentage of nitrogen		Uptake of nitrogen (kg ha^{-1})		Percentage of phosphorus		Uptake of phosphorus (kg ha^{-1})		Percentage of potassium		Uptake of potassium (kg ha^{-1})		Protein content of grain (%)	
	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1
F0	1.76^{abc}	1.09^{d}	16.78^{abcde}	11.92^{de}	0.52^{a}	0.52^{a}	5.13	5.25	1.51	1.56	14.53	14.55	23.29	22.90
F1	1.84^{abc}	2.07^{a}	20.88^{abc}	21.35^{ab}	0.47^{b}	0.52^{a}	5.24	5.25	1.51	1.66	16.28	12.86	20.49	23.99
F2	1.84^{abc}	1.74^{abc}	12.38^{dc}	12.91^{cde}	0.52^{a}	0.52^{a}	4.48	4.54	1.64	1.57	11.02	11.34	23.83	22.98
F3	1.44^{bcd}	2.06^{a}	13.60^{bcde}	22.70^{a}	5.52^{a}	0.43^{a}	5.09	5.38	1.34	1.52	13.47	16.33	25.80	25.77
F4	2.11^{a}	1.78^{abc}	17.88^{abcde}	11.31^{c}	0.52^{a}	0.50^{ab}	4.88	4.37	1.49	0.98	12.87	6.38	24.86	23.75
F5	1.30^{cd}	1.89^{ab}	14.61^{abcde}	19.87^{abcd}	0.52^{a}	0.50^{ab}	5.46	5.34	1.49	1.39	16.31	15.87	24.46	25.45
	S		S		S		NS		NS		NS		NS	

F - Fertilizer; T - Tillage level
NS - Non significant; S - Significant
The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

Table 13. Interaction effects between tillage and herbicide for content and uptake of nutrients and protein content of grains

F/T	Percentage of nitrogen		Uptake of nitrogen (kg ha^{-1})		Percentage of phosphorus		Uptake of phosphorus (kg ha^{-1})		Percentage of potassium		Uptake of potassium (kg ha^{-1})		Protein content of grain (%)	
	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1
T0	1.75	1.89	17.72	19.34	0.52	0.52	5.22	5.20	1.40	1.41	14.52	12.78	23.96	23.73
T1	1.68	1.66	14.32	14.01	0.51	0.51	4.86	4.81	1.59	1.48	13.64	13.00	23.62	25.21
	S		NS		NS		NS		NS		NS		S	

T - Tillage; H - Herbicide; S- Significant; NS - Non significant

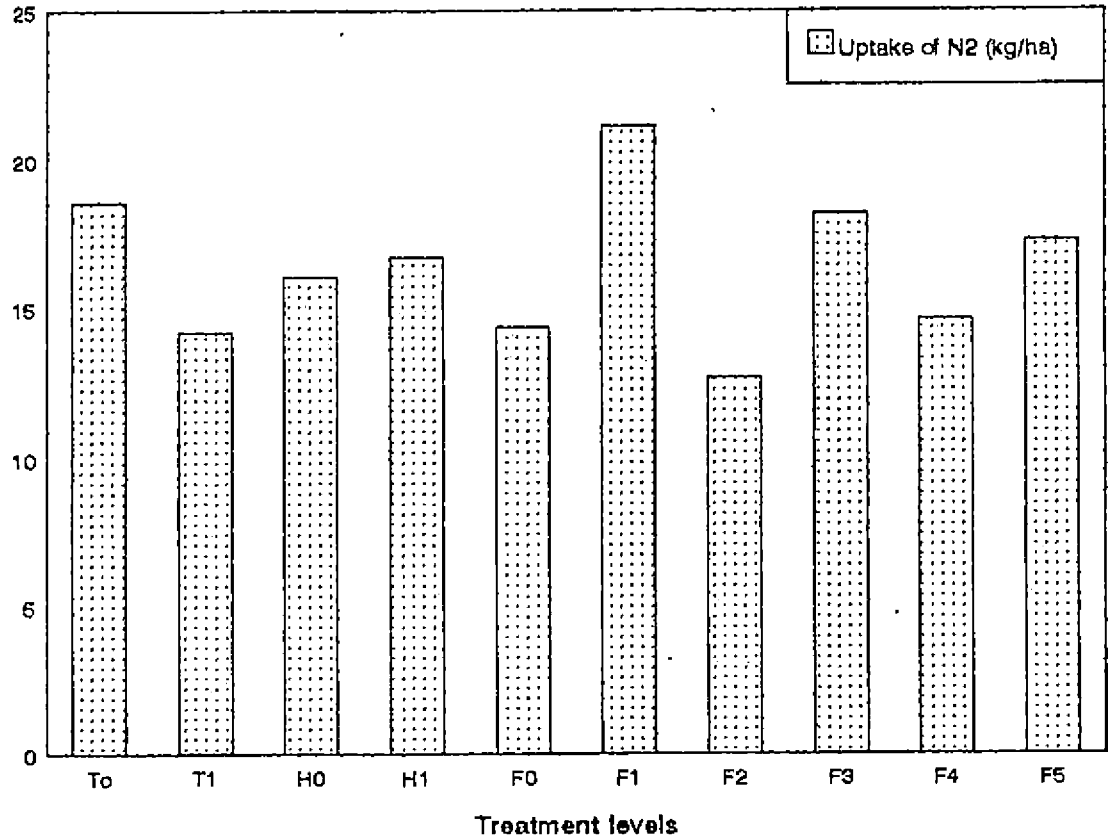


Fig.2 Uptake of nitrogen as influenced by tillage, herbicide and fertilizer levels

However the fertilizer levels had significant effect on nitrogen content of plants. The highest value was observed in plots which received full recommended doze of fertilizer. It was closely followed by the full recommended doze of fertilizer without organics. However half the recommended doze of fertilizer along with VAM and full organics alone were also comparable.

Among the various interactions tillage x fertilizer and herbicide x fertiliser were significant. In minimum tilled plots those which received application of full organics alone or half the recommended doze performed equally well. They were similar to application of full recommended doze or half the recommended doze along with VAM. But in plots where proper tillage was given full recommended doze of fertilizer or the same without organics fared equally well. In this case lowest value was observed in the plots which received full organics alone.

In general the uptake of nitrogen followed the same trend as that of content of nitrogen. Minimum tilled plots recorded the highest nitrogen uptake. In case of herbicide highest nitrogen uptake was obtained in herbicide applied plots (Fig.2).

Among the fertilizer levels full recommended doze of fertilizer gave the highest value of nitrogen uptake. It was comparable with half the recommended doze of fertilizer along with VAM application and application of full organics alone.

From the results in general nitrogen content and uptake were lower where normal tillage operations were carried out in plots treated with organics alone. This may be because any disturbance in the soil especially in summer would have decreased the residual moisture and there by the activity of the soil flora and fauna associated with the decomposition of applied organics. When organic manuring alone is resorted to, soil disturbance should be at the minimum so as not to disturb the activity of the soil microbes. As against this regular tilling operations are prefered when inorganics are applied. This is because the tilled plots facilitate the easy entry and availability of the nutrients present in inorganics, which other wise would have been lost by direct exposure to solar radiation and high temperature in summer. Though comparable nitrogen content was recorded in VAM inoculated plots with normal and minimum tillage, minimum tilled plots gave higher value indicating that like any other microbes, VAM also needs least disturbance in summer when high temperature and soil moisture stress prevails.

4.1.2 Content and uptake of phosphorus in the crop

Minimum tilled plots gave the highest value for phosphorus content though the difference was not significant. Herbicide treatments also had no significant difference. However P content in the crop was slightly higher in the herbicide treated crops.

Among the fertilizer levels higher values were observed in plots applied with half the recommended doze of fertiliser along with and without VAM inoculation. Application of full organics alone gave similar values. Lowest value of P content was noticed in full recommended doze of fertilizer.

Though uptake of phosphorus showed no significant difference, higher value was observed in minimum tilled plots. Similarly no herbicide treatment recorded higher value than the herbicide applied treatment (Fig.3).

With respect to the fertilizer levels application of full organics alone gave the highest value of P uptake that is 5.40 kg ha^{-1}. This was comparable with application of half the recommended doze of fertilizer plus VAM inoculation and

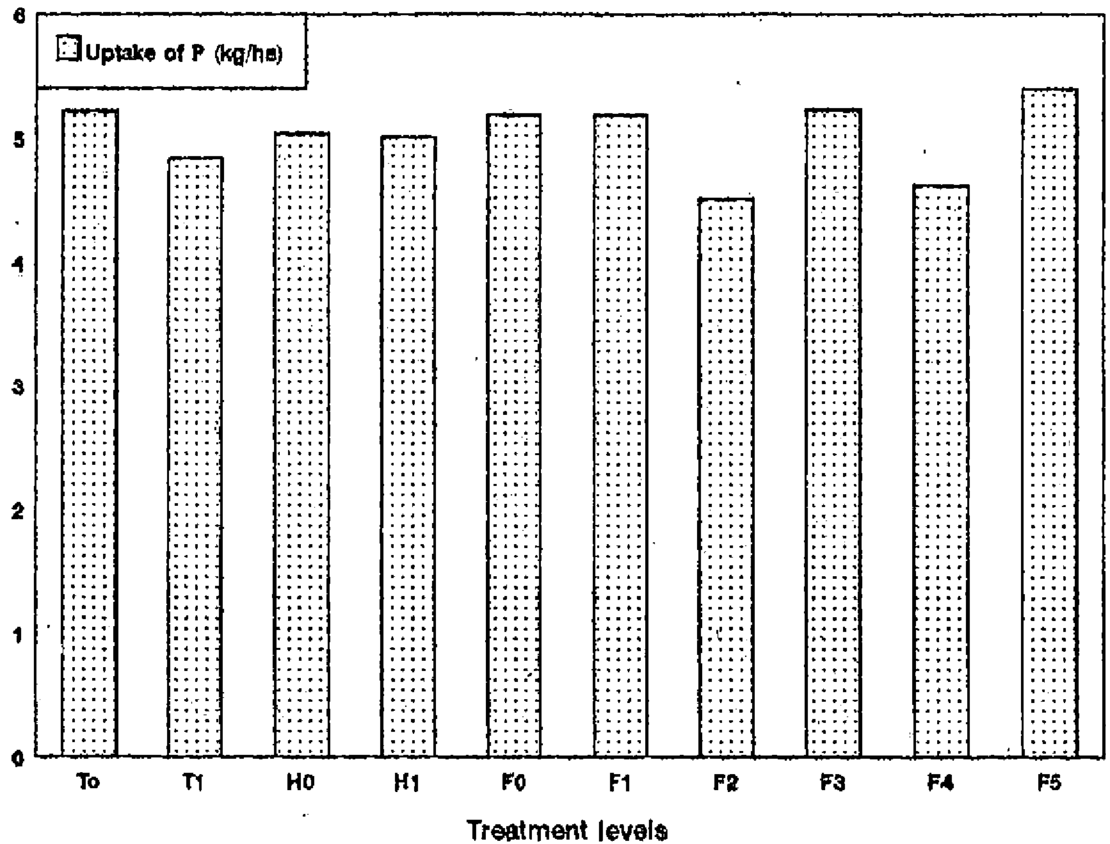


Fig.3 Uptake of phosphorus as influenced by tillage, herbicide and fertilizer levels

also full recommended doze of the fertilizer. At the same time treatment with half the recommended dose of fertiliser without VAM recorded the lowest P uptake.

Among the interaction effects all the interaction except herbicide - fertilizer interaction with reference to the content of phosphorus were not significant. Phosphorus content was similar in all interaction between herbicide - fertilizer levels except in case of interaction between without herbicide - full doze of recommended fertilizer.

In general P content and uptake were lower in plots which received inorganics alone or lesser amount of organics. This might be because whatever phosphorus taken up by the crop is from the native organic reserve rather than from the current application. The relatively high content and uptake of P in the VAM inoculated plots is because of its inherent ability to assimilate P from deeper soil layers (Klum, 1992; Eranna and Parama, 1994).

4.1.3 Content and uptake of Potassium in the crop

Though tillage as well as herbicide treatments had no significant effect on potassium content. Relatively higher potassium content was observed in minimum tilled plots and in the plots of no herbicide application.

Fertilizer levels had significant effect on the potassium uptake of the crop. Highest value was observed in the plots which received full doze of organics alone. This was comparable with half the recommended doze of fertilizer together with VAM inoculation (Fig.4).

Interactions were not significant.

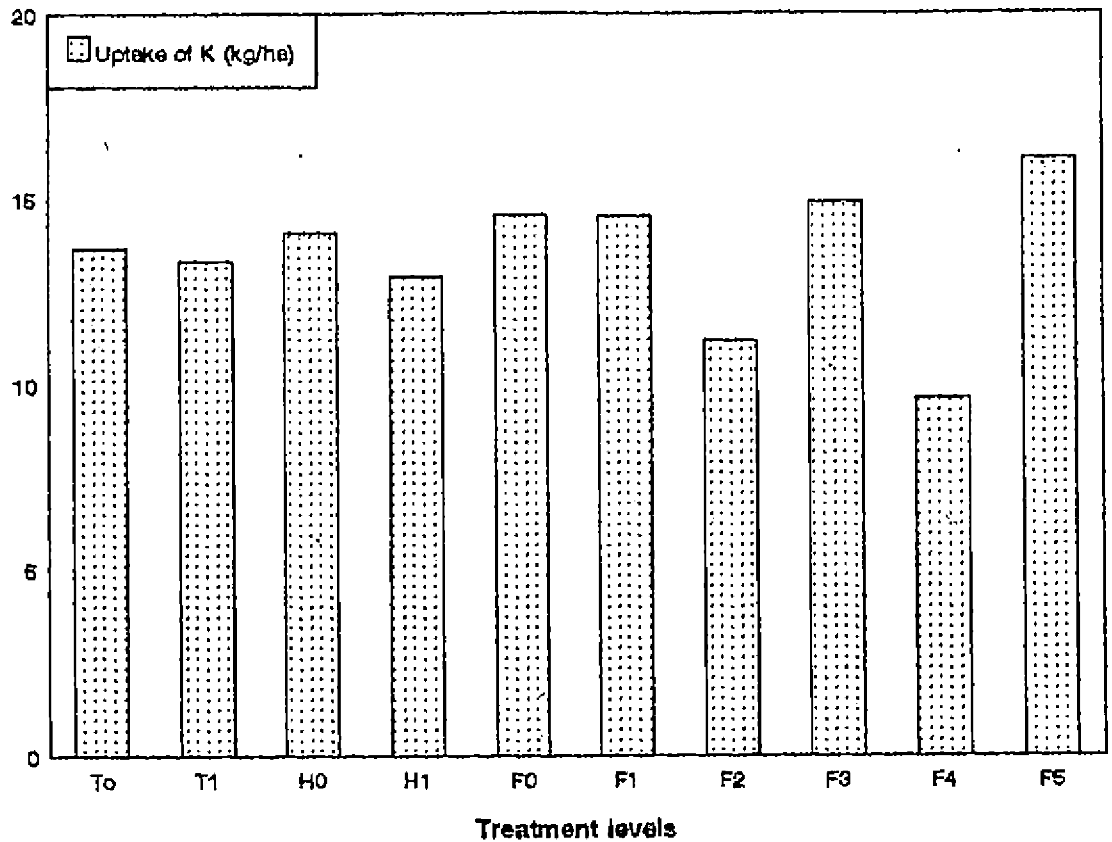


Fig.4 Uptake of potassium as influenced by tillage, herbicide and fertilizer levels

The lowest K content in full inorganics applied plots might be due to the fact that potassium is an element which is not converted to the organic form in soil and thereby more prone to easy loss. Always a combination of organics and inorganics is preferred to reduce the loss and enhance the availability to the plants. The highest K uptake obtained in plots which received full organics alone highlights the favourable effect of organic matter in sustaining nutrient availability to the crop.

5 Soil studies

All the observations are given in Table 14. Various interaction effects are shown in Tables 15, 16 and 17.

5.1 Organic carbon

Tillage and herbicide application had no significant effect on organic carbon content of the soil. However, minimum tilled plots recorded higher value of organic carbon. Similarly, plots without herbicide application recorded higher organic carbon content in soil. (Fig.5)

Among the fertilizer treatments half the recommended doze of fertilizer together with VAM inoculation gave the highest value of organic carbon content ie., 0.57 per cent. It was closely followed by the application of half the recommended doze of fertilizer. Organic carbon content of the soil were found to be lowest in plots which received full recommended doze of fertilizer.

Among the interaction tillage x herbicides, tillage x fertilizer, herbicide x fertilizer were significant. In herbicide-fertilizer interaction the highest organic

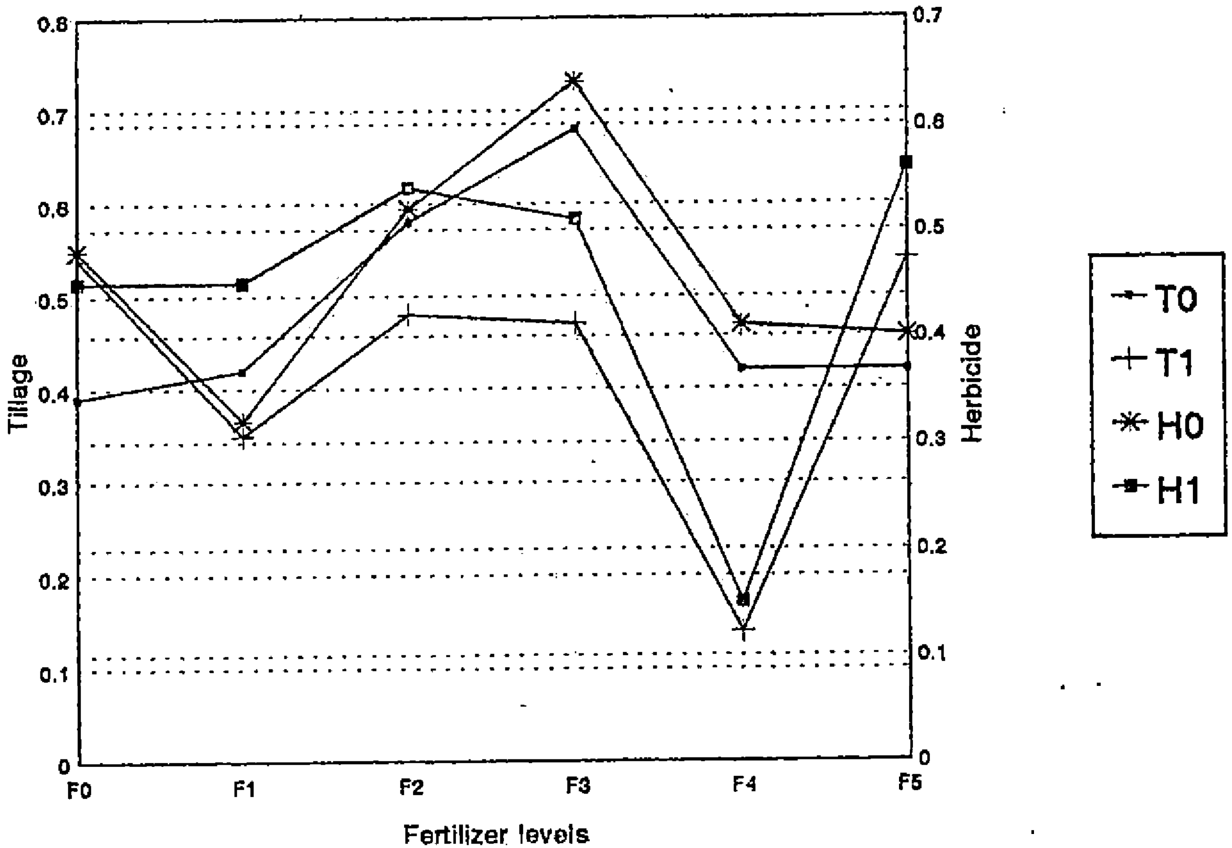


Fig.5 Interaction effect of fertilizer,tillage and herbicide levels on organic carbon

Table 14. Soil characters as influenced by tillage, herbicide and fertilizer levels

Variable	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	Available Zn (kg ha^{-1})
<u>Tillage</u>					
T0	0.48	136.24	14.64	212.28	0.14
T1	0.42	123.26	16.51	226.37	0.13
<u>Herbicide</u>					
H0	0.46	120.44	16.08	205.23	0.13
H1	0.44	139.06	15.07	233.42	0.14
<u>Fertilizer</u>					
F0	0.47^{ab}	118.25	14.00	201.97^{bc}	0.12
F1	0.38^{ab}	147.17	16.38	264.60^{a}	0.15
F2	0.53^{a}	144.40	15.81	219.93^{bc}	0.15
F3	0.57^{a}	142.13	19.38	230.09^{b}	0.12
F4	0.28^{b}	105.28	16.09	184.95^{c}	0.14
F5	0.48^{ab}	121.28	13.78	214.40^{bc}	0.12
	S			S	

T - Tillage level; H - Herbicide level; F - Fertilizer level; S - Significant
The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

Table 15. Interaction effects between fertilizers and tillage treatments for soil parameters

F/T	Organic carbon (%)		Available nitrogen (kg ha^{-1})		Available phosphorus (kg ha^{-1})		Available potassium (kg ha^{-1})		Available Zn (kg ha^{-1})	
	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1
F0	0.39bc	0.54abc	148.76	87.75	14.98	13.02	190.32def	213.62bcde	0.11	0.12
F1	0.42bc	0.35c	147.03	147.32	16.99	15.77	278.45a	250.75ab	0.15	0.15
F2	0.58ab	0.48bc	145.79	143.00	13.47	18.16	194.41def	245.46ab	0.15	0.15
F3	0.68a	0.47bc	143.73	140.53	15.79	18.97	227.41bcd	232.77bc	0.11	0.13
F4	0.42bc	0.14d	114.36	96.21	12.45	19.73	199.96cdef	169.94f	0.16	0.13
F5	0.42bc	0.54abc	117.78	124.78	14.15	13.41	183.13ef	245.66ab	0.14	0.11
	S		NS		NS		S		NS	

F - Fertilizer; T - Tillage level
NS - Non significant; S - Significant
The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

Table 16. Interaction effects between herbicide and fertilizer treatments for soil parameters and mycorrhizal observations

F/T	Organic carbon (%)		Available nitrogen (kg ha^{-1})		Available phosphorus (kg ha^{-1})		Available potassium (kg ha^{-1})		Available Zn (kg ha^{-1})		Spore count No./100 g soil		Infection percentage	
	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1
F0	0.48^{abc}	0.45^{abc}	106.88	129.63	14.79	13.21	179.49^{d}	224.46^{bc}	0.11	0.13	56.67	54.00	47.17	57.33
F1	0.32^{cd}	0.45^{abc}	122.08	172.26	17.05	15.71	249.89^{ab}	279.30^{a}	0.15	0.14	58.0	59.33	51.83	50.67
F2	0.52^{ab}	0.54^{ab}	139.18	149.61	16.81	14.82	196.30^{cd}	24.57^{ab}	0.14	0.15	60.33	59.33	52.00	50.00
F3	0.64^{a}	0.51^{abc}	146.57	137.69	18.20	16.56	190.12^{cd}	270.06^{a}	0.12	0.13	72.33	69.00	71.50	59.33
F4	0.41^{bc}	0.15^{d}	91.79	118.78	14.70	17.47	192.50^{cd}	177.40^{d}	0.14	0.15	57.67	56.67	49.50	52.83
F5	0.40^{bc}	0.56^{ab}	116.15	126.40	14.90	12.66	223.08^{bc}	205.71^{cd}	0.13	0.1	57.32	56.00	53.33	49.50
	S		NS		NS		NS		NS		NS		NS	

F - Fertilizer; H - Herbicide level

NS - Non significant; S - Significant

The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

Table 17. Interaction effects between tillage and herbicide for soil parameters and mycorrhizal observations

F/T	Organic carbon (%)		Available nitrogen (kg ha^{-1})		Available phosphorus (kg ha^{-1})		Available potassium (kg ha^{-1})		Available Zn (kg ha^{-1})		Spore count No./100 g soil		Infection percentage	
	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1	H_0	H_1
T0	0.58a	0.39b	13.36	141.12	14.48	14.79	203.69	220.86	0.14	0.13	61.44	59.56	52.22	52.39
T1	0.34b	0.50ab	109.53	137.00	17.67	15.35	206.76	245.97	0.12	0.14	59.33	58.56	56.22	54.17
	S		NS		NS		NS		NS		NS		NS	

F - Fertilizer; T - Tillage level; H - Herbicide level

NS - Non significant; S - Significant

The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

carbon obtained with interaction between half recommended doze of fertilizer along with VAM and without herbicide application. Highest organic carbon obtained with the interaction between minimum tillage and without herbicide which was on par with the interaction between normal tillage and herbicide application. Among the tillage x fertilizer interaction highest organic carbon content obtained with the interaction between minimum tillage and half of the recommended doze of fertilizer along with VAM.

Though the results revealed no significant difference between tillage treatments the higher organic carbon content in minimum tilled plots indicates the harmful effect of direct exposure of soil to solar radiation. The exposure to solar radiation leads to quick oxidation of carbonaeceous materials from the soil. By tillage more soil is brought to direct exposure to sunlight leading to a reduction in organic carbon content. The herbicide applied plots recorded a lower content of organic carbon. The herbicide along with the soil moisture stress and high atmospheric temperature might have triggered the oxidation process bringing about decrease in the organic carbon content.

The highest organic carbon content in the VAM inoculated plot indicates the beneficial role of VAM in assimilating soil nutrients and making them available to the plants. Above results also pinpoint the harmful effect of inorganic nutrition alone in destroying the fertility status of the soil. When inorganics alone are applied the chances of loss of nutrients from the soil is more because of the absence of organic matter. Even for a temporary locking up of the nutrient elements in the soil organic matter is essential.

The highest organic carbon content in the minimum tilled VAM inoculated plots indicates the minimum soil disturbance preferred by the fungi together with the reduced direct exposure of the soil to the sun. This again supports the lowest organic carbon content of 0.14 per cent in regularly tilled plots with inorganic nutrition alone (Table 15). Significance of organics in restoring soil fertility and minimum tillage in lessening the detereoration of soil are emphasized in the study. The highest organic carbon content in the minimum tilled plots without herbicide application might be because of two reasons. Initially, tillage brings about more soil under direct exposure to sun favouring oxidation of carbonaeceous materials. The weather induced soil stress aggravate the speed of the above process thus enabling the accumulation of organic carbon in least disturbed soil without herbicide application.

The herbicide fertilizer interaction showing the superiority of VAM inoculated treatment without herbicide application indicates that herbicide application is not favourable for the activity of VAM as the basic activity of VAM is to enhance the supply of plant nutrients by their cycling in the soil.

5.2 Available nitrogen

No significant difference was observed between tillage, herbicide and fertilizer treatments with respect to available nitrogen content of the soil. But available nitrogen content was higher in minimum tilled plots and in plots without herbicide application.

Among the fertilizer treatments available nitrogen was highest in plots treated with full recommended dose of fertilizer and lowest in plots where full recommended doze of inorganic fertilizer alone was given.

All the interactions were not significant.

The status in the soil followed the same trend as that of organic carbon because of the very same reasons.

5.3 Available phosphorus

Tilled plots recorded more available phosphorus content in the soil though the difference was not significant. Herbicide treatments also showed no significant difference. Any way plots without herbicide application registered relatively more available phosphorus (Fig.6).

With respect to fertilizer level highest value was observed in plots where half the recommended dose of fertilizer was applied along with VAM inoculation and it was followed by full recommended dose of fertilizer. Available phosphorus was lowest in plots treated with organics alone.

The interaction effects were not significant.

Though the fertilizer treatments had no significant difference VAM inoculation along with organics and inorganics recorded highest value because of its inherent ability to assimilate more phosphorus from deeper soil layer (Hamel, 1992).

5.4 Available potassium

No significant difference was observed between tillage levels. However available content of the soil was higher in tilled plots when compared with that in minimum tilled plots.

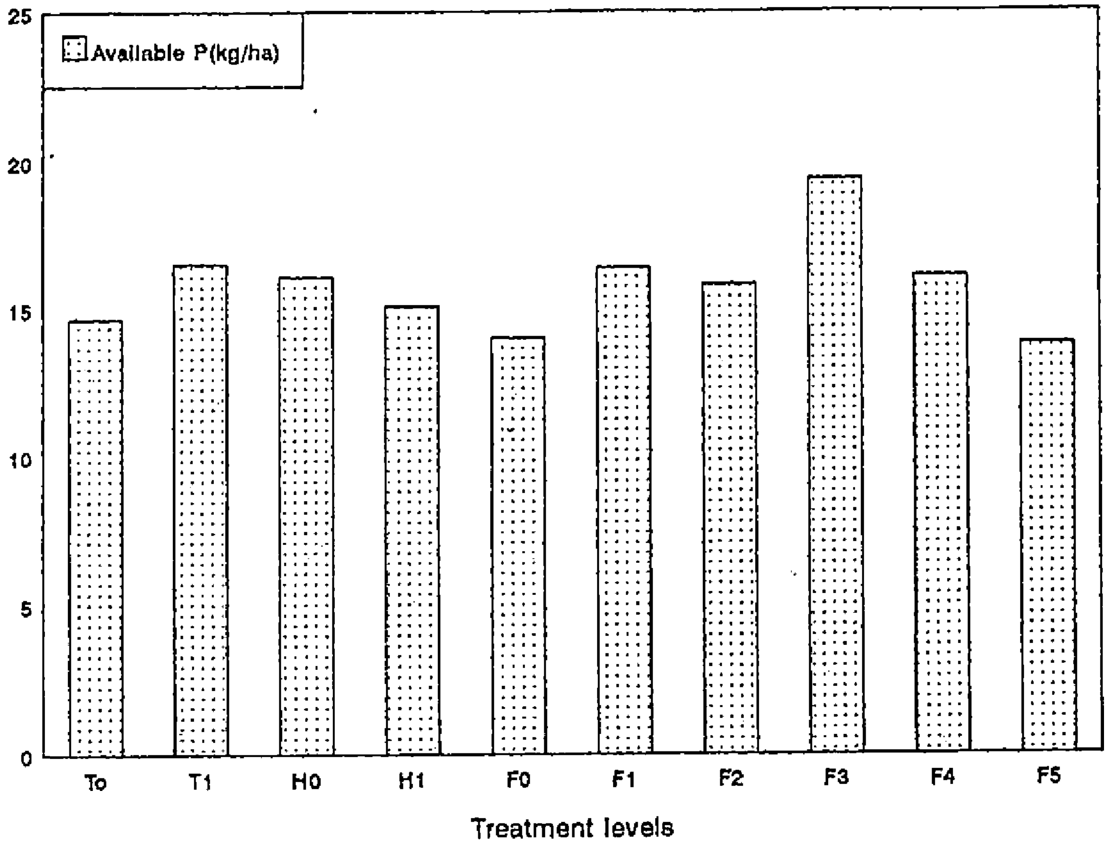


Fig.6 Available phosphorus as influenced by tillage, herbicide and fertilizer levels

Herbicide and fertiliser levels had significant effect on available K. Herbicide treated plots recorded more available K content in soil and it was superior to the no-herbicide treatment.

Among the fertilizer treatments full recommended dose of fertilizer registered the highest available K content in the soil. It was followed by half the recommended dose of fertilizer along with bioinoculant VAM. The lowest available K content was found in plots which received the application of inorganics alone.

Among the interactions herbicide x fertilizers and tillage x fertilizers interactions were found to be significant. In the case of interaction between tillage and fertilizer levels the highest available potassium obtained in the interaction between minimum tillage and full recommended doze of fertilizer. Interaction of full recommended dose of fertilizer, half the recommended dose and full organics alone with normal tillage showed the similar effect on available potassium in soil. In the case of herbicide-fertilizer interaction the highest value was obtained with the interaction of full recommended doze of fertilizer and with herbicide applied. It was followed by the interaction between half the recommended doze of fertilizer along with VAM and with herbicide.

Though the tillage operations had no significant difference available K was higher in regularly tilled plots indicating the favourable effect of soil exposure to direct sun. When the solar radiation is allowed to act upon the soil, potassium moved down into the soil will be brought back to the surface enhancing its availability to the plants. Potassium is not converted into any organic form in the soil and hence increasing the exposure to sunlight can increase the availability. So in terms of potassium availability to the plant tilling is always favourable. Higher available K in the herbicide applied plots indicates that, activity of microbes is less associated with the availability of this particular nutrient as against organic carbon or available nitrogen.

The highest available K content in plots which received full recommended doze of fertilizer highlights the point that this nutrient element is not converted to organic form in the soil and hence not at all related with the organic matter supply.

Full recommended doze of fertilizer with minimum tillage and regular tillage were comparable in available potassium content of the soil indicating the importance of combination of organics and inorganics maintaining the K status of the soil.

5.5 Available sulphur

Turbidemetric method (Massoumie and Cornfield, 1963; Hesse, 1971) was tried and repeated for the estimation of available sulphur but turbidity was not obtained in the analysis.

5.6 Available Zinc

Tillage, herbicide levels and fertilizer levels had no significant effect on available Zn content in soil. However, minimum tilled plots and herbicide applied plots recorded more value (Fig.7).

Highest Zn content was observed in plots where full recommended dose of fertiliser was given.

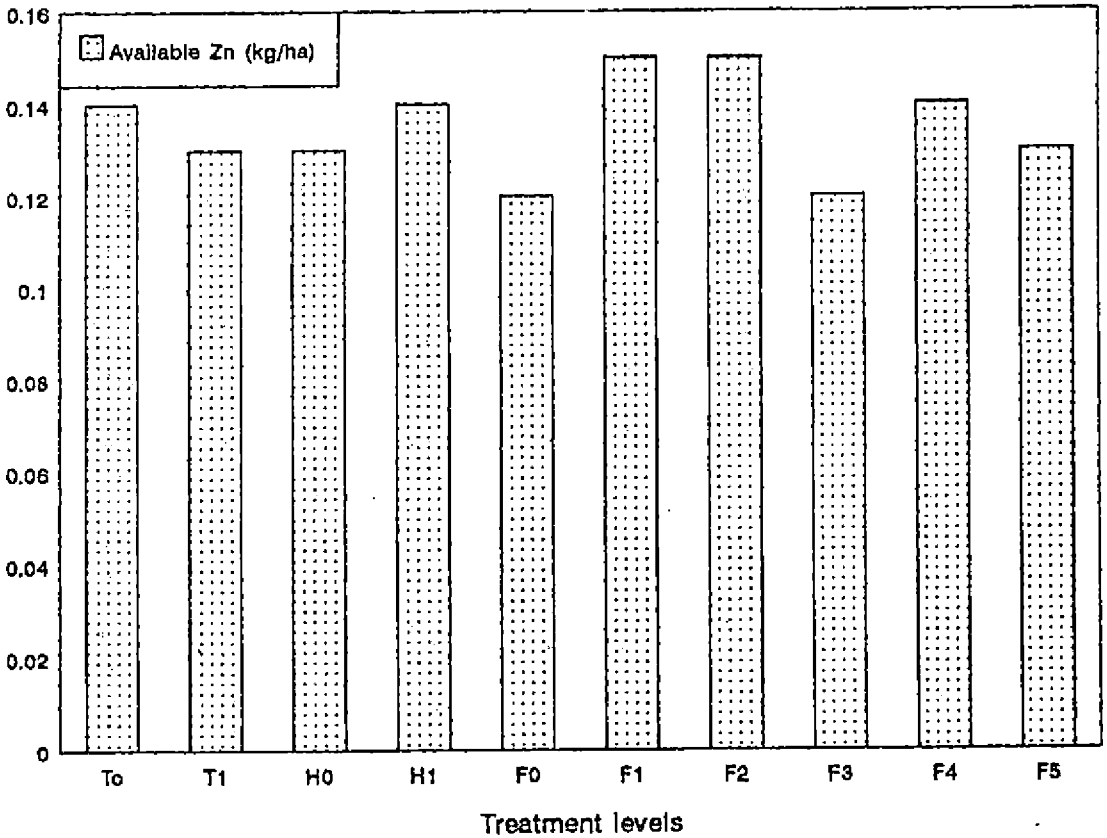


Fig.7 Available zinc as influenced by tillage, herbicide and fertilizer levels

In general plots received inorganic nutrition gave higher values for Zn content. Half the recommended dose of fertiliser together with VAM and full organics alone registered comparatively lower content of available Zn.

Interaction effects were not significant.

Addition of organics and inorganics to soil affects the availability of both added and native nutrients. This might be the reason for high Zn status in the plots which received full recommended doze of fertilizer.

6 Mycorrhizal observation

6.1 Spore count

A typical spore of *Glomus fasciculatum*(Plate 6)

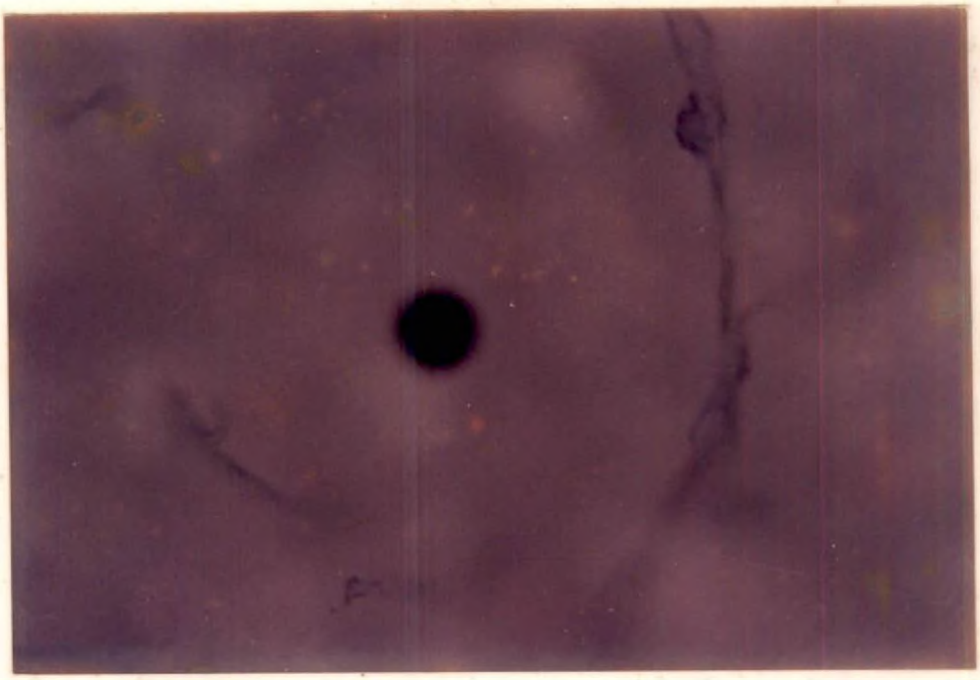
Though tillage and herbicide treatments had no significant effect on mycorrhizal spore count tilled plots and plots without herbicide application recorded more number of spores (Table 18).

With respect to fertilizer levels half the recommended dose of fertiliser along with VAM inoculation registered the highest value of 70.67. Lowest value was noticed in plots without any organics or inorganics. However, full and half the recommended dose of fertilizer gave similar results with half the recommended dose of fertilizer along with VAM recording more spore number.

All the interactions were not significant (Table 16,17 and19).

Plate 6. A typical spore of *Glomus fasciculatum*

Plate 7. Mycelia of VAM with small vesicles



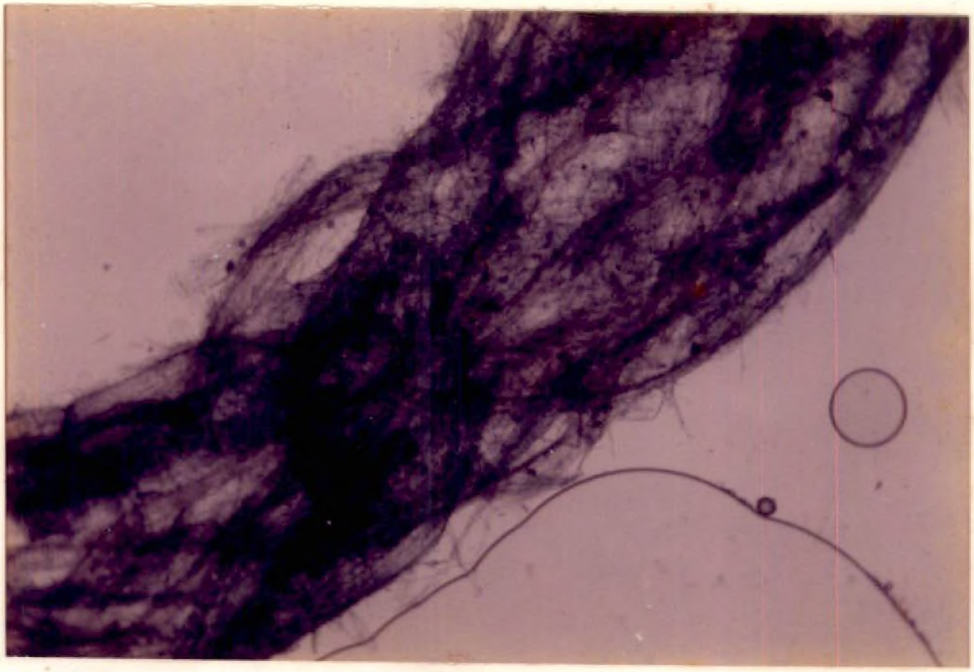


Table 18. Mycorrhizal observations as influenced by tillage, herbicide and fertilizer levels

Variables	Spore count (number/100 g soil)	Infection percentage (%)
Tillage		
T0	60.50	52.31
T1	58.94	55.19
Herbicide		
H0	60.39	54.22
H1	59.06	53.28
Fertilizer		
F0	55.33[b]	52.25
F1	58.67[ab]	51.25
F2	59.83[ab]	51.00
F3	70.67[a]	65.42
F4	57.17[b]	51.17
F5	56.67[b]	51.42
	S	

T - Tillage level; H - Herbicide level; F - Fertilizer level; S - Significant
The treatment means in the column with the same alphabets or having an alphabet in common do not differ significantly

Table 19. Interaction effect between fertilizers and tillage treatments for mycorrhizal observations

Fertilizers/ Tillage	Spore count (number/100 g soil)		Infection percentage (%)	
	T_0	T_1	T_0	T_1
F0	54.67	56.00	49.00	55.50
F1	58.00	59.33	50.67	51.83
F2	61.00	58.67	45.17	56.83
F3	70.33	71.00	69.67	61.17
F4	61.37	53.00	51.67	50.67
F5	57.67	55.67	47.67	55.17
	NS		NS	

T - Tillage level; H - Herbicide level; F - Fertilizer level
S - Significant

Inoculation of the bioinoculant contributed the higher spore count in the plots which received half the recommended doze of fertilizer along with VAM.

6.2 Infection percentage

Mycelia of VAM with small vesicles(Plate 7)

With respect to tillage and herbicide treatments. Infection percentage followed the same trend as that of spore count. Tilled plots and plots without the application of herbicide registered higher percentage infection.

Fertiliser levels had significant effect on infection percentage. Highest value was observed in plots which received half the recommended dose of fertilizer together with VAM.

The interaction were not significant.

Inoculation of VAM is responsible for the highest infection percentage in the treatment received half the recommended doze along with VAM.

Summary

SUMMARY

A field experiment was conducted at the Agricultural Research Station, Mannuthy, during the summer season (January-April, 1997) to study the effect of tillage practices and use of agrochemicals on VAM population in cowpea.

The experiment was laid out in strip plot design with 24 treatment combinations replicated thrice. Combination of tillage and herbicide levels were tried in parallel strips. Fertilizer levels were allotted across these strips. Tillage levels were minimum and normal tillage. Fertilizer levels consisted of control, full recommended dose of fertilizer i.e., inorganics and organics, half the recommended doze of fertilizer i.e., inorganics and organics, half the recommended doze of fertilizer i.e., inorganics and organics along with VAM, full recommended doze of inorganics alone and full recommended doze of organics alone.

The growth characters were plant height, number of branches per plant, leaf area, drymatter production and number and dry weight of nodules.

Though no significant difference was observed between tillage treatments, growth characters like plant height and drymatter production were favourably influenced by minimum tillage in summer. Herbicides also had no significant effect on growth characters. However, drymatter production was found to be favoured by no herbicide application.

Fertilizer levels had significant influence on leaf area and drymatter production. For all growth characters half the recommended doze of fertilizer along with VAM performed superior to full recommended dose of fertilizer or equally well with the same.

Yield attributing characters observed were days to 50 per cent flowering, total number of pods per plant, weight of pods per plant, weight of grains per plant, number of seeds per pod, weight of 100 seeds, pod yield per ha, grain yield per ha and stover yield per ha. Tillage and herbicide levels did not have any significant influence except in the case of 50 per cent flowering in which minimum tilled plots recorded earlier flowering. Number of pods per plant and weight of 100 seeds were significantly influenced by fertilizer levels.

Although tillage had no significant influence on most of the yield attributing characters, minimum tillage had advantage over normal tillage in most of the characters, except weight of grains per plant and number of seeds per pod. All the yield attributing characters except test weight were influenced favourably with no herbicide application. Among the fertilizer levels full recommended doze of fertilizer was superior to the other fertilizers levels in deciding characters like number of pods per plant, weight of pods per plant, weight of grains per plant, pod yield per ha and grain yield per ha. In most cases full recommended doze of fertilizer was comparable with half the recommended doze of fertilizer along with VAM and full organics alone. Half the recommended doze of fertilizer along with VAM was superior to full recommended doze and full organics alone in the case of number of seeds per pod and test weight of 100 seeds.

Minimum tillage had advantage over normal tillage with respect to nitrogen and potassium uptake and with phosphorus content in crop. In the case of phosphorus uptake normally tilled plots recorded higher value. Nitrogen uptake was highest in plots received full recommended doze of fertilizer where as phosphorus and potassium uptake were higher for half the recommended doze of fertilizer together with VAM and it was comparable with full organics alone in most of the cases.

Soil studies revealed higher organic carbon, available nitrogen, available potassium and available zinc content in minimum tilled plots. However, normally tilled plots recorded higher available phosphorus content. Only organic carbon and available nitrogen were higher in plots without herbicide application. Full recommended doze of fertilizer and half the recommended doze of fertilizer along with VAM performed equally well in most of the soil characters such as organic carbon, available phosphorus and available potassium content of soil.

Tillage operations had no significant influences on spore count and infection percentage. Higher spore count and infection percentage were observed in plots without herbicide application. Higher spore count and infection percentage were noticed in VAM inoculated treatments.

Among the interaction effects tillage x fertilizer interactions were significant in percentage nitrogen in plant, protein content of grain, organic carbon status and available potassium in soil. Herbicide x fertilizer interactions were significant in the case of percentage nitrogen, uptake of nitrogen, percentage phosphorus in plant, organic carbon status of soil and available potassium of soil. Tillage x herbicide interactions significantly influenced only on organic carbon status of soil.

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Appendices

APPENDIX-1

Weather data at monthly intervals during the experimental period (January 1997 to April 1997)

Month	Rainfall (mm)	Temperature °C		Relative humidity (%)	Sunshine (hrs)	Wind speed (Km/h)
		Maximum	Minimum			
January	0.0	32.0	22.9	61.5	9.6	6.9
February	0.0	33.9	21.8	60.5	9.3	3.9
March	0.0	35.7	24.0	59.5	9.5	4.0
April	8.2	35.2	24.5	66.5	9.6	3.3

APPENDIX-II

Treatment wise cost of cultivation

Comparison of cost of factors at different levels

a) Fertilizer	Rs./ha
F_0 Control	0
F_1 Full recommended doze (P-O-P)	9420
F_2 Half the recommended doze of (P-O-P)	4860
F_3 Half the recommended dize of (P-O-P) + VAM	5100
F_4 Full inorganic alone	819
F_5 Full organic alone	8900

*Fertilizer costs are inclusive of application charges

b) Tillage	
T_0 Minimum tillage (one tractor ploughing)	700
T_1 Normal tillage (tractor ploughing and secondary tillage with tiller)	1900

c) Herbicide	
H_0 Without herbicide	0
H_1 Herbicide	1150

ROLE OF TILLAGE/AGROCHEMICAL USE ON VAM IN COWPEA IN RICE FALLOW

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ABSTRACT OF THE THESIS

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ABSTRACT

A field experiment was conducted at the Agricultural Research Station, Mannuthy in summer rice fallow during January-April, 1997. The study was to assess the effect of tillage practices and use of agrochemicals on soil VAM and to analyse the possibility of any saving in inorganic fertilizer use. Effect of summer cropping on improvement of soil health was also aimed at.

The experiment was laid out in strip plot design with 24 treatment combinations replicated thrice. Combination of tillage and herbicide levels were tried in parallel strips. Fertilizer levels were given across these strips. Tillage levels included minimum and normal tillage. Fertilizer levels consisted of control, full recommended doze of fertilizer i.e., inorganics and organics, half the recommended doze of fertilizer i.e., inorganics and organics, half the recommended doze of fertilizer i.e., inorganics and organics along with VAM, full recommended dose of inorganics alone and full recommended doze of organics alone.

Results revealed that most of the growth characters were not significantly influenced by tillage treatments. However, with respect to plant height and drymatter production higher values were observed in minimum tilled plots. Yield attributing characters favourably influenced by minimum tillage were number of pods per plant, weight of pods per plant, test weight, pod yield per ha, grain yield per ha and stover yield per ha. Nitrogen and phosphorus uptake were favoured by minimum tillage. Organic carbon status, available nitrogen and available zinc were higher in minimum tilled plots.

Most of the growth and yield attributing characters were not affected by herbicide application. Soil studies revealed slightly lower values for organic carbon, available nitrogen and available phosphorus content in herbicide applied plants.

Fertilizer levels had more significant influence on yield attributes and soil nutrient levels. In all the growth characters half of the recommended doze of fertilizer along with VAM was superior or equally well as that of full recommended doze of fertilizer and full organics alone. The same combination fared well with most of the yield characters also.

Among the interaction effects tillage x fertilizer interactions were significant in percentage nitrogen in plant, protein content of grain, organic carbon status and available potassium in soil. Herbicide-fertilizer interactions were significant in the case of percentage nitrogen, uptake of nitrogen, percentage phosphorus in plant, organic carbon status of soil and available potassium of soil. Tillage and herbicide interactions significantly influenced only on organic carbon status of soil.

To conclude, minimum soil disturbance was preferred in summer cropping. The use of agrochemicals especially herbicide (Alachlor) in the normal recommended doze of 2.5 kg ai/ha was rather safe on VAM population in soil. Integrated nutrient management comprising of the use of organics, inorganics and bioinoculant was more cost effective and desirable in terms of crop performance and improvement in soil health.