INTEGRATED NUTRIENT MANAGEMENT IN CHILLI (*Capsicum annuum* L.)

By

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DECLARATION

I hereby declare that this thesis entitled **"Integrated nutrient management in chilli (*Capsicum annuum* L.)"** 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, associateship, fellowship or other similar title, of any other University or Society.

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Vellayani,
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CERTIFICATE

Certified that this thesis entitled **"Integrated nutrient management in chilli (*Capsicum annuum* L.)"** is a record of research work done independently by **Ms. Sharu. S. R.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Dedicated

to my beloved

Father

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LIST OF ABBREVIATIONS

@	-	at the rate of
CD	-	Critical difference
cm	-	centimetre
CF	-	Chemical fertilizer
CGR	-	Crop growth rate
DAT	-	Days after transplanting
DMP	-	Dry matter production
et al.	-	and others
FYM	-	Farmyard manure
Fig.	-	*Figure*
g	-	gram
ha	-	hectare
K	-	Potassium
kg	-	kilogram
LAI	-	Leaf area index
mg	-	milligram
m	-	metre
N	-	Nitrogen
NC	-	Neem cake
NAR	-	Net assimilation rate
P	-	Phosphorus
PM	-	Poultry manure
POP	-	Package of Practices
q	-	quintal
Rs.	-	Rupees
RGR	-	Relative growth rate
RBD	-	Randomised block design
SE	-	Standard error
t	-	tonnes
VC	-	Vermicompost

INTRODUCTION

1. INTRODUCTION

The current food production of India is 198 million tonnes. With this, the country is committed to add 35 million tonnes more by the year 2020 AD to feed an estimated population of 1025 million (Gowda and Babu, 1999). With the ever increasing population, the requirement of larger production of food grains and other agricultural commodities and existing low yield levels of most of the crops suggest the scope and need for increasing the production of almost all crops through intensification of agriculture. Intensive agriculture is nothing but a high input - high output system. Such a system has to be managed so as to ensure its sustainability accompanied by the maintenance of soil fertility and protection of environment (Motsara, 1999). Thus it become imperative to develop a technology or package which would bring about substantial increase in production with least disturbance to our precious earth and environment.

Vegetables are protective supplementary foods and are rich sources of vitamins and minerals. They serve as roughage and improve digestion. They can supply Ca, P and Fe in sufficient quantities. The green leafy vegetables are rich in vitamin A and vegetables like chilli, tomato and potato are rich in vitamin C.

India ranks second in vegetable production with an estimated area of 5 million hectare and production of 66 million tonnes. The productivity per hectare is 13.16 tonnes (Chadha, 1999).

As far as Kerala is concerned, the extent of cultivated land is limited and hence we should exploit the potential of vegetable production fully through proper agronomic practices. The indiscriminate use of chemicals and tendency of farmers to abandon the use of FYM, compost, green manure or incorporate crop residue in the soil, lead to soil degradation. A global loss of productive crop land due to soil degradation is estimated to be 60 to 70 lakh hectare each year (Misra *et al.*, 1999). Proper soil management without impairing soil health is a prerequisite for achieving higher productivity from agricultural land (Anina, 1995). Here comes the importance of Integrated Plant Nutrient Management (IPNM) which is ecologically sound, economically viable and socially just. The basic concept of IPNM for sustaining yield is the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of the benefit from all possible sources of plant nutrient in an integrated manner (Malik, 1999).

Inorder to improve and maintain soil fertility for sustaining the desired level of crop production, we need a judicious use of chemical fertilizer, organic manures and biofertilizers and not the total discard of fertilizer. The use of organic sources as fertilizers (nutrients) are known from the beginning of agriculture till 1952 (Gowda and Babu, 1999). India has a vast potential of manurial resources. FYM and poultry manure are commonly used organic manures. Poultry manure is a rich source of nutrients especially for vegetable production (Jose *et al.*, 1988). Neem cake contains the alkaloids nimbin and nimbidin which effectively inhibit the nitrification process (Sahrawat and Parmer, 1975; Reddy and Prasad, 1975; Rajkumar and Sekhon, 1981). Vermicompost contains various amino acids, minerals and micro organisms which humidify the organic matter in the surrounding soil and acts as a biofertilizer for plants (Shanbhag, 1999).

Chilli is one of the most important solanaceous vegetables which has a prominent position in Kerala. It is an indispensable adjunct to the diet of people. Chilli imparts pungency to culinary purpose and is used for adding red colour and seasoning. It is a rich source of vitamin C and A in its fresh state.

Keeping these views under consideration the present investigation entitled "Integrated nutrient management in chilli (*Capsicum annuum* L.)" was carried out in red loam soils of the Instructional Farm, College of Agriculture, Vellayani southern region of Kerala with the following objectives.

1. To study the combined effect of organic manures and chemical fertilizers on the productivity and quality of chilli.

2. To assess the possibility of substitution of fertilizers by organic manures, and

3. To work out the economics of production.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The demands for food has to be met by raising the productivity through increasing the fertility of the soils and bringing more area under irrigation. Fertilizer nutrients are costly inputs and pose problems on soil health and pollution on a long run. Therefore, during the recent past, our agriculture urged the use of organic sources of nutrients (Gowda and Babu, 1999).

An investigation was carried out at the College of Agriculture, Vellayani during the period from August to January 1999-2000 to study the combined effect of organic manures and chemical fertilizers on the productivity and quality of chilli. The literature collected pertaining to the above subject are reviewed hereunder. Wherever sufficient literature is not available on the crop tried in this experiment, results of similar experiments conducted on other related crops are also cited.

2.1 Organic manures

Organic manures contain more or less all nutrient elements required for plant growth. When it is applied to soil it helps to improve soil aeration, permeability, aggregation, water and nutrient holding capacity and biological properties of soil. The organic acids like hydroxy and tartaric acid, citric acid etc. trap the toxic elements like Fe and Al through chelation and remove them from root environment by forming insoluble precipitates. It also acts as a buffer and keeps the soil pH within the desired range (Banerjee, 1998).

2.1.1 Effect of organic manures on growth, yield, quality and soil properties of vegetables

Increase in the yield of chilli, bhindi, tomato and brinjal by organic manure application was reported by Gaur *et al.* (1984). Organic manures like FYM, compost, oilcakes, green leaf, poultry manure etc. improve the yield as well as quality of vegetable crops like tomato, onion, gourds, chillies etc.

Thamburaj (1994) found that organically grown tomato plants were taller with more number of branches. They yielded 28.18 t ha^{-1} which was on par with the recommended dose of FYM and NPK (20:100:100).

Luchnik (1975) reported that the use of organic manures resulted in high sugar and vitamin C content which resulted in better keeping quality of cabbage. Concentration of potassium in seedling tissues of vegetable crops like snap bean, cucumber, radish and tomato increased progressively as the levels of mushroom spent compost increased (Sherry Hsiao Lei Wang *et al.*, 1984). In oriental pickling melon the organic form of manures showed definite advantage over inorganic fertilizers in respect of storability while the degree of rotting increased in treatment which received inorganic form of NPK (KAU, 1987). Increase of ascorbic acid content in tomato, pyruvic acid in onion and minerals in gourds are the impact of application of organic manures to vegetable crops (Rani *et al.*, 1997).

Olsen *et al.* (1970) reported that addition of manures increased the soil pH. Srivastava (1985) observed that the application of organic manures resulted in increased organic carbon content, total N and available P and K status of soil. More (1994) reported that addition of farm waste and organic manures increased the status of available nitrogen and available phosphorus of the soil.

From the review, it is revealed that the yield, quality and nutrient uptake was positively influenced by the application of organic sources of nitrogen.

2.2 Poultry manure

Poultry manure is a good source of nutrient particularly for vegetable production. Singh and Srivastava (1971) and Singh *et al.* (1973) attributed the higher efficiency of poultry manure to its narrow C:N ratio and comparatively higher content of readily mineralisable nitrogen. In this manure, 60 per cent of the nitrogen is present as uric acid, 30 per cent as more stable organic nitrogen forms and balance as mineral nitrogen (Srivastava, 1988). When entire quantity of poultry manure is applied as basal, more than 60 per cent of its N present as uric acid rapidly changes to ammoniacal form. Besides this, of the nitrogen mineralised during the first two to three months of the application of organic source, 80 per cent is converted to NO_3 at the end of first three weeks (Tisdale *et al.*, 1995).

2.2.1 Effect of poultry manure on growth characters

In poultry manure 60 per cent of N is present as uric acid which readily changes to ammoniacal form of N which become available to plant immediately and thereby increase growth and yield of the plant (Smith, 1950). A study on optimum level of poultry manure requirement for cauliflower by Singh *et al.* (1970) revealed progressive increase in growth and yield of cauliflower when the dose was increased from 0 to 169.6 q ha^{-1}. Singh *et al.* (1973) reported that in potato, poultry manure application exhibited better response than FYM on yield and growth attributes like height of the plant, number of shoots and number of leaves per plant. Anitha (1997) reported that in chilli various growth attributes like plant height, number of branches and dry matter production were better with poultry manure application as compared to FYM or vermicompost.

2.2.2 Effect of poultry manure on yield and yield attributes

Abusaleha (1981) reported early flowering and highest yield of 18.02 t ha^{-1} with the application of half of nitrogen through poultry manure in bhindi. In lettuce, poultry manure applied at 0, 20 and 40 kg ha^{-1} either as entire basal dose or in splits increased the yield from 0.66 to 0.81 and 0.90 kg $plant^{-1}$ (Anez and Tavira, 1984). Mina (1986) reported that application of poultry manure alone and in combination with NPK fertilizer mixture irrespective of the rates significantly increased the yield of musk melon. Poultry manure treated chilli plants showed better yield and yield attributing characters as compared to FYM and vermicompost application (Anitha, 1997). Poultry manure treated plots showed maximum number of flowers and fruits leading to maximum fruit set percentage in brinjal. The marketable fruit yield was highest for the above treatment (Rekha, 1999).

2.2.3 Effect of poultry manure on quality aspects

Application of poultry manure showed a slight increase in the ascorbic acid content of cauliflower. The higher vitamin C content was obtained in the curds with 169.6 q ha^{-1} of poultry manure. The protein content of potato gradually increased with higher levels of poultry manure (Singh *et al.*, 1970). Importance of micronutrients like boron in keeping quality of fruits and tubers was indicated by Tisdale *et al.* (1995). Anitha (1997) reported that plants treated with poultry manure recorded the maximum ascorbic acid content of fruits as compared to vermicompost treated plants and control treatment in chilli. Joseph (1998) observed that in snake gourd, poultry manure treated plants recorded the highest crude protein content and lowest crude fibre content as compared to that of FYM and vermicompost treated plants.

2.2.4 Effect of poultry manure on soil properties

According to Bitzer and Sims (1988) poultry manure increased the levels of B, Ca, Mg, Cu and Zn in the soil. Anitha (1997) observed better uptake of N in poultry manure treated chillies as compared to control.

The review reveals that poultry manure greatly influence the growth and yield characters of vegetables. In general higher yield was obtained when poultry manure was applied in higher dose.

2.3 Vermicompost

Vermicompost is a potential organic manure that can be prepared in small farm holdings with family labour, its use can reduce the cost of cultivation substantially. Moreover vermicompost has a definite advantage over other organic manures in respect of quality and shelf life of the produce (Khankar, 1993).

Vermicompost contains significant quantities of available nutrients, a large beneficial microbial population and biologically active metabolites, particularly gibberellins, cytokinins, auxins and group B vitamins. It can be applied alone or in combination with organic or inorganic fertilizers so as to get better yield and quality of diverse crops. (Gavrilov, 1962; Tomati *et al.*, 1983; Bano *et al.*, 1987). Barve (1993) reported the superiority of vermiculture farming in grape cultivation when compared to chemical farming.

2.3.1 Effect of vermicompost on growth characters

Curry and Boyle (1987) obtained enhanced plant growth in the presence of earthworms which was attributed to an increased supply of readily available plant nutrients. Stolyarenko *et al.* (1992) reported that application of vermicompost stimulated the root and shoot growth of maize plant. In cardamom, Vadiraj *et al.* (1992) observed significant increase in height, number of roots per plant, length of root and fresh and dry weight of seedlings when vermicompost was used as potting mixture. Govindan *et al.* (1995) reported that when KAU package of practice recommendation of organic manure in bhindi @ 12t ha^{-1} was substituted with FYM and vermicompost, 100 per cent vermicompost was found good for biometric characters and yield. Pushpa (1996) observed that biometric observations *viz.*, height of the plant, number of leaves, number of flowers and number of fruits were greatly influenced by the application of vermicompost @ 25t ha^{-1} along with full dose of inorganic fertilizer. The use of vermicompost either as a seed inoculant or as an organic source gives better result in terms of yield as well as growth characters. The quantity of fertilizer can be reduced to half when vermicompost was used as seed inoculant in cowpea (Meera, 1998).

2.3.2 Effect of vermicompost on yield and yield attributes

Sacirage and Dzelilovic (1986) obtained higher dry matter yield in leek by growing in vermicompost applied plots compared to inorganic fertilizer. They also found that application of 4, 6 and 8 kg m^{-2} of vermicompost in cabbage, the dry matter yield increased from 1 to 66 per cent. Kale *et al.* (1991) reported that the level of chemical fertilizer could be brought down to 25-50 per cent when applied with vermicompost. Desai (1993) observed that the yield of capsicum in vermicompost treated plot was comparable to that of chemical fertilizer application. Ismail *et al.* (1993) conducted a comparative evaluation of vermicompost, FYM and fertilizers on yield of bhindi and water melon and observed an increase in yield in all the vegetables with vermicompost.

Sheshadri *et al.* (1993) noticed an increase in yield of chilli in vermicompost treated beds compared to FYM and fertilizer applied plots. Arunkumar (2000) reported highest yield in amaranthus during all harvests when vermicompost was applied @ 25 t ha^{-1} when compared to other organic manures like poultry manure, neem cake and FYM.

2.3.3 Effect of vermicompost on quality aspects

Sharpley and Syres (1977) found increased P availability to plants when vermiwash was used. Evangelista (1986) found that the application of pure earthworm cast showed significant effect on the weight of roots, nitrogen, phosphorus, calcium and magnesium content of the lettuce leaves. Tomati *et al.* (1990) reported that incorporation of vermicompost increased protein synthesis in lettuce and radish by 24 and 32 percentage. According to Anina (1995) application of Eudrillus compost increased the uptake of nutrients by plants. Pushpa (1996) reported an increased uptake of plant nutrients by tomato when vermicompost was used as a source of organic manure compared to FYM. Rajalekshmi (1996) observed an increase in the uptake of nutrients and higher yield in tomato and chilli by the application of vermicompost. Sagaya Alfred and Gunthilagaraj (1996) noticed more N content in amaranthus plant grown with earthworm application.

Scheu (1987) found large amounts of mineralised N in the presence of large earthworm biomass.

2.3.4 Effect of vermicompost on disease incidence

Niranjana (1998) reported that the treatment with vermicompost alone recorded the lowest incidence of leaf blight (4 per cent) in amaranthus.

2.3.5 Effect of vermicompost on soil properties

According to Haimi and Huhta (1990) earthworm increase either directly or indirectly the proportion of mineral N available for plants at any given time, although N was clearly immobilised in the initial stage. Kale *et al.* (1992) observed that vermicompost application enhanced the activity of beneficial microbes like nitrogen fixers and mycorrhizal fungi. It played a significant role in N fixation and phosphate mobilization, leading to higher nutrient uptake of plants. Vijayalekshmi (1993) noticed that soil properties such as porosity, soil aggregation, soil transmission, conductivity and dispersive power of wormcast treated soil were improved when compared with no worm cast amended soil. According to Joseph (1998) cation exchange capacity of soils increased in vermicompost applied plots compared to FYM and poultry manure.

The use of vermicompost as an organic source gave better result in terms of yield as well as growth characters in vegetables. The yield increase was comparable to that of FYM application.

2.4 Oilcakes

Oilcakes of non edible types like castor, neem and karanj are widely used as organic manure. Increase in plant height of bhindi due to oilcake application was reported by Singh and Sitaramaiah (1963). Most of the non edible oilcakes are valued much due to their alkaloid content which inhibits the nitrification process of nitrogen transformation in soil. Neemcake contains the alkaloids nimbin and nimbidin which effectively inhibit the nitrification process (Sahrawat and Parmer, 1975; Reddy and Prasad, 1975; Rajkumar and Sekhon, 1981). Islam and Haque (1992) mentioned the application of oilcakes as an organic manure during land preparation of brinjal, chilli and bhindi for getting higher yield.

2.4.1 Effect of neemcake on growth characters

Som *et al.* (1992) observed the influence of oilcakes on growth and yield of brinjal. The different oilcakes tried were karanj, mahua, mustard and neemcake. The highest plant height of 70.77 cm was recorded when neemcake @ 50 q ha^{-1} was applied.

2.4.2 Effect of neemcake on yield and yield attributes

Shanmugavelu *et al.* (1987) observed that application of mahua cake, castor cake and neemcake @ 500 kg ha^{-1} one day prior to transplanting of tomato, increased the fruit yield by 31.7, 27.8 and 9.0 per cent respectively over control. Studies conducted at KAU revealed that the application of neemcake @ 1 t ha^{-1} before planting gave maximum yield in ginger (KAU, 1990). Som *et al.* (1992) reported that maximum fruit weight of 125.38 g, highest per plant yield of 1.43 kg and highest fruit yield of 22.56 t ha^{-1} in brinjal was obtained when neemcake @ 50 q ha^{-1} was applied. Kadam *et al.* (1993) compared the effect of organic and inorganic sources on yield of betelvine. Among the various sources tried *viz.*, neemcake, karanj cake, neemcake + urea and urea alone, application of N through neem cake produced significant response in increasing the yield of betelvine.

2.4.3 Effect of neemcake on pest and disease incidence

Application of neemcake recorded low gall index or nematode attack in brinjal. This reduced nematode population might be due to the liberation of ammonia during decomposition of oilcakes which was significant to kill nematodes (Kumar, 1988). The combination of the use of 5 or 10 per cent aqueous extract of neemcake for seed treatment and soil drenching under field condition was found as effective as application of carbofuran at 2 kg a.i/ha or neemcake at 2 t ha^{-1} for the management of *Meloidogyne incognita* in okra (Rao *et al.*, 1997).

From the above review, it is clear that among different oilcakes, neem cake application increased the yield greatly and there was also a reduction in the intensity of pest and disease.

2.5 Effect of combined application of organic manure and chemical fertilizers

The balanced supply of nutrients is a prerequisite for successful agriculture. This can be achieved through integrated nutrient management which involves scientific use of organic manures along with chemical fertilizers for sustaining the crop productivity.

In an experiment with inorganic fertilizer and organic manures like FYM, the mixture of fertilizers and manure gave better results than organic manure given alone (Chinnaswamy, 1967). Luchnik (1975) opined that both organic and inorganic fertilization resulted in high sugar and vitamin C content in cabbage. Doikova (1977) recommended combined application of organics and inorganic chemicals, because application of FYM alone proved less effective in increasing the dry matter content in brinjal. Combination of organic manure with inorganic fertilizers had a moderating effect on soil reaction particularly under acidic soil and improvement in sustained availability of N, P, K, S and the micro nutrients particularly zinc (Nambiar and Abrol, 1989).

Nair and Peter (1990) reported highest yield in chilli with 15 t FYM and 5:40:25 kg NPK ha $^{-1}$ on the three season trial when compared to FYM alone or inorganic fertilizer alone. Studies conducted in KAU revealed that the organic and inorganic fertilizers and their combination had significant influence on vegetable productivity and higher rate of nitrogen along with FYM induced earliness and enhanced the fruit yield in clustered chilli (KAU, 1991).

From the review, it is clear that combined application of organic and inorganic fertilizer significantly influence the yield than inorganic manure application alone in vegetables.

2.5.1 Poultry manure and chemical fertilizers

Jose *et al.* (1988) observed an enhanced dry matter production in brinjal with the application of 50 kg N as poultry manure combined with 50 kg nitrogen as urea. In another experiment in brinjal, Abusaleha (1981) reported the highest uptake of nutrients with the combined application of nitrogen in the form of poultry manure and ammonium sulphate which is attributed to the increased dry matter accumulation in plants.

Singh *et al.* (1973) observed that application of 80 kg N through poultry manure along with 80 kg N through inorganic fertilizer produced the highest marketable potato tuber yield of 20.72 q ha^{-1} in comparison with the application of 60 kg N through poultry manure + 60 kg N through inorganic fertilizer (19.80 q ha^{-1}), 120 kg N through poultry manure (18.00 q ha^{-1}) or 160 kg N through poultry manure (16.52 q ha^{-1}) alone. In a trial conducted in bhindi, Abusaleha (1981) noticed early flowering with the application of half the nitrogen through ammonium sulphate and the remaining half through poultry manure. Helkiah *et al.* (1981) stated that the maximum grain yield of jowar was obtained with the application of combination of 30 t ha^{-1} of poultry manure and half the recommended dose of inorganic nutrients. Mina (1986) found out that application of poultry manure alone or in combination with chemical fertilizer irrespective of rate significantly increased the diameter of fruits, fruit weight and yield $plot^{-1}$ in musk melon. Application of 50 per cent of applied nutrient through chemical source together with remaining 50 per cent through poultry manure significantly increased the total tuber yield in potato. (Ifenkwe *et al.*, 1987)

Jose *et al.*, (1988) noticed that brinjal plants supplied with 50 kg N as poultry manure and 50 kg N as urea recorded the highest yield of 51.03 t ha^{-1}. Segovia (1988) observed the higher yields produced by melons when supplied with 100 kg N in conjunction with 10 t ha^{-1} poultry manure. Rala and Garcia (1992) reported that application of 50 per cent N from poultry manure + 50 per cent N from inorganic sources produced the highest yield of upland rice. Dahama (1996) pointed out that substitution of inorganic N with poultry manure upto 120 kg ha^{-1} increased the potato yield to 108 q ha^{-1} compared to control. Ramesh (1997) concluded that poultry manure can be safely substituted for inorganic N fertilizer upto 75 per cent level without any reduction in yield. Rekha (1999) noticed that when poultry manure was substituted with 50 per cent of the recommended chemical fertilizer and used in the ratio 1:1, marketable yield was highest in brinjal when compared to the substitution with neemcake and biogas slurry.

In a field experiment conducted in potato, Singh *et al.* (1973) reported that application of 80 kg ha^{-1} N through poultry manure along with 80 kg ha^{-1} chemical nitrogen produced higher crude protein content of 2.12 per cent compared to that obtained with the application of 160 kg N through poultry manure alone (1.91 per cent). P content of tuber was also significantly higher (0.319 %) with the above mentioned treatment when compared to the single application of 160 kg N through poultry manure (0.246 %). Liebhardt (1976) noticed significantly higher crude protein content in corn grain due to combined application of 22 t ha^{-1} of poultry manure along with chemical fertilizer compared to the check or fertilizer treatment alone. Rajasree (1999) observed that the shelf life of fruits at room temperature was more when nutrient nitrogen was supplied through 2:1 ratio of organic - chemical N substitution using FYM or poultry manure as an organic source.

Jose *et al.*(1988) noted that application of half (50 kg) N as poultry manure along with remaining half (50 kg) as urea increased the uptake of N, P, K, Ca and Mg in brinjal.

According to Liebhardt (1976) there was a significant decrease in the soil K on plots receiving high rates of poultry manure, but this reduction was less apparent when poultry manure was applied along with inorganic fertilizers. In another field experiment, Helkiah *et al.* (1981) noticed that when poultry manure was applied at the rate of 30 t ha^{-1} in combination with half the recommended dose of inorganic fertilizers, the bulk density was reduced and porosity was increased, compared with the application of full recommended dose as chemical fertilizers. In a field trial with poultry manure, Budhar *et al.* (1991) obtained increased post harvest nutrient status of soil NPK with the application of 5 t ha^{-1} of poultry manure along with 100 per cent recommended fertilizer. Rajasree (1999) reported that when FYM or poultry manure as organic source was used in equal or higher proportion with chemical N source, it showed moderating effect on the soil acidity.

The reviews revealed that dual application of poultry manure and chemical fertilizer increased the growth and yield to a substantial level. More specifically the yield increase was highest when they were applied in the ratio 1:1.

2.5.2 Neemcake and chemical fertilizers

Tandon (1989) observed that neemcake mixed with urea applied as basal dressing significantly increased the yield of chilli over split application of urea.

From the review it is revealed that application of neemcake positively influenced the yield.

2.5.3 Vermicompost and chemical fertilizers

Gunjal (1993) reported an increase in fruit yield to the tune of 40 per cent and 36 per cent due to the application of chemical fertilizer and vermicompost respectively over the control. Pushpa (1996) observed that yield attributes like mean fruit weight, girth of fruits and yield were significantly influenced by vermicompost application in tomato. Mean fruit weight (63 g), mean girth (18 cm) and yield (10.8 t ha^{-1}) were obtained with tomato plants receiving 25 t vermicompost along with full dose of inorganic fertilizers. Rajalekshmi (1996) observed that with regard to the yield and dry matter production of chilli crop, the treatment receiving vermicompost + NPK recorded highest yield. The use of vermicompost either as a seed inoculant or as an organic source gives better results in terms of yield as well as growth characters. The quantity of fertilizer can be reduced to half when vermicompost was used as seed inoculant (Meera, 1998).

Pushpa (1996) showed that highest protein content (20 %) was found in tomato plants receiving 100 t vermicompost whereas maximum carbohydrate content was found in tomato plants receiving 25 t vermicompost along with full dose of inorganic fertilizers.

Venkatesh (1995) reported that application of vermicompost @ 5 t per ha alone or in combination with recommended doses of inorganic fertilizers, increased the nutrient content of petioles and improved the yield and quality of Thompson seedless grapes. Vasanthi and Kumaraswamy (1996) observed highest content of K, Ca, Mg and micronutrients in the treatments that received vermicompost along with NPK fertilizers compared to NPK alone in rice. In an experiment conducted in cowpea the treatment vermicompost (20 t ha^{-1}) + lime + fertilizer was found to be superior with a mean grain weight of 10.91 g per plot (Bijulal, 1997).

From the review it is revealed that conjoint use of vermicompost and inorganic fertilizer increase the fruit yield considerably. The yield attributes like mean weight of fruits, girth of fruits etc. were positively influenced.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled 'Integrated nutrient management in chilli' was carried out to study the combined effect of organic manures and chemical fertilizers on the productivity and quality of chilli and to assess the possibility of substitution of fertilizers by organic manures. The experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani during September - January 1999-2000. The details of the materials used and methods followed are presented in this chapter.

3.1. Materials

3.1.1. Experimental site

The experimental site was in the garden land of the Instructional farm attached to the College of Agriculture, Vellayani, located at 8.5° N latitude and 76.9° E longitude at an altitude of 29 m above the mean sea level.

3.1.2. Soil

The soil of the experimental area was red loam, acidic in reaction, low in available nitrogen, medium in available phosphorus and low in available potassium. The important physico- chemical properties and the pH of the soil are presented in Table 3.1.

Table 3.1. Soil characteristics of the experimental site

A. Mechanical composition

Parameter	Content in soil (percentage)	Method used
Coarse sand	15	Bouyoucos, 1962
Fine sand	48	Hydrometer method
Silt	12	Bouyoucos, 1962
Clay	23	

B. Chemical composition

Parameter	Content (kg ha^{-1})	Rating	Method
Available N (kg ha^{-1})	225	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	42	Medium	Bray colorimetric method (Jackson, 1973)
Available K_2O (kg ha^{-1})	133	Low	Ammonium acetate method (Jackson, 1973)
pH	5.0	Acidic	pH meter with glass electrode (Jackson, 1973)

3.1.3. Cropping history of the field

The experimental area was under bulk crop of cowpea before the experiment.

3.1.4. Meteorological parameters

The experimental area enjoys a humid tropical climate. The data on various weather parameters like rainfall, minimum and maximum temperature, relative humidity and evaporation during the cropping period are given in Appendix I and graphically presented in Fig. 1.

In general, the weather conditions were favourable for the satisfactory growth of the crop.

3.1.5. Season

The field experiment was conducted during the period from 17-9-1999 to 2-1-2000.

3.1.6. Variety

The variety used was Jwalasakhi, a newly released high yielding variety of vegetable chilli evolved by Kerala Agricultural University by crossing Vellanotchi, a popular local cultivar of South Kerala with Pusa Jwala. It has got high yield potential, ideal for culinary purpose and suited for high density planting.

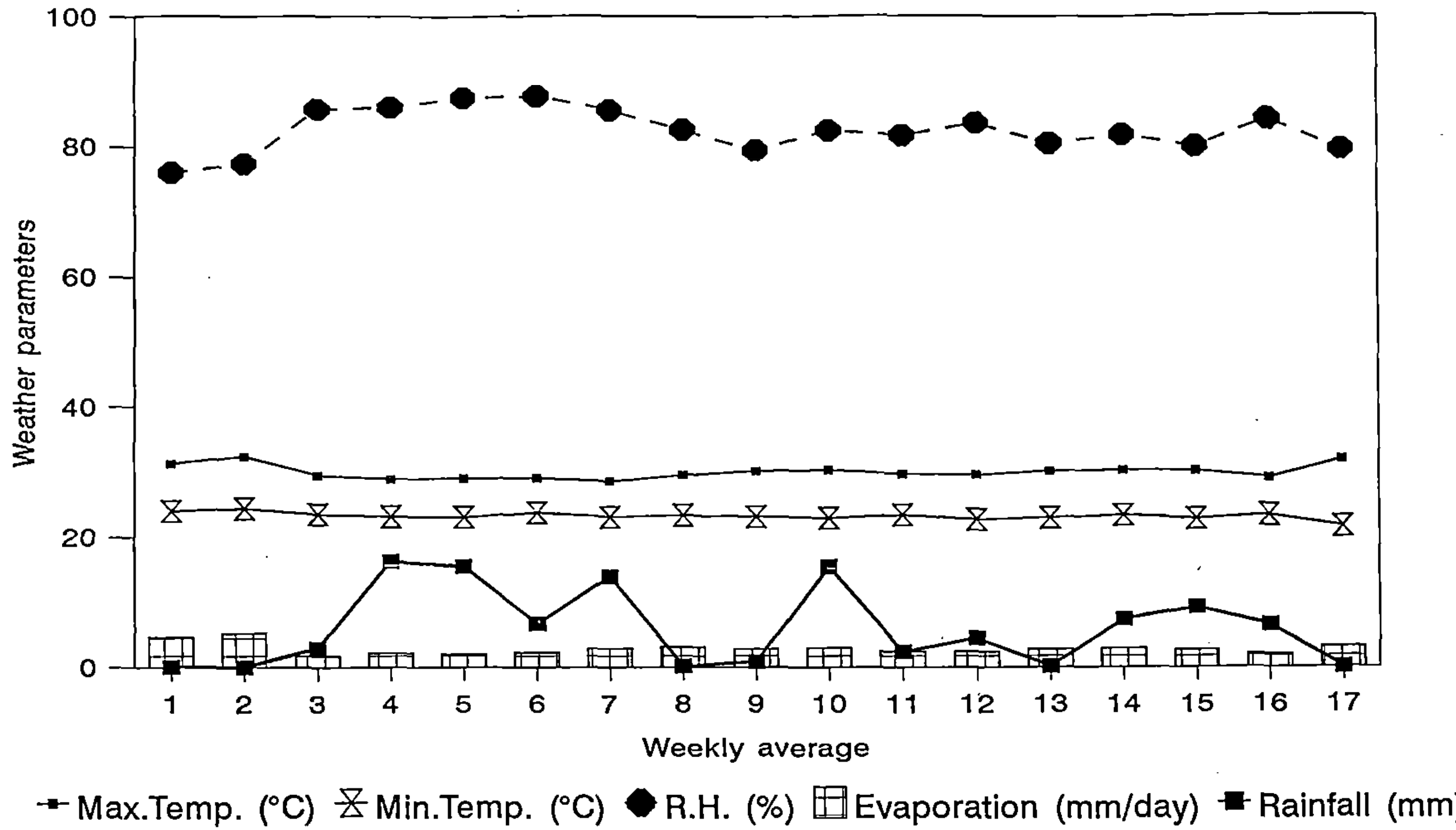

Fig. 1. Weather parameters during the crop period - weekly averages (September 1999 to January 2000)

The seed material was obtained from Department of plant breeding, College of Agriculture, Vellayani.

3.1.7. Manures and fertilizers

3.1.7.1. Organic manure

Poultry manure (1.2 per cent N), neemcake (5.2 per cent N) and vermicompost (1.5 per cent N) were used as organic sources.

3.1.7.2. Chemical fertilizers

Urea (46 per cent N), mussoriephos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as inorganic sources for N, P and K respectively.

3.1.8. Cultural operation

3.1.8.1. Nursery

Seeds were sown in well prepared nursery beds of size 1.2 m wide and 15 cm high with channels around them to facilitate the drainage. The seeds were sown on 17-8-1999. The seedlings were irrigated everyday. Hand weeding and plant protection measures were undertaken periodically as per the package of practices recommendations. The seedlings were ready for transplanting in 30-45 days.

3.1.8.2. Field culture

The main field was ploughed, clods broken, cleared off stubbles and plots were laid out with bunds of 30 cm width all round. Individual plots were again dug and perfectly levelled. Ridges and furrows were formed 45 cm apart. Plants were given uniform irrigation. Necessary shade was also provided for the first three days after planting using coconut fronds.

3.1.8.3. Manures and fertilizers

FYM @ 20 t ha^{-1} was applied uniformly to all the plots. N, P_2O_5 and K_2O were applied in the form of urea, mussoriephos and MOP. 0 per cent, 25 per cent, 50 per cent, 75 per cent and 100 per cent of recommended dose (75 kg N ha^{-1}) was applied to respective plots as per the treatment. Entire quantity of P_2O_5 and K_2O and ½ N were given as basal while ¼ N was applied 25 days after transplanting and the remaining ¼ N one month after the first application.

3.1.8.4. Transplanting

The seedlings were ready for transplanting in 30-45 days. They were pulled out and kept in trays. Planting was done at a spacing of 45 x 45 cm.

3.1.8.5. After cultivation

Gap filling was done with healthy seedlings. Regular irrigation and weeding were carried out.

3.1.8.6. Plant protection

Scoring was done for bacterial wilt. Ekalux was sprayed against grass hopper.

3.1.8.7. Harvesting

The crop was ready for first harvest 71 days after transplanting and subsequent harvest was done as and when the fruits were ready for harvest.

3.2. Methods

3.2.1. Design and layout

The experiment was laid out in randomised block design with three replications (Fig. 2). The details of the layout are given below.

Design	:	RBD
Treatments	:	13
Replication	:	3
Total number of plots	:	39
Gross plot size	:	2.7 x 2.7 m
Net plot size	:	2.25 x 2.25 m
Variety	:	Jwalasakhi
Duration	:	125 days

3.2.2. Treatments

Nutrient substitution with organic manures along with one control (POP)

Organic manures

Poultry manure (25, 50, 75 and 100 per cent substitution)

Vermicompost (25, 50, 75 and 100 per cent substitution)

Neemcake (25, 50, 75 and 100 per cent substitution)

Control

Package of practices recommendation (20 t ha^{-1} FYM + 75 : 40 : 25 kg N, P_2O_5 and K_2O ha^{-1})

Treatment combinations

T_1 - 25 per cent N as poultry manure + 75 per cent N as chemical fertilizer

T_2 - 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer.

T_3 - 75 per cent N as poultry manure + 25 per cent N as chemical fertilizer.

T_4 - 100 per cent N as poultry manure.

T_5 - 25 per cent N as vermicompost + 75 per cent N as chemical fertilizer.

T_6 - 50 per cent N as vermicompost + 50 per cent N as chemical fertilizer.

T_7 - 75 per cent N as vermicompost + 25 per cent N as chemical fertilizer.

T_8 - 100 per cent N as vermicompost.

T_9 - 25 per cent N as neemcake + 75 per cent N as chemical fertilizer.

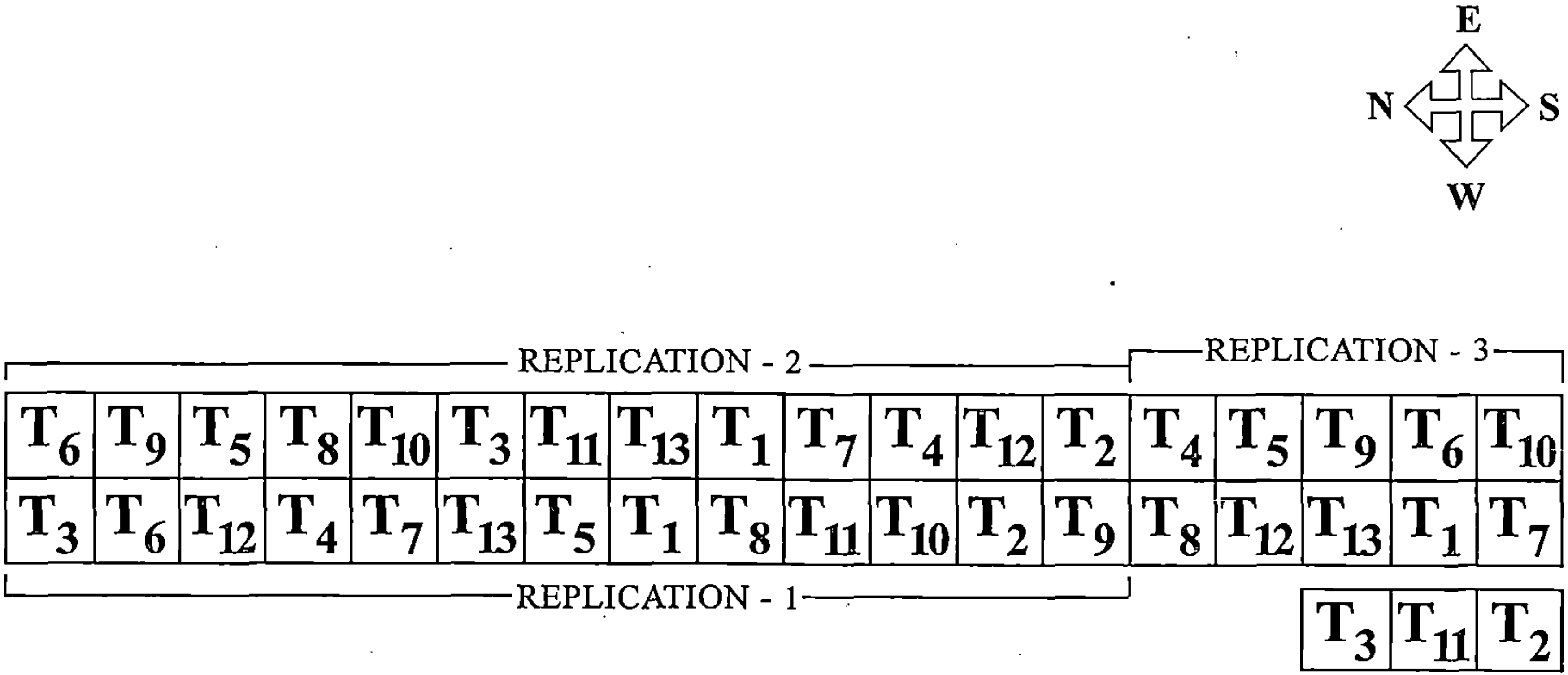

Fig. 2. Layout of the experimental plot

T_{10} - 50 per cent N as neemcake + 50 per cent N as chemical fertilizer.

T_{11} - 75 per cent N as neemcake + 25 per cent N as chemical fertilizer.

T_{12} - 100 per cent N as neemcake.

T_{13} - Package of practices recommendation (20 t ha^{-1} FYM + 75 : 40 : 25 kg N, P_2O_5 and K_2O ha^{-1})

3.3. Observations

Observations were taken on important parameters associated with growth, yield and quality of chilli. Five plants were selected for the purpose of study. Parameters considered and methods followed are briefly stated below.

3.3.1. Growth characters

3.3.1.1. Height of the plant

This observation was taken from five plants at random in each plot after eliminating border rows. The height of the plants was measured from the base to the growing tip of the plants at three stages *viz.* 35, 70 and 105 DAT. The mean plant heights were worked out and expressed in cm.

3.3.1.2. Number of branches per plant

The total number of branches per plant at three growth stages *viz.* 35th day, 70th day after transplanting and at final harvest were recorded from five observational plants and mean values recorded.

3.3.1.3. Canopy spread (E-W and N-S)

The canopy spread was measured as the maximum lateral diameter through the main stem of each plant both in East-West and North-South direction and expressed in cm.

3.3.1.4. Dry matter content

Dry matter content of each plant is obtained by summing up the dry weights of all the plant parts including stem, leaves and fruit and expressed in percentage.

3.3.1.5. Shoot/ root ratio

The plants were pulled out at three stages viz. 35th day, 70th day after transplanting and at final harvest without damaging the roots. The dry weights of shoots and roots were recorded after drying in sun. From this shoot-root ratio was calculated.

3.3.2. Yield and yield attributes

3.3.2.1. Fruit set (%)

Fruit set was calculated by dividing the total number of fruits formed in the plant with the total number of flowers produced in the same plant and it was worked out in five observational plants in each plot.

3.3.2.2. Number of fruits per plant

The total number of fruits on the five observational plants was recorded and the mean was worked out.

3.3.2.3. Length and breadth of fruits (cm)

Length of randomly selected 10 fruits were measured with twine and scale and the mean was worked out and expressed in cm. Fruits used for measuring length were also used for recording the girth. It was measured at the broadest part of fruits and expressed in cm.

3.3.2.4. Mean weight of single fruit (g)

Weight of randomly selected 10 fruits were taken and mean weight of single fruit was calculated by dividing the total weight with the total number of fruits and expressed in g.

3.3.2.5. Fruiting phase

The number of days from the first fruit set up to the last harvest was recorded in the five observational plants and mean worked out.

3.3.2.6. Number of seeds per fruit

Number of seeds of randomly selected 10 fruits were taken and the mean was worked out.

3.3.2.7. Fruit yield per plant and total yield (g)

Total yield was calculated by summing up the weight of fruits on the five observational plants and mean worked out and expressed in kg ha^{-1}. Fruit yield per plant was calculated by summing up the weight of fruits on the five observational plants and mean worked out and expressed in g.

3.3.2.8. Harvesting Intervals

Harvesting was done as and when the fruits mature.

3.3.3. Quality characters

3.3.3.1. Keeping quality

Sample fruits were taken treatment wise separately by selecting a single mature fruit from each plot. The fruit samples were kept inside polythene cover with good aeration and the number of days taken from the harvest of fruits to the stage at which fruits become shrunken and lost the firmness was recorded.

3.3.3.2. Ascorbic acid content

The ascorbic acid content of fruits was estimated by titrimetric method (Paul Gyorgy and Pearson, 1967)

3.3.3.3. Oleoresin content

The oleoresin content was estimated by soxhlet distillation method (A.O.A.C, 1975) and expressed as percentage on dry weight basis.

3.3.4. Physiological parameters

3.3.4.1. Leaf area index

Leaf area *index* was measured using LI-300 leaf area meter at three stages of growth *viz.*, 35th DAT, 70th DAT and at final harvest and expressed in square centimeter. Leaf area index was worked out using the equation given by Watson (1952)

$$\text{Leaf area index} = \frac{\text{Total leaf area}}{\text{Land area}}$$

3.3.4.2. Dry matter production

Dry matter production of each plant was obtained by summing up the dry weights of all the plant parts including stem, leaves and fruit and expressed in kg ha^{-1}.

3.3.4.3. Net assimilation rate (NAR)

This is the rate of increase in dry weight per unit leaf area per unit time expressed in mg cm^{-2} day^{-1} (William, 1946).

$$NAR = \frac{(w_2 - w_1) \times (\log_e l_2 - \log_e l_1)}{(t_2 - t_1) \times (l_2 - l_1)}$$

Where w_1 is the dry weight at time t_1

w_2 is the dry weight at time t_2

l_1 is the leaf area at time t_1

l_2 is the leaf area at time t_2

3.3.4.4. Relative growth rate (RGR)

This is rate of increase in dry weight per unit dry weight per unit time expressed as mg day^{-1} was calculated by formula suggested by Blackman (1919).

$$RGR = \frac{\ln w_2 - \ln w_1}{t_2 - t_1}$$

Where w_1 is the dry weight at time t_1

w_2 is the dry weight at time t_2

3.3.4.5. Crop growth rate (CGR)

This is the rate of increase in dry weight per unit area per unit time expressed in mg cm^{-2} day^{-1} (Hunt, 1978).

$$CGR = \frac{w_2 - w_1}{t_2 - t_1} \times \frac{1}{p}$$

Where w_1 is the dry weight at time t_1

w_2 is the dry weight at time t_2

p is the ground area

3.3.5. Plant analysis

Plant samples were analysed for nitrogen, phosphorus and potassium at final harvest. The plants were chopped and dried in a hot air oven at 80 ± 5° C separately till constant weights were obtained. Samples were then ground to pass through 0.5 mm mesh in a Willey mill. The required quantity of samples were then weighed out accurately in a physical balance and analysed.

The nitrogen content in plant was estimated by modified micro Kjeldahl method (Jackson, 1973) and the uptake of nitrogen was calculated based on the content of this nutrient in plants and the dry matter produced. The phosphorus content in plants were estimated colorimetrically (Jackson, 1973). Based on phosphorus contents in plants and the dry matter produced at harvest, the uptake was worked out. The potassium content in plants was estimated by the flame photometric method. The uptake of potassium was calculated based on potassium content in plants and dry matter produced.

3.3.6. Soil analysis

Soil samples were taken from experimental area before and after the experiment. Composite samples were collected from each plot, air dried, powdered and passed through a 2 mm sieve and analysed for available N, available P_2O_5 and available K_2O as per the standard analytical methods described below. Available N status of soil were estimated using alkaline potassium permanganate method (Subbiah and Asija, 1956), available P status by bray colorimetric method (Jackson, 1973) and available K status of soil by ammonium acetate method (Jackson, 1973).

3.3.7. Economics of treatments

3.3.7.1. Benefit : cost ratio

The economics of cultivation was worked out from the cost of cultivation and the income derived from the treatments.

$$\text{Benefit : cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.3.8. Scoring of bacterial wilt

Scoring of bacterial wilt was done by visual observation. Scoring was done by computing the percent of infection.

$$\text{Percent infection} = \frac{\text{Number of plants infected per plot}}{\text{Total number of plants per plot}}$$

3.3.9. Statistical analysis

Data relating to each character were analysed by applying the analysis of variance techniques as applied to randomised block design described by Cochran and Cox (1965) and the significance was tested by F test (Snedecor and Cochran, 1967). In cases where the effects were found to be significant, CD values were calculated by using standard technique.

RESULTS

4. RESULTS

An experiment was conducted at the College of Agriculture, Vellayani during the period from September-January 1999-2000. The objectives of the experiment were to study the combined effect of chemical fertilizers and organic manures on the productivity and quality of chilli, to assess the possibility of substitution of fertilizers by organic manures and also to work out the economics of production. The data collected were statistically analysed and the results are presented under the following sections.

4.1. Growth characters
4.2. Yield and yield attributes
4.3. Quality characters
4.4. Physiological parameters
4.5. Plant analysis
4.6. Soil analysis
4.7. Economics of treatments
4.8. Scoring of bacterial wilt

4.1 Growth characters

Observations on growth characters like plant height, number of branches per plant, canopy spread (E-W and N-S), dry matter content and shoot-root ratio were recorded and results are presented in Table 4.1 to 4.4.

4.1.1 Plant height

The mean plant height recorded in centimetres from 35 DAT to 105 DAT are presented in Table 4.1. The data revealed that plant height was significantly influenced by various treatments. The treatment T_1 recorded maximum plant height at all stages of growth *viz.* 35, 70 and 105 DAT (21.1 cm, 39.03 cm and 44.93 cm respectively).

At 35 DAT all treatments except T_8, T_{10} and T_{12} were on par with T_{13} (POP). Among the poultry manure applied plots, T_1, T_2, T_3 and T_4 were on par and recorded comparable plant heights with T_{13}. In the case of vermicompost applied plots all the treatments except T_8 were on par. Among neemcake treated plots, T_9 and T_{11} were on par with KAU package of practices recommendation. T_{13} was significantly superior to T_{10} and T_{12} and recorded a plant height of 20.67 cm.

At 70 DAT all the treatments except T_1, T_2 and T_3 were on par with POP recommendation. T_1, T_2 and T_3 were on par and were significantly superior to T_{13}. There was no significant difference in plant height among the poultry manure substituted plots. But in the case of vermicompost applied plots T_8 (100 per cent vermicompost) was significantly inferior to T_5, T_6 and T_7 which were on par. Among the neemcake substituted treatments, T_9 (3:1 ratio of chemical fertilizer and neemcake) recorded highest plant height (35.97 cm) and was on par with other ratios of substitution and POP (31.47 cm).

At 105 DAT, T_1 recorded highest plant height (44.93 cm) and was significantly superior to all the treatments except T_2, T_3, T_4, T_9 and T_{10} which were on par. T_{13} recorded a plant height of 35.27 cm.

Table 4.1 Plant height (cm) at 35, 70 and 105 DAT as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	35 DAT	70 DAT	105 DAT
T_1 (75% CF + 25% PM)	21.10	39.03	44.93
T_2 (50% CF + 50% PM)	19.90	38.43	43.00
T_3 (25% CF + 75% PM)	21.10	36.70	41.23
T_4 (100% PM)	18.37	35.57	41.27
T_5 (75% CF + 25% VC)	19.37	34.60	40.20
T_6 (50% CF + 50% VC)	17.53	34.83	39.73
T_7 (25% CF + 75% VC)	18.10	34.90	38.43
T_8 (100% VC)	12.97	28.50	34.20
T_9 (75% CF + 25% NC)	17.53	35.97	42.57
T_{10} (50% CF + 50% NC)	15.27	33.23	41.17
T_{11} (25% CF + 75% NC)	17.70	34.77	39.33
T_{12} (100% NC)	15.80	32.53	38.33
T_{13} (POP)	20.67	31.47	35.27
F	3.36**	2.67*	5.11**
CD	3.85	5.03	3.84

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

4.1.2 Number of branches

Table 4.2 indicates the variation in number of branches due to various treatments. Application of chemical fertilizers and organic manures in various combinations had significant influence on the number of branches per plant.

At 35 DAT, T_1 and T_2 recorded highest number of branches (6.23 and 5.89 respectively) and these two treatments were significantly superior to all other treatments except T_3. At 70 DAT, treatment T_2 (17.27) recorded maximum number of branches and it was on par with T_1 (16.87) and T_3 (15.53) and were significantly superior to all other treatments except T_4, T_5, T_6 and T_7. At 105 DAT also, maximum number of branches was registered by the treatment T_1 (23.75) which was on par with T_2 (23) and T_3 (22.4) and were significantly superior to all other treatments including POP (18.67).

4.1.3 Canopy spread (E-W and N-S)

There was no significant difference in the canopy spread among the various treatments.

4.1.4 Shoot/root ratio

The results revealed that the treatment T_5 recorded the highest shoot-root ratio (4.73) which was on par with T_4 (4.22), T_6 (4.45) and T_{10} (3.98) and these four treatments were significantly superior to all the treatments except T_2, T_3, T_{11} and T_{13} (3.18).

Table 4.2 Number of branches at 35, 70 and 105 DAT as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	35 DAT	70 DAT	105 DAT
T_1 (75% CF + 25% PM)	6.23	16.87	23.75
T_2 (50% CF + 50% PM)	5.89	17.27	23.00
T_3 (25% CF + 75% PM)	5.33	15.53	22.40
T_4 (100% PM)	4.93	15.07	18.80
T_5 (75% CF + 25% VC)	4.60	15.07	21.80
T_6 (50% CF + 50% VC)	4.27	13.93	19.40
T_7 (25% CF + 75% VC)	4.27	13.73	18.07
T_8 (100% VC)	2.13	8.40	9.80
T_9 (75% CF + 25% NC)	4.40	12.40	18.67
T_{10} (50% CF + 50% NC)	3.80	11.47	20.13
T_{11} (25% CF + 75% NC)	3.80	11.93	17.33
T_{12} (100% NC)	3.27	11.35	19.87
T_{13} (POP)	4.13	10.47	18.67
F	20.15**	17.55**	39.47**
CD	0.70	1.82	1.63

** Significant at 1% level

Table 4.3 Canopy spread (E-W and N-S) (cm) and shoot-root as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	Canopy spread (cm) E-W	Canopy spread (cm) N-S	Shoot-root ratio
T_1 (75% CF + 25% PM)	32.78	39.13	2.89
T_2 (50% CF + 50% PM)	35.37	38.39	3.15
T_3 (25% CF + 75% PM)	26.57	37.02	3.18
T_4 (100% PM)	32.40	32.51	4.22
T_5 (75% CF + 25% VC)	31.66	29.47	4.73
T_6 (50% CF + 50% VC)	29.22	35.75	4.45
T_7 (25% CF + 75% VC)	25.27	32.92	2.35
T_8 (100% VC)	23.62	29.21	1.94
T_9 (75% CF + 25% NC)	29.01	32.29	2.19
T_{10} (50% CF + 50% NC)	30.77	31.69	3.98
T_{11} (25% CF + 75% NC)	35.12	31.42	3.38
T_{12} (100% NC)	30.23	33.01	2.45
T_{13} (POP)	34.37	35.09	3.18
F	1.944^{NS}	1.856^{NS}	8.47^{**}
CD	–	–	0.89

NS : Not significant ** Significant at 1% level

Among poultry manure applied plots, T_4 recorded highest shoot-root ratio of 4.22 and was significantly superior to T_1, T_2 and T_3. In the case of vermicompost applied treatments, T_5 and T_6 were on par and were significantly superior to T_7 and T_8. Among neemcake applied plots, T_{10} recorded highest shoot-root ratio and was significantly superior to T_9 and T_{12}.

4.1.5 Dry matter content

The data on the dry matter content at various stages (35, 70 and 105 DAT) are presented in Table 4.4. At 35 DAT, among various treatments, the combined application of chemical fertilizer and poultry manure in the ratio of 1:1 (T_2) recorded highest dry matter content (57.35 per cent) and was significantly superior to all other treatments including POP (49.1 per cent). Among vermicompost substituted plots T_6 recorded maximum dry matter content (50.53 per cent) which was on par with T_5 and was significantly superior to T_7 and T_8. The treatments T_{10}, T_{11} and T_{12} were on par and were significantly superior to T_9

At 70 DAT, T_3 (58.76 per cent) recorded highest dry matter content which was on par with T_2 (57.31) and T_{10} (56.73) and was significantly superior to all the treatments excluding T_1 and T_7. Among poultry manure treated plots T_2 and T_3 were significantly superior to T_1 and T_4. The treatment T_7 recorded highest value (55.41 per cent) among vermicompost substituted plots and T_{10} (56.73 per cent) reported highest value for neemcake substituted plots.

Table 4.4 Dry matter content (per cent) at 35, 70 and 105 DAT as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	35 DAT	70 DAT	105 DAT
T_1 (75% CF + 25% PM)	48.53	54.64	54.28
T_2 (50% CF + 50% PM)	57.35	57.31	58.19
T_3 (25% CF + 75% PM)	50.28	58.76	56.47
T_4 (100% PM)	46.05	50.03	51.43
T_5 (75% CF + 25% VC)	48.66	51.54	56.23
T_6 (50% CF + 50% VC)	50.53	54.06	52.17
T_7 (25% CF + 75% VC)	46.73	55.41	57.07
T_8 (100% VC)	43.30	50.03	50.45
T_9 (75% CF + 25% NC)	48.53	53.78	55.17
T_{10} (50% CF + 50% NC)	52.48	56.73	54.03
T_{11} (25% CF + 75% NC)	52.47	52.13	58.53
T_{12} (100% NC)	52.37	53.20	56.10
T_{13} (POP)	49.10	49.53	49.53
F	8.95**	10.53**	12.22**
CD	3.44	2.64	2.44

** Significant at 1% level

At 105 DAT, maximum dry matter content was observed by the treatment T_{11} (58.53 per cent) which was on par with T_2, T_3, T_5, T_7 and T_{12}. POP recommendation recorded a value of 49.53 per cent.

4.2 Yield characters

4.2.1 Length of fruit

The influence of various treatments on fruit length are presented in Table 4.5. The results showed that all the treatments except T_8 (100 per cent vermicompost) and T_{10} (50 per cent neemcake + 50 per cent chemical fertilizer) responded similarly with POP (7.36 cm). The treatment T_6 recorded maximum fruit length (7.89 cm) closely followed by T_7 (7.74 cm).

4.2.2 Girth of fruit

Girth of fruit did not show any significant difference among various treatments. The treatment T_5 recorded highest fruit girth (4.99 cm) and the treatment T_8 recorded the lowest fruit girth of 3.99 cm.

4.2.3 Number of seeds per fruit

Results presented in table 4.5 revealed that treatments influenced significantly the number of seeds per fruit. T_3 recorded maximum number of seeds per fruit (68.11) and it was on par with all other treatments excluding T_8 and T_{10}. The number of seeds per fruit in the case of POP recommendation was found to be 65.17.

Table 4.5 Fruit length (cm), fruit girth (cm), number of seeds per fruit and mean weight of single fruit (g) as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	Fruit length (cm)	Fruit girth (cm)	No. of seeds/ fruit	Mean wt. of single fruit (g)
T_1 (75% CF + 25% PM)	6.99	4.85	64.59	3.93
T_2 (50% CF + 50% PM)	7.36	4.39	62.73	3.89
T_3 (25% CF + 75% PM)	7.05	4.82	68.11	4.37
T_4 (100% PM)	7.56	4.75	65.53	3.86
T_5 (75% CF + 25% VC)	7.55	4.99	67.00	3.41
T_6 (50% CF + 50% VC)	7.89	4.36	67.30	4.25
T_7 (25% CF + 75% VC)	7.74	4.46	67.94	3.92
T_8 (100% VC)	5.79	3.99	55.60	3.07
T_9 (75% CF + 25% NC)	7.19	4.71	61.88	3.69
T_{10} (50% CF + 50% NC)	6.51	4.35	57.19	3.47
T_{11} (25% CF + 75% NC)	7.47	4.4	65.77	3.75
T_{12} (100% NC)	6.96	4.46	62.8	3.88
T_{13} (POP)	7.36	4.49	65.17	3.69
F	2.221^{*}	1.238^{NS}	2.659^{*}	5.099^{**}
CD	1.134	–	7.290	0.458

NS : Not significant * Significant at 5% level ** Significant at 1% level

4.2.4 Mean weight of single fruit

Various treatments had significant influence on the mean weight of fruits. The treatment T_3 (75 per cent poultry manure + 25 per cent chemical fertilizer) recorded highest fruit weight (4.37g) which was on par with T_1 (3.93 g), T_6 (4.25g) and T_7 (3.92g). The lowest fruit weight was recorded by T_8 (3.07g) (100 per cent vermicompost). POP recommendation recorded a fruit weight of 3.69g.

4.2.5 Fruiting phase

The data presented in Table 4.6 showed that treatments significantly influenced the fruiting phase. Maximum fruiting phase was observed by the treatment T_1 (3:1) (61 days) and it was significantly superior to all other treatments including POP recommendation (52 days). T_2 and T_6 were on par and T_2 was significantly superior to all other treatments except T_1.

4.2.6 Number of fruits per plant

Table 4.6 gives the number of fruits per plant. It was found that highest number of fruits was obtained from the treatment T_2 (54.6) which was on par with T_1, T_3 and T_5. These treatments were significantly superior to T_4, T_8, T_9, T_{10}, T_{11}, T_{12} and T_{13}. T_{10} and T_{11} were on par with T_{13} (37.4). Lowest number of fruits per plant was produced by the treatment T_8 (17.87).

Table 4.6 Fruiting phase (days), number of fruit per plant and fruit setting percentage as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	Fruiting phase (days)	No. of fruit per plant	Fruit setting percentage
T_1 (75% CF + 25% PM)	61.00	54.20	43.30
T_2 (50% CF + 50% PM)	57.33	54.60	43.16
T_3 (25% CF + 75% PM)	53.00	50.87	41.43
T_4 (100% PM)	53.00	47.07	42.03
T_5 (75% CF + 25% VC)	50.33	52.60	37.63
T_6 (50% CF + 50% VC)	55.00	47.93	39.23
T_7 (25% CF + 75% VC)	49.33	48.20	38.00
T_8 (100% VC)	51.00	17.87	38.37
T_9 (75% CF + 25% NC)	49.67	44.93	35.43
T_{10} (50% CF + 50% NC)	50.67	39.40	35.00
T_{11} (25% CF + 75% NC)	53.33	40.87	35.47
T_{12} (100% NC)	50.67	19.53	34.93
T_{13} (POP)	52.00	37.40	38.23
F	14.88**	87.03**	27.31**
CD	2.53	3.74	1.69

** Significant at 1% level

4.2.7 Fruit setting percentage

Fruit setting percentage was *significantly influenced* by various treatments. T_1 recorded highest fruit setting percentage (43.3) and was significantly superior to all the treatments except T_2 and T_4. Treatments T_5, T_6, T_7 and T_8 were on par and responded similarly with T_{13} (38.23). The treatments T_9, T_{10}, T_{11} and T_{12} were on par and were significantly inferior to all other treatments including POP recommendation.

4.2.8 Harvesting intervals

The harvesting interval was lowest in the treatment T_2 (50% chemical fertilizer + 50% poultry manure) (7.13 days) closely followed by T_3 (7.4 days) which were on par and were *significantly* superior to all the treatments except T_1 and T_4. Treatments T_{11} and T_{12} were on par and responded equally with POP (10.6 days). Highest harvesting interval was recorded by the treatment T_8 (11.6 days) and was significantly inferior to all other treatments.

4.2.9 Fruit yield per plant (g)

Fruit yield per plant was markedly high in the treatment T_2 (273.32g) and was significantly superior to all other treatments except T_1 and T_5. T_2 was on par with T_1 and T_5. T_{10} and T_{11} were on par with T_{13} (187.28g). The fruit yield per plant was markedly low for T_8 (64.33g) and T_{12} (98.21g) which were significantly inferior to all other treatments. In the case of poultry manure treated plots and vermicompost applied plots the treatment receiving 100 per cent as organic manure was

Table 4.7 Harvesting interval (days), fruit yield per plant (g) and total yield ($t\ ha^{-1}$) as influenced by *different ratios of substitution of fertilizers by* organic manures

Treatments	Harvesting intervals (days)	Fruit yield per plant (g)	Total yield ($t\ ha^{-1}$)
T_1 (75% CF + 25% PM)	7.73	271.63	9.53
T_2 (50% CF + 50% PM)	7.13	273.32	9.66
T_3 (25% CF + 75% PM)	7.40	254.71	8.94
T_4 (100% PM)	7.87	235.89	8.28
T_5 (75% CF + 25% VC)	9.07	263.43	9.25
T_6 (50% CF + 50% VC)	8.73	240.10	8.43
T_7 (25% CF + 75% VC)	9.80	241.31	8.47
T_8 (100% VC)	11.60	64.33	2.26
T_9 (75% CF + 25% NC)	9.47	225.24	7.91
T_{10} (50% CF + 50% NC)	9.87	197.47	6.93
T_{11} (25% CF + 75% NC)	10.47	205.03	7.19
T_{12} (100% NC)	10.53	98.21	3.45
T_{13} (POP)	10.60	187.28	6.57
F	46.83**	102.22**	110.86**
CD	0.59	18.59	0.63

** Significant at 1% level

significantly inferior to all other ratios of substitution. In the case of neemcake substituted plots, T_9 was significantly superior to T_{10}, T_{11} and T_{12}

4.2.10 Total yield

The fruit yield was significantly high in the treatment T_2 (9.66 t ha^{-1}) which was significantly superior to all other treatments except T_1 and T_5. T_{10} and T_{11} were on par with T_{13} (6.57) and were significantly inferior to all other treatments except T_8 and T_{12}.

T_1, T_2, T_3 were significantly superior to T_4 in the case of poultry manure applied plots. The same trend was followed in the case of vermicompost substituted plots. Among neemcake applied plots, T_9 (7.91 t ha^{-1}) was significantly superior to T_{10}, T_{11} and T_{12}.

4.3 Quality characters

4.3.1 Keeping quality

The keeping quality was significantly influenced by various treatment combinations. The treatment T_4 (4.5 days) recorded markedly high keeping quality and was on par with T_2, T_3, T_7, T_8, T_{11} and T_{12}. POP recommendation recorded a keeping quality of 3.33 days which was on par with T_1, T_5, T_6, T_9 and T_{10}.

4.3.2 Ascorbic acid content

The result presented in Table 4.8 revealed that T_3 registered highest ascorbic acid content (98.67 mg/100 g) and was significantly

Table 4.8 Keeping quality (days), ascorbic acid content (mg/100g) and oleoresin content (per cent) as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	Keeping quality (days)	Ascorbic acid content (mg/100g)	Oleoresin content
T_1 (75% CF + 25% PM)	3.77	98.00	9.50
T_2 (50% CF + 50% PM)	4.07	98.33	9.67
T_3 (25% CF + 75% PM)	4.00	98.67	9.70
T_4 (100% PM)	4.50	97.00	9.50
T_5 (75% CF + 25% VC)	3.83	96.00	9.57
T_6 (50% CF + 50% VC)	3.87	96.67	9.57
T_7 (25% CF + 75% VC)	4.27	96.33	9.60
T_8 (100% VC)	4.23	95.67	9.59
T_9 (75% CF + 25% NC)	3.73	97.00	9.60
T_{10} (50% CF + 50% NC)	3.57	97.67	9.57
T_{11} (25% CF + 75% NC)	4.13	98.00	9.59
T_{12} (100% NC)	4.37	95.67	9.63
T_{13} (POP)	3.33	95.67	9.53
F	2.63*	7.57**	0.64^{NS}
CD	0.59	1.14	–

* Significant at 5% level ** Significant at 1% level NS : Not significant

superior to all other treatments except T_1, T_2, T_{10} and T_{11} which were on par. All the treatments involving various combinations of chemical fertilizer and vermicompost and T_{12} responded similarly with POP (95.67 mg/100g).

4.3.3 Oleoresin content

The results on the oleoresin content of fruits are presented in Table 4.8. There was no significant difference among the various treatments. However the highest value was recorded by the treatment T_3 (9.7 per cent).

4.4 Physiological characters

4.4.1 Leaf area index

The leaf area index at different stages *viz.*, 35, 70 and 105 DAT were profoundly influenced by various treatments. It was observed that poultry manure substituted plants produced maximum LAI at all stages of growth. At 35 DAT, highest LAI was produced by the treatment T_2 (0.22) which was on par with T_3 (0.21) and these treatments were significantly superior to all the treatments including POP (0.139).

At 70 DAT, T_3 recorded highest LAI (0.78) which was on par with all the poultry manure substituted ratios. The treatments T_5, T_6 T_{10}, T_{11} and T_{12} responded similarly with POP recommendation which recorded a LAI of 0.7.

Table 4.9 Leaf area index at 35, 70 and 105 DAT as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	35 DAT	70 DAT	105 DAT
T_1 (75% CF + 25% PM)	0.19	0.78	0.86
T_2 (50% CF + 50% PM)	0.22	0.76	0.85
T_3 (25% CF + 75% PM)	0.21	0.78	0.84
T_4 (100% PM)	0.18	0.75	0.85
T_5 (75% CF + 25% VC)	0.17	0.71	0.82
T_6 (50% CF + 50% VC)	0.18	0.71	0.81
T_7 (25% CF + 75% VC)	0.16	0.74	0.81
T_8 (100% VC)	0.15	0.54	0.61
T_9 (75% CF + 25% NC)	0.19	0.74	0.82
T_{10} (50% CF + 50% NC)	0.18	0.73	0.83
T_{11} (25% CF + 75% NC)	0.19	0.72	0.81
T_{12} (100% NC)	0.15	0.71	0.81
T_{13} (POP)	0.14	0.70	0.73
F	25.79**	25.79**	124.47**
CD	0.013	0.034	0.017

** Significant at 1% level

At 105 DAT, it was observed that T_1 recorded highest LAI (0.86) which was on par with T_2 (0.85) and T_4 (0.85). These treatments were significantly superior to all other treatments except T_3. POP recommendation (0.73) was significantly inferior to all other treatments except T_8.

4.4.2 Dry matter production

Data pertaining to the dry matter production at 35, 70 and 105 DAT are given in Table 4.10. It was seen that at 35 DAT, there was no significant difference among the various treatments.

At 70 DAT, treatment T_1 recorded maximum DMP (25.69 g plant^{-1}) closely followed by T_2 (23.86 g plant^{-1}). T_1 was significantly superior to all the treatments including T_{13} (17.96 g plant^{-1}). At 105 DAT also, highest DMP was obtained by T_1 (55.71 g plant^{-1}). T_4 and T_{12} were on par with T_{13} (43.15 g plant^{-1}) and were significantly inferior to all other treatments except T_8 (35.76 g plant^{-1}).

4.4.3 Net assimilation rate (NAR)

The data pertaining to NAR are furnished in Table 4.11. It was noticed that maximum NAR was registered by T_8 (0.00057 mg cm^{-2} day^{-1}) which was on par with T_6 (0.00054 mg cm^{-2} day^{-1}). T_8 was significantly superior to all the treatments except T_6. POP recommendation recorded a NAR of 0.00047 mg cm^{-2} day^{-1}.

Table 4.10 Dry matter production (g plant^{-1}) at 35, 70 and 105 DAT as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	35 DAT	70 DAT	105 DAT
T_1 (75% CF + 25% PM)	2.45	25.69	55.71
T_2 (50% CF + 50% PM)	2.36	23.86	52.75
T_3 (25% CF + 75% PM)	2.44	20.46	48.22
T_4 (100% PM)	2.18	16.34	42.86
T_5 (75% CF + 25% VC)	2.36	21.65	52.66
T_6 (50% CF + 50% VC)	2.03	18.72	50.77
T_7 (25% CF + 75% VC)	2.13	19.27	47.84
T_8 (100% VC)	1.65	10.56	35.76
T_9 (75% CF + 25% NC)	2.06	22.42	49.88
T_{10} (50% CF + 50% NC)	1.92	22.99	53.66
T_{11} (25% CF + 75% NC)	2.06	20.11	49.81
T_{12} (100% NC)	1.87	19.29	42.92
T_{13} (POP)	2.29	17.96	43.15
F	2.04^{NS}	22.32^{**}	56.71^{**}
CD	-	2.35	2.17

NS : Not significant ** Significant at 1% level

Table 4.11 NAR, CGR and RGR as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	NAR mg cm^{-2} day^{-1}	CGR mg cm^{-2} day^{-1}	RGR mg day^{-1}
T_1 (75% CF + 25% PM)	0.00048	0.00041	0.009
T_2 (50% CF + 50% PM)	0.00045	0.00038	0.009
T_3 (25% CF + 75% PM)	0.00045	0.00038	0.012
T_4 (100% PM)	0.00043	0.00037	0.011
T_5 (75% CF + 25% VC)	0.00051	0.00042	0.010
T_6 (50% CF + 50% VC)	0.00054	0.00044	0.011
T_7 (25% CF + 75% VC)	0.00048	0.00039	0.011
T_8 (100% VC)	0.00057	0.00035	0.014
T_9 (75% CF + 25% NC)	0.00046	0.00037	0.009
T_{10} (50% CF + 50% NC)	0.00051	0.00042	0.010
T_{11} (25% CF + 75% NC)	0.00049	0.00041	0.010
T_{12} (100% NC)	0.00040	0.00032	0.009
T_{13} (POP)	0.00047	0.00034	0.010
F	5.20**	4.82**	2.36*
CD	0.00005	0.00004	0.002

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

4.4.4 Relative growth rate (RGR)

With respect to RGR also, T_8 recorded highest value (0.014 mg day^{-1}) which was significantly superior to all other treatments except T_3. All the treatments except T_3 and T_8 responded similarly with POP (0.0103 mg day^{-1}).

4.4.5 Crop growth rate (CGR)

It is evident from the Table 4.11, that the highest CGR (0.00044 mg cm^{-2} day^{-1}) was recorded by the treatment receiving vermicompost and chemical fertilizer in equal proportion (T_6), and was significantly superior to all the treatments except T_1, T_5, T_{10} and T_{11} which were on par. POP recommendation recorded a CGR of 0.00034 mg cm^{-2} day^{-1}.

4.5 Plant analysis

4.5.1 Content of N, P and K

4.5.1.1. Nitrogen content of plants

Data presented in Table 4.12 revealed that highest nitrogen content was recorded by the treatment T_3 (2.03 per cent) which was on par with T_1, T_2 and T_6 and was significantly superior to all other treatments including POP (1.6 per cent). Treatments T_4, T_7, T_{10} and T_{11} were on par with T_{13}.

4.5.1.2 Phosphorus content of plants

The data on the P content of plants is shown in Table 4.12. It was observed that integrated application of chemical fertilizer and poultry

Table 4.12 Plant nutrient content (per cent) as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	N	P	K
T_1 (75% CF + 25% PM)	1.96	0.27	2.23
T_2 (50% CF + 50% PM)	1.93	0.31	2.37
T_3 (25% CF + 75% PM)	2.03	0.36	2.47
T_4 (100% PM)	1.56	0.30	2.40
T_5 (75% CF + 25% VC)	1.86	0.19	2.23
T_6 (50% CF + 50% VC)	1.90	0.27	2.23
T_7 (25% CF + 75% VC)	1.70	0.27	2.43
T_8 (100% VC)	0.89	0.18	1.40
T_9 (75% CF + 25% NC)	1.23	0.18	2.00
T_{10} (50% CF + 50% NC)	1.53	0.21	1.90
T_{11} (25% CF + 75% NC)	1.63	0.22	1.93
T_{12} (100% NC)	1.26	0.19	1.83
T_{13} (POP)	1.60	0.18	1.87
F	48.03**	24.13**	56.91**
CD	0.14	0.03	0.12

** Significant at 1% level

manure in the ratio 1:3 recorded higher P content of plants (0.36 per cent) and was significantly superior to all the treatments including POP recommendation (0.18 per cent).

4.5.1.3 Potassium content of plants

Data showing the K content of plants are given in Table 4.12. It was found that K content of plants was highest for T_3 (2.47 per cent) which was on par with T_2, T_4 and T_7 and these four treatments were significantly superior to all the treatments including POP recommendation (1.87 per cent).

4.5.2 Uptake of N, P and K

4.5.2.1 Nitrogen uptake (kg ha^{-1})

The nitrogen uptake of plants was significantly influenced by various ratios of substitution. It was noted that T_1 recorded highest nitrogen uptake by plants (38.45 kg ha^{-1}) and was significantly superior to all the treatments including POP recommendation. T_{13} was on par with T_4 and recorded a nitrogen uptake of 24.23 kg ha^{-1}.

4.5.2.2 Phosphorus uptake (kg ha^{-1})

Phosphorus uptake by plants was profoundly influenced by various treatments. Highest P uptake was noticed for the treatment T_3 (6.08 kg ha^{-1}) which was on par with T_2 (5.67 kg ha^{-1}) and was significantly superior to all other treatments including POP. POP recommendation recorded a P uptake of 2.75 kg ha^{-1} and was on par with T_8, T_9 and T_{12}.

Table 4.13 Plant nutrient uptake (kg ha^{-1}) as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1 (75% CF + 25% PM)	38.45	5.40	44.31
T_2 (50% CF + 50% PM)	35.62	5.67	43.82
T_3 (25% CF + 75% PM)	34.39	6.08	41.74
T_4 (100% PM)	23.56	4.51	36.11
T_5 (75% CF + 25% VC)	34.48	3.45	41.27
T_6 (50% CF + 50% VC)	33.84	4.79	39.85
T_7 (25% CF + 75% VC)	28.54	4.53	40.86
T_8 (100% VC)	11.29	2.29	17.57
T_9 (75% CF + 25% NC)	21.55	3.23	35.00
T_{10} (50% CF + 50% NC)	28.89	3.95	35.81
T_{11} (25% CF + 75% NC)	28.63	3.79	33.82
T_{12} (100% NC)	19.06	2.96	27.62
T_{13} (POP)	24.23	2.75	28.26
F	74.06**	31.19**	61.76**
CD	2.63	0.62	2.85

** Significant at 1% level

4.5.2.3 Potassium uptake (kg ha^{-1})

Potassium uptake was markedly influenced by various ratios of substitution. T_1 recorded highest K uptake (44.31 kg ha^{-1}) closely followed by T_2 (43.82 kg ha^{-1}) and T_3 (41.74 kg ha^{-1}). T_1 was significantly superior to all the treatments except T_2 and T_3 which were on par. POP recommendation was on par with T_{12} and recorded a K uptake of 28.26 kg ha^{-1}.

4.6 Soil analysis

4.6.1 Available nitrogen status of soil

Data on available nitrogen status of soil is given in the Table 4.14. Available nitrogen in soil was highest for the treatment T_4 (325.09 kg ha^{-1}) closely followed by T_3 (321.96 kg ha^{-1}) and these two treatments were significantly superior to all the treatments including POP which recorded an available N status of 268.65 kg ha^{-1}.

4.6.2 Available phosphorus status of soil

Data on available P status of soil is given in the Table 4.14. The residual P status of soil was highest for the treatment T_2 (93.4 kg ha^{-1}) which was on par with T_3 (93.13 kg ha^{-1}) and these two treatments were significantly superior to all the treatments including POP (63.33 kg ha^{-1}).

4.6.3 Available potassium status of soil

The data on available K status of soil is given in the Table 4.14. With regard to available K status of soil, highest value was obtained for

Table 4.14 Soil NPK status (kg ha^{-1}) as influenced by different ratios of substitution of fertilizers by organic manures

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1 (75% CF + 25% PM)	287.50	89.96	117.87
T_2 (50% CF + 50% PM)	302.10	93.40	125.07
T_3 (25% CF + 75% PM)	321.96	93.13	121.60
T_4 (100% PM)	325.09	89.67	114.80
T_5 (75% CF + 25% VC)	225.79	51.42	146.53
T_6 (50% CF + 50% VC)	232.06	55.03	168.93
T_7 (25% CF + 75% VC)	288.51	61.60	169.20
T_8 (100% VC)	279.10	61.13	170.13
T_9 (75% CF + 25% NC)	304.19	85.00	144.00
T_{10} (50% CF + 50% NC)	293.74	85.27	144.67
T_{11} (25% CF + 75% NC)	301.06	89.77	171.07
T_{12} (100% NC)	311.51	89.20	170.53
T_{13} (POP)	268.65	63.33	152.13
F	87.21**	609.32**	58.22**
CD	9.55	1.90	8.33

** Significant at 1% level

treatment T_{11} (171.07 kg ha^{-1}) which was on par with T_6, T_7, T_8 and T_{12} and these treatments were significantly superior to all other treatments including T_{13} (152.13 kg ha^{-1}).

4.7 Economics

Economics of cultivation is given in Table 4.15. The data showed that among the various treatments, application of poultry manure and chemial fertilizer in the ratio 1:1 (T_2) registered the maximum net profit of Rs.45162.57 ha^{-1} and was on par with that recorded by 75% CF + 25% PM (Rs.44402.01 ha^{-1}) and was significantly superior to all other treatments including POP (Rs.9632.51 ha^{-1}). In the case of treatment T_8 (100% of vermicompost alone) there was a loss of Rs.52257.72 ha^{-1}. T_{12} also registered a loss of Rs.35492.9 ha^{-1}.

With respect to benefit-cost ratio, application of poultry manure and chemical fertilizer in the ratio 1:1 recorded highest benefit-cost ratio (1.64) which was significantly superior to all other treatments. Package of practice recommendation registered a benefit-cost ratio of 1.14 which was on par with T_{10} (1.14).

4.8 Scoring of bacterial wilt

The treatment T_9 recorded less disease score (3.73 per cent) whereas highest disease score was observed by POP recommendation (9.23 per cent).

Table 4.15 Economics of chilli

Treatments	Total cost ha^{-1} (Rs)	Gross return ha^{-1} (Rs)	Net return ha^{-1} (Rs)	B : C ratio
T_1 (75% CF + 25% PM)	70006.00	114408	44402.01	1.63
T_2 (50% CF + 50% PM)	70749.44	115912	45162.57	1.64
T_3 (25% CF + 75% PM)	71490.66	107284	35793.33	1.50
T_4 (100% PM)	72231.91	99352	27120.09	1.38
T_5 (75% CF + 25% VC)	71797.41	110960	39162.59	1.55
T_6 (50% CF + 50% VC)	74312.06	101132	26819.94	1.36
T_7 (25% CF + 75% VC)	76837.06	101636	24798.95	1.32
T_8 (100% VC)	79357.71	27100	-52257.72	0.34
T_9 (75% CF + 25% NC)	71176.00	94872	23696.00	1.33
T_{10} (50% CF + 50% NC)	73093.48	83180	10086.52	1.14
T_{11} (25% CF + 75% NC)	74981.47	86356	11374.53	1.15
T_{12} (100% NC)	76852.57	41360	-35492.90	0.54
T_{13} (POP)	69251.50	78884	9632.51	1.14
F	2.89*	110.87**	234.79**	970788.7**
CD	5211.24	7539.64	2650.21	0.001

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

Cost of inputs
- Urea - Rs. 5.00 per kg
- Mussoriephos - Rs. 3.50 per kg
- MOP - Rs. 4.30 per kg
- Poultry manure - Rs. 1.00 per kg
- Vermicompost - Rs.3 per kg
- Neem cake - Rs. 8 per kg

Cost of produce
- Chilli - Rs. 12 per kg

Table 4.16 Scoring of bacterial wilt (per cent) as influenced by chemical fertilizers and organic manures

Treatment	Per cent
T_1 (75% CF + 25% PM)	7.40
T_2 (50% CF + 50% PM)	5.57
T_3 (25% CF + 75% PM)	7.40
T_4 (100% PM)	8.30
T_5 (75% CF + 25% VC)	4.67
T_6 (50% CF + 50% VC)	5.60
T_7 (25% CF + 75% VC)	4.67
T_8 (100% VC)	5.57
T_9 (75% CF + 25% NC)	3.73
T_{10} (50% CF + 50% NC)	5.60
T_{11} (25% CF + 75% NC)	4.67
T_{12} (100% NC)	8.30
T_{13} (POP)	9.23
F	3.41^{**}
CD	2.72

** Significant at 1% level

DISCUSSION

5. DISCUSSION

Vegetable cultivation in our State is carried out on commercial scale mostly by the application of chemical fertilizers. The increasing use of NPK fertilizers made the soils deficient in micronutrients like Zn, Fe, Cu, Mn, Mo etc. The plant nutrients in soils thus are imbalanced and the organic carbon status of the soils has fallen. So emphasis must be given to reverse this situation by popularising the concept of INM, which involves the conjuctive use of macro and micro nutrient fertilizers with organic manures. INM aims at harnessing the benefits of positive nutrient interactions to the maximum possible extent to maximize crop yield and nutrient use efficiency.

The present investigation was envisaged to develop such an INM practice for chilli. The growth, yield and quality of chilli and economics of its cultivation were studied. It was also compared with a control, POP recommendation.

The data collected on various growth characters, yield and yield attributes, quality characters, nutrient uptake, soil nutrient status and benefit-cost ratio were analysed statistically and the results are discussed in this chapter.

The treatments included chemical fertilizer and organic manure in the ratio 3:1, 1:1, 1:3 and 0:2. Control treatment was POP recommendation for chilli (20 t ha^{-1} FYM + 75:40:25 kg N, P_2O_5 and K_2O ha^{-1}).

5.1 Combined application of chemical fertilizer and poultry manure Vs POP

5.1.1. Growth characters

The growth characters were significantly influenced by the integrated application of chemical fertilizer and poultry manure in various ratios. The result indicated that highest values for mean plant height at 35, 70 and 105 DAT (21.1 cm, 39.03 cm and 44.93 cm respectively), number of branches at 35 and 105 DAT (6.23 and 23.75 respectively) and LAI at final stage (0.86) were recorded by the treatment receiving chemical fertilizer and poultry manure in the ratio 3:1, whereas the corresponding values for POP recommendation were 20.67 cm, 31.47 cm and 35.27 cm respectively for plant height (Fig. 3) and 4.13 and 18.67 respectively for number of branches (Fig. 4) and 0.73 for LAI. Similarly the same treatment (T_1) recorded maximum value for all other growth characters like DMP at all stages, canopy spread, NAR and CGR. When chemical fertilizer and poultry manure were applied in 3:1 ratio, more of the nutrient nitrogen may be in the readily available form and only a part may be in the slowly available form. Influence of N in increasing the vegetative growth of the plant is a universally accepted fact. This increased growth characters may be due to the increased availability of N from chemical fertilizer. Increased nitrogen level increases the growth characters as reported by Joseph (1982).

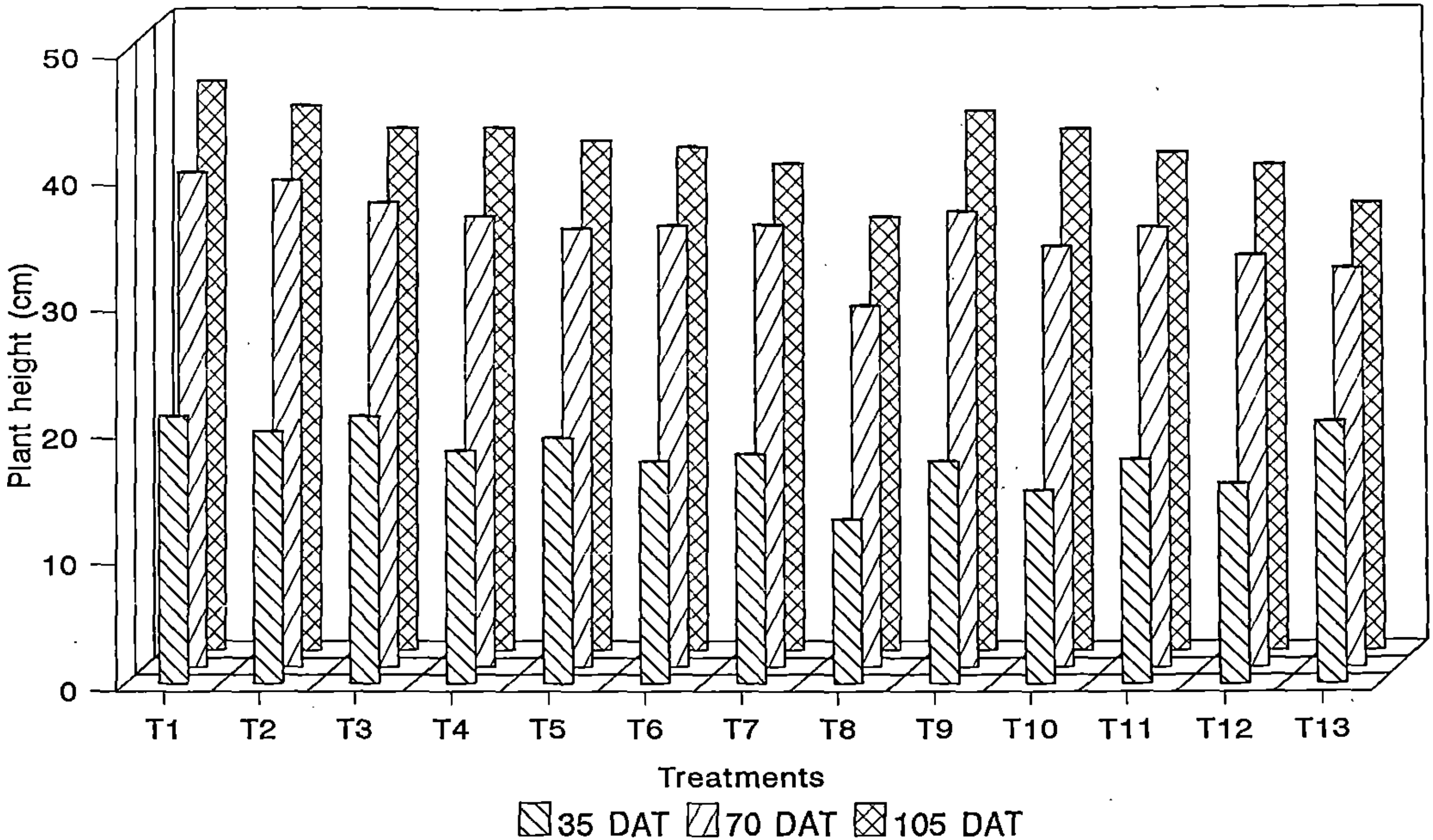

Fig. 3. Effect of different sources and ratios of organic and inorganic fertilizers on the plant height of chilli

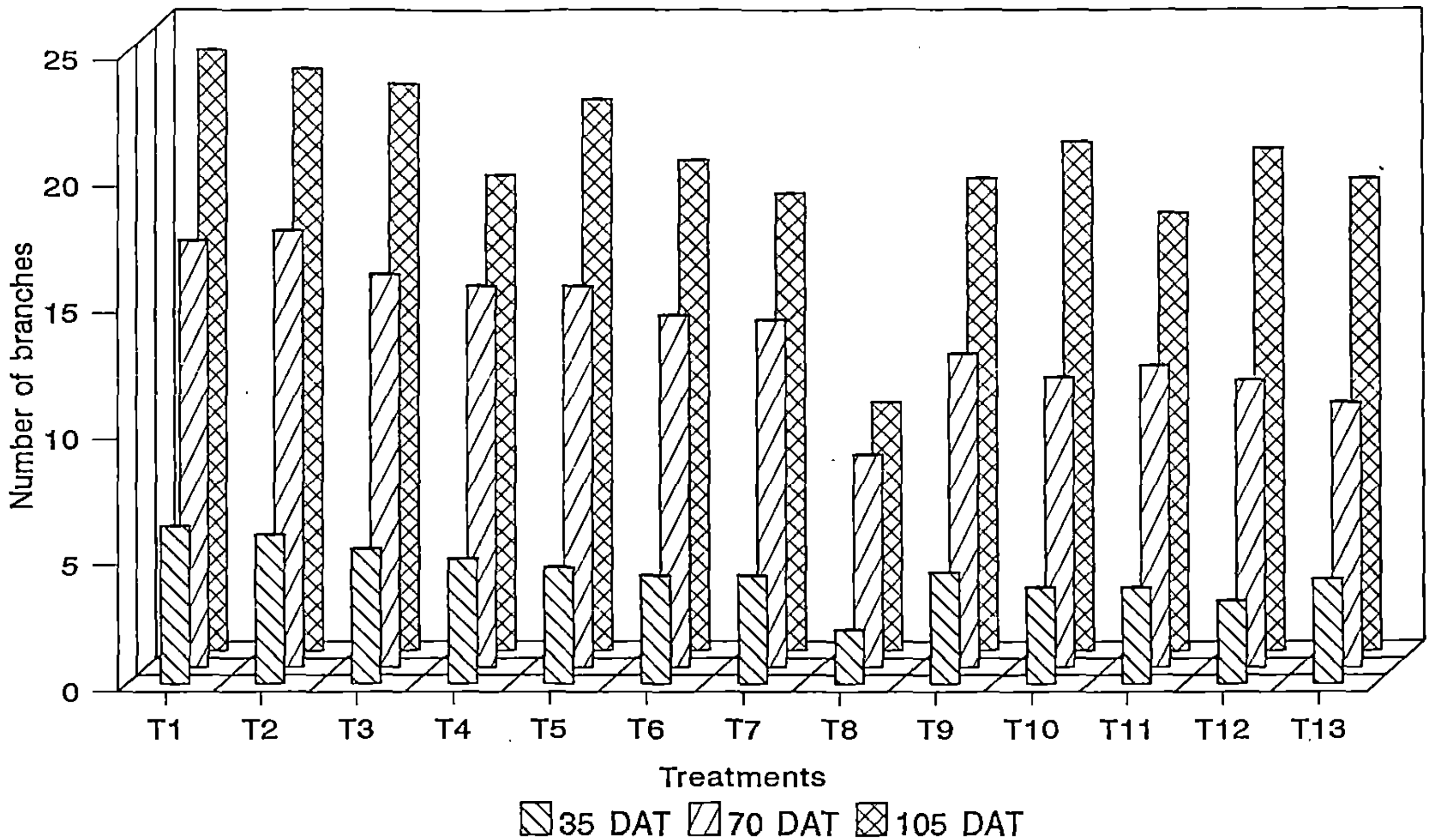

Fig. 4. Effect of different sources and ratios of organic and inorganic fertilizers on the number of branches

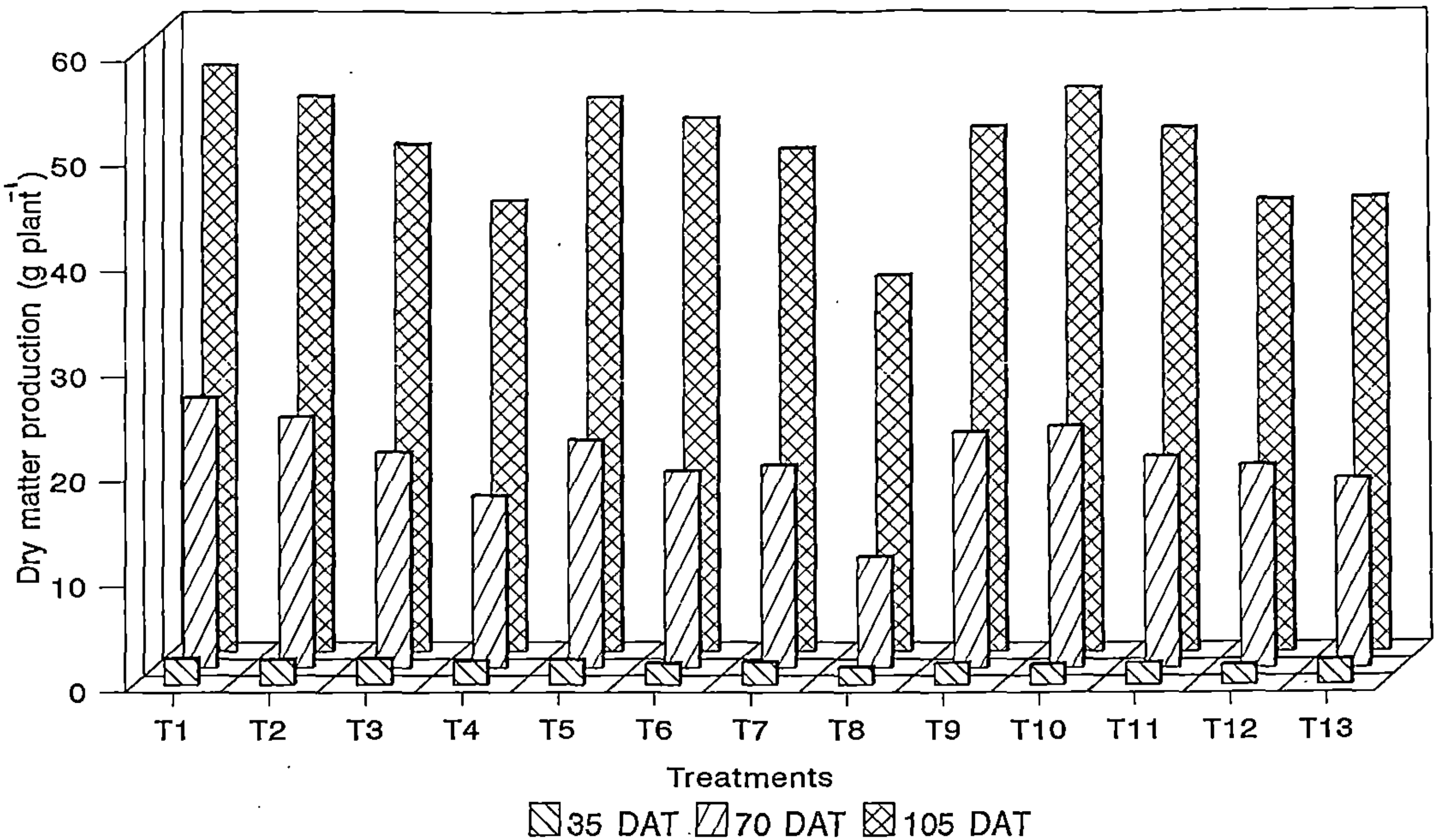

Fig. 5. Effect of different sources and ratios of organic and inorganic fertilizers on the dry matter production

The value of other growth parameters like shoot-root ratio (3.18) was highest for the treatment T_3 (1:3 ratio) as compared to POP recommendation (3.18). When the ratio of 1:3 was adopted the amount of organic matter was more. Organic manure constitute a dependable source of major and minor nutrient elements. In poultry manure, 60% of the N is present as uric acid which rapidly gets converted to ammoniacal form and is easily utilised by the plant (Smith, 1950). This increased nutrient status might have increased the photosynthetically active surface area and in turn higher photosynthates for providing more shoot growth. Similar results were reported by Sherly (1996).

The canopy spread (E-W) was not significantly influenced by various treatments. However the highest value was recorded for the treatment T_2 (1:1 ratio). The application of equal ratio of chemical fertilizer and poultry manure might have increased the nutrient levels. Increased nutrient level might have enhanced cell division of canopy as reported by Ahmed and Tanki (1991).

5.1.2. Yield characters

The yield and yield components were also significantly influenced by integrated application. The treatment T_1 recorded maximum value for fruit setting percentage (43.3 per cent), fruiting phase (61 days) and girth of fruit (4.85 cm) in comparison with the POP where the values were (38.23 per cent), (52 days) and (4.49 cm) respectively. This may be due to the increased supply of nitrogen to the plants from chemical fertilizer.

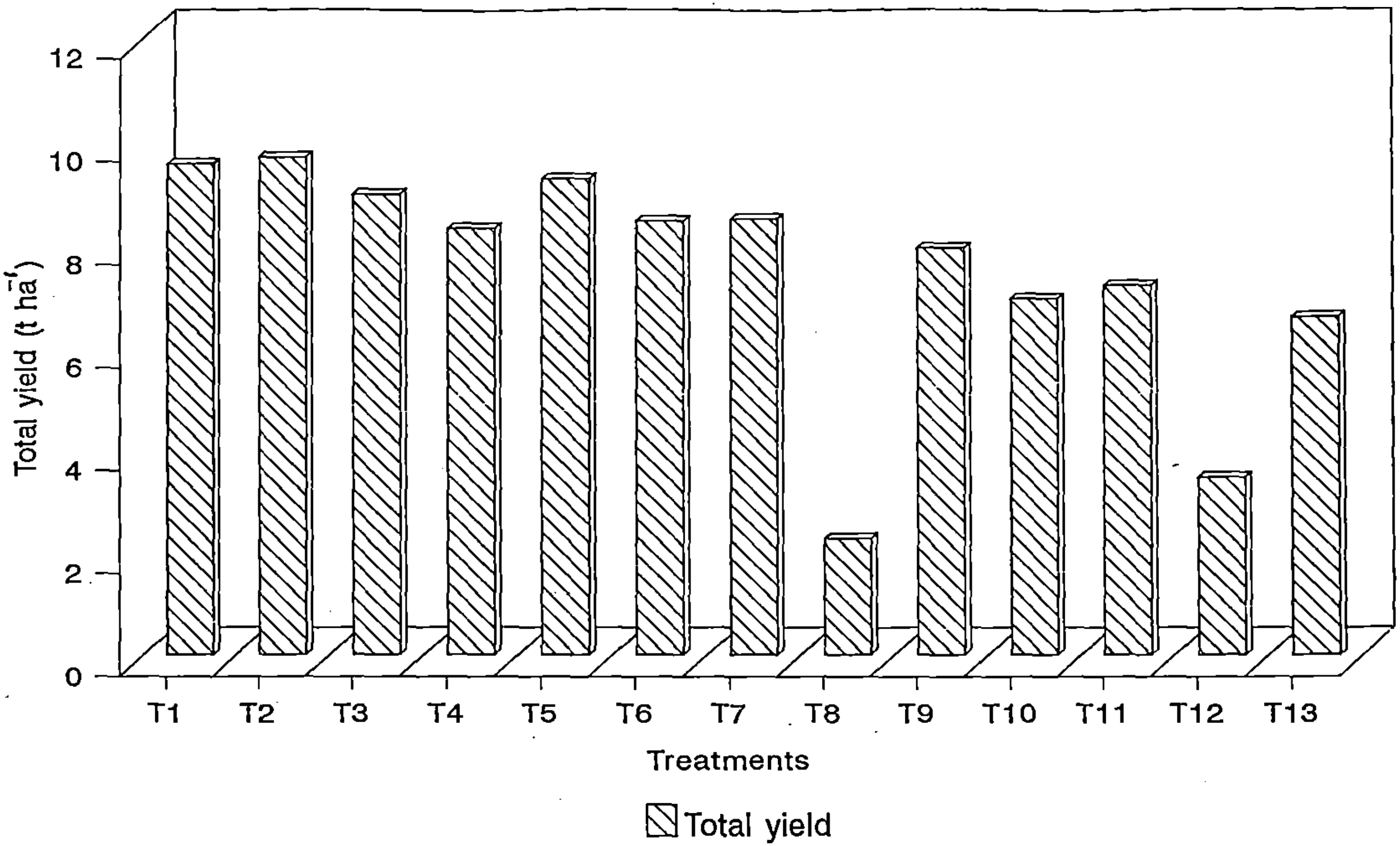

Fig. 6. Effect of different sources and ratios of organic and inorganic fertilizers on the total yield of chilli

This is in conformity with the findings of Splittstoesser and Gerber (1986), John (1989) and Goyal *et al.* (1989).

The results presented in Tables 4.5, 4.6 and 4.7 revealed that T_2 recorded the highest values for number of fruits per plant (54.6), fruit length (7.36 cm) and fruit yield per hectare (9.66 t/ha) when compared to POP. The respective values for POP were 37.4, 7.36 cm and 6.57 t/ha respectively. The harvesting interval was also least for this treatment. In the case of 1:1 ratio, the chemical fertilizer and poultry manure was applied in equal proportion. In poultry manure the nitrogen mineralised during the first two-three months of the application, 80% is converted to NO_3 at end of first three weeks (Tisdale *et al.*, 1995). This might have resulted in better availability and uptake of nutrients which might have resulted in increased yield and yield attributes. The beneficial effect of the combination of chemical fertilizer and poultry manure in the ratio 1:1 in increasing yield parameters were reported by Rekha (1999). This is in agreement with the findings of Singh *et al.* (1973), Ifenkwe *et al.* (1987) Jose *et al.* (1988) and Segovia (1988).

The mean weight of fruit (4.37 g) was found to be highest for the treatment in which the integrated application was followed in the ratio 1:3 and was found significantly superior to POP (3.69 g). This may be due to the higher number of seeds per fruit in this treatment. This conforms with the findings of Asha (1999). In this treatment major portion of the nutrients is supplied by the organic component (poultry manure). Due to the increased nitrogen availability the P uptake might have improved which might have increased the P content in plants. Synergistic influence of N nutrition on P content was reported by Singh *et al.* (1970) in cauliflower. All these factors might have increased the yield and yield attributes.

5.1.3. Quality characters

There was significant increase in keeping quality (4.07 days) when chemical fertilizer was applied along with poultry manure in the ratio 1:1 (Table 4.8). The fruit produced from the control plot remained without damage only for 3.33 days (Fig. 9). This is in accordance with the findings of Rekha (1999). The increased keeping quality might be due to the decreased discolouration which may be due to the increased K uptake as reported by Asano *et al.* (1981).

Vitamin C which is an important quality parameter was found to be highest in the treatment in which dual application in the ratio 1:3 was practised. The value was 98.67 mg/100 g of fruit sample as compared to POP (95.67 mg/100 g of fruit). In the case of oleoresin content there was no significant difference, even then the highest value was found to be for this treatment. Combined application of chemical fertilizer and poultry manure might have raised the availability of nutrients throughout the growing period. Increased ascorbic acid content might be due to the increase in protein synthesis and enhancement of enzymatic activities for amino acid synthesis at higher level of nutrient which is instrumental in improving the quality (Kaminwar and Rajagopal, 1993). Increased vitamin

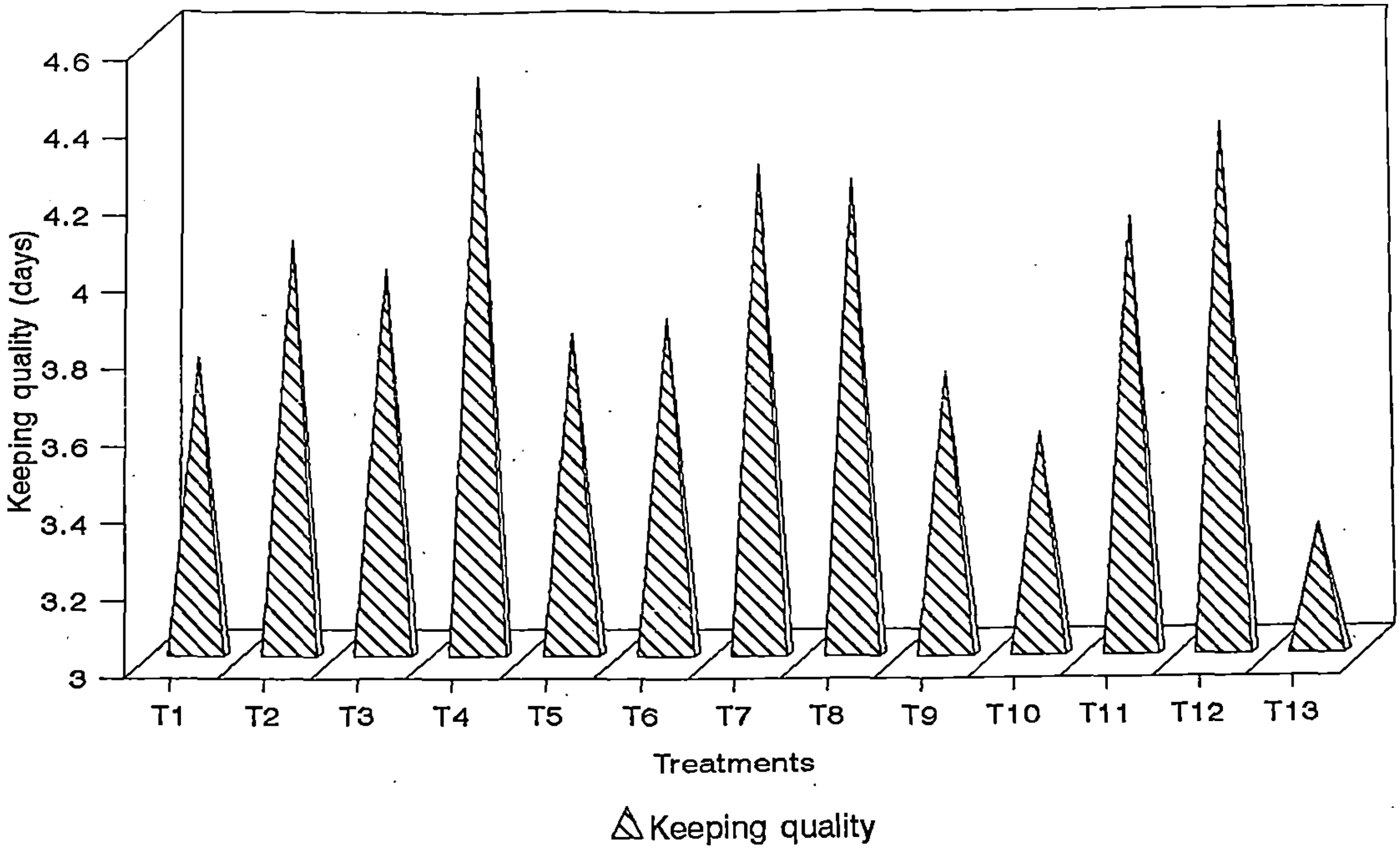

Fig. 7. Effect of different sources and ratios of organic and inorganic fertilizers on keeping quality

C content with the highest level of poultry manure has been reported by Arunkumar (2000).

5.1.4. Nutrient availability, nutrient uptake and nutrient content

Nutrient availability was significantly influenced by various treatments. Among the various combinations, the highest value for soil P (93.4 kg ha^{-1}) was recorded by the 1:1 combination, while the corresponding value recorded by the POP recommendation for the same treatment was 63.33 kg ha^{-1} (Fig. 8). The combined application of chemical fertilizer and poultry manure (organic manure) is important to maintain and sustain a higher level of soil fertility and crop productivity. Due to the increased microbial activity in organic matter, P solubilisation is improved. This might have increased the P status of soil.

With respect to soil N, Plant N and P uptake the highest values were recorded by treatment T_3 as against POP recommendation. Similar trend was followed in the case of P and K content of plants. The integrated application might have increased the microbial activity in soil which improved the N fixation. And this might have increased the N status of soil. Phosphorus is an important structural component of a wide variety of biochemicals including nucleic acid, coenzymes, nucleotides, phosphoproteins, phospholipids and sugar phosphates. Therefore it could be persumed that increased supply of N might result in increased production of P containing biochemicals under non limited

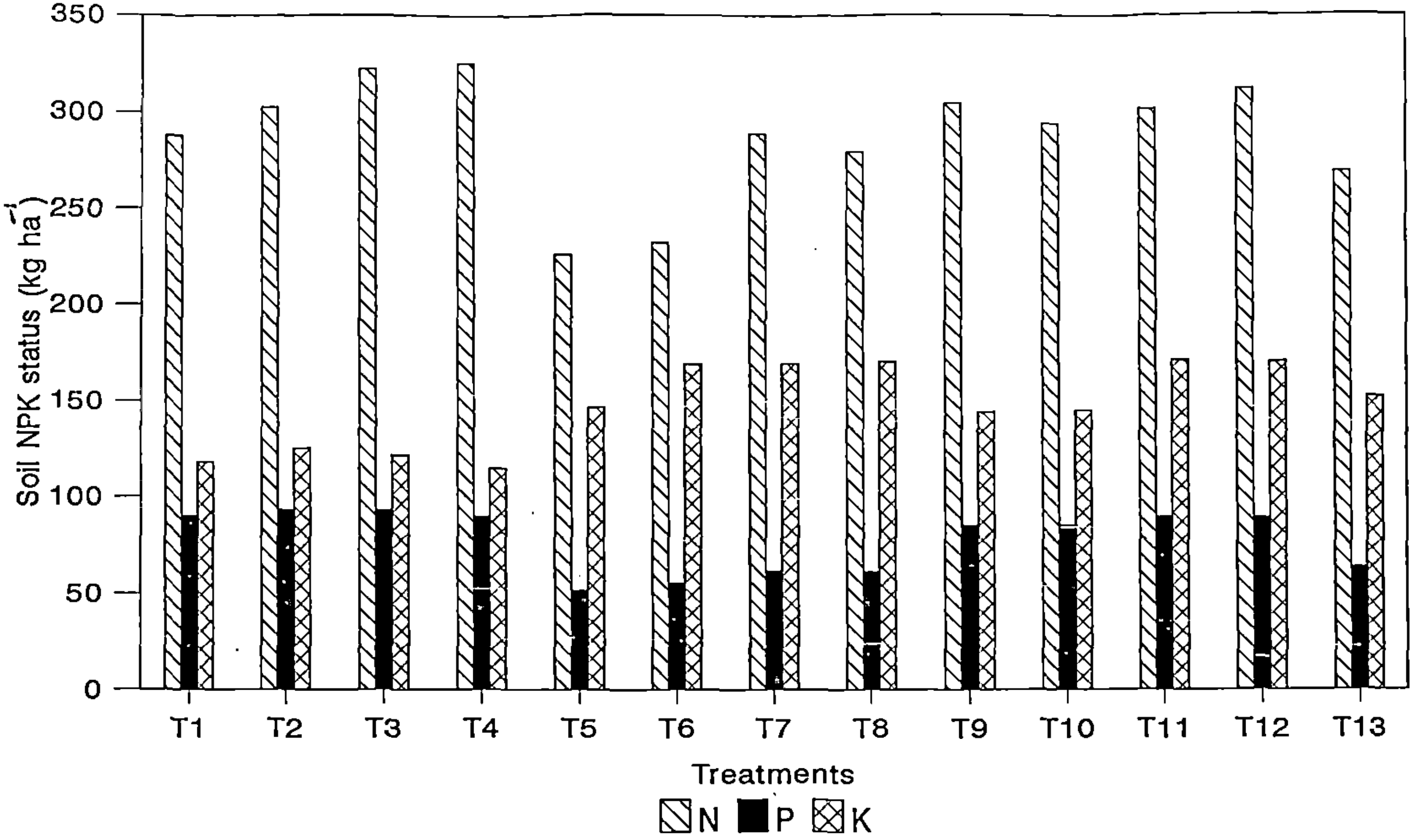

Fig. 8. Effect of different sources and ratios of organic and inorganic fertilizers on the NPK status of soil

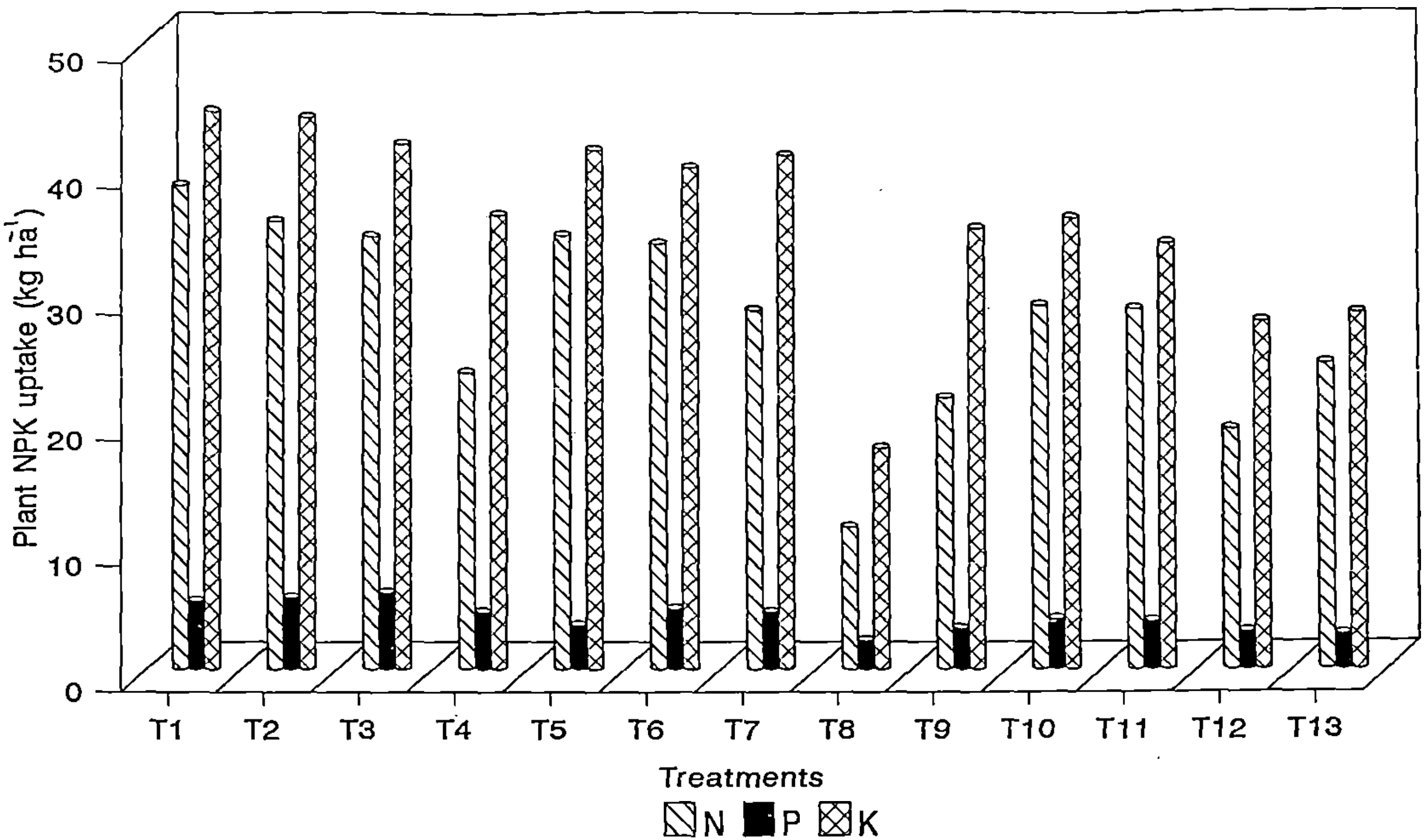

Fig. 9. Effect of different sources and ratios of organic and inorganic fertilizers on the plant NPK uptake

conditions of P supply which would have contributed to improved P content in plant. Synergistic influence of N nutrition on P content was previously reported by Singh *et al.* (1970) in cauliflower. Besides, the organic matter application in higher proportion would have resulted in vigorous root growth which might have increased the P and K content in plants.

The highest dose of chemical fertilizer recorded the highest N and K uptake (Fig. 9). The dual application of chemical fertilizer and poultry manure might have improved the soil properties. Organic manure improves the soil aeration, permeability, water and nutrient holding capacity and biological properties of soil as reported by Banerjee (1998). This improved soil properties might have produced better development of root system. As uptake of K is mostly through root interception, better the root system, the more is the K uptake. This agrees with the findings of Niranjana (1998).

5.1.5. Economics

The treatment (T_2) involving integrated application of poultry manure and chemical fertilizer in the ratio 1:1 gave the best performance with respect to gross income, net profit (Fig. 11) and B:C ratio (Fig. 10). This higher returns may be due to the best performance of the crop with respect to yield and fertilizer use efficiency. The fertilizer use efficiency of chemical fertilizers increased with the combined application with organic amendments (Anitha, 1997).

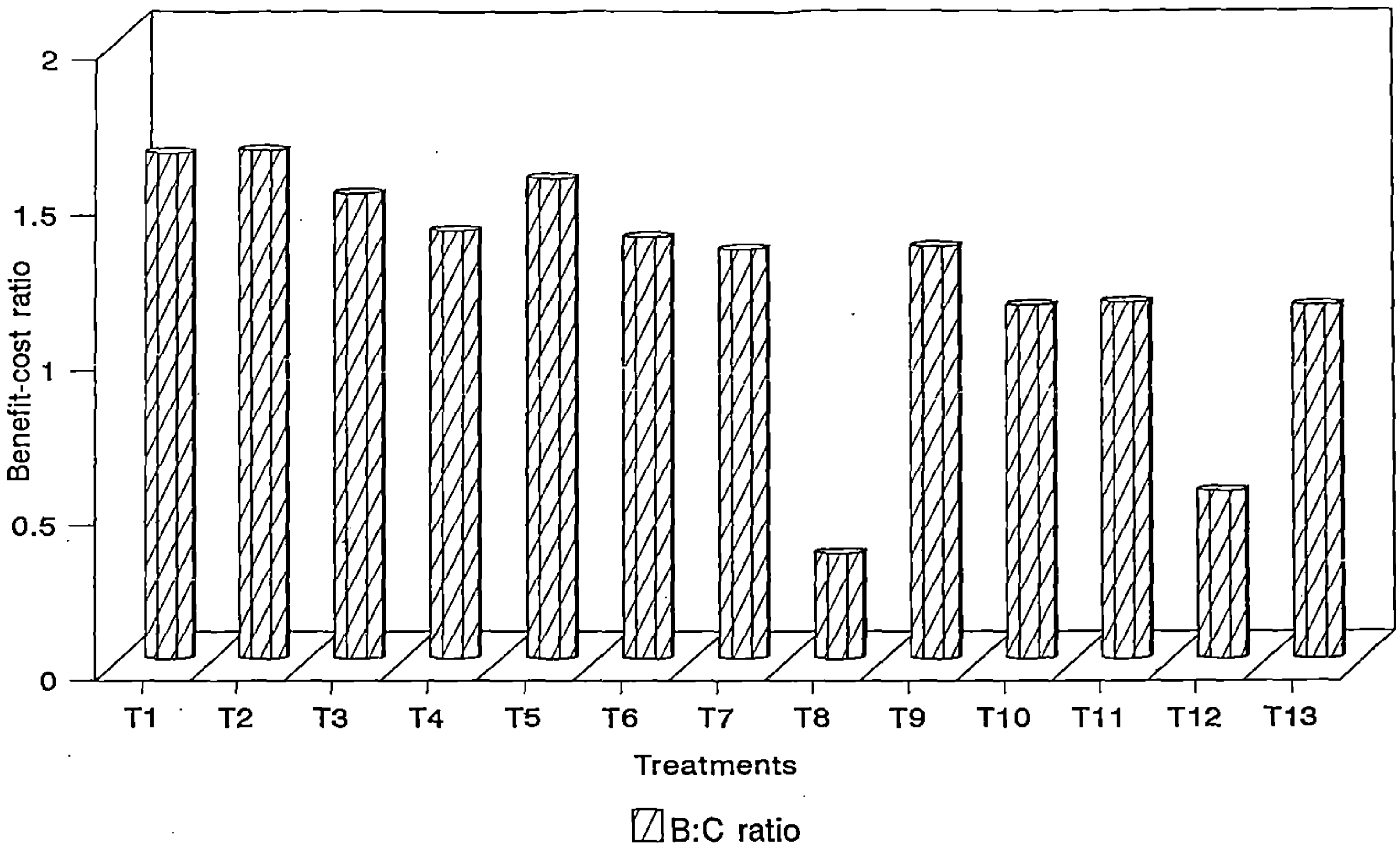

Fig. 10. Effect of different sources and ratios of organic and inorganic fertilizers on benefit cost ratio

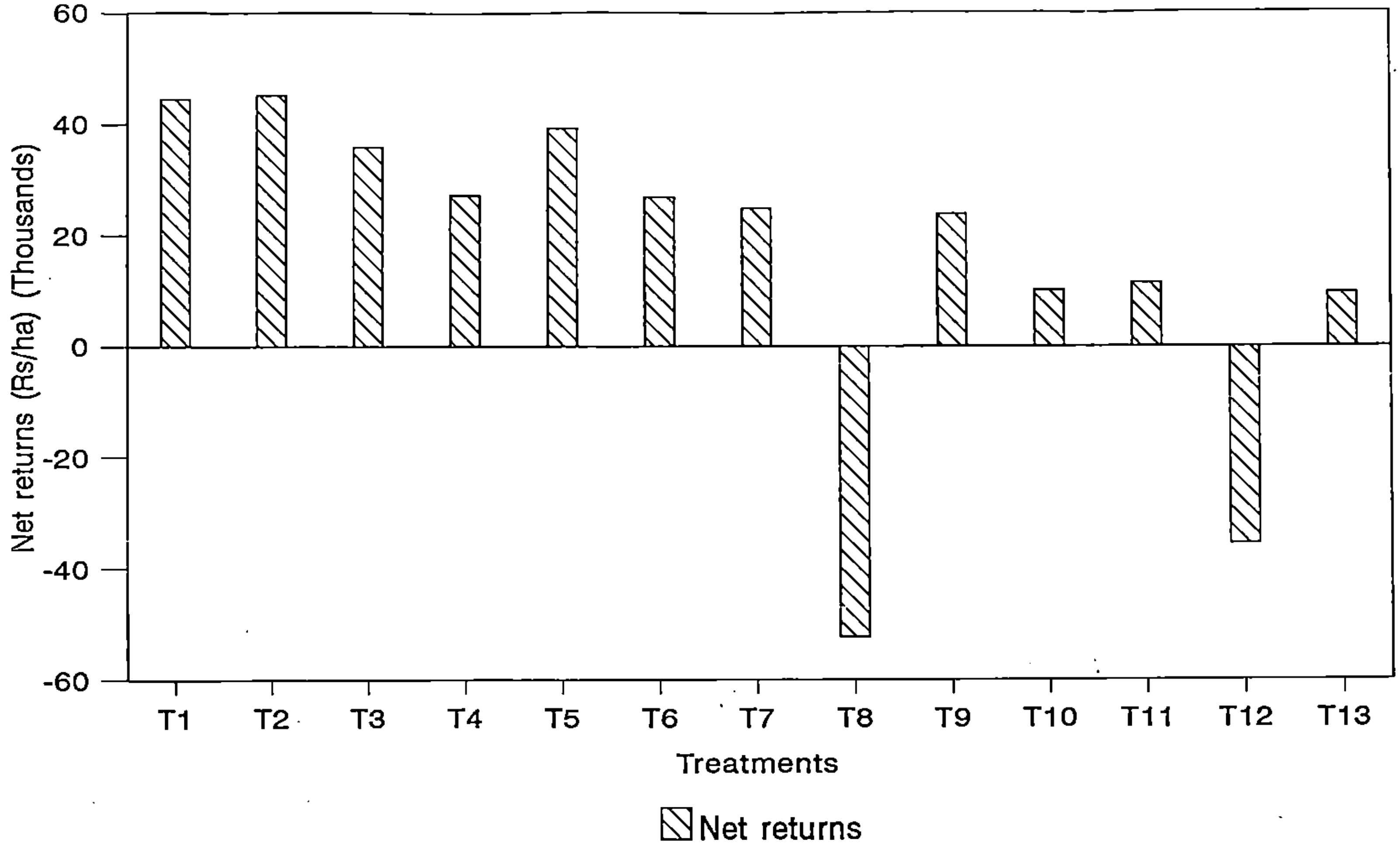

Fig. 11. Effect of different sources and ratios of organic and inorganic fertilizers on net returns

5.2 Poultry Manure Vs POP

Application of poultry manure gave best performance with respect to growth, yield and quality of chilli. There was also a significant improvement in nutrient status of soil, nutrient uptake and nutrient content of plants. The values for various growth characters were 35.57 cm and 41.27 cm (plant height at 70 and 105 DAT) respectively, 4.93, 15.07 and 18.8 (Number of branches at 35, 70 and 105 DAT) respectively, 0.18, 0.75 and 0.85 (LAI at 35, 70 and 105 DAT) respectively, 47.07 (number of fruits per plant), 8.28 t ha^{-1} (fruit yield per hectare) 97 mg/100g of fresh fruit sample (vitamin C content) and 4.5 days (keeping quality). These values were found to be lowest for POP recommendation where the loss of nutrients is more. Similar reports on improved growth, yield and quality due to poultry manure application was reported by Anitha (1997), Asha (1999) and Arunkumar (2000).

Poultry manure is a good source of nutrients particularly for vegetable production. In this manure, 60% of N is present as uric acid, 30% as more stable organic nitrogen form and the balance as mineral nitrogen (Srivastava, 1988). The rapid release of nutrients from poultry manure might have improved the nutrient availability, nutrient uptake and nutrient content in plants, which in turn might have resulted in increased growth and yield characters.

Favourable influence of poultry manure on N uptake was indicated by Heathman *et al.* (1995). Higher levels of poultry manure registered increased K uptake. Application of poultry manure might have enhanced the root zone temperature which would have favourably influenced the K uptake by plants. Nkansah and Ito (1995) observed increased K uptake due to the higher root zone temperature. Synergestic influence of N nutrition on P content was previously reported by Singh *et al.* (1970) in cauliflower.

When poultry manure is applied, long term increase in soil nutrient levels like B, Ca, Mg, Cu and Zn can be expected (Bitzer and Sims, 1988). The importance of micronutrients like B in keeping quality of fruits and tubers were indicated by Tisdale *et al.* (1995). It was pointed out that boron deficiency causes cracking or rotting of fruits and tubers thereby reducing the storage life. Therefore poultry manure application seemed to have a favourable influence on shelf life of fruits. Higher vitamin C in fruits raised under total organic farming was reported by Shanmugavelu (1989).

From the results, it is clearly evident that application of poultry manure and chemical fertilizers in different ratios is significantly superior to POP recommendation.

In POP recommendation, nutrients are supplied mainly through chemical fertilizer and only a part through FYM. Nitrogen as urea was applied in three equal split doses, one as basal, second and third splits at one month and two months after transplanting. For urea, nutrients mineralize very quickly and are susceptible to leaching loss (Tisdale *et al.*, 1997). This quick mineralisation and leaching losses might have resulted in declining the nutrient availability during early stages, thus reducing the yield. The availability of nutrients present in FYM is very low. FYM is having high residual effect and only one half of the nitrogen, one sixth of phosphoric acid and a little more than one half of the potash alone are readily available to the crop (Thampan, 1993). Thus the nutrients from FYM and chemical fertilizers were not fully available to the plants, especially at the critical stages of crop growth and reproduction. This might have resulted in decreased crop growth and yield. Unlike chemical fertilizers, the nutrients in poultry manure are readily available within a period of two to three months and are less susceptible to leaching loss. Thus the superiority of poultry manure in accelerating growth and yield when compared to POP is well brought out.

5.3 Combined application of chemical fertilizers and vermicompost Vs POP

5.3.1. Growth characters

The various growth characters were significantly influenced by integrated application involving vermicompost and chemical fertilizer. When chemical fertilizers were applied with vermicompost in the ratio 3:1 plant height at 105 DAT was highest (40.2 cm) while the corresponding value for POP recommendation was 35.27 cm (Fig. 3). Shoot-root ratio was also highest for this particular treatment (4.73) in comparison with POP (3.18). Similarly the performance of other growth characters like

DMP, number of branches at all stages of growth and LAI at final stage reported maximum values. As the level of chemical fertilizers was increased, the growth characters were found to be responding well. Significant increase in yield of vegetative parts as a result of higher N levels was observed by several workers in cabbage (Peck, 1981) and Amaranth (Singh, 1984). The enhanced growth characters by the dual application of chemical fertilizer with vermicompost is in accordance with the findings of Pushpa (1996).

The increase in plant height and number of branches is attributed to the rapid meristematic activity due to the positive influence of vermicompost in increasing the vegetative growth of plant. When vermicompost was applied, the available nitrogen content in soil was increased, thereby development of shoot and other plant parts also were influenced. This might have led to an increase in the shoot weight with a higher value for shoot-root ratio.

As the nitrogen supply increased, the extra protein content produced might have allowed the plant leaves to grow larger and hence to have more surface area available for photosynthesis (Russel, 1973). Increase in leaf area, through higher nitrogen in solanaceous vegetables was reported by Joshi and Nankar (1992). These works, support the results of the present study.

At the early stage of plant growth (35 DAT) the LAI was more when vermicompost and chemical fertilizers were applied in 1:1 ratio. CGR was also highest for this treatment. This may be due to more content of nutrients from both chemical and organic source. Steineek (1964) opined that more the available nitrogen, the greater the effect of potassium on the growth of shoot, number of leaves and longivity of leaves.

The performance of highest dose of vermicompost along with chemical nitrogen was good at 70 DAT in the case of growth characters like plant height and LAI. As the levels of organic manures increased, the vegetative growth was promoted which naturally increased the height of plants. Similar observations of increased plant growth by the application of vermicompost have been reported by Tomati *et al.* (1983).

5.3.2. Yield characters

Vermicompost can act not only as a growth determinant but also as an yield determinant.

Number of fruits per plant (52.6), fruit yield per plant (263.43 g $plant^{-1}$) and total yield (9.25 t ha^{-1}) was highest when fertilizers and vermicompost were applied in 3:1 ratio. The corresponding values for POP recommendation were 37.4, 187.28 g $plant^{-1}$ and 6.57 t ha^{-1} respectively. Vermicompost is reported to contain about three times more nutrients than FYM. (Prabhakumari *et al.*, 1995). The increased growth and yield attributes may be due to the better nutrient content and soil improving property of vermicompost. Sheshadri *et al.* (1993) showed that the yield of dry chillies obtained from vermicompost was higher than the control. Similar observations were reported by Shuxin *et al.* (1991)

and Rajalekshmi (1996). The primary factor governing the soil health is the organic matter content of soil and the concept of organic farming is widely acclaimed now. But the results of the present study revealed that the integration of inorganics and organics gave the highest yield and this supports the concept of Integrated Plant Nutrient Management System. But again when the organic source was vermicompost instead of FYM, the results were very much encouraging with respect to yield as well as other biometric characters.

The present study clearly depicts the importance and need for IPNM. When this system was followed with chemical fertilizer and vermicompost in 1:1 ratio, the length of fruit (7.89 cm), mean weight of fruit (4.25 g), fruiting phase (55 days) and fruit setting percentage (39.23 per cent) were found to be highest, than the POP where the values were 7.36 cm, 3.69 g, 52 days and 38.23 per cent respectively. The harvesting intervals was also lowest in this treatment (T_6). The higher availability of plant nutrients created due to the improved physical environment brought about by vermicompost can be cited as the major reason for the above desirable effects. The present study is in conformity with the findings of Rajalekshmi (1996).

The fruit yield per plant (241.31 g plant^{-1}), number of fruits per plant (48.2), total yield (8.47 t ha^{-1}), length of fruit (7.74 cm), mean weight of fruits (3.92 g) has attained highest value in the integrated application of chemical fertilizer and vermicompost in 1:3 ratio, in comparison with POP. For POP these values were 187.28 g plant^{-1}, 37.4, 6.57 t ha^{-1}, 7.36 cm and 3.69 g respectively. Other yield attributes like harvesting intervals was lowest in this treatment. As the organic matter was increased the yield was more. The findings of Arunkumar (2000) supports this view. The decomposed organic manures like vermicompost improved both the physical and chemical fertility of the soil, thereby increasing the available plant nutrients in soil and nutrient content in the plant parts. This could be the main reason for the increased yield with this treatment.

5.3.3. Quality characters

The keeping quality (3.83 days) and ascorbic acid content (96.00 mg/100g) was more when compared to POP in the 3:1 treatment combination. This may be due to the balanced availability of nitrogen throughout the growth stages. In the case of POP, where the entire quantity is applied as chemical source there will be more leaching loss of nutrients. Increase in the vitamin C content of fruits with increasing level of nitrogen was reported by Dod *et al.* (1992) in chilli. The increased keeping quality might be due to the increased vitamin C content.

In the case of 1:1 and 1:3 treatment combinations also, the keeping quality and vitamin C content was found to be high compared to package of practice recommendation of KAU. From this, it is clear that as the organic matter (vermicompost) content was increased, the quality of fruits was also improved. Similar results of increased quality in vermicompost treated plots were reported by Gavrilov (1962) and Tomati *et al.* (1983).

5.3.4. Nutrient availability, nutrient uptake and nutrient content

Integration of fertilizer with vermicompost in 3:1 ratio recorded highest N, P and K uptake (34.48 kg ha^{-1}, 3.45 kg ha^{-1} and 41.27 kg ha^{-1} respectively) and P and K content in plants (0.19 per cent and 2.23 per cent respectively) compared to POP. In this treatment the NPK status of soil was lower than POP. The increased mineralisation of native soil P as a result of production of organic acids during the decomposition of organic matter might be the reason for increased P content of plant parts. The solubilisation of P by the micro organisms was attributed to the excretion of organic acids like citric, glutamic, succinic, lactic, oxalic, glyoxalic, maleic, fumaric and tartaric acid. This was observed by Rao (1983). These reactions had taken place in the rhizosphere and since the organisms rendered more P into the solution that required for their own growth and metabolism, the surplus was made available for the plant parts thereby increasing the P uptake and P content. This view was supported by Shuxin *et al.* (1991). In the presence of vermicompost, the K fixation might have reduced thereby releasing more of K in the soil. The enhanced proliferation of roots might have helped in the increased uptake of K. The increased uptake of nutrients might have resulted in the low NPK status of soil.

In the case of 1:1 ratio, available K status, P and K uptake, N, P and K content of plants were more when compared to POP.

The highest dose of vermicompost along with chemical fertilizer registered highest values for available N and P, K in soils and K uptake and P and K content of plants. Highest values were obtained for the highest level of vermicompost. The increase in available N content of soil and increased N recovery due to the use of organic source of N has been reported by Srivastava (1985). The higher degree of decomposition and mineralisation in vermicompost may be one of the reasons for high N content and this might have finally contributed to the available N status of soil. The increased availability of K due to the addition of vermicompost may be due to the increased concentration of available and exchangeable K contents in wormcast compared to surrounding soil. Baskar *et al.* (1992) inferred that earthworms increases the availability of K by shifting the equilibrium among the forms of K from relatively unavailable forms to more available forms. The earthworms stimulate P uptake by the redistribution of organic matter and by increasing the enzymatic activation of phosphatase (Mackay *et al.*, 1982). The increased mineralisation of soil P as a result of production of organic acids during decomposition of organic matter may also be one of the reasons for increased P uptake by the plants. The solubilization of P by these microorganisms is attributed to excretion of organic acids like citric acid, glutamic acid, succinic acid, lactic acid, oxalic acid, glyoxillic acids, maleic acid, fumaric acid and tartaric acid (Rao, 1983).

5.3.5. Economics

In all the treatment combinations involving chemical fertilizer and vermicompost, benefit-cost ratio was more compared to POP recommendation. The benefit-cost ratio for 3:1, 1:1 and 1:3 ratios were

1.55, 1.36, 1.32 respectively (Fig. 10) and for POP recommendation it was 1.14. B:C ratio showed an increasing trend when the level of chemical fertilizer was increased, up to 75 per cent.

5.4. Vermicompost Vs POP

The performance of the treatment T_{13} (POP) was good, when it was compared with organic farming with vermicompost. When vermicompost alone was applied, the growth and yield was considerably reduced and the nutrient uptake and content was also less. But the residual nutrient, the keeping quality of fruits and ascorbic content was higher when compared to POP recommendation. The significant quantities of available nutrients, biologically active metabolites particularly gibberellines, cytokinins, auxins and group B vitamins might have contributed to better quality due to vermicompost treatments. Similar results of increased quality of vermicompost treatment was reported by Bano *et al.* (1987). The higher keeping quality might be due to the higher vitamin C content. When vermicompost was applied in higher doses, the growth and yield was comparatively lower. Eventhough vermicompost contain many growth promoting hormones, vitamins, enzymes etc. in addition to plant nutrients, the superiority could not be reflected in yield when given without inorganic fertilizer. This is in close agreement with the observations of Pushpa (1996). Hence the superiority of the integrated application is well understood.

5.5. Combined application of chemical fertilizer and neemcake Vs POP

5.5.1. Growth characters

Growth characters showed significant influence with integrated application compared to POP recommendation. The highest plant height at 70 and 105 DAT (35.97 cm and 42.57 cm), number of branches at 35 and 70 DAT (4.4 and 12.4), LAI at 35 and 105 DAT (0.19 and 0.74) was recorded by the treatment receiving highest dose of chemical fertilizer along with neemcake (3:1 ratio). In chemical fertilizers, nutrients mineralise very quickly and is susceptible to leaching loss. But when they are applied in combination with neemcake, the nutrient availability will be increased. Due to the presence of certain alkaloids, neemcake inhibit the population of *Nitrosomonas* sp which reduces the nitrification process. Thus the leaching and denitrification losses are checked and resulted in the increased supply of nitrate nitrogen throughout the growth period (Sahrawat and Parmer, 1975). All these factors might have resulted in increased rate of growth characters with increase in nutrients. Increased level of nutrients increased the growth characters as reported by Prabhakar *et al.* (1987) and John (1989).

The highest dry matter production at 70 and 105 DAT (22.99 g plant^{-1} and 53.66 g plant^{-1}) and shoot root ratio (3.98) was observed for the treatment T_{10} (1:1 ratio). Neemcake is a concentrated organic manure rich in plant nutrients. In addition it contain some alkaloids which possess nitrification inhibiting properties. (Rajkumar and Sekhon, 1981). These might have resulted in increased growth characters.

5.5.2. Yield and yield attributes

The highest dose of chemical fertilizer along with neemcake recorded highest value for number of fruits per plant (44.93) and fruit yield per hectare (7.91 t ha^{-1}). The harvesting interval was also lowest (9.47 days) for this treatment. Girth of fruit was highest even though there was no significant difference among the treatments. Dual application resulted in increased availability of nutrients. Increased nutrients in turn increased production, translocation and assimilation of photosynthates to growing points thereby stimulating plants to produce more number of flowers $plant^{-1}$ and subsequently more fruit $plant^{-1}$. Similar results were reported by Kaminwar and Rajagopal (1993).

In the case of fruiting phase (53.33 days) and mean weight of fruit (3.75 g) maximum value was recorded when fertilizers and neemcake were applied in 1:3 ratio whereas the respective values for POP were 52 days, and 3.69g respectively. The increase in the nutrient supply might have resulted in increased absorption of nutrients and translocation of photosynthates resulting in more weight of fruits in chilli. Similar results were noted by Joseph (1982) and Ahmed and Tanki (1991).

5.5.3. Quality characters

There was no significant difference in ascorbic acid content among the different treatments. But the vitamin C content and keeping quality was highest when fertilizer and neemcake were applied in 1:3 ratio. Application of neemcake lead to the production of organic constituent, which would have indirectly contributed to the higher shelf life of fruits. As the levels of inorganic fertilizer decreased, ascorbic acid content showed an increasing trend. This increased vitamin C content might have resulted in increased storage life. Luchnik (1975) reported that the use of organic manures resulted in increased vitamin C content which inturn resulted in better keeping quality of cabbage.

5.5.4. Nutrient availability, nutrient uptake and nutrient content in plants

The highest level of chemical fertilizer along with neemcake application (3:1 ratio) resulted in increased available nitrogen in soil (304.19 kg ha^{-1}) and plant K (2.00 %), whereas these values for POP were 268.65 kg ha^{-1} and 1.86% respectively. The highest N availability might be due to the high content of chemical N and also due to the slow releasing character of neemcake. The highest K content may be due to the high content of K (1.4%) in neemcake.

With respect to uptake of P and K, the highest value was found to be for the 1:1 ratio. Application of neemcake in equal proportion might have resulted in vigorous root growth thereby increasing the P uptake. Also the P content of neemcake is more when compared to other organic manures (1.0%). The neemcake in integrated supply system would have enhanced the moisture retention capacity of soil. This would have accelerated the K^+ diffusion to roots as pointed out by Tisdale *et al.* (1995) which would have resulted in better K uptake.

Available P and K in soil and P content in plant was highest when fertilizer and neemcake were applied in 1:3 ratio. This increase might be due to higher contenı of P and K in neemcake.

5.5.5. Scoring of bacterial wilt

Bacterial wilt was lowest when 50 per cent of fertilizer was substituted with neemcake. Integrated application might have reduced the disease incidence. A correlation between high wilt incidence and heavy root knot infestation in the field has been reported by Kelman (1953). Libman *et al.* (1964) opined that *Meloidogyne hapla* increased the incidence and severity of tomato wilt. Application of neemcake might have decreased the nematode population which might have reduced the percentage of bacterial wilt. The reduction of nematode population by the application of neemcake has been previously reported by Kumar (1988) and Rao *et al.* (1997).

5.5.6. Economics

Application of fertilizer and neemcake in 3:1 ratio was found to be more profitable for this treatment. The gross income, net profit and benefit-cost ratio were 94872 Rs. ha^{-1}, 23696.00 Rs. ha^{-1} and 1.33 respectively, whereas the corresponding values for POP were Rs. 78884 ha^{-1}, 9632.51 Rs. ha^{-1} and 1.14 respectively. The better profit obtained by this treatment may be due to the higher returns obtained from the treatment and the better return might be due to the higher yield performance.

5.6. Neemcake Vs POP

Organic nutrition involving neemcake was not significantly influenced by growth and yield characters. But the growth characters like plant height, number of branches, dry matter production and leaf area index were found to be on par with POP. The harvesting intervals was lowest for this treatment (10.53 days). The mean weight of fruit was highest when nutrients were supplied through neemcake alone (3.88 g per fruit). POP recorded a fruit weight of 3.69 g.

When neemcake alone was applied without any fertilizers, the keeping quality was found to be highest (4.37 days). The vitamin C content of this treatment was found to be on par with T_{13} (POP). The incidence of bacterial wilt was also lowest for this treatment. Similar reports on improved growth and yield characters due to neemcake application was reported by Som *et al.* (1992) in brinjal.

Neemcake is a concentrated organic manure rich in plant nutrient contents. In addition to nutrients, it possess some alkaloids like nimbin, nimbidin and certain sulphur compounds, which have nitrification inhibiting properties. As a result, neemcake act like a slow releasing nitrogenous fertilizer, by inhibiting the nitrification process of soil and nutrients are available within a period of two to three months according to the crop demand. Thus apart from the nutrient content in neemcake, the retention capacity of nutrients especially nitrogen to a prolonged period and its balanced availability might have resulted in producing better yield characters due to neemcake application as compared to POP recommendation.

Neemcake acted as efficient nitrification inhibitor thereby conserving more nitrogen, resulting in the minimisation of losses of nitrogen through leaching, denitrification and runoff. This might have increased the soil N status (Table 4.14). The higher available P and K in soil may be due to the higher level of P and K in neemcake. The increased available N might have increased the P uptake and P content in plants. Synergistic influence of N nutrition on P content was previously reported by Singh *et al.* (1970) in cauliflower.

The best keeping quality obtained for this treatment might be due to the high ascorbic acid content of fruits. Fruits with high ascorbic acid content is associated with good keeping quality due to the effective antioxygenic property of ascorbic acid. Application of neemcake might have increased the vitamin C content. Increased ascorbic acid content in tomato by the application of organic manures to vegetable crops was reported by Rani *et al.* (1997).

The net returns (Rs.-35492.90 ha^{-1}) and benefit-cost ratio (0.54) of this treatment (T_{12}) involving the application of neemcake alone was low when compared to Package of Practice Recommendation, where these values were Rs.9632.51 ha^{-1} and 1.14 respectively.

The decreased net returns and benefit-cost ratio of the treatment T_{12}, may be due to the high cost of neemcake when compared to chemical fertilizers. This emphasize the need for the integrated application of chemical fertilizers and neemcake.

5.7. Comparative performance of different sources of nitrogen

5.7.1. Growth and yield characters

In this investigation the sources of N were organic manures and chemical fertilizers. The different organic manures used were poultry manure, vermicompost and neemcake.

The result indicated that poultry manure was superior to all other organic manures and chemical fertilizers on equivalent nitrogen basis. Poultry manure recorded significant increase in plant height, number of branches, dry matter production, shoot-root ratio and leaf area index. As the entire quantity of poultry manure was applied fully as basal dose, it could be presumed that major portion of nitrogen would have been thus recovered by the plant which increases the seedling vigour. As discussed earlier the recovery of nitrogen from poultry manure is quick when compared to other organic sources. The uric acid rapidly gets converted to ammoniacal form and easily utilized by the plant. All these factors might have increased the growth characters.

The yield attributes like number of fruits per plant, fruit yield per ha, mean weight of fruits, fruit setting percentage and fruiting phase were higher for poultry manure treatments.

Significant difference was noticed in all these parameters. Rapid conversion of uric acid present in poultry manure may be one of the reason for higher yield recorded by poultry manure (Smith, 1950). Another factor contributing to it may be its high P_2O_5 content (Singh and Srivastava, 1970). Singh *et al.* (1973) attributed higher efficiency of poultry manure due to its narrow C:N ratio and comparatively higher content of readily mineralisable nitrogen.

5.7.2. Quality characters

Poultry manure application recorded highest keeping quality and vitamin C content. Asano *et al.* (1981) reported decreased discolouration in brinjal and cucumber. Further more application of poultry manure brings about long term increases in micronutrients such as B in soil (Bitzer and Sims, 1988) which might have favourably influenced the keeping quality of fruits as suggested by Tisdale *et al.* (1995).

5.7.3. Nutrient availability, uptake and content

Soil N and Soil P were highest for poultry manure application. The uptake of P, K and content of P and K were also highest for this treatment. Higher soil N may be due to the rapid availability of nutrients. The highest soil P may be due to the higher nutrient supplying capacity of poultry manure and its narrow C:N ratio (Singh *et al.*, 1973).

Phosphorus and potassium uptake was highest in poultry manure treated plots. The highest P uptake may be due to the high P content and favourable C/P ratio in poultry manure which in turn increased the available phosphorus content in soil. The increased moisture retention in soil due to poultry manure application might have increased the K^+ diffusion by roots, which would have resulted in better K uptake and higher K concentration in plants. Application of poultry manure also improves the soil structure and increase the development of roots. As uptake of K is mostly through root interception, better the root system, better is the K uptake.

The soil K was highest for neemcake application. This may be due to the relatively higher content of K in neemcake.

5.8. Comparative performance of various ratios of chemical fertilizer and organic manures

5.8.1. 3:1 ratio

The plant height, number of branches, dry matter production, shoot-root ratio and leaf area index was highest in this treatment. As the chemical fertilizer is more in this ratio, most of the nutrients will be readily available in the early growth stage itself. This might be the reason for the increased growth characters. Application of a part of the organic manure might have helped in improving the soil aeration and soil structure which might have resulted in increased K uptake.

A major portion of the nutrients will be utilized for the early vegetative growth and a part of the nutrient will be lost by leaching, denitrification etc. So during critical stages, nutrients will not be available. As a result vegetative growth will be ceased and flowering and fruiting will be initiated. This might be the reason for the highest fruiting phase and fruit setting percentage.

5.8.2. 1:1 ratio

The yield and yield attributes were significantly influenced by this treatment. The length of fruit, number of fruits per plant and fruit yield was found to be superior when compared to other ratios. Soil P was also highly influenced by this treatment.

Substituting a part of the total N requirement with organic sources on equivalent nitrogen basis is the principle of integrated nutrient management. Application of 50% of applied nutrients through chemical source together with the remaining 50 per cent through poultry manure significantly increased the total tuber yield in potato (Ifenkwe *et al.* 1987). Jose *et al.* (1988) observed that plants supplied with 50 kg nitrogen as urea recorded the highest yield of brinjal fruits (51 t ha^{-1}). Studies conducted in KAU revealed that the organic and inorganic fertilizers and their combination had significant influence on vegetable productivity (KAU, 1991).

5.8.3. 1:3 ratio

The yield and quality aspects was highly influenced by this treatment. Mean weight of fruit recorded highest value. Highest number of seeds per fruit may be the reason for the increased mean weight of single fruit. Ascorbic acid content and oleoresin content was higher. Soil K, plant P and K, P uptake were also found to be increased in comparison with other ratios.

A progressive increase in the yield with increasing levels of organic manures were noted. Higher levels of organic manures permitted higher content of vitamin C. (Arunkumar, 2000). Higher vitamin C in fruits raised under partial organic farming was reported by Shanmugavelu (1989).

5.8.4. 0:2 ratio (Organic farming)

In the case of poultry manure and neemcake, organic farming could produce better growth and yield than POP and IPNS. But with respect to vermicompost, the yield and growth characters were significantly inferior. The nutrient availability was also poor. But the quality aspects like keeping quality and vitamin C content was comparatively higher. A sudden switch over to organic nutrition may do more harm than good. Hence there should be a gradual shift from chemical to organic nutrition. Gradual substitution of chemical fertilizers with the organic sources of nutrients can take care of these negative effects, as well as improve the production of superior quality vegetables.

SUMMARY

6. SUMMARY

The study entitled "Integrated nutrient management in chilli (*Capsicum annuum* L.)" has been carried out at the Instructional Farm attached to the College of Agriculture, Vellayani, Thiruvananthapuram during 1999-2000. The main objectives of the study were to find out the combined effect of organic manures and chemical fertilizers on the productivity and quality of chilli, to assess the possibility of substitution of fertilizers by organic manures and also to work out the economics of production.

The experiment was conducted in RBD with thirteen treatments and three replications. The treatments included the integrated application of chemical fertilizer and organic manure in various ratios of 3:1, 1:1, 1:3 and 0:2. The organic manures consisted of poultry manure, vermicompost and neemcake.

The salient findings of this investigation are summerised below.

1. The effect of various treatments on growth, yield and quality of chilli was significant. Plant height differed significantly with various treatments at all stages of growth. Plant height was highest for the integrated application of chemical fertilizer and poultry manure in

the ratio 3:1. With increase in the level of chemical fertilizer, the plant height was found to be increased.

2. Number of branches per plant increased significantly with increased level of chemical nitrogen. Integrated application of chemical fertilizer and poultry manure at 3:1 ratio recorded maximum number of branches per plant at 35 and 105 DAT. But at 70, DAT highest number of branches was produced by the treatment receiving chemical fertilizer and poultry manure in the ratio of 1:1.

3. Shoot-root ratio differed significantly with various treatments. Application of chemical fertilizer and vermicompost in 3:1 ratio recorded maximum value of shoot-root ratio. As the level of organic manure was increased shoot-root ratio was found to be decreased.

4. At 35 and 70 DAT, dry matter content was highest for poultry manure applied treatments. Neemcake and vermicompost treated plots also gave good result. At the final stage, the highest level of neemcake together with chemical fertilizer gave maximum dry matter content.

5. LAI and DMP was highest for poultry manure treated plots. Highest dose of vermicompost alone recorded highest NAR and RGR. CGR was maximum for application of equal proportion of vermicompost and chemical fertilizer.

6. Highest level of chemical fertilizer along with poultry manure recorded highest value for fruiting phase and fruit set. Integrated

application of chemical fertilizer and poultry manure in 1:1 ratio gave best performance with regard to harvesting interval, number of fruits per plant and total yield.

7. Length of fruit was highest when chemical fertilizer was substituted with vermicompost in 1:1 ratio. Increased level of poultry manure (1:3) gave highest mean weight of fruits.

8. Poultry manure application registered maximum keeping quality of fruits. Vitamin C content was highest for highest dose of organic manure along with chemical fertilizer with respect to poultry manure and neemcake. In the case of vermicompost, 1:1 ratio registered highest value.

9. Application of highest dose of poultry manure along with chemical fertilizer obtained highest value for NPK content of plants. The same treatment recorded highest value for P uptake. The performance of vermicompost application alone (0:2) was very poor. Lowest level of poultry manure along with chemical fertilizer produced highest K uptake value.

10. Neemcake application at its highest level together with chemical fertilizer gave highest soil K. Highest level of poultry manure recorded highest level of soil N. The soil P status was significantly influenced by equal proportion of poultry manure and chemical fertilizer.

11. The highest net profit and benefit-cost ratio was registered by the treatment receiving equal proportion of poultry manure and chemical fertilizer.

12. Incidence of bacterial wilt was lowest for neemcake applied plot (3:1). Highest disease incidence was noted by POP recommendation.

The present investigation revealed that an integrated application of chemical fertilizers and organic manures was beneficial for increasing the growth, yield and quality characters with minimum incidence of bacterial wilt compared to POP and organic farming.

Among the different types of organic manures used, poultry manure proved to be the best and among various combinations tried, 1:1 ratio of chemical fertilizer and organic manure turned to be the best for increasing the growth, yield and quality of chilli, with reduced incidence of bacterial wilt.

Future line of work

Considering the beneficial effects of integrated application of chemical fertilizers and organic manures on soil and plant environment, it would be more appropriate to undertake studies on the various combinations of other organic manures like green manures and enriched compost. From the present study it is evident that poultry manure is a very promising organic manure for chilli. Similar studies with poultry manures on other vegetable crops will explore the importance of this manure in augmenting the vegetable production of our State.

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* Originals not seen

APPENDIX

APPENDIX - I

Weather data for the crop period - weekly averages (September 1999 - January 2000)

Sl. No.	Period From	To	Max. Temp. (°C)	Min. Temp. (°C)	Relative humidity (%)	Rainfall (mm)	Evaporation (mm)
1.	14-09-1999	20-09-1999	31.29	24.00	76.00	0.11	4.63
2.	21-09-1999	27-09-1999	32.40	24.40	77.36	0.00	5.24
3.	28-09-1999	04-10-1999	29.50	23.49	85.64	2.90	1.75
4.	05-10-1999	11-10-1999	28.90	23.13	86.00	16.26	2.17
5.	12-10-1999	18-10-1999	29.00	23.06	87.50	15.50	1.97
6.	19-10-1999	25-10-1999	29.10	23.76	87.70	6.70	2.24
7.	26-10-1999	01-11-1999	28.60	23.10	85.60	14.00	2.90
8.	02-11-1999	08-11-1999	29.50	23.30	82.60	0.14	3.10
9.	09-11-1999	15-11-1999	30.10	23.10	79.40	0.83	2.80
10.	16-11-1999	22-11-1999	30.30	22.90	82.40	15.46	2.98
11.	23-11-1999	29-11-1999	29.70	23.40	81.70	2.40	2.40
12.	30-11-1999	06-12-1999	29.56	22.70	83.60	4.46	2.40
13.	07-12-1999	13-12-1999	30.10	22.94	80.50	0.14	2.77
14.	14-12-1999	20-12-1999	30.22	23.36	81.79	7.40	2.88
15.	21-12-1999	27-12-1999	30.20	22.84	80.07	9.24	2.69
16.	28-12-1999	04-01-2000	29.10	23.38	84.71	6.51	2.00
17.	05-01-2000	11-01-2000	31.81	21.56	79.50	0.00	3.07

INTEGRATED NUTRIENT MANAGEMENT IN CHILLI (*Capsicum annuum* L.)

By

SHARU. S.R.

ABSTRACT OF THE THESIS
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COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

2000

ABSTRACT

A field experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani during 1999-2000 to study the combined effect of chemical fertilizers and organic manures on the productivity and quality of chilli, to assess the possibility of substitution of fertilizers by organic manures and also to work out the economics of production. The treatments consisted of combined application of chemical fertilizers and organic manures viz. poultry manure, vermicompost and neemcake in various ratios of 3:1, 1:1, 1:3 and 0:2. The control treatment was POP recommendation of KAU (20 t ha^{-1} of FYM + 75:40:25 kg N, P_2O_5 and K_2O). The experiment was laid out in randomised block design. An abstract of the result is given below.

Plant height, number of branches, shoot-root ratio and dry matter content differed significantly with various treatments. All these parameters were found to be increasing with increased level of chemical nitrogen. Shoot-root ratio was highest for vermicompost applied plots whereas the maximum value for all other growth parameters was produced by poultry manure treatments.

All the yield parameters were significantly influenced by various treatments. Higher fruiting phase and fruit set was observed with

increasing chemical nitrogen level and maximum value was obtained for poultry manure treatment (3:1). Poultry manure treatment (1:1) gave good performance with respect to number of fruits per plant, harvesting interval and total yield. Higher levels of poultry manure along with chemical fertilizers also performed well. Length of fruit was highest for vermicompost treated plots along with chemical fertilizers (1:1).

Highest level of chemical fertilizer along with poultry manure gave good results with respect to LAI and dry matter production. RGR, CGR and NAR was highest for vermicompost applied plots. Keeping quality and ascorbic acid content was higher for poultry manure treatments.

Regarding residual nutrients high soil K was registered by higher level of neemcake along with chemical fertilizer. Highest soil N was noted by highest dose of poultry manure (0:2). Poultry manure and chemical fertilizer in equal proportion obtained highest value for soil P. Highest dose of poultry manure together with chemical nitrogen gave good result for NPK content of plants. NPK uptake was also higher for poultry manure treatments. Incidence of bacterial wilt was least in dual application of chemical fertilizer and neemcake in the ratio 3:1.

The economics of cultivation revealed that poultry manure and chemical fertilizer application in equal proportion (1:1) gave maximum net returns and benefit-cost ratio.