INTEGRATED NUTRIENT MANAGEMENT IN BRINJAL
(*Solanum melongena* L.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Integrated nutrient management in brinjal (*Solanum melongena* 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.

Vellayani,
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CERTIFICATE

Certified that this thesis entitled **"Integrated nutrient management in brinjal (*Solanum melongena* L)"** is a record of research work done independently by **Mrs. Rekha. 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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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

FYM	-	Farm Yard Manure
t	-	Tonne
ha	-	Hectare
BW	-	Bacterial Wilt
MT	-	Million Tonnes
cm	-	Centimeter
mg	-	Milligram
%	-	Percentage
Kg	-	Kilogram
DAT	-	Days after transplanting
DMP	-	Dry matter production

INTRODUCTION

1. INTRODUCTION

India has achieved food security and now there is urgent need for providing health security to our population. This can be achieved through balanced diet of which vegetables form the most important component. It is universally accepted that vegetables are an important source of "protective food". Vegetables are a rich source of most of the vitamins, minerals, proteins and dietary fibre.

The world scenario indicates that India is the second largest producer of vegetables after China. India produced 48 million tonnes of vegetables from an estimated area of 4.5 million hectare. The per capita daily consumption of vegetables is only about 135 grams which is low when compared to the 180 grams recommended by the nutrition wing of the Health department for a balanced diet. By 2000 AD the requirement of vegetables will be 110 MT. Hence, we must increase the production to meet the requirements of our growing population. There is great scope for bringing the entire vegetable industry on more scientific and productive levels in the country.

In spite of the immense potential for production of vegetables in Kerala, we are far short of our requirement. The state is blessed with a very favourable agroclimate as well as elite farmers. Yet our potential for vegetable production remains untapped.

With the indiscriminate use of fertilizers and chemicals there is increasing risk of health hazards. Since the vegetables are mostly consumed fresh or only partially cooked, they should be devoid of residual effect of chemical fertilizers. Apart from that the continuous use of chemical fertilizers has resulted in the depletion of soil health. For all these reasons, now much importance is being given to organic farming all over the world. The Integrated Nutrient Supply System has been widely accepted by scientists and farmers. The basic principle behind this concept is to supply both chemical and organic fertilizers for sustainable crop production in the most efficient manner. It also helps in maintaining stability in crop production in certain soils through correction of marginal deficiencies of secondary and micronutrient elements, at the same time helps in mineralisation of organic manures and provides favourable soil physical and biological conditions.

Thus there is an urgent need to generate efficient integrated nutrient supply and management practices using locally available resources like compost, farm yard manure, farm wastes, green manure, banana leaves, sewage sludge etc. Moreover measures should be developed to quantify the effect of these resources so as to make necessary adjustment in chemical fertilizers. Integration of various sources of nitrogen is a possible way of not only substituting a part of fertilizer nitrogen but also achieving sound sustainable agriculture (Swaminathan, 1987). FYM favourably affects the vegetative mass dry weight, rate of drymatter increment per unit leaf area (Cerna, 1980 and Valsikova and Ivanic, 1982) and is a good source of macro and micronutrients. Poultry manure is a rich source of nutrients especially for vegetable production. (Jose *et al.,* 1988) The non-edible oilcakes contain high amount of plant nutrients (Joseph M.K. *et al.*,1983). Most of them are valued much due to the alkaloid content which inhibit the nitrification process in soil. Biogas slurry is a valuable manure which improves soil structure, water holding capacity, hydraulic conductivity and porosity along with yield increase of vegetables. (Vyas, 1992).

Use of microbial inoculants to supplement a part of nitrogen requirement has attained immense importance.. These biofertilizers are cost effective as well as environment friendly. Azospirillum is an associative symbiotic nitrogen-fixing bacteria having high nitrogen fixing capacity. Importance of Azospirillum inoculation on vegetable production has been reported by Dart (1986), Balasubramani (1988). Wam and Konde (1986) etc.

Among the various crops grown in our country solanaceous vegetables especially brinjal play an important role in nutrition. Nutritionally it can be compared with tomato. It contains vitamins, minerals like Ca, Mg, Na K and Fe. Being an annual crop its cultivation can be repeated in a single year with very high yield potential.

With this background the present investigation was taken up to study the combined effect of organic manures, chemical fertilizers and biofertilizers on the productivity and quality of brinjal and to assess the possibility of substitution of fertilizer by organic manures and biofertilizers.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The use of organic materials as alternatives to the costlier and environment damaging inorganics in agriculture is gaining importance in the present decade. These can effectively act as slow release fertilizers and many of the organic amendments bring about pest suppression (Gaur, *et al.*, 1984). Regular additions of organic manures in sufficient quantities lead to the maintenance of the organic matter content at optimum levels (Thampan, 1993).

An investigation was carried out in the College of Agriculture, Vellayani during the period from July to November, 1998 to study the combined effect of organic manures, chemical fertilizers and bio fertilizers on the productivity and quality of brinjal. The literature collected, pertaining to the above subject are reviewed here under.

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

Cerna (1980) reported that farmyard manure favourably influenced the vegetative mass, dry weight, plant height, rate of dry matter increment per unit leaf area of capsicum. The beneficial effect of organic amendments in increasing the growth parameters were reported by Zhang *et al.* (1988) and Pushpa (1996). Stalin *et al.* (1993) observed the best germination and seedling growth in silver oak pretreated with organic manure and various combinations of *Azospirillum braziliense* and phosphobacteria. Thamburaj (1994) found that organically grown tomato plants were taller with more number of branches. They yielded 18 – 28 t ha^{-1} which was on par with the recommended dose of FYM and NPK (20:100:100).

FYM, compost, oilcakes, greenleaf and poultry manure improve the yield as well as the quality of vegetables in crops like tomato, onion, gourds, chillies etc. Application of 10 t ha^{-1} of fresh cattle manure increased the yield of egg plant and chinese cabbage (Omori, 1972). Increases in the yield of chilli, bhindi, tomato and brinjal by organic manure application was reported by Gaur *et al.* (1984). Hilaman and Suwandi (1989) found that sheep manure when applied at the rate of 30 t ha^{-1} gave highest yield of 1.05 kg $plant^{-1}$ in tomato. Joseph (1998) reported that in snakegourd yield attributing characters viz., length, weight and number of fruits per plant were highest in FYM treated plants.

Similar results of increased plant growth and yield of tomato plants by the addition of organic amendments were reported by Gianquinto and Borin (1990).

Asano *et al.* (1981) reported that decreased hardening of fruit surface, decreased browning and discolouration in brinjal fruits and cucumber consequent to the application of fertilizer nitrogen. In oriented 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). Joseph (1998) reported that shelf life of snakegourd grown with organic residues is much higher as compared to that grown with fertilizers.

Addition of organics like farmyard manure, poultry manure, green manure, oilcakes, compost etc improves physical, chemical and biological properties of soil and there by enhance the productivity of soil. The favorable effect of farmyard manure application on the structural properties of the soil were observed by several investigators

(Biswas *et al.*, 1969, Muthuvel *et al.*, 1982). Olsen *et al.* (1970) reported that addition of manures increased the soil pH. Sathianathan(1982) found in cassava that neem and mahua cake treatments were efficient in retaining more nitrogen in the ammoniacal form under field condition. Thus these oil cakes reduced leaching losses and extended the period of availability of nitrogen to the crop from applied nitrogen. Loganathan(1990) reported that application of organic amendments viz.saw dust, groundnut, shell powder, coir dust and FYM each at 2.5 and 5 tones per hectare improved the soil physical characterestics like infiltration rate, total porosity and hydraulic conductivity of the red soil with hard pan. Farm yard manure application resulted in lowest acidity due to the decrease in the exchangable and soluble Al in the soil (Nambiar, 1994 and Patiram, 1996). Organic manures constitute a dependable source of major and minor nutrient elements. Apart from this they have a profound influence on soil physical properties resulting in better structure, greater water retention, more favourable environment for root growth and better infiltration of water (Tandon, 1994).

2.1 Poultry manure

Poultry manure is a good source of nutrient particularly for vegetable production. 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). According to Tisdale *et al.* (1995) 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 2 to 3 months of the application of organic source, 80 per cent is converted to NO_3^- at the end of first three weeks. 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.

Field experiments conducted in black clayey soils to study the efficacy of poultry manure in comparison with other organic manures and green manures in combination with inorganic fertilizers resulted in significant influence on the yield of grain and straw of rice (Budhar *et al.* 1991)

2.1.1 Effect of poultry manure on growth characters

In poultry manure 60 per cent of nitrogen is present as uric acid, which readily changes to ammoniacal form of nitrogen which become available to plant immediately and thereby increase growth and yield of the plant (Smith, 1950).

Singh *et al.* (1973) reported that in potato, poultry manure application exhibited better response than Farm Yard Manure 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.

2.1.2 Effect of poultry manure on yield and yield attributes

A progressive increase in growth and yield of cauliflower was observed when the level of poultry manure was increased from 0 to 169.6 q ha^{-1}(Singh *et al.* 1970). Morelock and Hall (1980) compared the effects of broiler litter applied at different rates with a pre planting application of commercial fertilizers ($N_{10}P_{20}K_{10}$) at 280 to 840 kg ha-1 on field grown tomato plants. Marketable fruit yield was found to increase with broiler litter application. 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. 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 (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 muskmelon. Jose *et al.* (1988) observed that plants supplied with 50kg N as poultry manure and 50 kg N as urea recorded the highest yield of brinjal followed by 50 kg N given as pig manure and 50 kg as urea. A trial conducted by Rala and Garcia(1992) in upland rice revealed that application of 50 per cent N as inorganic sources produced higher yield of rice. Poultry manure treated chilli plants showed better yield and yield attributing characters as compared to FYM and vermicompost application.(Anitha, 1997).

2.1.3. 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 author also reported that the protein content of potato gradually increased with higher levels of poultry manure (Singh *et al.* 1970).

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 snakegourd, poultry manure treated plants recorded the highest crude protein content and lowest crude fibre content as compared to that of farm yard manure and vermicompost treated plants.

According to Bitzer and Sims (1988) when poultry manure is applied, long term increase in soil levels of nutrients like B, Ca, Mg, Cu and Zn can be expected.

Importance of micro nutrients like B is keeping quality of fruits and tubers was indicated by Tisdale *et al.,* 1995.

2.2 Oil cakes

Oilcakes of non edible types likes castor, neem and karanja are widely used as organic manure. Most of the non edible oilcakes are valued much due to their alkaloid contents which inhibits the nitrification process of nitrogen transformation of soil. Neem cake contains the alkaloids nimbin and nimbidin which effectively inhibit the nitrification process (Sinha, 1964, Sahrawat and Parmar, 1975, Reddy and Prasad, 1975, Rajkumar and Sekhon, 1981). The non edible oil cakes contain high amount of plant nutrients (Mercy Kutty Joseph *et al.*, 1983).

2.2.1. Effect of neem cake on growth characters

Jain and Hasan (1986) in a field experiment found that the oil cakes increased the chlorophyll content of leaves and neem cake recorded the maximum chlorophyll content of leaves. Som *et al.* (1992) observed the influence of organic manures on growth and yield of brinjal. The different oil cakes tried were karanj, mahua, mustard and neem cake. The highest plant height of 70.77 cm was recorded in the treatment receiving neem cake @ 50 q ha^{-1} followed by mustard cake at its higher dose.

2.2.2. Effect on yield and yield attributes

Shanmugavelu (1987) observed that application of manhua cake, castor cake and neem cake @ 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. Anon (1990) reported that application of neem cake @ 1 ton ha^{-1} before planting gave maximum yield in ginger. Studies conducted at KAU revealed that application of neem cake @ one t ha^{-1} before planting gave maximum yield in ginger (KAU, 1990). In the view of soil and fertilizer management for vegetable production in Bangladesh, Islam and Haque (1992) mentioned the application of oil cakes as an organic manure during land preparation to brinjal, chillies and bhindi for getting higher yield. Som *et al.* (1992) observed the influence of organic manures on growth and yield of brinjal. The different oil cakes tried were karanj, mahua, mustard and neem cake. Neem cake @ 50 q ha^{-1} produced the 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}. Kadam *et al.* (1993) compared the effect of organic and inorganic sources on yield of betelvine. Among the various sources tried viz., neem cake, karanj cake, neem cake + urea and urea alone application of N through neem cake produced significant response in increasing the yield.

2.2.3. Effect on pest and disease incidence

Application of neem cake recorded low gall index or nematode attack in brinjal. This reduced nematode population may be due to the liberation of ammonia during decomposition of oil cakes which was sufficient to kill nematodes (Kumar, 1988). Singh and Sitharamayyah (1996) in a pot experiment found that the application of neem cake to the infested soil @ 2 per cent 3 WBP reduced the intensity of root gall development on tomato plants. The combination of the use of 5 or 10 per cent aqueous extract of neem cake for seed treatment and soil drenching under field condition was found as effective as an application of carbofuran at 2 kg a.i/ ha or neem cake at 2 t ha^{-1} for the management of *Meloidogyne incognita* in okra (Rao *et al.*, 1997). Organic amendments of oil seed cakes of *Madhuca* neem and mustard were incorporated into soil infected with *Meloidogyne incognita.*

Soil amendments increased sprout emergence of pointed gourds grown in the infected soil. Of the oil cakes investigated, neem cake resulted in the highest sprouting (Verma *et al.*, 1998).

2.3 Biogas slurry

Biogas slurry is a valuable manure, even superior to FYM. In a green house experiment conducted at Banaras Hindu University, Varanasi, with rice as the test crop, it has been shown that dipping the roots of rice seedlings in biogas slurry containing 22.5ppm of nitrogen was comparable to soil application of 45ppm nitrogen. (Srivasthava, 1985). The effectiveness of biogas slurry in combination with chemical fertilizer was studied. Application of slurry to replace half nitrogen gave better yields in vegetable crops. (Dahia and Vasudevan, 1986). Biogas digested slurry improved soil structure, water holding capacity, hydraulic conductivity and porosity and increased soil humus content and biological activity, along with yield increase of various crops and vegetables. (Vyas, 1992). Prasad (1994) reported that among the different organic manure used for crops, slurry coming out from biogas plants has been found to be superior to FYM in respect of nutrient status and has the potential to improve soil physical properties.

2.4 Azospirillum

Biofertilizers were found to have positive contribution to soil fertility resulting in an increase in crop yield without causing any type of environmental, water or soil hazards. Significant improvement in growth, yield and quality of vegetables with respect to *Azospirillum* application has been reported in various crops.

Over the past twenty years in the case of 60-70 per cent of the experiments done worldwide, an increase in yield due to Azospirillum inoculation could be observed.

2.4.1. Effect on growth characters

According to Smith *et al.* (1978) *Azospirillum* inoculation resulted in the increased root and shoot growth and biomass accumulation of crop plants. Azospirillum has the ability for better root induction in inoculated plants mainly due to the production of plant growth hormones like IAA and GA. As a result of this, such plants are capable of absorbing more and more available nutrients from the soil which in turn results better establishment of plant seedling and subsequent growth (Tien *et al.*, 1979, Govindan and Purushothaman, 1989). Manib *et al.* (1979) reported increased dry weight of tomato plants by 5-12 per cent due to inoculation of *Azospirillum*. Kapulnic *et al.* (1981) studied the effect of *Azospirillum* inoculation on wheat, sorghum and panicum and observed that inoculation with *A. braziliense* resulted in significant increase in plant height in all the three crops. Use of *Azospirillum* alone produced better growth response equivalent to that of 30 kg N ha^{-1} in rice (Prasad and Singh, 1984). There was significant increase in root length (3.5 per cent) root dry weight (50 per cent) and total leaf area of 18 days old tomato seedlings due to *Azospirillum* inoculation (Okon, 1987). A study conducted by Balasubramani (1988) revealed that the seed and soil treatments of *Azospirillum* were superior to untreated check and the *Azospirillum* seed treatment enhanced germination per cent, plant height, root length, root width, days to first flowering, first fruit node and dry matter production. Inoculation of *Azospirillum* to seed, soil and seedling increased the plant height, number of primary, secondary and tertiary branches. The length of tap root and root spread was also increased by the treatment (Amrithalingam, 1988). *Azospirillum* application increased plant height. The same trend was observed in plant girth and number of leaves also (Parvatham *et al.*, 1989). In *Azospirillum* treated brinjal seedlings, the plant height was significantly increased from 11.2 to

15.3 mm as compared to unionculated treatment. There was also significant increase in dry weight of foliage and number of leaves per plant to *Azospirillum* inoculation (Bashen *et al.*, 1989). Dhanalakshmi and Pappiah (1995) reported that the *Azospirillum* treated tomato seeds have the highest germination percentage, shoot and root length, vigour index, fresh and dry weight of seedlings, number of primary, secondary roots and better rate of establishment. Increased plant height, number of primary branches / plant, number of lateral roots in chilli were noticed when inoculated with Azospirillum (Paramaguru and Nataraja, 1993). Bhindi gave highest yield when *Azospirillum* was given as seed and soil treatment along with 30 kg N ha^{-1} compared to control (Balasubramani and Pappiah, 1995). Rajasekhar *et al.* (1995) got better yield in bhindi when plants were treated with *Azospirillum*, FYM and inorganic.fertilizers. In knol-khol *Azospirillum* inoculation resulted in increased leaf area and plant height (Chatto *et al.*, 1997).

2.4.2. Effect on yield

Chattoo *et al.* (1997) observed that in knol khol, *Azospirillum* inoculation markedly increased growth, yield and quality attributes over control. Cohen *et al.* (1980) obtained increased yield for a wide range of tropical and temperate crops by *Azospirillum* inoculation. The mechanisms by which the plants inoculated with *Azospirillum* and *Azotobacter* derive positive benefits in terms of increased grain yield, plant biomass and N uptake are attributed to small increase in N input from BNF, development and branching of roots, production of plant growth hormones, enhancement on uptake of NO_3, NH_4, H_2PO_4, K^+, Pb^+ and $Fe2^{2+}$, improved water status of plants, increased nitrate reductase activity in plants, production of antibacterial and antifungal c ompound (Okon, 1985, Pandey and Kumar,1989, Wani, 1990). *Azospirillum* inoculation was known to increase the yield of crops by 5-20 per cent with savings of 40 per cent of the recommended dose of N (Dart, 1986). Amrithalingam (1988) observed earliness in first flower appearance and 50 per cent flowering by *Azospirillum* treatment. The treatment increased the number of flowers, fruits / plant, fresh and dry weight of pod per plant, length and girth and pod, number of seeds and weight of seeds per pod. The dry matter production was also increased. A study conducted by Balasubramani (1988) revealed that yield attributes like number of fruits per plant, length, girth and weight of fruits were increased by *Azospirillum* seed and soil treatment. Pandey and Kumar (1989) reported that application of *Azotobacter* and *Azospirillum* to wheat, maize and vegetables under irrigated and rainfed conditions with or without the application of NPK increased the yield. Field experiment conducted on the interaction of *Azospirillum* and fertilizer N on bhindi indicated that at 50 per cent of the recommended dose of N, soil application had beneficial effect to improve the yield (Subbiah, 1991). Okon and Gonzalez (1994) by evaluating world wide data over the past 20 years on field inoculation experiment with *Azospirillum* concluded that these bacteria are capable of promoting the yield of agriculturally important crops in different soils and climatic regions. The results showed significant increase in yield of the order of 5-30 per cent. Studies on the effect of N and P with *Azospirillum* and phosphobacteria in pumpkin revealed that application of 9 kg N and 18 kg P/ha along with biofertilizers recorded the highest fruit yield of 16.9 and 17.79 kg plant^{-1} during rabi and kharif as against 9.49 and 8.68 kg at the recommended dose of 12 kg N and 24 kg P respectively (Karuthamani *et al.*, 1995). Dhanalekshmi and Pappiah (1995) reported that the *Azospirillum* treated tomato plants showed early flowering to the extent of 5 days with highest number of flowers, fruit set and maximum yield as compared to unionculated plants. Zachariah (1995) showed that application of Eudrillus compost enriched with both Azospirillum and P solubilising organisms to plants gave maximum per plant yield in chilli.

2.4.3. Effect on quality

Inoculation with *Azospirillum* increased capsicin and ascorbic acid contents in chilli (Balakrishnan, 1988). *Azospirillum* inoculation has been reported to significantly increase the growth, yield, nutrient uptake, dry matter and vitamin C contents in cabbage, cauliflower and tomato. (Subbiah, 1990, Kalyani *et al.*, 1992, Jeevajothi *et al.*, 1993). Kumaraswamy and Madalageri (1990) reported that *Azospirillum* treated tomato plants gave fruits with high TSS (8.46 per cent) and ascorbic acid (32.91 mg 100^{-1}). Zambre *et al.* (1984) reported increased protein content when wheat was inoculated with *Azotobacter* and *Azospirillum*. *Azospirillum* treatment recorded the highest ascorbic acid and capsicin content (Amrithalingam, 1988). Chattoo *et al.* (1997) observed that in knol khol, *Azospirillum* increased yield and quality attributes over control. There was a non significant increase in dry matter and vitamin C over control.

2.4.4. Effect on nutrient uptake

Plant inoculation with *Azospirillum* affected the foliage, and the changes were attributed to positive bacterial effect on mineral uptake by plants. Saring *et al.* (1984) reported that the *Azospirillum* inoculation enhanced the uptake of NO_3, NH_4, P and K in plants as compared to unionculated plants. Pacovsky *et al.* (1985) observed an increase in P and other nutrient concentration in the foliage of *Azospirillum* inoculated sorghum plants. Boddey and Victoria (1986) using N-15 labeled $(NH_4)_2\ SO_4$ as a source of nitrogen fertilizer to wheat plants observed high quantity of N-15 in inoculated than in unionculated plants. *Azospirillum* seed and soil treatment increased the uptake of N, P and K by plants as reported by Balasubramani (1988). Better uptake of N and P due to *Azospirillum* inoculation was reported by Parvatham *et al.* (1989). Subbiah (1991) observed that soil application of *Azospirillum* to bhindi crop had beneficial effect to improve N, P and K uptake as compared to unionculated plants. *Azospirillum* inoculation improved N, P and K uptake in chilli as compared to no inoculation (Anitha, 1997).

2.5 Effect of combined application of organic manure and chemical fertilizers

The higher levels of chemical fertilizers affect the quality of the plant produce and deplete the soil properties. Hence substituting a part of the total nitrogen requirement with organic nitrogen sources on equivalent nitrogen basis is a remedy to this problem. Fritz and Habben (1992) reported that K fertilizers increase the durability of the fruit by lowering the activity of enzymes which breakdown carbohydrate. In the case of fertilizers especially urea, nutrients mineralise very quickly and are susceptible to leaching losses (Tisdale *et al.*, 1995).

Doikova (1977) recommended combined application of organics and inorganic chemicals because application of FYM alone proved less effective in increasing the drymatter content in brinjal. Jose *et al.* (1988) observed and enhanced dry matter production in brinjal with the application of 50 kg N as poultry manure compared with 50 kg N as urea. In another experiment in okra, Abusaleha (1992) 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.

In an experiment with inorganic fertilizers and organic manure like FYM, the mixture of fertilizers and manure gave better results than organic manure given alone. (Chinnaswamy, 1967). Katyal (1977) observed that for a successful crop of bittergourd, 50t/ha FYM and 100kg/ha of ammonium sulphate are beneficial. Cerna (1980) reported that the application of chemical fertilizers in the absence of FYM retarded the formation of vegetative organs and subsequently the reproductive organs and resulted in lower flower production. A combination of 12.5 t ha^{-1} FYM and 50 per cent recommended dose of fertilizer was found to be beneficial for improving yield. (Subbiah *et al.* 1983). Jose *et al.* (1988) observed that plants supplied with 50 kg nitrogen as poultry manure and 50kg N as urea recorded the highest yield of brinjal fruits (51 t ha^{-1}) followed by plants supplied with 50 kg N as pig manure and 50 kg as urea. Rivera Segovia (1988) observed the higher yields produced by melons when supplied with 100 kg N in conjuction with 10 t ha^{-1} poultry manure. Nair and Peter (1990) reported that highest yield in chilli with 15t FYM and 5:40:25 kg NPK ha^{-1} in 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 alone with FYM induced earliness and enhanced the fruit yield in clustered chilli (KAU, 1991). Onion was grown in pots filled with sandy loam soil amended with N, P, Zn and FYM. The highest bulb yield of 50.6 g pot^{-1} was obtained from plants fertilized with FYM 10 t ha^{-1}, 40 kg N and 60 kg P ha^{-1} (Singh *et al.*, 1995). Dahama (1996) pointed out that substitution of inorganic nitrogen with poultry manure upto 120 kg ha^{-1} increased the potato yield to 108 q ha^{-1} compared to control.

Singh *et al.* (1970) reported that in cauliflower, application of 80 kg N through FYM along with 80 kg chemical nitrogen produced a higher crude protein per cent of 2.02 compared with 1.58 per cent obtained with 160 kg ha^{-1} N through FYM alone. The number and weight of unmarketable fruits after 10 days of storage from harvest of green chillies increased with increasing rates of NPK along with FYM (Nair and Peter, 1990). Shanmughavelu (1989) pointed out that the application of a mixture of FYM and inorganic fertilizer mixture was found to be best for firmness, storage life and keeping quality of tomato for a long time. Sujatha and Krishnappa (1995) conducted studies in potato to note the quality attributes of potato tubers influenced by different fertilizer levels. Highest reducing sugars were observed in treatments with 120 : 100 : 120 kg NPK ha^{-1} and 50 t ha^{-1} of FYM. Shelf life of fruits under room temperature was more (4 days) when nitrogen nutrition was given through 2 : 1 ratio of organic-chemical N using poultry manure as organic source in equivalent N basis (Rajasree, 1999).

Helkiah *et al.* (1981) recorded the lowest bulk density (1.25 g cc^{-1}) and higher porosity (60.43 per cent) with the application of 30 t ha^{-1} of FYM in conjuction with half of the recommended dose of inorganic fertilizers when compared with the application of inorganic fertilizer alone. Combination of organic manure with inorganic fertilizer 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).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Integrated Nutrient Management in Brinjal" was carried out to study the effect of organic manures, chemical fertilizers and biofertilizers on the productivity and quality of brinjal and to assess the possibility of substitution of fertilizers by organic manures and biofertilizers. The experiment was conducted during the month of July to November 1998 at the Instrucitonal Farm, College of Agriculture, Vellayani. The details of the materials used and methods adopted are presented in this chapter.

3.1 Experimental Site

Instructional Farm, Vellayani is located at 8°30' N and 76°54' E longitude at an altitude of 29 m above MSL. The experimental area was under the bulk crop of amaranthus (*Amaranthus tricolor*) during the previous season.

3.2 Soil

Soil of the experimental area belong to the textural class of sandy clay loam and of the order oxisol. The important physico-chemical properties of soil are presented in Table 3.1. The soil was rated low in available nitrogen, high in available phosphorus and low in available potassium. The pH of the soil was 4.8.

Table 3.1. Soil Characteristics of the experimental site

A. Mechanical Composition		
Parameters	Content in Soil (percentage)	Method used
Coarse sand	16	Bouyoucos Hydro-meter Method (Bonyoncos, 1962)
Fine sand	48	”
Silt	12	”
Clay	23	”

B. Chemical Properties			
Parameter	Value kg ha^{-1}	Rating	Method
Available N (kg ha^{-1})	188.16	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	68.32	High	Bray calorimetric method (Jackson, 1973)
Available K_2O (kg ha^{-1})	133.86	Low	Ammonium acetate method (Jackson 1973)
pH	4.80	Acidic	pH meter with glass electrode (Jackson, 1973)

3.3 Climate and season

The data o n weather parameters during the cropping period are given in Appendix 1.

3.4 Variety and seed material

The variety used for the experiment was Swetha. Resistant to BW bushy growth habit with light purple tinge on leaf stalk. Flowers violet, plants non prickly.

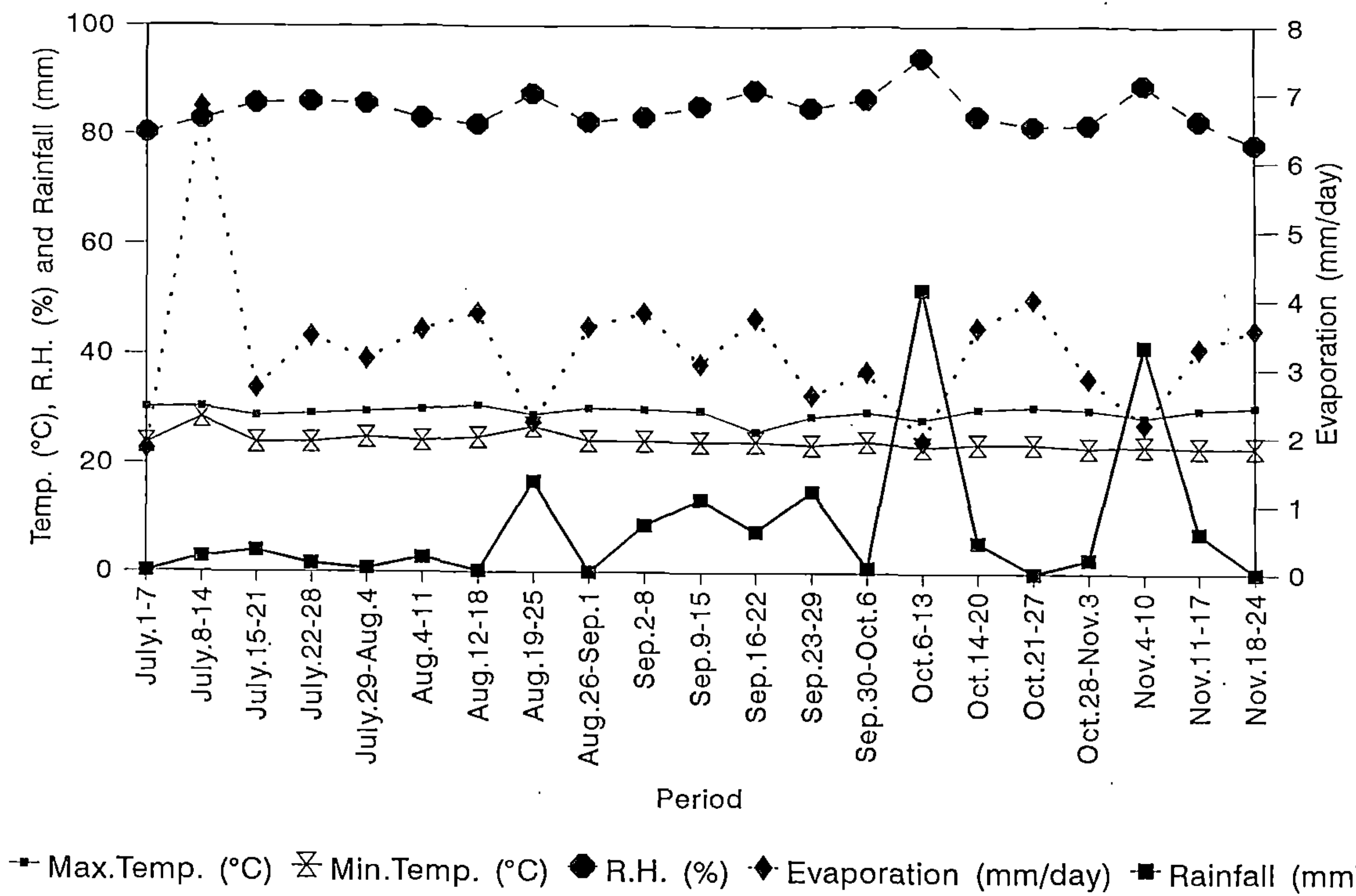

Fig. 1. Weather parameters during the crop period (July 1998 to November 1998)

Duration 4½ - 5 months, early harvesting with short span. Fruits white, medium long. High yield, excellent cooking quality. Tolerant to fruit borer yield potential 31.5 t ha^{-1} through out the country.

3.5 Manures and Fertilizers

3.5.1 Organic Manure

Poultry manure (1.2 per cent N) Neem cake (5.2 per cent N, 1.0 per cent P, 1.4 per cent K) and bio-gas slurry (2 per cent N) were used as organic sources.

3.5.2 Chemical Fertilizers

Urea (46% N) Mussuriphos (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.

3.5.3 Bio-fertilizers

Azospirillum culture maintained in the department of Plant Pathology, College of Agriculture, Vellayani was used.

3.6 Methods of cultural operation

3.6.1 Nursery

Seeds were sown in well prepared raised nursery beds of size 1.2 m wide and 15cm high with channels around them to facilitate drainage of excess

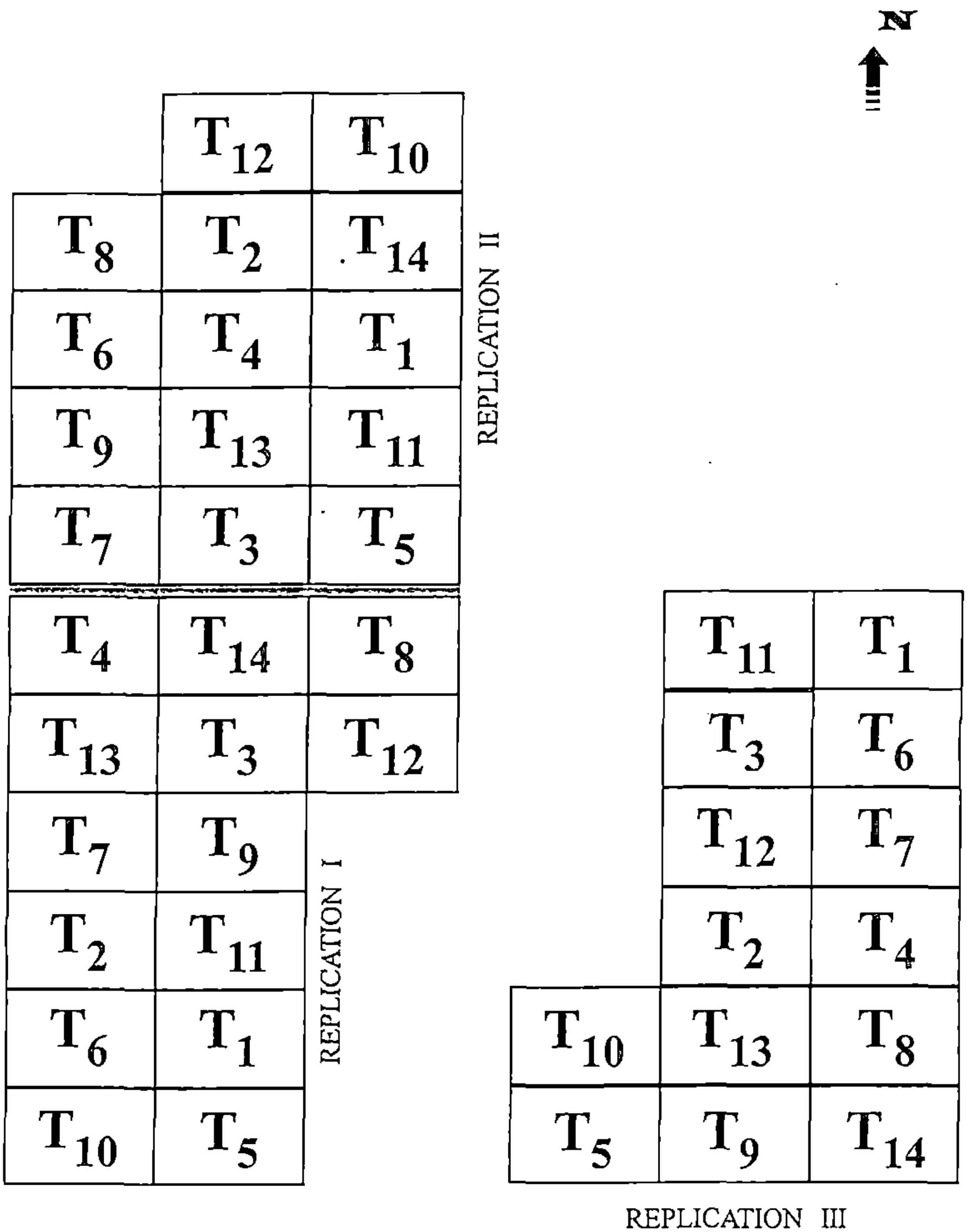

Fig. 2. Layout plan of the experiment

water. Seedlings were irrigated everyday. Hand weeding and plant protection measures were undertaken periodically. The seedlings were ready for transplanting in 30-45 days.

3.6.2 Field culture

The experimental plots were ploughed, clods broken, cleared off stubbles and the field was laid out into blocks and plots. Bunds were taken at 30cm width around each plot.

3.6.3 Manures and fertilizers

N, P_2O_5 and K_2O were applied in the form of urea, mussuriephos and MOP. 50 percent of the recommended nitrogen dose (75 kg ha^{-1}) was applied to respective plots as per the treatment. Entire quantity of P_2O_5 and K_20 and half N were given as basal while ¼ N was applied 25 days after transplanting and the remaining ¼ one month after the first application. FYM @20 t ha^{-1} was applied only to the control plot.

3.6.4. Transplanting

Seedlings were pulled out and kept in trays. Inoculated seedlings were dipped in *Azospirillum* solution for 30 minutes before transplanting. Planting was done at a spacing of 60 x 75 cm. Shade was provided to the transplanted seedlings using coconut fronds and banana leaves. Light irrigation was given.

3.6.5 After cultivation

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

3.6.6 Plant protection

Scoring was done for pest and disease attack. Sevin 50 WDP was sprayed against shoot and fruit borer attack.

3.6.7 Harvesting

First harvest was taken 45 DAT and subsequent harvests were done as and when furits mature.

3.7 Outline of Technical Programme

3.7.1 Design and layout

Design	:	Factorial RBD
Replication	:	3
Plot size (gross)	:	3.0 m x 2.4 m
(net)	:	2.25 m x 1.8 m
Spacing	:	75 cm x 60 cm
Variety	:	Swetha

3.7.2. Treatments

Four combinations of three factors viz. sources of N, organic manures, biofertilizer and control.

Factors

A. Sources of N

1. 50 per cent N as organic source + 50 per cent as inorganic source.
2. 100 per cent N as organic source

B. Organic manures (N on equivalent basis)

1. Poultry manure
2. Neem cake
3. Biogas slurry

C. Biofertilizers

1. No biofertilizer
2. Azospirillum

Control

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

2. Package of practice recommendation (75:40:25 Kg N, P_2O_5 and K_2O ha^{-1} without FYM)

Treatment combinations

1. T1 = 50 per cent chemical + 50 per cent poultry manure + No Azospirillum.
2. T2 = 50 per cent chemical + 50 per cent poultry manure + Azospirillum
3. T3 = 50 per cent chemical + 50 per cent Neem cake + No Azospirillum
4. T4 = 50 per cent chemical + 50 per cent Neem cake + Azospirillum
5. T5 = 50 per cent chemical +50 per cent biogas slurry + No Azospirillum
6. T6 = 50 per cent chemical + 50 per cent biogas slurry + Azospirillum
7. T7 = 100 per cent poultry manure + No Azospirillum
8. T8 = 100 per cent poultry manure + Azospirillum.
9. T9 = 100 per cent neem cake + No Azospirillum

10. T10 = 100 per cent neem cake + Azospirillum

11. T11 = 100 per cent biogas slurry + No Azospirillum

12. T12 = 100 per cent biogas slurry + Azospirillum

13. T13 = Package of practice recommendation (75-40-25 Kg N, P_2O_5 and K_2O and 20 t ha^{-1} of FYM

14. T14 = Package of practice recommendation (75-40-25 Kg N, P_2O_5 and K_2O ha^{-1}) without FYM

3.8 Observations

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

3.8.1 Growth characters

3.8.1.1 Height of the plant

Heights of the four selected observational plants from each plot were measured. The height was measured from the ground level to the growing leaf bud. Mean plant heights were worked out and expressed in cm.

3.8.1.2 Number of branches

The number of branches in the observational plants was counted and their mean worked out.

3.8.1.3 Number of leaves per plant

Total number of leaves in each observational plant was counted and the mean recorded for each plant.

3.8.1.4 Leaf area index

Leaf area index was worked out using the equation

$$\text{Leaf area index} = \frac{\text{Total leaf area}}{\text{Land area}}$$ (Watson, 1952)

3.8.2 Yield and yield attributes

3.8.2.1 Time to 50 per cent flowering

Total number of days taken for 50 percent of the plant population to flower in each treatment was recorded.

3.8.2.2 Number of flowers and fruits per plant

Flower production on plants was recorded from the first flower opening till the last harvest. The total number of fruits harvested was counted and average worked out for each treatment.

3.8.2.3 Fruit set

This was worked out by dividing the total number of fruits harvested per plot by the total number of flowers produced per plot and the percentage fruit set was worked out.

3.8.2.4 Marketable fruit yield plant^{-1}(g)

The total number of fruits harvested from all the plants were weighed and the fruit yield was computed by adding the weights of each harvest and is expressed in g plant^{-1}.

3.8.2.5 Harvest index

From the yield data, harvest index was calculated using the formula

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.8.3 Physiological parameters

3.8.3.1 Dry matter production

Dry matter production of each plant as obtained by summing up the dry weights of all the plant parts including roots, stem, leaves and fruits.

3.8.3.2 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).

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

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

3.8.3.3 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

3.8.3.4 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 w1 is the dry weight at time t_1

w_2 is the dry weight at time t_2

p is the ground area.

3.8.4 Plant analysis

Plant samples were analysed for nitrogen, phosphorous and potassium at final harvest. The plants were chopped and dried in an 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 phosphorous content in plants was estimated calorimetrically (Jackson,1973). Based on the phosphorous content 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.

3.8.5 Soil analysis

Soil samples were taken from the 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 and available K 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 calorimetric method.(Jackson, 1973) and available K status of soil by ammonia acetate method (Jackson, 1973).

3.8.6 Economics of treatments

3.8.6.1 Net returns

Net returns (Rs ha^{-1}) = Gross income – Cost of cultivation

3.8.6.2 Benefit : cost ratio

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

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

3.8.7 Scoring of pests and diseases

Scoring of pests and diseases was done by visual observation. Pest scoring was done by calculating the percentage of infestation of the major pest shoot and fruit borer in brinjal.

$$\text{Percentage infestation} = \frac{\text{Number of fruits infested plant}^{-1}}{\text{Total number of fruits plant}^{-1}}$$

Disease scoring was done by computing the per cent of infection by the diseased fruit of brinjal.

$$\text{Percentage infection} = \frac{\text{Number of plants infected plant-1}}{\text{Total number of plants plot}^{-1}}$$

3.8.8 Keeping quality of fruits at ambient conditions

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 fruit to the stage at which fruits become shrunken and lost the firmness was recorded.

RESULTS

4. RESULTS

An experiment was conduced at the College of Agriculture, Vellayani during the period from July to November 1998. The objective of the experiment was to study the combined effect of organic manures, chemical fertilizers and biofertilizers on the productivity and quality of brinjal and to assess the possibility of substitution of fertilizers by organic manures and biofertilizers. The data collected were statistically analysed and the results are presented in this chapter.

4.1. Biometric observations

Observations on growth characters like plant height, number of leaves and number of branches per plant were recorded and the results are presented in Tables.

4.1.1. Plant height

Data presented in Table 1 revealed that source of nitrogen significantly increased the plant height at all stages of growth except 30 DAT. At 45, 60 and 75 DAT, the treatment S_1, receiving 50 per cent of the recommended nitrogen as organic and 50 per cent as inorganic manures recorded maximum plant height (30.29 cm, 35.81 cm and 37.97 cm respectively) and was significantly superior to the treatment S_2 receiving 100 per cent as organic manure.

Table 1. Height of the plant (cm) as influenced by source of nitrogen, organic manures and biofertilizers

Treatments	30 DAT	45 DAT	60 DAT	75 DAT
Source of nitrogen				
S_1 (50 % N as organic + 50 % N as inorganic source)	13.45	30.29	35.81	37.97
S_2 (100 % organic manure)	12.56	26.99	32.86	35.50
F	2.36^{NS}	6.71^{S}	9.22^{S}	9.05^{S}
CD	—	2.62	1.99	1.67
Organic manures				
O_1 (Poultry manure)	14.66	31.10	37.52	39.85
O_2 (Neem cake)	12.76	25.60	32.19	34.81
O_3 (Biogas slurry)	11.59	29.21	33.29	35.50
F	9.38^{S}	6.34^{S}	11.23^{S}	9.38^{S}
CD	1.47	3.21	2.44	1.47
Biofertilizers				
B_1 (No Azospirillum)	12.52	29.74	34.85	37.42
B_2 (With Azospirillum)	13.49	27.54	33.82	36.03
F	2.75	2.96	1.12	2.92
CD	—	—	—	—
Control				
POP (C_1)	11.5	27.33	33.00	35.25
POP without FYM (C_2)	10.03	28.41	31.75	34.33
F	—	—	—	—
CD	—	—	—	—

Table 2. Number of leaves per plant as influenced by source of nitrogen, organic manure and biofertilizers

Treatments	30 DAT	45 DAT	60 DAT	75 DAT
Source of nitrogen				
S_1 (50 % N as organic + 50 % N as inorganic source)	7.19	32.85	46.76	58.82
S_2 (100 % organic manure)	6.58	27.63	41.97	54.43
F	1.27	3.37	2.45	1.88
CD	—	—	—	—
Organic manures				
O_1 (Poultry manure)	7.73	38.38	57.17	70.11
O_2 (Neem cake)	5.56	23.77	36.08	48.27
O_3 (Biogas slurry)	7.38	28.56	39.83	51.50
F	6.13^S	9.13^S	18.08^S	18.08^S
CD	1.37	7.16	7.69	8.06
Biofertilizers				
B_1 (No Azospirillum)	6.86	29.61	43.17	55.84
B_2 (With Azospirillum)	6.92	30.86	45.56	57.42
F	0.01	0.19	0.61	0.24
CD	—	—	—	—
Control				
POP (C_1)	5.58	37.08	47.33	59.75
POP without FYM (C_2)	5.83	29.25	39.41	48.83
F	—	—	—	—
CD	—	—	—	—

Different types of organic manures showed significant difference in plant height at all the growth stages. At 30 DAT, O_1, (poultry manure) recorded maximum plant height (14.66 cm) and was significantly superior to other organic manures tried. At 45 DAT, O_1, (31.10 cm) and O_3 (29.21 cm) were on par and was significantly superior to O_2. At 60 and 75 DAT O_1, (poultry manure) recorded maximum plant height (37.52 cm and 39.85 cm respectively) and was significantly superior to O_2 and O_3.

The influence of *Azospirillum* on plant height was not significant during the growth period.

Interaction effects of treatments was not significant influence on plant height.

4.1.2. Number of leaves

Total number of leaves per plant were counted at different growth stages and are presented in Table 2.

Source of nitrogen showed no significant influence on the number of leaves per plant.

Organic manure significantly increased the number of leaves per plant. Among the three organic manures tried, O_1 (poultry manure) recorded highest number of leaves per plant at all growth stages.

At 30 DAT, O_1 and O_3 (biogas slurry) were on par and was significantly superior to O_2 (neem cake). At 45, 60 and 75 DAT, poultry manure recorded

Table 3. Number of branches per plant as influenced by source of nitrogen, organic manures and biofertilizers

Treatments	30 DAT	45 DAT	60 DAT	75 DAT
Source of nitrogen				
S_1 (50 % N as organic + 50 % N as inorganic source)	1.09	7.63	14.26	16.32
S_2 (100 % organic manure)	0.64	5.79	12.08	14.32
F	2.49	9.53^S	7.80^S	6.76^S
CD	—	1.22	1.60	1.58
Organic manures				
O_1 (Poultry manure)	1.44	8.44	16.21	18.77
O_2 (Neem cake)	0.33	5.33	11.40	13.48
O_3 (Biogas slurry)	0.83	6.35	11.92	13.71
F	4.90^S	9.47^S	15.26^S	20.16^S
CD	0.73	1.50	1.97	1.94
Biofertilizers				
B_1 (No Azospirillum)	0.65	7.07	13.53	15.94
B_2 (With Azospirillum)	1.08	6.35	12.82	14.69
F	2.26	1.48	0.82	2.64
CD	—	—	—	—
Control				
POP (C_1)	0.75	7.33	12.75	13.75
POP without FYM (C_2)	0.41	5.75	12.16	13.83
F	—	—	—	—
CD	—	—	—	—

the highest number of leaves (38.38, 57.17 and 70.11 respectively) and was significantly superior to neem cake and biogas slurry which were on par.

Azospirillum inoculation enhanced the number of leaves per plant, though the difference doesnot reach the level of significance at any stage growth.

4.1.3. Number of branches

Number of branches per plant were counted at different stages and are presented in Table 3.

Source of nitrogen has a favourable influence in increasing the number of branches. When nitrogen was applied as 50 per cent organic and 50 per cent as chemical fertilizer, the number of branches per plant was increased significantly at all stages of growth except 30 DAT.

Organic manures recorded a significant influence on this character. When nitrogen was applied as poultry manure (O_1) it increased the number of branches at all stages and was significantly superior to the other organic manures O_2 and O_3.

Biofertilizers did not record any significant variation in the number of branches. Control treatments also had no significant difference in the number of branches per plant.

Interaction effects of treatments had no significant influence on the number of branches.

Table 4. Leaf area index of brinjal as influenced by source of nitrogen, organic manure amd biofertilizer

Treatments	30 DAT	45 DAT	60 DAT	75 DAT
Source of nitrogen				
S_1 (50 % N as organic + 50 % N as inorganic source)	0.20	0.77	0.84	0.79
S_2 (100 % organic manure)	0.18	0.72	0.78	0.74
F	12.68^{S}	274.72^{S}	88.04^{S}	61.60^{S}
CD	0.01	0.01	0.01	0.01
Organic manures				
O_1 (Poultry manure)	0.25	0.79	0.87	0.80
O_2 (Neem cake)	0.18	0.73	0.79	0.75
O_3 (Biogas slurry)	0.14	0.70	0.77	0.75
F	327.93^{S}	364.01^{S}	80.72^{S}	26.03^{S}
CD	0.01	0.01	0.02	0.02
Biofertilizers				
B_1 (No Azospirillum)	0.20	0.74	0.81	0.76
B_2 (With Azospirillum)	0.18	0.74	0.81	0.77
F	20.15^{S}	0.56	1.73	3.38
CD	0.01	—	—	—
Control				
POP (C_1)	0.12	0.69	0.71	0.70
POP without FYM (C_2)	0.10	0.60	0.72	0.69
F	—	—	—	—
CD	—	—	—	—

Table 5. Interaction effect of various treatments on leaf area index of brinjal

Treatments	30 DAT	45 DAT	60 DAT	75 DAT
S_1O_1	0.25	0.82	0.89	0.82
S_1O_2	0.18	0.78	0.83	0.78
S_1O_3	0.16	0.71	0.80	0.77
S_2O_1	0.25	0.77	0.84	0.77
S_2O_2	0.18	0.69	0.75	0.72
S_2O_3	0.13	0.69	0.75	0.73
F	5.92^S	40.91^S	1.53	1.05
CD	0.01	0.01	—	—
S_1B_1	0.20	0.76	0.85	0.78
S_1B_2	0.19	0.77	0.83	0.80
S_2B_1	0.19	0.72	0.78	0.73
S_2B_2	0.18	0.72	0.78	0.74
F	0.02	2.27	1.30	0.11
CD	—	—	—	—
O_1B_1	0.26	0.79	0.87	0.79
O_1B_2	0.25	0.79	0.86	0.80
O_2B_1	0.19	0.74	0.80	0.74
O_2B_2	0.16	0.73	0.79	0.76
O_3B_1	0.15	0.69	0.77	0.74
O_3B_2	0.14	0.70	0.77	0.75
F	3.76^S	1.32	0.44	4.23^S
CD	0.01	—	—	0.03

Table 6. Interaction effect of various treatments on leaf area index of brinjal

Treatments	30 DAT	45 DAT	60 DAT	75 DAT
$S_1O_1B_1$	0.27	0.81	0.89	0.81
$S_1O_1B_2$	0.23	0.83	0.89	0.83
$S_1O_2B_1$	0.19	0.77	0.83	0.76
$S_1O_2B_2$	0.18	0.78	0.82	0.80
$S_1O_3B_1$	0.15	0.71	0.81	0.78
$S_1O_3B_2$	0.16	0.70	0.78	0.76
$S_2O_1B_1$	0.24	0.78	0.85	0.78
$S_2O_1B_2$	0.26	0.76	0.83	0.77
$S_2O_2B_1$	0.20	0.70	0.76	0.71
$S_2O_2B_2$	0.15	0.68	0.75	0.72
$S_2O_3B_1$	0.14	0.67	0.73	0.71
$S_2O_3B_2$	0.11	0.70	0.76	0.74
F	23.31^S	19.61^S	4.40^S	4.23^S
CD	0.02	0.01	0.03	0.03

4.1.4. Leaf area index

The data on leaf area index (LAI) recorded at 30, 45, 60 and 75 DAT are presented in Tables 4, 5 and 6.

Source of nitrogen significantly increased the leaf area index at all growth stages. The treatment S_1 receiving 50 per cent of the recommended dose as chemical and 50 per cent as organic manure recorded highest LAI (0.20, 0.77, 0.84 and 0.79 respectively) and was significantly superior to S_2 receiving 100 per cent as organic manure.

Different organic manures had favourable influence on LAI. Treatment O_1 recorded highest LAI at all stages (0.25, 0.79, 0.87 and 0.80 respectively) and was significantly superior to O_2 and O_3.

Leaf area index recorded significant variation due to *Azospirillum* inoculation only during the early stages. At 30 DAT, B_2 was significantly superior to B_1. During later stages, *Azospirillum* could not register any significant influence.

Interaction between source of nitrogen and organic manures indicated the significant response during early stages (30 and 45 DAT). At 30 DAT, LAI was highest for the treatments S_1O_1 (50 per cent as chemical and 50 per cent as poultry manure) and S_2O_1 (100 per cent as poultry manure) (0.25) which were significantly superior to all other treatments. At 45 DAT, the treatment S_1O_1 was found significantly superior to others with a LAI of 0.82.

Interaction between organic manure and biofertilizer (O x B) increased the LAI significantly at 30 and 75 DAT. At 30 DAT, the treatment O_1B_1 (poultry

Table 7. Time to 50 per cent flowering, number of flowers, number of fruits and percentage of fruit set influenced by source of nitrogen, organic manure and biofertilizers

Treatment	Time to 50 % flowering (days)	No. of flowers	No. of fruits	Percentage fruit set
Source of nitrogen				
S_1 (50 % N as organic + 50 % N as inorganic source)	53.17	8.26	6.22	74.73
S_2 (100 % organic manure)	52.17	6.19	4.56	69.82
F	0.37	5.56^S	5.33^S	4.62^S
CD	—	1.81	1.46	4.70
Organic manures				
O_1 (Poultry manure)	48.50	8.27	6.67	80.60
O_2 (Neem cake)	55.92	7.42	5.42	69.84
O_3 (Biogas slurry)	53.58	6.00	4.08	66.39
F	7.13^S	2.28	4.43^S	14.04^S
CD	4.13	—	1.78	5.75
Biofertilizers				
B_1 (No Azospirillum)	51.28	6.90	5.33	74.34
B_2 (With Azospirillum)	54.06	7.56	5.44	70.21
F	2.87^S	0.55	0.02	3.27
CD	—	—	—	—
Control				
POP (C_1)	57.00	8.16	6.66	81.6
POP without FYM (C_2)	61.33	7.41	4.66	59.70
F	—	—	—	—
CD	—	—	—	—

manure + no *Azospirillum*) recorded the highest LAI (0.26) but was on par with O_1B_2 (0.25) and significantly superior to other treatments. At 75 DAT, the treatment O_1B_2 registered significantly superior value of LAI (0.80) compared to other treatments.

Interaction effect of source of nitrogen, organic manure and biofertilizer also showed significant influence of LAI, at all stages of growth. At 30 DAT, the treatment $S_1O_1B_1$ (50 per cent as chemical and 50 per cent as poultry manure) recorded highest LAI (0.27) and it was on par with $S_2O_1B_2$ (0.26) and was significantly superior to others. At 60 and 75 DAT, the treatment $S_1O_1B_2$ recorded highest LAI (0.89, 0.83 respectively). At 60 DAT, the treatments $S_1O_1B_1$ and $S_1O_1B_2$ were comparable (0.89 each).

4.2. Yield and yield attributes

Data depicted in Tables 7, 8 and 9 revealed the significant effect of various treatments and their interaction on yield and yield attributing characters of brinjal.

4.2.1. Time to 50 per cent flowering

Different organic manures registered significant influence on time to 50 per cent flowering. The treatment O_2 (neem cake) recorded the maximum time to 50 per cent flowering (55.92 days) which was on par with O_3 (53.58) and significantly superior to O_1.

Source of nitrogen and biofertilizer application didnot show any significant influence.

Table 8. Interaction effect of various treatments on days to 50 per cent flowering, number of flowers, number of fruits and percentage fruit set

Treatment	Time to 50 % flowering (days)	No. of flowers	No. of fruits	Percentage fruit set
S_1O_1	49.00	8.67	6.83	78.54
S_1O_2	52.50	8.79	6.83	77.41
S_1O_3	58.00	7.33	5.00	68.26
$S_2$01	48.00	7.88	6.50	82.66
S_2O_2	59.33	6.04	4.00	62.28
S_2O_3	49.17	4.67	3.17	64.52
F	7.60^S	0.53	1.05	5.98^S
CD	5.84	—	—	8.14
S_1B_1	50.11	9.42	7.44	78.26
S_1B_2	56.22	7.11	5.00	71.26
S_2B_1	52.44	4.39	3.22	70.43
S_2B_2	51.89	8.00	5.89	69.21
F	4.13	11.35^S	13.00^S	1.63
CD	—	2.55	2.06	—
O_1B_1	47.50	6.92	5.83	84.34
O_1B_2	49.50	9.63	7.50	76.86
O_2B_1	55.17	8.42	6.00	64.28
O_2B_2	56.67	6.42	4.83	75.41
O_3B_1	51.17	5.38	4.17	74.41
O_3B_2	56.00	6.63	4.00	68.37
F	0.40	2.51	1.37	12.33^S
CD	—	—	—	8.14

Table 9. Interaction effect of various treatments on days to 50 per cent flowering, number of flowers, number of fruits and percentage fruit set

Treatment	Time to 50 % flowering (days)	No. of flowers	No. of fruits	Percentage fruit set
$S_1O_1B_1$	47.00	9.42	8.00	85.72
$S_1O_1B_2$	51.00	7.92	5.67	71.36
$S_1O_2B_1$	53.00	12.42	9.67	76.89
$S_1O_2B_2$	52.00	5.17	4.00	77.92
$S_1O_3B_1$	50.33	6.42	4.67	72.16
$S_1O_3B_2$	65.67	8.25	5.33	64.35
$S_2O_1B_1$	48.00	4.42	3.67	82.96
$S_2O_1B_2$	48.00	11.33	9.33	82.37
$S_2O_2B_1$	57.33	4.42	2.33	51.66
$S_2O_2B_2$	61.33	7.67	5.67	72.90
$S_2O_3B_1$	52.00	4.33	3.67	76.67
$S_2O_3B_2$	46.33	5.00	2.67	52.38
F	5.40^S	4.19^S	5.76^S	6.13^S
CD	8.26	4.42	3.57	11.51

S x O interaction effect showed that the treatment combination S_2O_2 had the significantly higher value (59.33 days) which was on par with S_1O_3 (58.0 days) when compared to other treatment combinations.

S x O x B interaction effect also showed significant variation. The treatment $S_1O_3B_2$ recorded the highest value (65.57 days) which was on par with $S_2O_2B_2$ (61.33 days) and was significantly superior to other treatment combinations.

4.2.2. Number of flowers per plant

Source of nitrogen recorded significant variation in the number of flowers per plant. S_1 recorded highest number of flowers per plant (8.26) and was significantly superior to S_2 (6.19).

Different organic manures did not show any significant variation in the number of flowers per plant. Control treatments also showed no significance in increasing the number of flowers per plant. Interaction effect of source of nitrogen and biofertilizers showed that the treatment S_1B_1 recorded highest number of flowers per plant (9.42) and it was on par with S_2B_2 (8.00) but significantly superior to S_1B_2 and S_2B_1.

Interaction effect of various treatments revealed that the treatment $S_1O_2B_1$ recorded highest number of flowers per plant (12.42) and was on par with $S_2O_1B_2$ (11.33), $S_1O_1B_1$ (9.42) and $S_1O_3B_2$ (8.25) and was significantly superior to all the other treatment combinations.

4.2.3. Number of fruits per plant

Effect of sources of nitrogen, different organic manures and biofertilizers on number of fruits per plant are presented in Table 7, 8 and 9.

Source of nitrogen had a favourable influence on number of fruits per plant. The treatment S_1 showed highest number of fruits per plant (6.22) and was significantly superior to S_2 (4.56).

Among the various organic manures used, the treatment receiving O_1 recorded maximum number of fruits (6.67) which was on par with O_2 (5.42) and was significantly superior to O_3.

Interaction effect of source of nitrogen and biofertilizers showed significant response in number of fruits per plant. The highest number of fruits per plant was recorded by the treatment S_1B_1 (7.44) which was on par with S_2B_2 (5.89) and was significantly superior to other treatments.

Interaction effect of source of nitrogen, organic manure and biofertilizer also showed significant influence in this character. The treatment $S_1O_2B_1$ registered highest number of fruits per plant (9.67) which was on par with $S_2O_1B_2$ (9.33) and $S_1O_1B_1$ (8.00) and was significantly superior to all other treatment combinations.

4.2.4. Percentage fruit set

There was significant variation in setting percentage of fruits due to different sources of nitrogen and organic manures. Treatment S_1 (74.73) recorded increased setting percentage and was significantly superior to S_2. Among the different organic manures, poultry manure recorded high fruit set percentage (80.6) and was significantly superior to the other organic manures O_2 and O_3. *Azospirillum* inoculation did not show any significant influence on percentage fruit set.

Interaction effect of source of nitrogen and organic manures was significant. The treatment S_2O_1 recorded highest per cent fruit set (82.66) and was on par with treatments S_1O_1 (78.51) and S_1O_2 (77.41) and was significantly superior to other treatment combinations.

Organic manure and biofertilizer interaction had significant influence on percentage fruit set. The treatment O_1B_1 recorded highest fruit set percentage (84.34) and it was on par with O_1B_2 (76.86 per cent) but significantly superior to all other combinations.

Among the interaction effect of various treatments, $S_1O_1B_1$ recorded highest fruit set percentage (85.72) and was on par with $S_2O_1B_1$ (82.96), $S_2O_1B_2$ (82.37), $S_1O_2B_2$ (77.92), $S_1O_2B_1$ (76.89) and $S_2O_3B_1$ (76.67) and was significantly superior to the other treatment combinations.

4.2.5. Marketable fruit yield per ha

Main effects of treatments on marketable fruit yield per ha are presented in Tables 10 and 11.

The mature green fruits which are free from disease and pest infestation were recorded as marketable fruit yield.

Table 10. Marketable fruit yield, harvest index and keeping quality of fruits influenced by source of nitrogen, organic manure and biofertilizer

Treatment	Marketable fruit yield/ha (t)	Harvest index	Keeping quality of fruits (days)
Source of nitrogen			
S_1 (50 % N as organic + 50 % N as inorganic source)	25.01	0.45	3.39
S_2 (100 % organic manure)	18.68	0.41	3.22
F	9.55^S	28.91^S	0.77
CD	4.21	0.01	—
Organic manures			
O_1 (Poultry manure)	25.11	0.48	3.83
O_2 (Neem cake)	19.41	0.43	3.50
O_3 (Biogas slurry)	21.01	0.38	2.58
F	2.75	73.72^S	15.42^S
CD	—	0.02	0.48
Biofertilizers			
B_1 (No Azospirillum)	22.01	0.43	3.39
B_2 (With Azospirillum)	21.68	0.43	3.22
F	0.03	0.25	0.77
CD	—	—	—
Control			
POP (C_1)	18.90	0.38	2.66
POP without FYM (C_2)	17.90	0.35	2.33
F	—	—	—
CD	—	—	—

Table 11. Interaction effect of treatments on marketable fruit yield, harvest index and keeping quality of fruits

Treatment	Marketable fruit yield/ha (t)	Harvest index	Keeping quality of fruits (days)
S_1O_1	26.70	0.48	4.17
S_1O_2	26.87	0.45	3.50
S_1O_3	21.45	0.40	2.50
$S_2$01	23.52	0.47	3.50
S_2O_2	11.95	0.40	3.50
S_2O_3	20.58	0.35	2.67
F	4.52^S	4.28^S	1.79
CD	7.29	0.02	—
S_1B_1	26.58	0.45	3.56
S_1B_2	23.43	0.44	3.22
S_2B_1	17.43	0.41	3.22
S_2B_2	19.93	0.41	3.22
F	1.91	1.80	0.77
CD	—	—	—
O_1B_1	22.67	0.48	4.00
O_1B_2	27.54	0.47	3.67
O_2B_1	24.35	0.44	3.50
O_2B_2	14.47	0.42	3.50
O_3B_1	19.00	0.37	2.67
O_3B_2	23.03	0.39	2.50
F	5.47^S	2.82	0.26
CD	7.29	—	—

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Among the two sources of nitrogen S_1 (50 per cent as chemical and 50 per cent as organic manure) recorded highest marketable yield per hectare (25.01 t ha^{-1}) and was significantly superior to S_2 (18.68 t ha^{-1}).

Different organic manures and *Azospirillum* could not influence the marketable yield ha^{-1}. However poultry manure recorded the highest marketable fruit yield per ha (25.11 t).

S x O and O x B interaction registered significant influence on the marketable yield ha^{-1}. Among the S x O interaction, S_1O_1 and S_1O_2 recorded highest fruit yield (26.7 and 26.87 t ha^{-1} respectively) and these two treatments were comparable with all other treatments except S_2O_2.

Among the O x B interaction, O_1B_2 recorded highest marketable fruit yield (27.54 t ha^{-1}) and this was comparable with all other treatments except O_3B_1 and O_2B_2.

4.2.6. Yield per harvest

Data presented in Tables 12, 13 and 14 indicated the significant influence of the source of nitrogen and different organic manures on the yield per harvest. Among the two sources of nitrogen, the treatment S_1 significantly increased the fruit yield during the third and fourth harvests (1344.43 g $plant^{-1}$ and 575.28 g $plant^{-1}$ respectively) and was significantly superior to S_2.

Different organic manures did not influence the fruit yield per harvest in the first three harvests. During the fourth harvest O_1 (poultry manure) and O_2 (neem cake) recorded highest fruit yield (514.17 kg $plant^{-1}$ and 491.67 kg $plant^{-1}$ respectively) which were on par and was significantly superior to O_3.

Table 12. Yield per harvest of brinjal as influenced by source of nitrogen, organic manures and biofertilizers (g $plant^{-1}$)

Treatments	First	Second	Third	Fourth
Source of N_2				
S_1 (50 % N as organic + 50 % N as inorganic source)	1037.78	1546.67	1344.43	575.28
S_2 (100 % organic manure)	834.44	1260.00	961.11	310.83
F	—	—	6.33^S	17.14^S
CD	—	—	313.17	131.31
Organic manures				
O_1 (Poultry manure)	1151.67	1642.08	1240.41	514.57
O_2 (Neem cake)	728.33	1124.58	1175.83	491.67
O_3 (Biogas slurry)	928.33	1443.33	1092.08	323.33
F	2.11	2.42	0.22	3.56
CD	—	—	—	160.83^S
Biofertilizers				
B_1 (No Azospirillum)	928.89	1415.00	1163.06	455.56
B_2 (With Azospirillum)	943.33	1391.67	1142.50	430.56
F	0.01	0.01	0.02	0.15
CD	—	—	—	—
Control				
POP (C_1)	813.33	1283.33	1066.66	250.00
POP without FYM (C_2)	780.00	1341.66	1056.66	253.33
F	—	—	—	—
CD	—	—	—	—

Table 13. Interaction effect of various treatments on yield per harvest of brinjal (g plant^{-1})

Treatments	First	Second	Third	Fourth
S_1O_1	1190.0	1729.17	1325.0	566.67
S_1O_2	1020.0	1545.00	1525.0	746.67
S_1O_3	903.0	1365.83	1183.33	412.50
S_2O_1	1113.33	1555.00	1105.83	461.67
S_2O_2	436.67	704.17	776.67	236.67
S_2O_3	953.33	1520.83	1000.83	234.17
F	1.32	2.28	1.44	3.81^S
CD	—	—	—	227.44
S_1B_1	1077.78	1666.11	1408.33	630.56
S_1B_2	997.78	1427.22	1280.56	520.0
S_2B_1	780.00	1163.89	917.78	280.56
S_2B_2	888.89	1356.11	1004.44	341.11
F	0.31	1.24	0.50	1.79
CD	—	—	—	—
O_1B_1	1076.67	1408.33	1163.33	436.67
O_1B_2	1226.67	1875.83	1267.50	591.67
O_2B_1	806.67	1495.00	1371.67	705.00
O_2B_2	650.00	754.17	930.00	278.33
O_3B_1	903.33	1341.67	954.17	225.00
O_3B_2	953.33	1545.00	1230.00	421.67
F	0.29	3.58^S	2.02	9.92^S
CD	—	690.41	—	227.44

Table 14. Interaction effect of various treatments on yield per harvest of brinjal (g plant^{-1})

Treatments	First	Second	Third	Fourth
$S_1O_1B_1$	1166.77	1591.67	1175.00	433.33
$S_1O_1B_2$	1213.33	1866.67	1475.00	700.00
$S_1O_2B_1$	1153.33	2048.33	1950.00	1150.00
$S_1O_2B_2$	886.67	1041.67	1100.00	343.33
$S_1O_3B_1$	913.33	1358.33	1100.00	303.33
$S_1O_3B_2$	893.33	1373.33	1266.67	516.67
$S_2O_1B_1$	986.67	1225.00	1151.67	440.00
$S_2O_1B_2$	1240.00	1885.00	1060.00	483.33
$S_2O_2B_1$	460.00	941.67	793.33	260.00
$S_2O_2B_2$	413.33	466.67	760.00	213.33
$S_2O_3B_1$	893.33	1325.00	808.33	141.67
$S_2O_3B_2$	1013.33	1716.67	1193.33	326.67
F	0.01	0.02	1.31	5.52^S
CD	—	—	—	321.65

S x O interaction could influence the fruit yield during the fourth harvest only. S_1O_2 recorded highest fruit yield (746.67 g plant^{-1}) and this was on par with S_1O_1 (566.67 g plant^{-1}) and was significantly superior to other treatments.

O x B interaction increased the fruit yield during the second and fourth harvest. During second harvest, the treatment O_1B_2 recorded highest fruit yield (1875.83 g plant^{-1}) and was on par with all the other treatments except O_2B_2. During the fourth harvest, O_2B_1 recorded highest fruit yield (705.0 g plant^{-1}) and was on par with O_1B_2 and wa s significantly superior to the other combinations.

Interaction effect of various treatments could influence the fruit yield only during the fourth harvest. The treatment combination $S_1O_2B_1$ recorded highest fruit yield (1150.0 g plant^{-1}) and was significantly superior to all other treatment combinations.

4.2.7. Harvest Index

Source of nitrogen showed significant influence on harvest index. Treatment S_1 showed highest HI (0.45) which is significantly superior to S_2.

Among the different types of organic manures tried, O_1 (poultry manure) recorded the highest HI of 0.48 which was significantly superior to O_2 and O_3.

Biofertilizer application did not show any significant influence.

Interaction effect of source of nitrogen and organic manure showed significant variation. The treatment S_1O_1 recorded highest HI (0.48) which was on par with S_2O_1 and were significantly superior to other combinations.

S x O x B interaction effect revealed that the treatment $S_1O_1B_2$ had the maximum HI (0.49) which was on par with $S_1O_2B_1$ (0.48), $S_2O_1B_1$ (0.48), $S_1O_1B_1$ (0.47) and were significantly superior to all other treatments.

4.3. Physiological parameters

4.3.1. Dry matter production

Dry matter production was computed at different growth stages and the values are presented in Tables 15, 16 and 17.

Nitrogen sources registered significant influence on dry matter production only at 45 and 60 DAT. At 45 DAT and 60 DAT the treatment S_2 recorded the highest DMP (957.96 kg ha^{-1} and 1415.42 kg ha^{-1} respectively) and were significantly superior to S_1.

Different organic manures and biofertilizers did not record any significant response.

Interaction effect of source of nitrogen and organic manure (S x O) recorded significant variation only at 60 DAT. At 60 DAT the treatment S_2O_1 (100 per cent as poultry manure) recorded highest DMP (1554.24 kg ha^{-1}) which was on par with S_1O_1 (1571.35 kg ha^{-1}) and was significantly superior to other treatments.

Data on interaction between source of nitrogen and biofertilizers (S x B) revealed that there is significant influence on dry matter production during 30 and 60 DAT. At 30 DAT, the treatment S_1B_1 recorded highest DMP (511.35 kg ha^{-1})

Table 15. Dry matter production in brinjal as influenced by source of nitrogen, organic manures and biofertilizers (kg ha^{-1})

Treatments	30 DAT	45 DAT	60 DAT	75 DAT
Source of nitrogen				
S_1 (50 % N as organic + 50 % N as inorganic source)	486.19	781.50	1360.18	1267.90
S_2 (100 % organic manure)	450.59	957.96	1415.42	1384.65
F	3.50	9.92	28.66^S	1.17
CD	—	47.40	21.21	—
Organic manures				
O_1 (Poultry manure)	469.49	704.90	1562.80	1419.59
O_2 (Neem cake)	444.87	852.20	1252.49	1281.80
O_3 (Biogas slurry)	490.81	852.08	1348.11	1285.37
F	1.95	2.55	316.50^S	1.16
CD	—	—	25.97	—
Biofertilizers				
B_1 (No Azospirillum)	465.35	958.38	1365.02	1728.69
B_2 (With Azospirillum)	471.43	981.00	1410.58	1315.79
F	3.10	0.08	19.49^S	1.17
CD	—	—	21.21	—
Control				
POP (C_1)	469.25	854.65	1387.79	1113.46
POP without FYM (C_2)	511.10	813.69	1356.66	1178.20
F	—	—	—	—
CD	—	—	—	—

Table 16. Interaction effect of various treatments on dry matter production (kg ha^{-1})

Treatments	30 DAT	45 DAT	60 DAT	75 DAT
S_1O_1	459.36	1045.55	1571.35	1384.43
S_1O_2	460.59	1074.088	1180.73	1173.67
S_1O_3	538.62	812.96	1328.46	1245.60
S_2O_1	479.62	1103.51	1554.24	1454.76
S_2O_2	429.14	879.18	1324.24	1499.90
S_2O_3	442.99	891.21	1367.76	1325.15
F	3.10	2.54	20.81^S	1.17
CD	—	—	36.73	—
S_1B_1	511.35	1106.66	1270.87	1232.15
S_1B_2	461.03	913.10	1449.49	1303.64
S_2B_1	419.35	1066.95	1459.17	1225.20
S_2B_2	481.82	848.98	1371.66	1327.95
F	8.78^S	0.09	166.43^S	1.17
CD	55.33	—	29.99	—
O_1B_1	492.66	956.58	1556.69	1473.76
O_1B_2	446.33	453.30	1568.91	1365.42
O_2B_1	441.89	625.10	1324.06	1452.60
O_2B_2	447.85	819.21	1180.91	1170.97
O_3B_1	461.51	833.48	1214.32	1159.76
O_3B_2	520.10	870.69	1481.91	1410.99
F	2.53	7.47^S	134.76	1.17
CD	—	107.30	—	—

Table 17. Interaction effect of treatments on dry matter production of brinjal (kg ha^{-1})

Treatments	30 DAT	45 DAT	60 DAT	75 DAT
$S_1O_1B_1$	398.51	564.81	1449.61	1380.05
$S_1O_1B_2$	520.22	747.80	1693.09	1388.80
$S_1O_2B_1$	566.29	529.30	1184.73	1185.91
$S_1O_2B_2$	354.88	920.95	1176.73	1161.43
$S_1O_3B_1$	569.25	855.33	1178.28	1130.50
$S_1O_3B_2$	507.99	770.58	1478.64	1360.69
$S_2O_1B_1$	586.81	1348.35	1663.76	1567.46
$S_2O_1B_2$	372.44	858.66	1444.72	1342.05
$S_2O_2B_1$	317.48	1040.88	14633.39	1319.20
$S_2O_2B_2$	540.81	717.47	1185.10	1180.50
$S_2O_3B_1$	353.77	811.62	1250.35	1189.02
$S_2O_3B_2$	532.22	970.80	1485.17	1461.28
F	36.96^S	7.48^S	30.86^S	1.17
CD	95.84	18.90	51.95	—

Table 18. RGR, CGR and NAR as affected by source of nitrogen, organic manure and biofertilizer

Treatment	RGR (mg day^{-1})	CGR (mg cm^{-2} day^{-1})	NAR (mg cm^{-2} day^{-1})
Source of nitrogen			
S_1 (50 % N as organic + 50 % N as inorganic source)	0.03	0.005	0.0031
S_2 (100 % organic manure)	0.02	0.005	0.0032
F	507.11	130.76	0.00
CD	0.00^S	0.00^S	0.00^S
Organic manures			
O_1 (Poultry manure)	0.03	0.0045	0.0023
O_2 (Neem cake)	0.02	0.0041	0.0023
O_3 (Biogas slurry)	0.03	0.0043	0.0025
F	326.82	423.75	0.71
CD	0.00^S	0.00^S	—
Biofertilizers			
B_1 (No Azospirillum)	0.03	0.0021	0.0013
B_2 (With Azospirillum)	0.03	0.0021	0.0015
F	18.09	0.02	0.06
CD	0.00^S	—	—
Control			
POP (C_1)	1.7666×10^{-2}	1.666×10^{-2}	0.0079
POP without FYM (C_2)	2.6667×10^{-2}	2.533×10^{-3}	0.0015
F	—	—	—
CD	—	—	—

Table 19. Interaction effect of various treatments on RGR, CGR and NAR

Treatment	RGR (mg day^{-1})	CGR (mg cm^{-2} day^{-1})	NAR (mg cm^{-2} day^{-1})
S_1O_1	0.05	0.002	0.0031
S_1O_2	0.02	0.0021	0.0032
S_1O_3	0.03	0.0025	0.0025
S_2O_1	0.02	0.001	0.0023
S_2O_2	0.02	0.0011	0.0023
S_2O_3	0.02	0.002	0.0021
F	327.69	396.71	0.06
CD	0.00^S	0.00^S	—
S_1B_1	0.04	0.004	0.0013
S_1B_2	0.03	0.0038	0.0015
S_2B_1	0.02	0.0039	0.0016
S_2B_2	0.02	0.0038	0.0016
F	100.17	0.41	0.10
CD	0.00^S	—	—
O_1B_1	0.04	0.0021	0.0013
O_1B_2	0.03	0.0039	0.0015
O_2B_1	0.02	0.0025	0.0016
O_2B_2	0.02	0.002	0.0025
O_3B_1	0.02	0.0021	0.0026
O_3B_2	0.03	0.0019	0.0025
F	52.70	126.60	0.23
CD	0.00^S	0.00^S	—

Table 20. Interaction effect of various treatments on RGR, CGR and NAR

Treatment	RGR (mg day^{-1})	CGR (mg cm^{-2} day^{-1})	NAR (mg cm^{-2} day^{-1})
$S_1O_1B_1$	0.06	0.005	0.0031
$S_1O_1B_2$	0.03	0.005	0.0032
$S_1O_2B_1$	0.02	0.0039	0.0031
$S_1O_2B_2$	0.02	0.0038	0.0023
$S_1O_3B_1$	0.04	0.0021	0.0023
$S_1O_3B_2$	0.01	0.002	0.0025
$S_2O_1B_1$	0.03	0.0043	0.0013
$S_2O_1B_2$	0.02	0.0045	0.0015
$S_2O_2B_1$	0.02	0.0025	0.0016
$S_2O_2B_2$	0.02	0.002	0.0008
$S_2O_3B_1$	0.03	0.001	0.0009
$S_2O_3B_2$	0.02	0.0011	0.0008
F	666.49	186.92	0.47
CD	0.00^S	0.00^S	—

which was on par with S_2B_2 (481.82 kg ha^{-1}) and S_1B_2 (461.03 kg ha^{-1}) and was significantly superior to S_2B_1. At 60 DAT, the treatment S_2B_1 (100 per cent as organic manure) recorded the highest DMP (1459.17 kg ha^{-1}) which was on par with S_1B_2 (1449.49 kg ha^{-1}) and these two were significantly superior to other treatments.

O x B interaction revealed significant influence on dry matter production only at 45 DAT. At 45 DAT, the treatment O_1B_1 recorded the highest DMP (956.58 kg ha^{-1}) which was on par with O_3B_2 (870.69 kg ha^{-1}) and was significantly superior to other combinations.

In S x O x B interaction, significant response was obtained upto 60 DAT. At 30 and 45 DAT, the treatment $S_2O_1B_1$ recorded the highest DMP (586.81 and 1348.35 kg ha^{-1} respectively) and were significantly superior to others.

4.3.2. RGR, CGR, NAR

Source of nitrogen showed significant variation in RGR and CGR. The treatment S_1 showed the highest RGR and CGR. Among the organic manures O_3 and O_1 showed maximum RGR and O_1 showed maximum CGR and were significantly superior to other treatments.

4.4. Plant analysis

The contents of N, P and K in plants were analysed and uptake of N, P and K calculated and presented in Tables 21, 22 and 23.

Table 21. Plant nutrient content as influenced by source of nitrogen, organic manures and biofertilizers (%)

Treatment	N	P	K
Source of nitrogen			
S_1 (50 % N as organic + 50 % N as inorganic source)	2.23	0.76	2.94
S_2 (100 % organic manure)	2.49	0.70	2.35
F	14.95^S	24.47^S	330.61^S
CD	0.13	0.02	0.07
Organic manures			
O_1 (Poultry manure)	2.20	0.76	2.93
O_2 (Neem cake)	2.71	0.70	2.38
O_3 (Biogas slurry)	2.17	0.74	2.63
F	29.01^S	7.77^S	94.45^S
CD	0.16	0.03	0.08
Biofertilizers			
B_1 (No Azospirillum)	2.42	0.70	2.60
B_2 (With Azospirillum)	2.30	0.76	2.69
F	3.65	25.41^S	8.57^S
CD	—	0.02	0.07
Control			
POP (C_1)	2.86	0.51	2.74
POP without FYM (C_2)	2.53	0.54	2.92
F	—	—	—
CD	—	—	—

Table 22. Interaction effect of treatments on the plant nutrient status (%)

Treatment	N	P	K
S_1O_1	2.33	0.68	3.01
S_1O_2	2.56	0.71	2.73
S_1O_3	1.81	0.89	3.08
S_2O_1	2.07	0.83	2.84
S_2O_2	2.86	0.70	2.03
S_2O_3	2.53	0.58	2.17
F	18.72^S	126.32^S	45.98^S
CD	0.23	0.04	0.12
S_1B_1	2.18	0.65	2.88
S_1B_2	2.28	0.87	3.01
S_2B_1	2.66	0.75	2.32
S_2B_2	2.32	0.65	2.38
F	11.50^S	180.69^S	1.19
CD	0.19	0.03	—
O_1B_1	2.39	0.82	3.02
O_1B_2	2.01	0.70	2.84
O_2B_1	2.46	0.62	2.41
O_2B_2	2.96	0.79	2.35
O_3B_1	2.41	0.67	2.36
O_3B_2	1.93	0.81	2.89
F	22.61^S	61.90^S	45.26^S
CD	0.23	0.04	0.12

Table 23. Interaction effect of treatments on the plant nutrient status (%)

Treatment	N	P	K
$S_1O_1B_1$	2.35	0.67	2.92
$S_1O_1B_2$	2.31	0.70	3.11
$S_1O_2B_1$	1.95	0.60	2.65
$S_1O_2B_2$	3.17	0.82	2.80
$S_1O_3B_1$	2.26	0.69	3.05
$S_1O_3B_2$	1.36	1.10	3.11
$S_2O_1B_1$	2.44	0.97	3.11
$S_2O_1B_2$	1.70	0.69	2.57
$S_2O_2B_1$	2.98	0.64	2.17
$S_2O_2B_2$	2.74	0.75	1.89
$S_2O_3B_1$	2.56	0.65	1.67
$S_2O_3B_2$	2.49	0.52	2.67
F	26.47^S	27.79^S	61.76^S
CD	0.33	0.06	0.16

4.4.1. Contents of N, P and K

The results on the nitrogen, phosphorus and potassium content of the plant are presented in Tables 21, 22 and 23.

4.4.1.1. Nitrogen content of plants

Nitrogen content of plants was favourably influenced by the source of nitrogen and type of organic manure. Treatment S_2 (as 100 per cent organic manure) recorded highest nitrogen content in plants (2.49 per cent) and was significantly superior to S_1. Among the organic manures, O_2 (neem cake) recorded the highest plant nitrogen content (2.71 per cent) and was significantly superior to O_1 and O_3.

Biofertilizer application did not show any significant response in the N content of plant. Control treatments also showed no significant variation in its N content.

Interaction effect of source of N and type of organic manures showed that treatment S_2O_2 recorded highest plant nitrogen content (2.86 per cent) and was significantly superior to all other treatments.

Interaction effect of various treatments recorded significant influence on the plant N content. The treatment S_2O_2 recorded highest plant N content (2.86 per cent) and was significantly superior to all other combinations. Among S x B interactions, S_2B_1 (2.66 per cent) was significantly superior to all other treatments. Interaction between organic manure and biofertilizer revealed that the treatment

O_2B_2 (100 per cent as neem cake + Azospirillum) recorded highest plant nitrogen content of 2.96 per cent and it was significantly superior to all other treatments. Among the various treatment combinations, $S_1O_2B_2$ recorded the highest plant N content (3.17 per cent) and it was on par with $S_2O_2B_1$ and $S_2O_2B_2$ (2.98 and 2.74 per cent respectively) and was significantly superior to all other treatment combinations.

4.4.1.2. Phosphorus content of plants

Source of nitrogen had a favourable influence on phosphorus content of plants. Highest P content was recorded by the treatment S_1 (0.76 per cent) and was significantly superior to S_2 (0.70 per cent). Among the different organic manures O_1 (poultry manure) recorded the highest plant P content (0.76 per cent) and was on par with O_3 (0.74 per cent) and was significantly superior to O_2.

Azospirillum inoculation also showed significant variation. Treatment B_2 recorded maximum plant P content (0.76 per cent) and was significantly superior to B_1.

Interaction effect also showed significant response. Data on interaction between source of nitrogen and organic manure revealed that the treatment S_1O_3 recorded the highest plant P content (0.89 per cent) and was significantly superior to other treatment combinations.

S x B interaction also showed significant variation in plant P content. The highest P content was recorded by the treatment S_1B_2 (0.87 per cent) and was significantly superior to all other treatments.

O x B interaction showed significant influence on plant P content. The *treatment* O_1B_1 *recorded the highest plant* P (0.82 per cent) and was significantly superior to other treatments.

S x O x B interaction also significantly influenced the P content in plant. The treatment $S_1O_3B_2$ recorded the highest plant P content (1.10 per cent) which was significantly superior to all other combinations.

4.4.1.3. Potassium content of plants

Effect of source of N, type of organic manure and biofertilizers significantly influenced the K content in plants. Treatment S_1 registered highest plant K content (2.94 per cent) and was significantly superior to S_2. Among the different organic manures, O_1 (poultry manure) recorded the highest plant K content (2.93 per cent) and was significantly superior to the other two organic manures O_2 and O_3. Azospirillum inoculation significantly increased the plant K content. Control treatment had no significant influence on the potassium content in plants.

Interaction between source of nitrogen and organic manure revealed that S_1O_3 (3.08 per cent) and S_1O_1 (3.01 per cent) were on par and were significantly superior over other treatments.

O x B interaction significantly influenced the K content in plants. The treatment O_1B_1 (100 per cent N as poultry manure) recorded the highest content of potassium in plants (3.02 per cent) and was significantly superior to all other treatments.

Significant difference was noticed in the interaction effect of source of nitrogen organic manure and biofertilizers. Treatments $S_1O_1B_1$, $S_1O_3B_2$ and $S_2O_1B_1$ recorded highest K contents (3.11 per cent) and were on par with $S_1O_3B_1$ (3.05 per cent) and were significantly superior to all other treatment combinations.

4.4.2. Uptake of N, P and K

Plant nutrient uptake of brinjal (kg ha^{-1}) are computed and presented in Tables 24, 25 and 26.

4.4.2.1. Uptake of nitrogen

Source of nitrogen had a favourable influence on nitrogen uptake. The treatment S_2 (100 per cent N as organic manure) recorded maximum uptake of nitrogen (33.33 kg ha^{-1}) and was significantly superior to S_1.

Among the various organic manures tried O_2 (neem cake) recorded significantly higher nitrogen uptake value (33.02 kg ha^{-1}) compared to O_1 and O_3. Biofertilizer did not reveal any significant variation in nitrogen uptake.

Interaction effect of various treatments showed significant difference. Among the S x O interactions, treatment S_2O_2 recorded highest nitrogen uptake (36.02 kg ha^{-1}) which was on par with S_2O_3 (33.45 kg ha^{-1}) and was significantly superior to other treatment combinations.

S x B interaction revealed that the highest N uptake was recorded by the treatment S_2B_1 (36.12) which was significantly superior to other treatment combinations.

O x B interaction also showed significant variation in uptake of N. The treatment O_1B_1 showed maximum nitrogen uptake (35.31 kg ha^{-1}) which was on par with O_2B_2 (34.62 kg ha^{-1}) and was significantly superior to others.

S x O x B interaction also indicated the significant response with respect to N uptake. The treatment $S_2O_2B_1$ recorded maximum N uptake (36.69) which was on par with treatments $S_2O_1B_1$ (38.24), $S_1O_2B_2$ (36.90 kg ha^{-1}) and $S_2O_3B_2$ (36.48 kg ha^{-1}) and was significantly superior to other treatments.

4.4.2.2. Uptake of phosphorus

Source of nitrogen had no significant influence on the uptake of P. Different organic manures showed significant variation in P uptake. Highest P uptake of 10.84 kg ha^{-1} was recorded by O_1 (poultry manure) and was significantly superior to O_2 and O_3. Biofertilizer application also showed significant variation in the uptake of phosphorus. The treatment B_2 recorded the maximum P uptake (10.0 kg ha^{-1}) and was significantly superior to B_1.

Interaction effect of various treatments showed significant influence on uptake of P (Table 25). S x O interaction effect revealed that highest P uptake was shown by S_2O_1 (12.25 kg ha^{-1}) which was significantly superior to other treatments combinations.

S x B interaction presented in Table 25 also showed significant variation. The treatment S_1B_2 recorded maximum P uptake (12.19 kg ha^{-1}) and was significantly superior to other treatments.

S x O x B interaction effect showed that the treatment $S_2O_1B_1$ (15.19 kg ha^{-1}) and $S_1O_3B_2$ (14.96 kg ha^{-1}) were on par and were significantly superior to others.

4.4.2.3. Uptake of Potassium

Source of nitrogen had a favourable influence on uptake of K. The treatment S_1 has the maximum K uptake (37.72 kg ha^{-1}) which was significantly superior to S_2.

Different organic manures showed significant variation in this character. Among the three organic manures tried, poultry manure (O_1) recorded highest K uptake (41.67 kg ha^{-1}) which was significantly superior to neem cake (O_2) and biogas slurry (O_3).

Biofertilizer application could not record any significant influence on K uptake in plants.

Data on S x O interaction effect showed that the treatments S_1O_1 and S_2O_1 recorded significantly higher K uptake values (41.72 and 41.61 kg ha^{-1} respectively) compared to other treatments.

S x B interaction effect revealed that the treatment S_1B_2 has the highest K uptake (39.34 kg ha^{-1}) which was significantly superior to other treatments.

O x B interaction effect also had a significant influence. The data revealed that the treatment O_1B_1 recorded the maximum K uptake (44.48 kg ha^{-1}) which was significantly superior to others.

Table 24. Plant nutrient uptake of brinjal as influenced by source of nitrogen, organic manure and biofertilizer (kg ha^{-1})

Treatment	N	P	K
Source of nitrogen			
S_1 (50 % N as organic + 50 % N as inorganic source)	28.08	9.70	37.72
S_2 (100 % organic manure)	33.33	9.55	31.77
F	37.73^S	0.62	58.50^S
CD	1.76	—	1.60
Organic manures			
O_1 (Poultry manure)	31.37	10.84	41.67
O_2 (Neem cake)	33.02	8.49	29.30
O_3 (Biogas slurry)	27.73	9.54	33.27
F	13.33^S	51.07^S	87.71^S
CD	2.15	0.48	1.96
Biofertilizers			
B_1 (No Azospirillum)	31.56	9.25	34.57
B_2 (With Azospirillum)	29.85	10.00	34.91
F	4.02	15.48^S	0.19
CD	—	0.39	—
Control			
POP (C_1)	31.88	5.70	30.57
POP without FYM (C_2)	29.81	6.44	34.37
F	—	—	—
CD	—	—	—

Table 25. Interaction effect of various treatments on plant nutrient uptake (kg ha^{-1})

Treatment	N	P	K
S_1O_1	32.21	9.44	41.72
S_1O_2	30.01	8.29	32.99
S_1O_3	22.00	11.36	38.45
S_2O_1	30.53	12.25	41.61
S_2O_2	36.02	8.68	25.61
S_2O_3	33.45	7.71	28.09
F	19.83^S	99.77^S	15.31^S
CD	3.05	0.68	2.77
S_1B_1	27.01	8.01	36.10
S_1B_2	29.15	11.38	39.34
S_2B_1	36.12	10.48	33.05
S_2B_2	30.55	8.61	30.48
F	20.33^S	190.21^S	13.92^S
CD	2.49	0.55	2.26
O_1B_1	35.31	12.19	44.48
O_1B_2	27.43	9.49	38.85
O_2B_1	31.41	7.80	31.23
O_2B_2	34.62	9.18	27.37
O_3B_1	27.97	7.75	28.02
O_3B_2	27.49	11.32	38.52
F	14.53^S	93.36^S	43.08^S
CD	3.05	0.68	2.77

Table 26. Interaction effect of various treatments on plant nutrient uptake (kg ha^{-1})

Treatment	N	P	K
$S_1O_1B_1$	32.38	9.20	40.29
$S_1O_1B_2$	32.04	9.67	43.15
$S_1O_2B_1$	23.12	7.07	33.47
$S_1O_2B_2$	36.90	9.52	32.52
$S_1O_3B_1$	25.51	7.76	34.54
$S_1O_3B_2$	18.50	14.96	42.36
$S_2O_1B_1$	38.24	15.19	48.68
$S_2O_1B_2$	22.82	9.30	34.54
$S_2O_2B_1$	39.69	8.52	28.99
$S_2O_2B_2$	32.34	8.84	22.23
$S_2O_3B_1$	30.43	7.74	21.49
$S_2O_3B_2$	36.48	7.68	34.68
F	37.89^{S}	17.24^{S}	17.21^{S}
CD	4.31	0.96	3.92

Interaction effect of source of nitrogen, organic manures and biofertilizer indicated that treatment combination $S_2O_1B_1$ recorded significantly higher K uptake (48.68 kg ha^{-1}) compared to all other treatment combinations.

4.5. Soil Analysis

Soil samples after the experiment were analysed to assess the available nutrient status of the soil and are presented in Tables 27, 28 and 29.

4.5.1. Available nitrogen status in soil (kg ha^{-1})

Source of nitrogen favourably affected the available N status of soil. The treatment S_2 has the maximum soil N status (252.10 kg ha^{-1}) and was significantly superior to S_1.

Among the three organic manures used, poultry manure (O_1) recorded highest available nitrogen status of soil (249.05 kg ha^{-1}) and was significantly superior to O_2 and O_3.

Biofertilizers did not show any favourable influence.

Data on interaction between source of nitrogen and organic manure revealed that the treatment S_2O_1 (100 per cent poultry manure) recorded the highest available nitrogen in soil (308.9 kg ha^{-1}) and was significantly superior to others.

Treatment S_2B_1 recorded the maximum soil nitrogen (265.86 kg ha^{-1}) and was significantly superior to other treatments.

S x O x B interaction effect also showed significant influence. The treatment $S_2O_1B_1$ recorded significantly higher value (310.46 kg ha^{-1}) which was on par with $S_2O_1B_2$ (307.33 kg ha^{-1}) when compared to other treatment combinations.

4.5.2. Available phosphorus status of soil (kg ha^{-1})

Different organic manures recorded significant variation in available P status of soil. Among the three types tried, the treatment O_1 recorded maximum soil P (105.84 kg ha^{-1}) which was on par with O_2 (99.27 kg ha^{-1}) and was significantly superior to O_3.

Source of nitrogen and biofertilizer application could not influence the P status of soil.

Interaction effect of various treatments showed positive response in soil P status. The data on S x O interaction effect revealed that the treatment S_2O_1 has the maximum P status (124.69 kg ha^{-1}) which was on par with S_1O_2 (109.20) and was significantly superior to other combinations.

Among the S x B interaction, the treatment S_1B_1 showed highest soil P content (109.76 kg ha^{-1}) which was on par with S_2B_2 (104.41 kg ha^{-1}) and was significantly superior to others.

Organic manure x biofertilizer interaction also showed significant response in soil P status. The treatment O_1B_1 has the maximum soil P after the experiment (116.48 kg ha^{-1}) which was on par with O_2B_2 (112.56 kg ha^{-1}) and was significantly superior to other treatments.

The interaction effect of S x O x B also showed significant influence in this character. The treatments $S_1O_2B_2$ and $S_2O_1B_2$ recorded significantly superior values (130.29 kg ha^{-1} each) which were on par with $S_1O_3B_1$ (127.31 kg ha^{-1}) and $S_2O_1B_1$ (119.09 kg ha^{-1}) and $S_1O_1B_1$ (113.87 kg ha^{-1}) when compared to other treatment combinations.

4.5.3. Available potassium status of soil (kg ha^{-1})

Source of nitrogen and biofertilizer application couldnot influence the available K status of soil.

Among the different organic manures, O_3 showed the maximum soil K status (157.64 kg ha^{-1}) and was significantly superior to others.

The S x O interaction effect showed that the treatment S_1O_3 has the maximum K content (159.97 kg ha^{-1}) which was on par with treatments S_1O_2 and S_2O_3 (151.55 kg ha^{-1}) and 155.31 kg ha^{-1} respectively) and was significantly superior to others.

S x B interaction effect also recorded significant variation in soil K status. The treatment S_2B_1 has the maximum soil K (162.90 kg ha^{-1}) which was significantly superior to other combinations.

O x B interaction effect revealed that the treatment O_3B_1 has the maximum soil K content (171.36 kg ha^{-1}) which was significantly superior to other treatment combinations.

Table 27. Soil NPK status (kg ha^{-1}) as influenced by source of nitrogen, organic manures and biofertilizers

Treatment	N	P	K
Source of nitrogen			
S_1 (50 % N as organic + 50 % N as inorganic source)	191.47	96.94	146.97
S_2 (100 % organic manure)	252.10	89.77	146.41
F	—	—	—
CD	7.36	—	—
Organic manures			
O_1 (Poultry manure)	249.05	105.84	134.49
O_2 (Neem cake)	179.01	94.27	147.93
O_3 (Biogas slurry)	237.29	79.97	157.64
F	146.38^S	5.86^S	46.47^S
CD	9.01	15.56	6.34
Biofertilizers			
B_1 (No Azospirillum)	239.38	92.45	157.24
B_2 (With Azospirillum)	204.19	94.27	136.14
F	96.67^S	0.09	140.35^S
CD	7.36	—	3.66
Control			
POP (C_1)	162.72	76.16	168.74
POP without FYM (C_2)	221.61	136.91	137.38
F	—	—	—
CD	—	—	—

Table 28. Interaction effect of treatments on soil NPK status (kg ha^{-1})

Treatment	N	P	K
S_1O_1	189.20	86.99	123.39
S_1O_2	175.09	109.20	157.55
S_1O_3	210.11	94.64	159.97
S_2O_1	308.90	124.69	145.60
S_2O_2	182.93	79.33	138.32
S_2O_3	264.47	65.29	155.31
F	82.14^S	13.18^S	46.47^S
CD	12.75	22.01	6.34
S_1B_1	212.90	109.76	151.57
S_1B_2	170.04	84.12	142.36
S_2B_1	265.86	75.14	162.90
S_2B_2	238.34	104.41	129.92
F	4.59^S	19.73^S	44.55^S
CD	10.41	17.97	5.18
O_1B_1	244.08	116.48	138.69
O_1B_2	254.01	95.20	130.29
O_2B_1	226.31	75.97	161.65
O_2B_2	131.71	112.56	134.21
O_3B_1	247.75	84.89	171.36
O_3B_2	226.84	75.04	143.92
F	75.05^S	8.20^S	12.71^S
CD	12.75	22.01	6.34

Table 29. Interaction effect of treatments on the soil NPK status (kg ha^{-1})

Treatment	N	P	K
$S_1O_1B_1$	177.70	113.87	117.70
$S_1O_1B_2$	200.70	60.11	129.17
$S_1O_2B_1$	212.20	88.11	168.30
$S_1O_2B_2$	137.98	130.29	146.72
$S_1O_3B_1$	248.79	127.31	168.75
$S_1O_3B_2$	171.43	61.97	151.20
$S_2O_1B_1$	310.46	119.09	159.70
$S_2O_1B_2$	307.33	130.29	131.41
$S_2O_2B_1$	240.43	63.84	154.93
$S_2O_2B_2$	125.44	94.83	121.71
$S_2O_3B_1$	246.70	42.48	173.97
$S_2O_3B_2$	282.24	88.11	136.64
F	46.78^S	8.30^S	5.60^S
CD	18.03	31.13	8.97

S x O x B interaction effect also registered significant response in this character. The treatment combination $S_2O_3B_1$ registered significantly higher value (173.97 kg ha^{-1}) which was on par with the treatments $S_1O_3B_1$ and $S_1O_2B_1$ (168.75 kg ha^{-1} and 168.30 kg ha^{-1} respectively) when compared to other treatment combinations.

4.6. Scoring of pest and diseases

Incidence of pest was negligible during the period of cultivation. Minor incidence of *Epilachna*beetle attack was effectively controlled by spraying with chemical.

Incidence of diseases was also negligible during the experimental period. The fruits affected by fruit rot disease were removed mechanically by hand picking.

4.7. Keeping quality of fruits

Different organic manures showed significant variation in keeping quality of fruits. The treatment O_1 has the maximum value (3.83 days) which was on par with O_2 (3.50) and was significantly superior to O_3.

Source of nitrogen and biofertilizer had no significant influence on keeping quality of fruits.

4.8. Economics of production

The data on total cost of production, gross income ha^{-1}, net returns ha^{-1} and benefit cost ratio are shown in Tables 30 and 31.

Table 30. Economics of brinjal cultivation

Treatment	Total cost Rs. ha^{-1}	Gross return (Rs.)	Net return (Rs.)	B : C ratio
T_1	115860.36	443580.10	327720.00	3.85
T_2	116554.80	418024.26	301470.00	3.59
T_3	121485.30	446265.20	324780.00	3.67
T_4	122179.70	424894.00	302715.00	3.47
T_5	121616.60	363776.40	242160.00	2.99
T_6	122360.30	365900.00	243540.00	2.99
T_7	122638.10	436528.00	313890.00	3.56
T_8	123790.90	408160.00	284370.00	3.29
T_9	125943.60	375933.20	249990.00	2.98
T_{10}	126638.10	351068.03	224430.00	2.77
T_{11}	125943.80	357573.60	231630.00	2.84
T_{12}	126638.10	359596.30	239625.00	2.84
T_{13}	196234.80	451474.00	255240.00	2.29
T_{14}	116235.40	344895.30	228660.00	2.96
F			0.07	0.00
CD			32904.20^{S}	—

Table 31. Economics of brinjal cultivation

Treatment	Net return	B : C ratio
Source of nitrogen		
S_1 (50 % N as organic + 50 % N as inorganic source)	290397.50	3.42
S_2 (100 % organic manure)	257322.50	3.05
F	26.08^S	51.89^S
CD	13433.08	0.11
Organic manures		
O_1 (Poultry manure)	306862.50	3.57
O_2 (Neem cake)	275478.80	3.22
O_3 (Biogas slurry)	239238.80	2.91
F	36.40^S	52.58^S
CD	16452.10	0.13
Biofertilizers		
B_1 (No Azospirillum)	281695.00	3.31
B_2 (With Azospirillum)	266025.00	3.16
F	5.85	9.05^S
CD	13433.08	0.11
Control		
POP (C_1)	255240.00	2.29
POP without FYM (C_2)	228660.00	2.96
F	10.666	20.92
CD	—	—

The data showed that among the two sources of nitrogen, the treatment S_1 registered highest net returns (Rs. 290397.50 ha^{-1}) and the maximum benefit cost ratio of 3.42. Among the various organic manures tried, the treatment O_1 showed the maximum net returns Rs. 306862 ha^{-1} and the highest B : C ratio of 3.57.

The interaction between source of nitrogen and organic manures showed that S_1O_1 had the maximum net returns of Rs. 314595.0 ha^{-1}. S x B interaction effect revealed that the treatment S_1B_1 had the highest net returns Rs. 298220.00 ha^{-1}. In the S x O x B interaction the treatment $S_1O_1B_1$ registered the significantly higher value for net returns (Rs. 327720.00 ha^{-1}) when compared to other treatment combinations.

DISCUSSION

DISCUSSION

Many developing countries including India have attained self sufficiency in food production. Eventhen, modern agriculture has got its own problems. One such melody is the rapid depletion of desirable soil properties due to constant use of chemical fertilizers often beyond the recommended level for many crops. Today much emphasis is given to reverse this situation by popularising the concepts of organic farming and integrated nutrient management. In the latter technology emphasis is given to reduce the use of chemical fertilizers by substituting it with organic manures and biofertilizers. The present investigation was envisaged to develop such an integrated nutrient management practice for brinjal.

The data collected on various growth characters, yield and yield attributes plant and soil analysis and benefit cost ratio were analysed statistically and the results are discussed in this chapter.

5.1. Source of nitrogen Vs POP recommendations

The treatments included 50 per cent chemical fertilizer and 50 per cent organic manures (S1), and 100 per cent organic manures (S2). Control treatments included POP recommendation (C1) and POP recommendation without FYM (C2).

The average plant height registered by the source of nitrogen was increased by 20.8 per cent, 2.76 per cent, 6.05 per cent and 5.57 per cent over POP recommendation at 30, 45, 60 and 75 DAT respectively. In the case of number of leaves the increase was 20.7 per cent 2.28 per cent and 4.31 per cent at 30, 60 and 75 DAT respectively. Similar increasing trend was registered in number of branches, dry matter production (DMP) and LAI. The beneficial effect of organic and inorganic manures and their combination in increasing the growth parameters were reported by Doikova (1977), Singh *et al.* (1973) and KAU (1991) (Fig. 3 and 4).

Yield and yield attributes were also significantly influenced by source of nitrogen. Days to 50 per cent flowering was less for treatments receiving organic manures (52.67 days) as compared to POP recommendation. Corresponding values for number of flowers and number of fruits were 7.22 and 5.39 for different sources of nitrogen and 7.79 and 5.66 for POP recommendation. Percentage of fruit set was significantly higher for different sources of N (72.27 per cent) compared to POP recommendations (70.652 per cent). Marketable fruit yield and yield per harvests (21.85 t ha^{-1} and 936.11 g $plot^{-1}$) were also significantly higher than the POP recommendations (18.41 t ha^{-1} and 796.66 g $plot^{-1}$ respectively).

From the above results it is evident that application of nutrients as 100 per cent organic manure or applying chemical and organic material in 1 : 1 ratio was more beneficial than the POP recommendations in improving the growth and yield characters. This better expression of growth and yield may be due to the role played by organic amendments. Organic manures constitute a dependable source of major and minor nutrient elements. Similar increase in yield of chilli was reported by Nair and Peter (1990) with the application 15 t FYM and 5:40:25

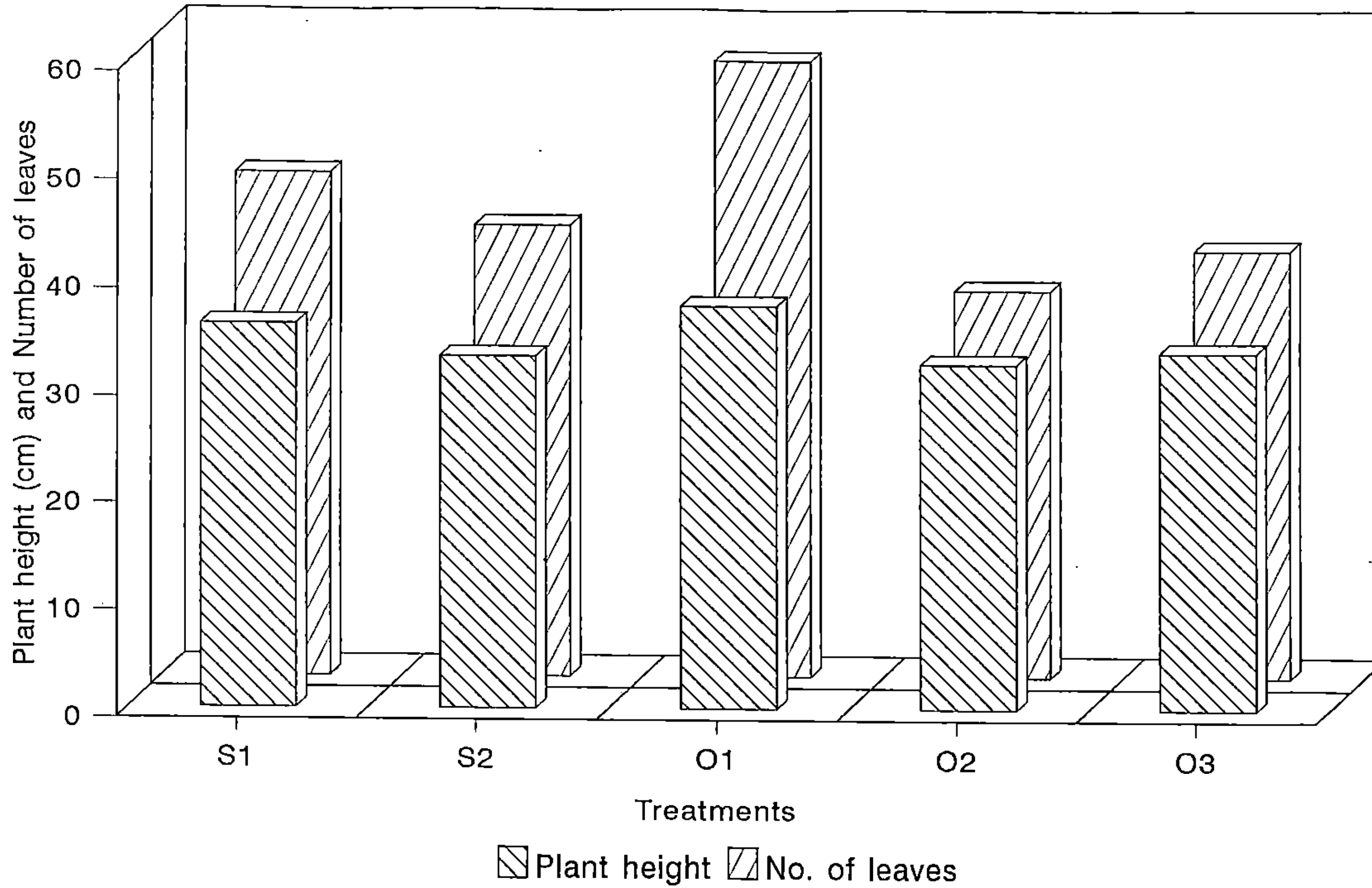

Fig. 3. Plant height and number of leaves at 60 DAT as influenced by source of nitrogen and organic manures

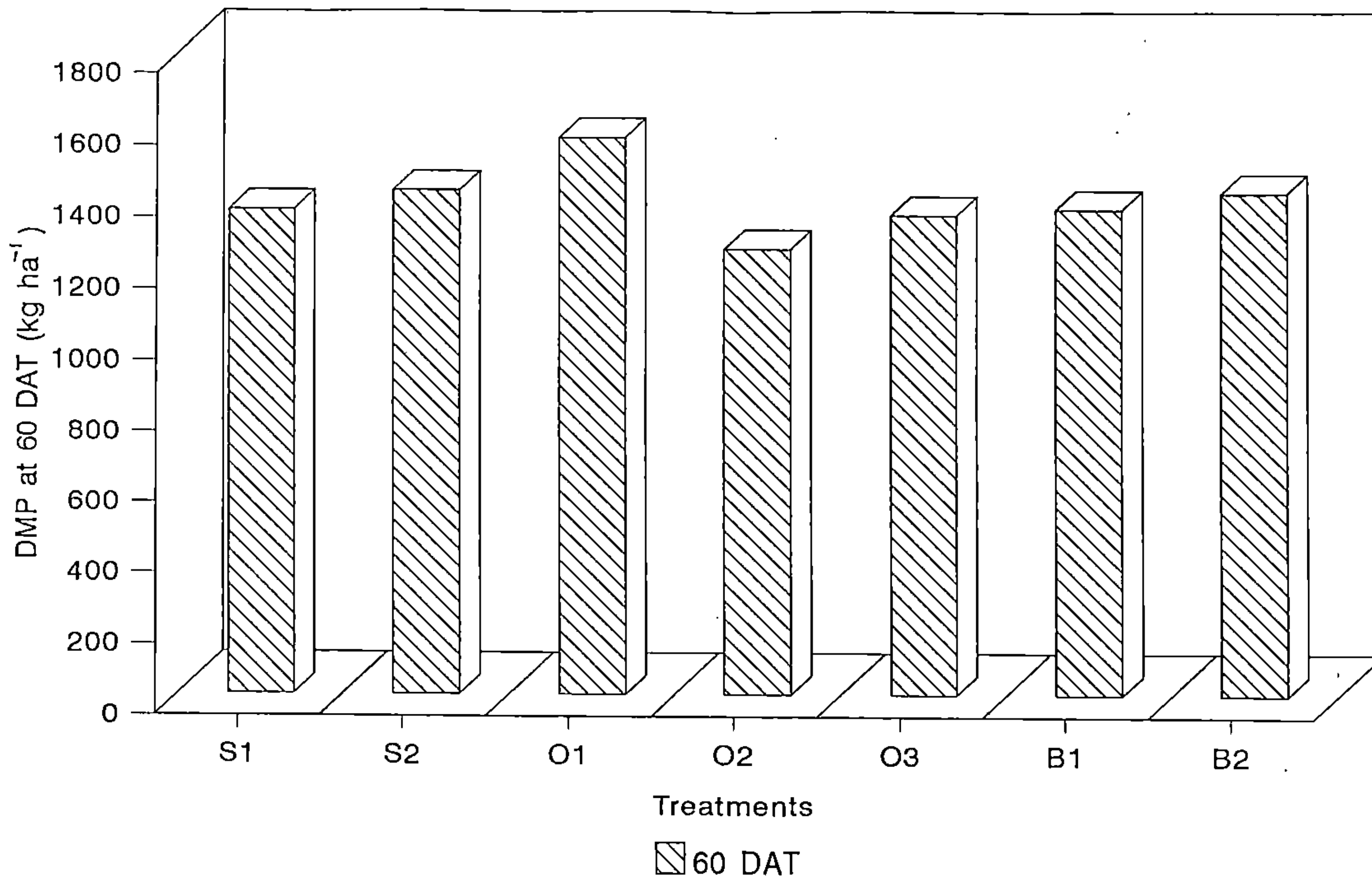

Fig. 4. Dry matter production at 60 DAT as influenced by source of nitrogen, organic manures and biofertilizers

kg NPK ha^{-1} in the three season trial when compared to FYM alone or inorganic fertilizer alone.

The combined application of organic manures and chemical fertilizers is important to sustain a higher level of soil fertility and crop productivity. Due to the increased microbial activity in organic matter amended soil the N fixation and P solubilisation are also improved. All these factors might have resulted in enhancing nutrient availability in the soil treated with organic manures along with chemical fertilizers.

The better nutrient availability in the soil might have resulted in enhancing the uptake of N, P and K by plants. The average N, P and K uptake values for different sources of nitrogen were 30.7 kg ha^{-1}, 9.62 kg ha^{-1} and 34.75 kg ha^{-1} respectively, where as the corresponding values for POP recommendation was only 30.84 kg ha^{-1}, 6.07 kg ha^{-1} and 32.47 kg ha^{-1}. This better uptake of nutrients might have resulted in better performance of brinjal supplied with different sources of nitrogen (Fig. 10).

In POP recommendation, nutrients are supplied mainly through chemical fertilizers and only a part through FYM. Nitrogen through urea was applied in three equal spilt doses, one as basal second and third splits at one month and two months after transplanting. For urea, nutrients mineralise very quickly and are susceptible to leaching losses (Tisdale *et al.*, 1995). Thus quick mineralisation and leaching losses might have resulted in declining the nutrient availability during the early stages thus reducing the yield. The availability of nutrients present in FYM is very low 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

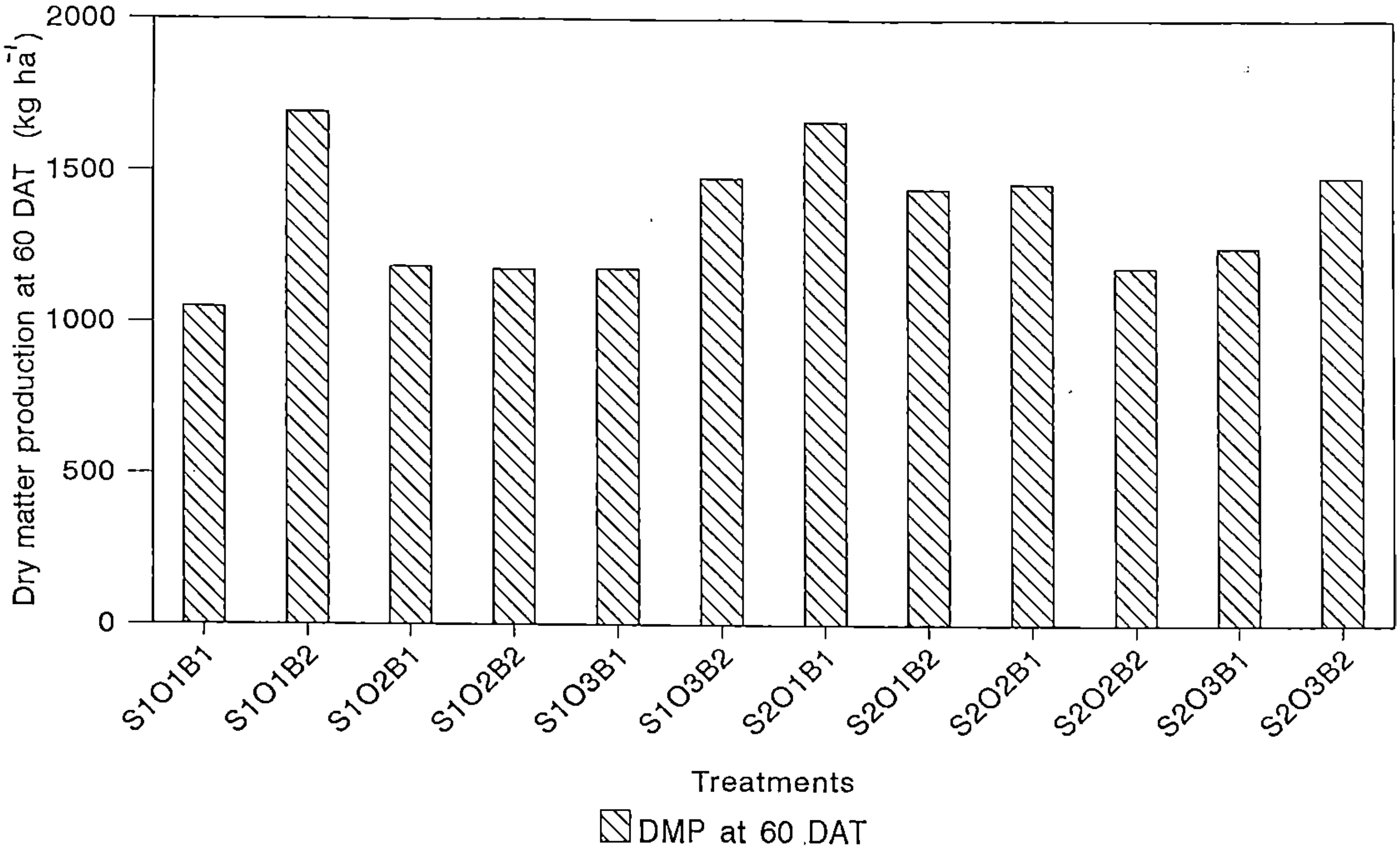

Fig. 5. Dry matter production (kg/ha) as influenced by the interaction effect of source of nitrogen, organic manure and biofertilizer

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 organic manures such as neem cake and poultry manure are available slowly within two to three months according to crop demand and are less susceptible to leaching loss.

Apart from this the keeping quality of fruits was higher for different sources of nitrogen (3.3 days) when compared to POP recommendations (2.49 days). Higher sugar and vitamin C in fruits raised under partial or total organic farming are reported to be responsible for this (Shanmugavelu, 1989).

Among the different sources of nitrogen, the integrated application of organic manures and chemical fertilizers in 1 : 1 ratio was found to be more beneficial in improving the growth and yield characters than POP recommendations. The increase for various attributes were 16.95 per cent, 10.81 per cent, 8.51 per cent and 7.63 per cent (plant height at 30, 45, 60 and 75 DAT), 45.33 per cent 4.09 per cent, 11.84 per cent and 18.69 per cent (number of branches at 30, 45, 60 and 75 DAT), 57.97 per cent, 11.06 per cent, 17.22 per cent and 12.33 per cent (LAI at 30, 45, 60 and 75 DAT) and 3.6 per cent (DMP at 30 DAT). Similarly the yield attributes were also increased. The percentage increase was 32.28 per cent for marketable fruit yield per ha. Similar reports on improved growth and yield due to an integrated application of nutrients was reported by Subbiah *et al.* (1983), Jose *et al.* (1988) and KAU (1991). Yield per harvest of brinjal was significantly higher in all the harvests as compared to POP recommendations.

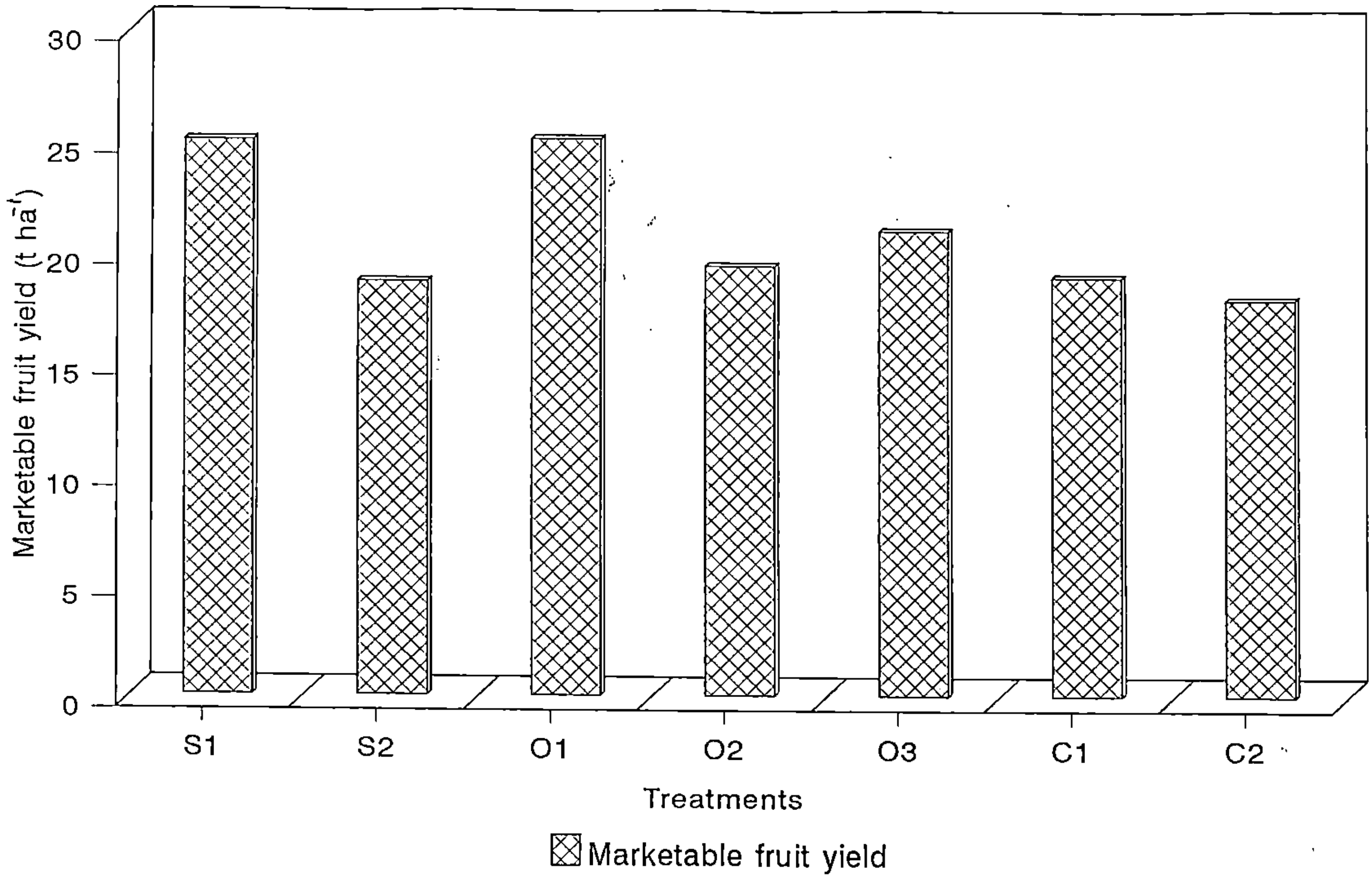

Fig. 6. Marketable fruit yield as influenced by source of nitrogen and organic manures

The higher levels of chemical fertilizer application is costly and may also affect the quality of the plant produce. Hence by substituting a part of the total nitrogen requirement with organic sources of nitrogen on equivalent nitrogen basis is a remedy to this problem. Enriched plant growth and higher yield with the application of poultry manure and inorganic fertilizers has been reported by Abusaleha (1992) in bhindi. 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).

Integrated application of organic and inorganic chemicals significantly increased the soil nutrient status also. The increase was 17 per cent (N in kg ha^{-1}) and 27 per cent (P in kg ha^{-1}). The combined application of organic manures and chemical fertilizers is important to maintain and sustain a higher level of soil fertility and sustain a higher level of soil fertility and crop productivity. The increase in soil nutrients also increased the plant nutrient uptake. The uptake of P and K were increased by 70.02 per cent and 23.38 per cent respectively over POP recommendations. According to Tisdale *et al.* (1995) plant analysis is based on the presumption that the amount of a given nutrient in a plant is directly related to the availability of the nutrient in soil. Hence the increased amount of soil P and K due to the integrated application of organic and inorganic chemicals might have led to the increase in plant uptake of P and K when compared to POP recommendations. When nitrogen was applied as a combination of organic manures and inorganic chemicals, the organic manure would have lead to vigorous root growth of plants thereby increasing 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. Organic manures in the integrated nutrient supply systems would have enhanced the moisture retention capacity of soil. This would

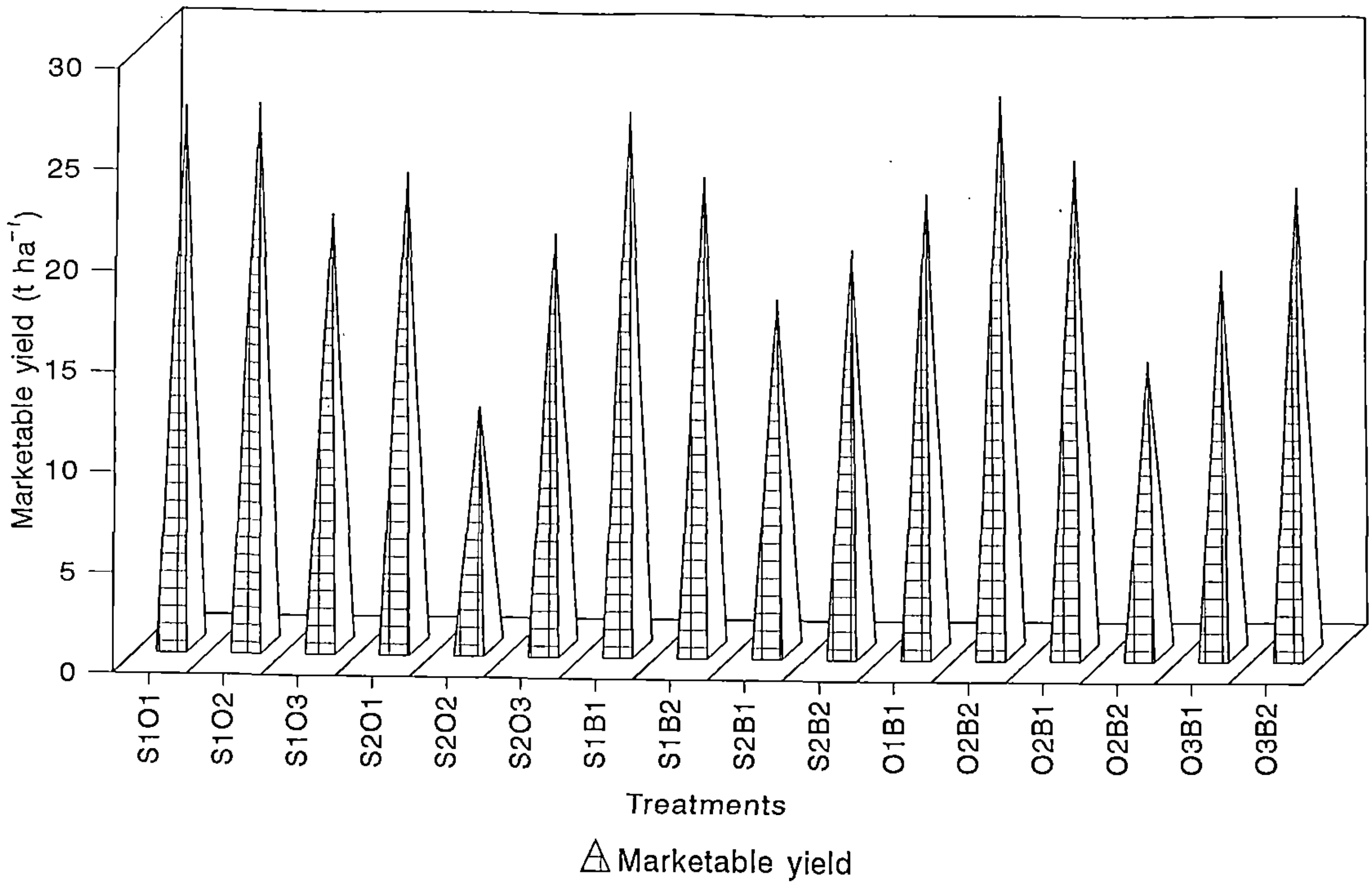

Fig. 7. Interaction effect of various treatments on marketable fruit yield

have accelerated the K^+ diffusion to roots as pointed out by Tisdale *et al.* (1995) which would have resulted in better K uptake and higher K concentration in plants.

Integrated application of organic manures and chemical fertilizers increased the keeping quality of fruits (3.39 days) over POP recommendations (2.67 days). Similar results were reported by Shanmugavelu (1989).

Application of nutrients as 100 per cent organic manures significantly influenced the yield and yield attributes. The time taken to 50 per cent flowering was only 52.17 days when compared to the POP recommendation (57.0 days). Organic manures provided more favourable environment for root growth and better water infiltration. This might have led to better availability of nutrients. The N availability at the late growth phase must have been utilised for producing female flowers (Singh *et al.*, 1982).

Organic manure application increased the plant uptake and thereby plant concentration of N. Amount of a given nutrient in a plant is directly related to the availability of the nutrient in soil (Tisdale *et al.*, 1995). The increase in soil N due to organic manure application was 4.54 per cent over POP recommendation. This increased soil N might have helped in increasing the plant N content and uptake after the experiment.

The keeping quality of fruits was also high for organic manure applied plots (3.22 days) as compared to POP recommendation (2.67 days). Application of organic amendments produce organic constituents which would have indirectly contributed to the higher shelf life of fruits.

5.2 Organic manures vs POP recommendations

Poultry manure, neem cake and biogas slurry are the different organic manures used in the present investigation.

The average plant height registered by organic manure application was 20.84 per cent, 2.73 per cent, 6.06 per cent and 5.57 per cent higher than the POP recommendations at 30, 45, 60 and 75 DAT. Similarly the number of leaves and number of branches were comparatively higher for organic manure application. The increase in LAI was 66.66 per cent, 15.63 per cent , 12.5 per cent and 10.14 per cent over POP recommendation at 30, 45, 60 and 75 DAS. The beneficial effect of organic amendments in increasing the growth parameters were reported by Zhang *et al.* (1988), Pushpa (1996) and Anitha (1997).

Not only the growth parameters, the yield and yield attributes also significantly improved the organic manure application. Days to 50 per cent flowering was lowered by organic manure application (52.66 days) as compared to that of POP recommendations (59.17 days). Early flower initiation due to organic manure application have been reported in crops such as bhindi (Abusaleha, 1981) and tomato (Dhanalakshmi and Pappiah, 1995). Percentage fruit set was significantly higher for organic manure application (72.28 per cent) than that of POP recommendation (70.65 per cent). Marketable fruit yield per ha was significantly higher for organic manure applied plants (21.84 t ha^{-1}) as compared to that of POP recommendations (18.41 t ha^{-1}). Similar results in increased plant growth and yield of tomato by the application of organic amendments were reported by Gianguinto and Borin (1990).

The multidynamic role played by organic manures may be the reason for the better expression of growth and yield parameters. Organic manures constitute a dependable source of major and minor nutrient elements. Apart from this they helps in maintaining stability in crop production in certain soils through correction of marginal deficiencies of secondary and micronutrient elements. They improve the soil physical properties like water retention capacity, soil structure and provide a favourable environment for root growth and infiltration of water (Tandon, 1994). Due to the increased microbiological activity in organic matter amended soils, N fixation and P solubilisation are also improved. All these factors might have led to better growth and thereby increase in yield of brinjal in organic manure applied plots.

Keeping quality of fruits were also significantly influenced by organic amendments. The keeping quality of fruits was increased by organic manure application (3.3 days) as compared to POP recommendations (2.5 days). Organic manure application lead to the production of organic constituents which would have indirectly contributed to the higher shelf life of fruits. In addition to this the better quality might be due to the high K uptake in organic manure treated plants compared to POP recommendation. Fritz and Habben (1992) reported that K fertilizers increase the durability of the fruit by lowering the activity of enzymes which breakdown carbohydrates.

The results on available nutrient status of soil revealed that the nitrogen status of soil was increased by organic manure application. The nitrogen status by organic manure application was 221.81 kg ha^{-1} as compared to 192.165 kg ha^{-1}. This increased soil N status would have led to high uptake of N and thereby high concentration of N in plants. Tisdale *et al.* (1995) opined that plant analysis

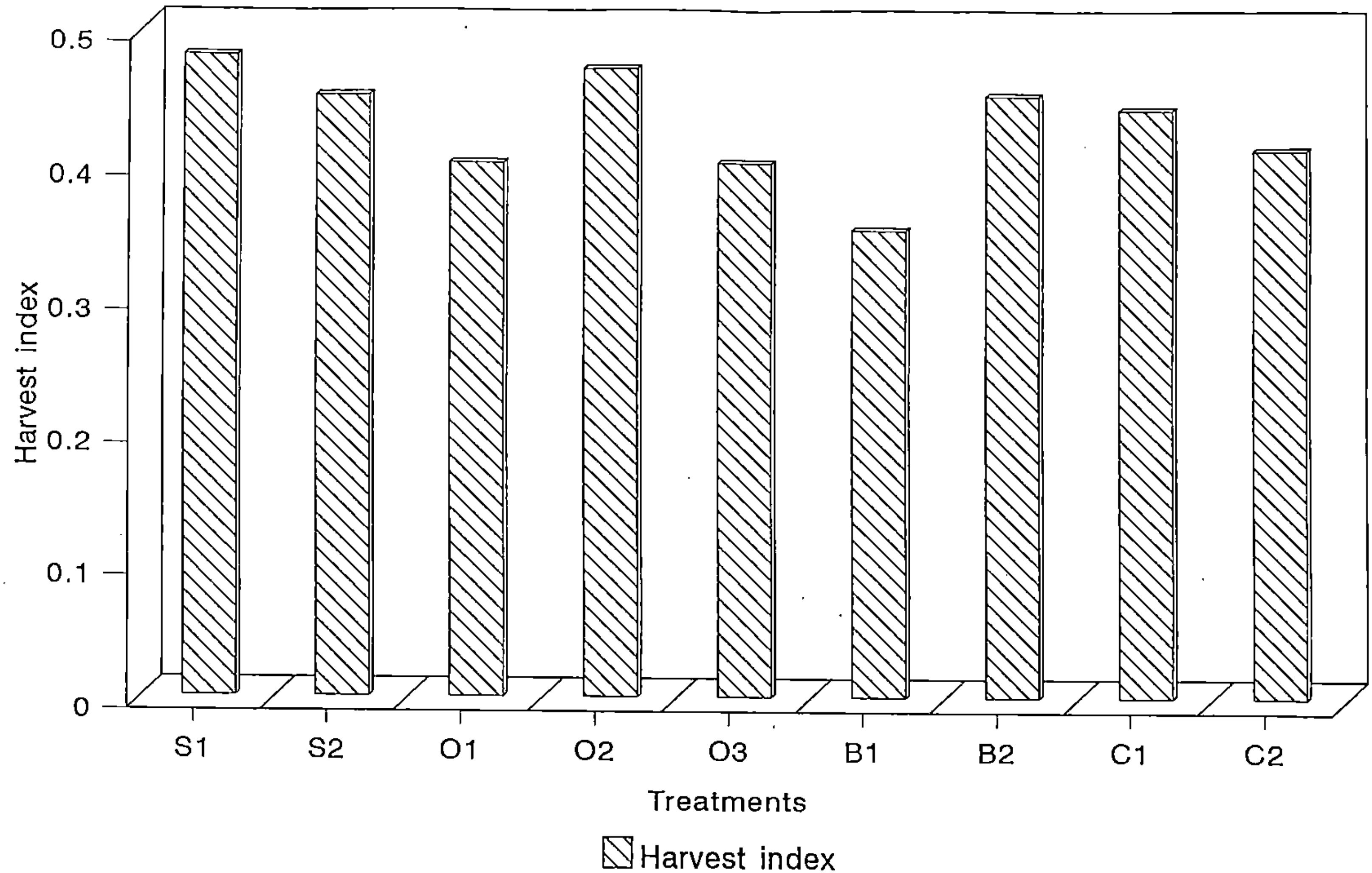

Fig. 8. Harvest index as influenced by source of nitrogen, organic manures biofertilizer on comparison with control treatments

is based on the presumption that the amount of a given nutrient in a plant is directly related to the availability of nutrients in soil.

Poultry manure vs POP recommendation

There was significant improvement in growth, yield and quality of brinjal due to the application of poultry manure. The increase for various attributes were 27.47 per cent, 11.58 per cent, 15.90 per cent and 14.57 per cent (plant height at 30, 45, 60 and 75 DAT), 35.93 per cent (LAI at 45 DAT) and 23.88 per cent (DMP at 75 DAT), yield attributes were also increased. Increase in number of flowers, per cent of fruit set and marketable fruit yield ha^{-1} were 6.16 per cent, 14.08 per cent and 36.39 per cent respectively. Keeping quality of fruits was increased (3.83 days) due to poultry manure application as compared to POP recommendation (2.49 days). Similar reports on improved growth and yield due to poultry manure application was reported by Anitha (1997).

Poultry manure is a good source of nutrients particularly for vegetable production. In this manure 60 per cent of the N is present as uric acid, 30 per cent as more stable organic nitrogen form and the balance as mineral N_2 (Srivastava, 1988). Recovery of nitrogen from poultry manure is quick when compared to other organic sources like farm yard manure. The uric acid present in poultry manure rapidly gets converted to ammonicial form and is easily utilised by the plant (Smith, 1950). The rapid release of nutrients from poultry manure might have, helped in increasing the growth and yield characters. It could be presumed that these plant available forms of N released during the peak nitrogen requirement stages of the crop would have utilised for the dry matter accumulation.

Neem cake vs POP recommendation

Plant supplied with neem cake showed significant response with respect to growth, yield and quality of brinjal as compared to plants supplied with POP recommendations. Plant height at 30 DAT (12.76 cm), LAI at 60 DAT (0.79) marketable fruit yield per ha (19.41 t ha^{-1}) and keeping quality of fruits (3.50 days) were highest for neem cake applied plants. Yield per harvests were higher for neem cake treated plants during 3rd and 4th harvests (1175.83 g $plot^{-1}$ and 491.67 g $plot^{-1}$ respectively).

Neem cake is a concentrated organic manure rich in plant nutrient contents. In addition to nutrients, it posses some alkaloids like nimbin, nimbidin and certain sulphur compounds which have nitrification inhibitory properties. As a result neem cake acts as a slow releasing nitrogenous fertilizer by inhibiting the nitrification process of soil. Nutrients will be available within a period of 2-3 months according to the crop demand. This prolonged availability of nitrogen might have resulted in producing better yield due to neem cake application.

Biogas slurry vs POP recommendation

Performance of brinjal was better under biogas slurry application as compared to POP recommendation. Growth attributes like plant height at 30 DAT (11.59 cm), number of leaves at 30 DAT (7.38), number of branches at 30 DAT (0.83), LAI at 45 and 60 DAT (0.70 and 0.77 respectively) DMP at 45 and 75 DAT (852.08 and 1285.37 kg ha^{-1} respectively) and yield attributes like marketable fruit yield per ha (21.01 t ha^{-1}) were higher for biogas slurry treated plants.

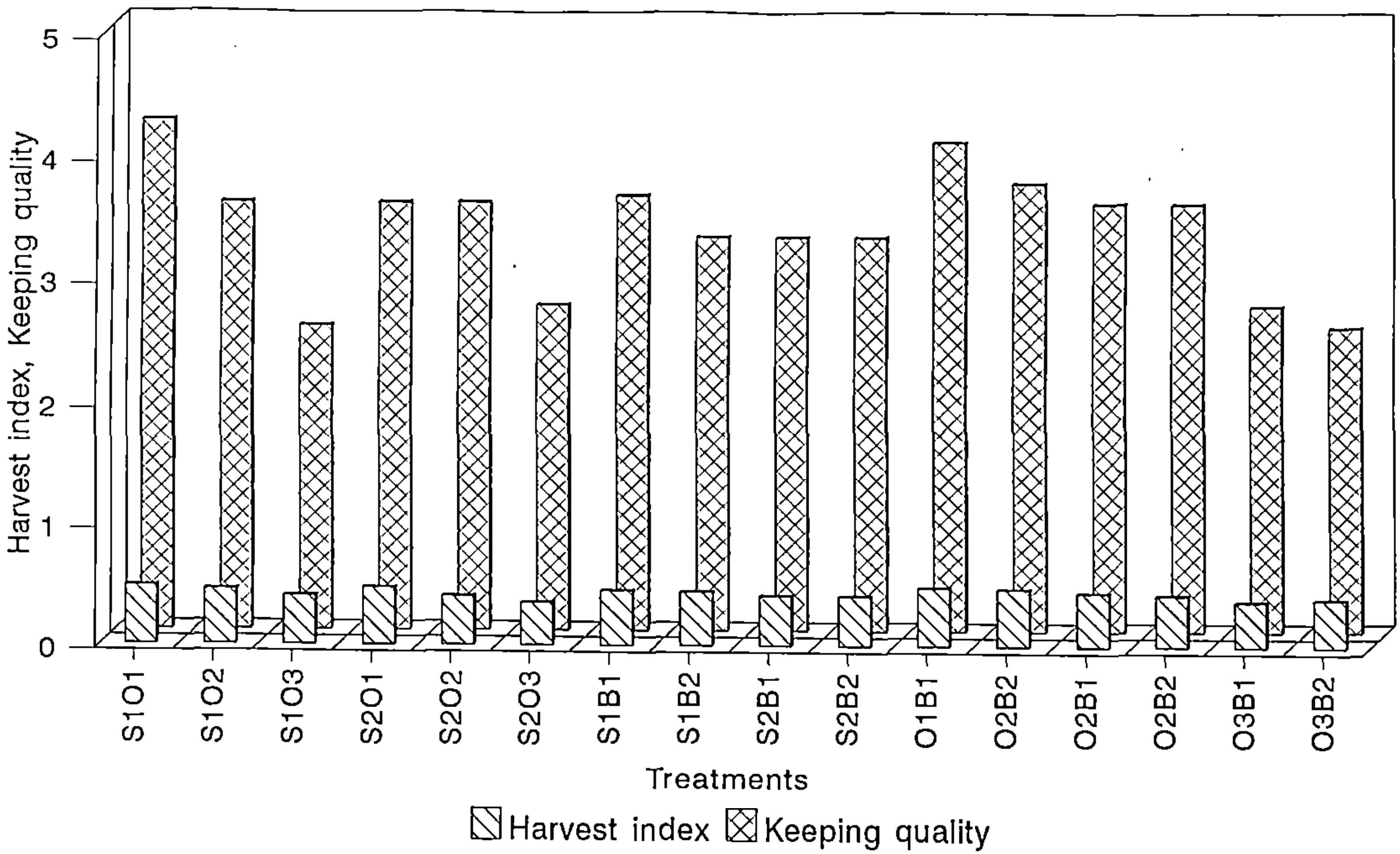

Fig. 9. Harvest index and keeping quality of fruits as influenced by the interaction effect of source of nitrogen, organic manure and biofertilizer

Biogas slurry is a valuable manure even superior to FYM. According to Vyas (1992), biogas digested slurry improved soils structure, water holding capacity and increased soil humus content and biological activity along with yield increase of various crops and vegetables.

Another control treatment C_2 (POP recommendation without FYM) was found to be inferior to C_1 in all the growth and yield attributes. This might be due to the beneficial effect of FYM on crop growth and yield. Balanced use of NPK fertilizer in conjunction with FYM produced the highest yield and maintained the available NPK status in the soil at a high level (Muthuswamy *et al.*, 1990). According to Malik (1999) from the long term fertilizer experiments conducted at different locations in the country, it has now been very well established that the plots receiving organic manure (FYM) along with NPK sustained the soil fertility and productivity.

Comparative performance of various organic nitrogen sources with respect to growth, yield and quality of brinjal

Organic manures compared to this study were poultry manure, neem cake and biogas slurry.

The results showed that poultry manure was superior to all other organic manures on equivalent nitrogen basis. Poultry manure recorded significant increase in plant height, number of leaves, number of branches, LAI and DMP. 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 utilised by the plants.

Yield attributes like time to 50 per cent flowering is considerably reduced by poultry manure application (48.50 days) when compared to other organic manures. Number of flowers and fruits per plant were higher for poultry manure treatments (8.27 and 6.67 respectively). Percentage of fruit set showed a significant increase by poultry manure application (80.60 per cent). Rapid conversion of uric acid present in poultry manure may be one reason for higher yield recorded by poultry manure (Smith, 1950). Another factor contributing to the higher yield with poultry manure might be its high P_2O_5 content (Singh and Srivastava, 1971). Singh *et al.* (1973) attributed higher efficiency of poultry manure to its narrow C:N ratio and comparatively higher content of readily mineralisable nitrogen.

Nutrient uptake by crops as influenced by organic nitrogen sources

Total nitrogen uptake by plants was highest in neem cake treated plants (33.02 kg ha^{-1}) as compared to other organic sources of nitrogen. Due to the presence of certain alkaloids, neem cake inhibited the population of *Nitrosomonas* sp. thereby reducing the nitrification process. Thus they checked the leaching, denitrification and run off losses of nitrogen resulting in an even availability of nitrate nitrogen throughout the growth period (Sahrawat and Parmer, 1975). As a result nitrogen availability in soil increased which in turn increased the nitrogen uptake. The results are in confirmity with the findings of Sathianathan (1982) in cassava, Prasad *et al.* (1986) and Ahmed and Baroova (1992) in wheat.

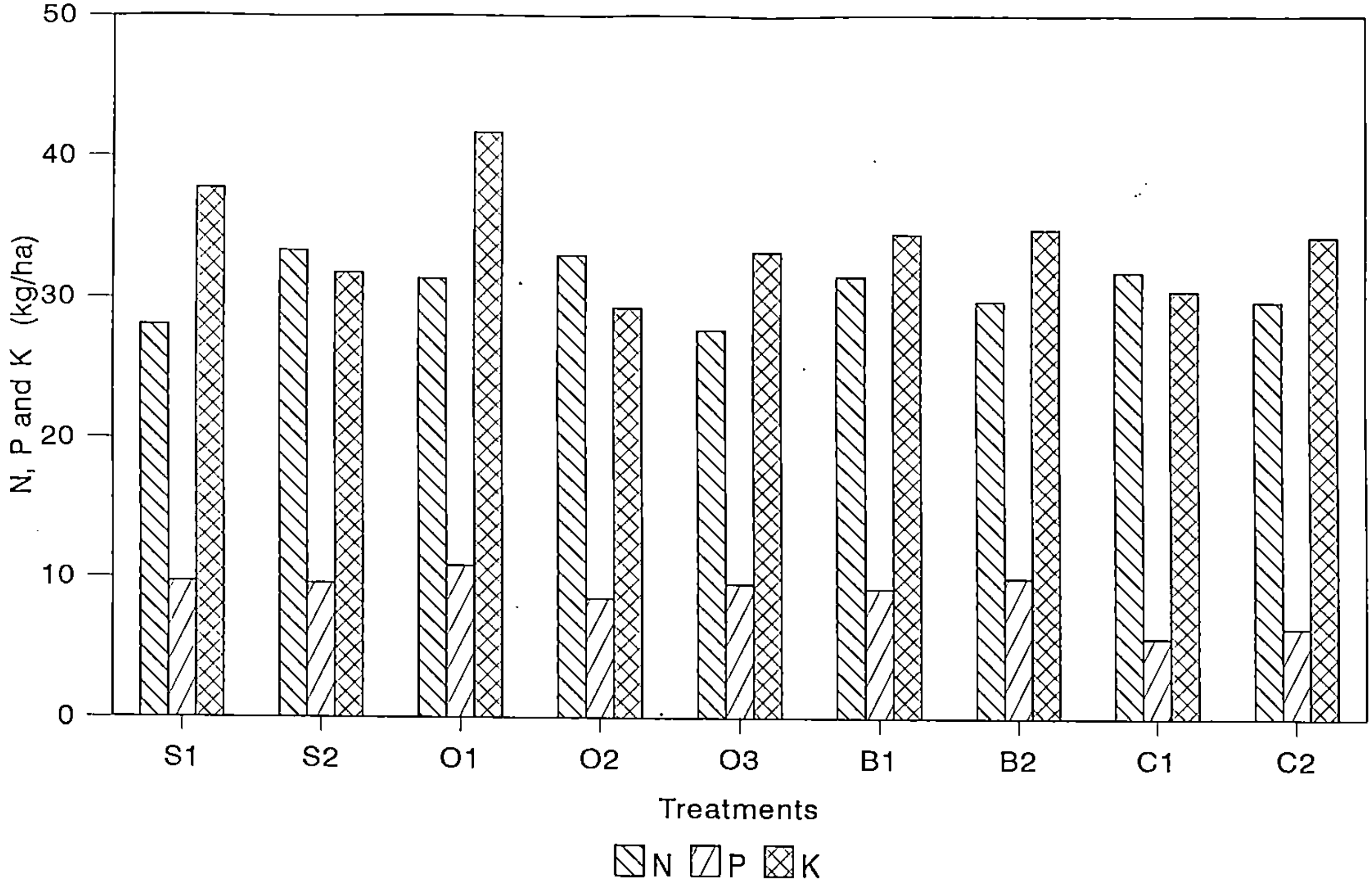

Fig. 10. Plant nutrient uptake as influenced by source of nitrogen, organic manures and biofertilizer

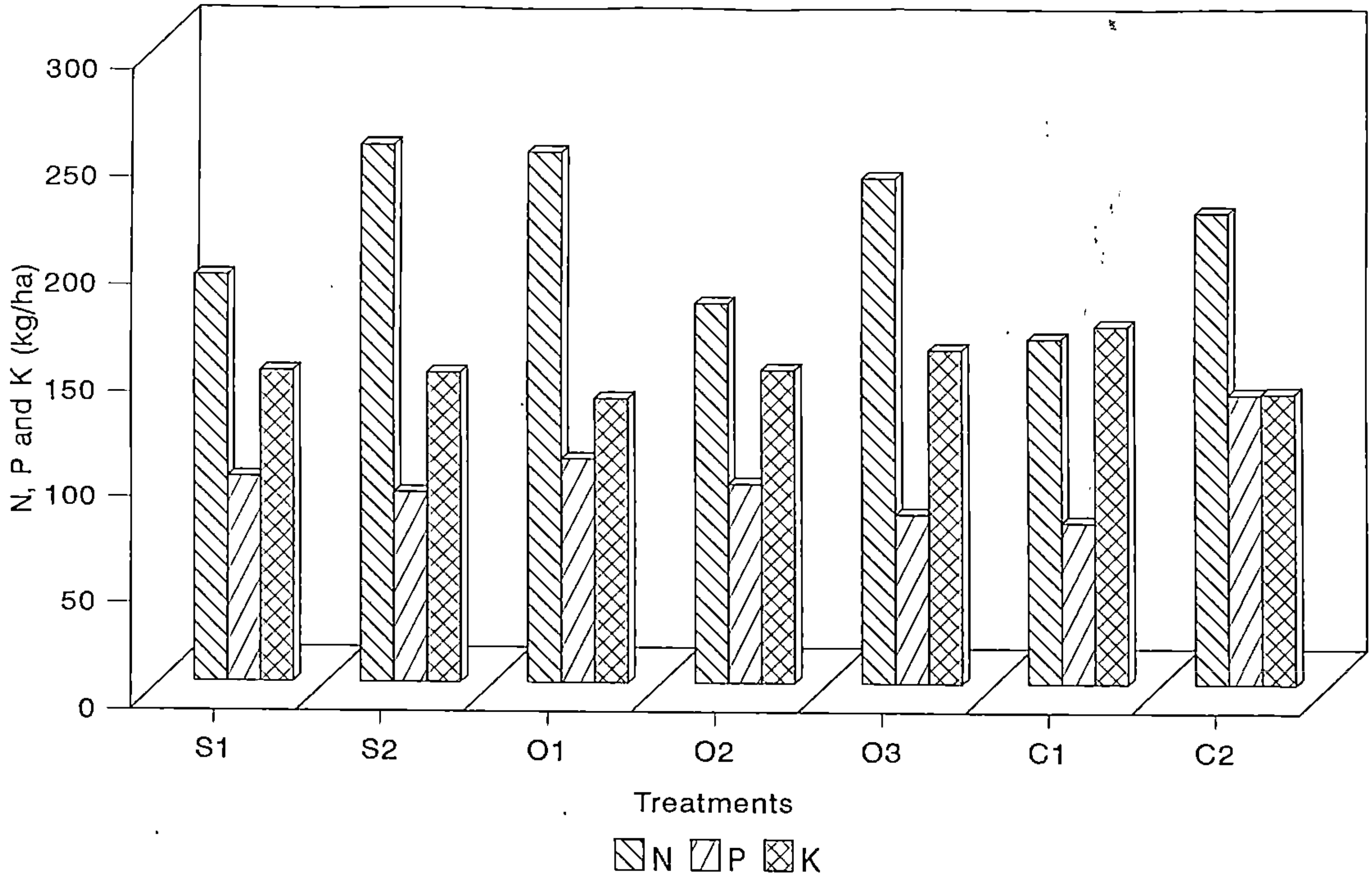

Fig. 11. Soil NPK status as influenced by source of nitrogen and organic manures in comparison with control treatments

Phosphorus and and potassium uptake was highest in poultry manure treated plots (10.84 and 41.67 kg ha^{-1}). The high 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. Apart from this the vigorous root growth of plants by poultry manure increased the P uptake of plants. Synergistic influence of N nutrition on P content was previously reported by Singh *et al.* (1970) in cauliflower (Fig. 10).

The increased moisture content and retention in soil due to poultry manure application might have increased the K^+ diffusion to roots as pointed out by Tisdale *et al.* (1995) which would have resulted in better K uptake and higher K concentration in plants.

Available nutrient status of soil after the experiment

Available nutrient status in the soil after experiment was higher for poultry manure application. Available nitrogen in soil was 249.05 kg ha^{-1} in poultry manure treated plants. This might be due to rapid availability of nutrients from poultry manure.

Available soil phosphorus was highest with 105.84 kg ha^{-1} by poultry manure application. This might be due to the higher nutrient supplying ability of poultry manure and its narrow C:N ratio Singh *et al.* (1973).

Available potassium content was highest (157.64 kg ha^{-1}) in biogas slurry treated plots. This might be due to the higher nutrient status in biogas digested slurry (Prasad, 1994).

Keeping quality

Among the organic sources, poultry manure recorded the highest keeping quality. Brinjal fruits remained undamaged at room temperature for 3.83 days when poultry manure was applied.

Asano *et al.* (1981) reported decreased hardening of fruit surface and discolouration in brinjal and cucumber. When poultry manure is applied long term increases in soil levels of nutrients like B, Ca, Mg, Cu and Zn can be expected (Bitzer and Sims, 1988). Importance of micronutrients like boron in keeping quality of fruits and tubers was 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 application of poultry manure seemed to have a favourable influence on shelf life of fruits.

Interaction effect of source of nitrogen and type of organic manure on yield of brinjal

Interaction effect of source of nitrogen and organic manures revealed that, the treatment S_1O_2 recorded the highest marketable yield per ha (26.87 t ha^{-1}) which was on par with all other treatments except S_2O_2. Among the two sources of nitrogen, S_1 treatments in combination with organic manures recorded the highest marketable yield (21.45 to 26.87 t ha^{-1}) than the corresponding S_2 treatments (11.95 to 23.52 t ha^{-1}) (Fig. 7).

Apart from marketable fruit yield per ha, yield per harvests was also highest for treatments involving S_1. In the first and second harvests the treatment combination S_1O_1 recorded the highest yield (1190 g plot^{-1} and 1729.17 g plot^{-1}) while on the third and fourth harvests the treatment S_1O_2 recorded the maximum yield (1525 g plot^{-1} and 746.67 g plot^{-1}).

Substituting a part of the total nitrogen requirement with organic sources on equivalent nitrogen basis is the principle of integrated nutrient management. Application of 50 per cent 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 poultry manure and 50 kg N 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). These might be the reason for the significantly higher yields obtained due to integrated application of nutrients.

Interaction effect of source of nitrogen and biofertilizers on yield of brinjal

The interaction between source of nitrogen and biofertilizers showed that the S_1B_1 (26.58 t ha^{-1}) followed by S_1B_2 (23.43 t ha^{-1}). In the S_2 combinations, the treatment S_2B_2 recorded the highest yield (19.93 t ha^{-1}) than S_2B_1. From this finding it is obvious that the beneficial effect of Azospirillum is more pronounced when it is applied along with 100 per cent organic manure. Wani (1990) opined that use of FYM, green manure or other organic amendments enhanced the benefits from inoculation. Application of Eudrillus compost enriched with both Azospirillum and P solubilising organisms to plants gave maximum per plant yield in chilli Zachariah (1995).

Interaction effect of organic manures and biofertilizers on yield of brinjal

Interaction between organic manure and biofertilizers revealed that the treatment combination O_1B_2 recorded the highest marketable yield per ha (27.54 t ha^{-1}) and was on par with O_2B_1 (24.35 t ha^{-1}), O_3B_2 (23.03 t ha^{-1}) and O_1B_1 (22.67 t ha^{-1}) and were significantly superior to all other treatments.

As discussed earlier the better yield obtained due to the addition of organic manures and biofertilizers might be due to the enhancement of Azospirillum inoculation in the presence of organic manure. Similar results have also been reported by Wani (1990) and Zachariah (1995).

Interaction effect of source of nitrogen, organic manures and biofertilizers on yield of brinjal

Interaction between source of nitrogen organic manure and biofertilizer revealed that the treatment combination $S_1O_2B_1$ recorded the highest marketable yield (35.09 t ha^{-1}).

Integrated nutrient approach to crops by the combination of organics, chemical fertilizers and biofertilizers have numerous environmental benefits over chemical sources of nitrogen alone. It also helps in maintaining stability in crop production and productivity (Swaminathan, 1987). Neem cake contains certain alkaloids which have nitrification inhibiting properties. As a result neem cake acts as a slow releasing nitrogenous fertilizer. Thus apart from nutrient content in neem cake, the retention capacity of nutrients especially nitrogen might have resulted in producing better yield along with chemical fertilizer.

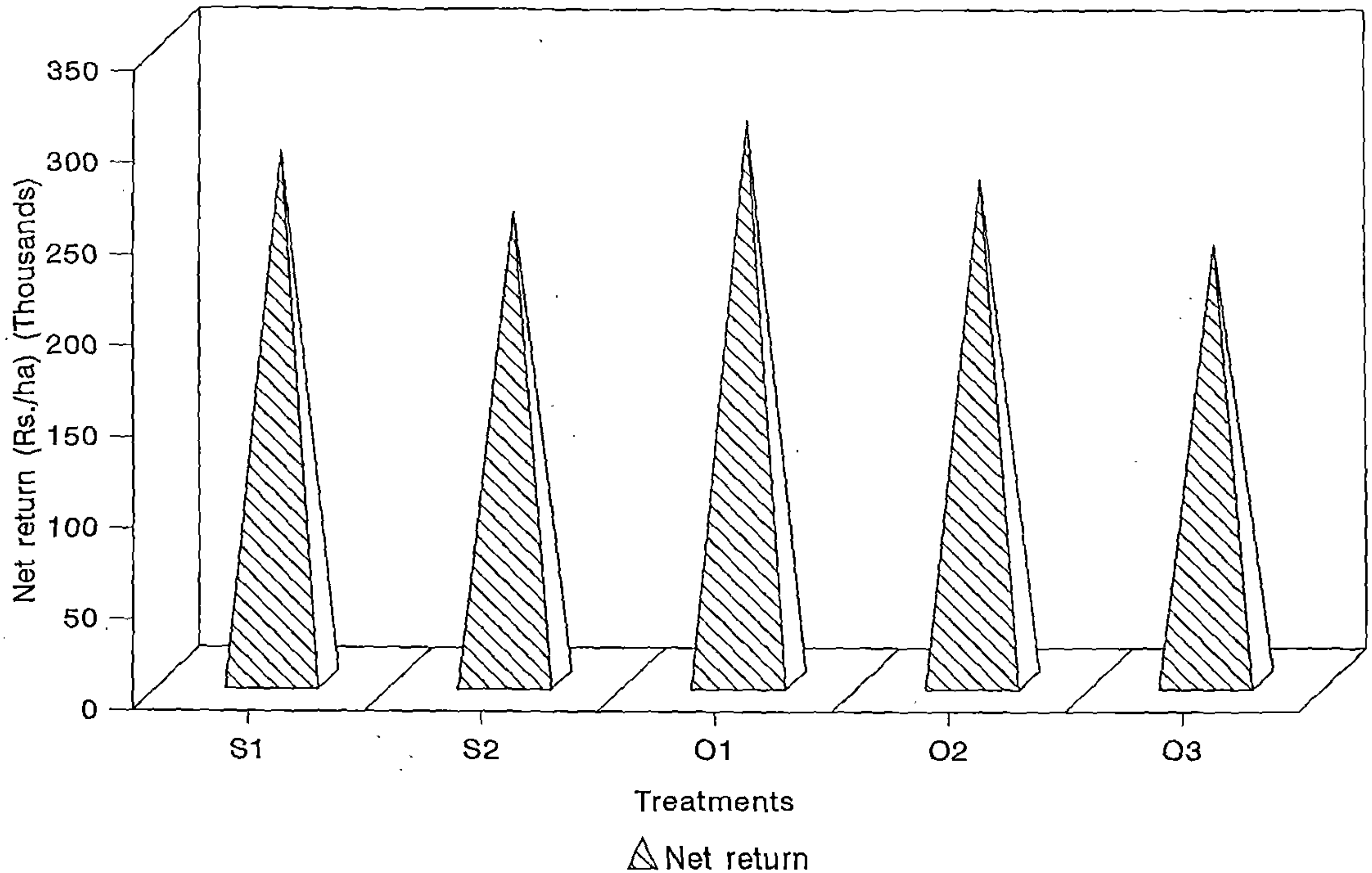

Fig. 12. Net return as influenced by source of nitrogen and organic manure

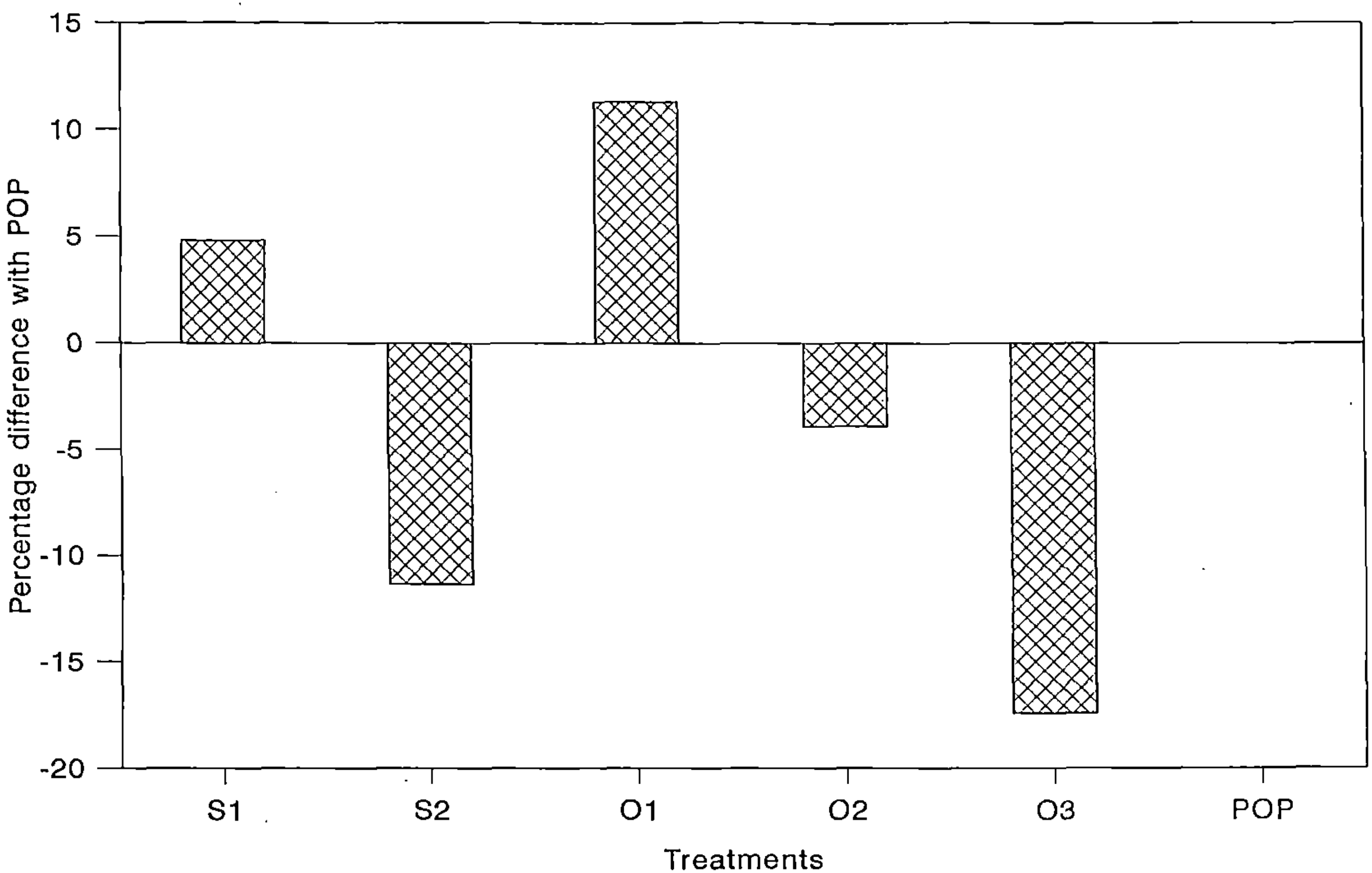

Fig. 13. Benefit cost ratio as influenced by source of nitrogen and organic manures

Economics of production

Among the two sources of nitrogen, the combined application of organic and inorganic sources of 1:1 ratio showed the maximum net profit of Rs. 290397.50 ha^{-1}. The higher profit obtained by the treatment might be due to the higher returns obtained from the treatment S_1. The organic manure component might have helped in producing better quality produce which contribute to the higher returns.

Poultry manure showed the maximum returns (Rs. 306862.50 ha^{-1}) among the various organic manures tried. This might be due to the rapid release of nutrients from poultry manure which lead to better growth and yield of plants.

SUMMARY

SUMMARY

The investigation titled "Integrated Nutrient Management in Brinjal (*Solanum melongena*)" was carried out at the Instructional Farm, Vellayani during the period from July to November, 1998. The objectives of the experiment were to study the effect of organic manures, chemical fertilizers and biofertilizers on the productivity and quality of brinjal and to assess the possibility of substitution of fertilizer by organic manures and biofertilizers.

The experiment was conducted with two sources of nitrogen S_1 (50 per cent organic manure + 50 per cent chemical fertilizer) and S_2 (100 per cent organic manure), three types of organic manures (poultry manure, neem cake and biogas slurry), two levels of biofertilizers (B_1 - without Azospirillum and B_2 - with Azospirillum) and two control treatments - C_1 POP recommendation with FYM and C_2 - POP recommendation without FYM.

The salient findings of the experiment are given below

When nitrogen was supplied as 50 per cent chemical fertilizer and 50 per cent organic manure, the plant height was significantly increased at all stages of growth. Among the different types of organic manures tried poultry manure recorded significantly higher values for plant height at all stages of growth. Azospirillum application increased the plant height and number of branches only during the early stages of growth.

Combined application of organic manures and inorganic sources in 1:1 ratio increased the number of leaves and number of branches per plant at all growth stages. Poultry manure recorded the highest number of leaves and number of branches per plant. Azospirillum inoculation increased the number of leaves per plant at all stages except 30 DAT.

LAI, RGR and CGR were highest for plant treated with organic manure and chemical fertilizers in 1:1 ratio. Poultry manure significantly increased the LAI, RGR and CGR. Azospirillum application showed increased LAI and NAR at later stages. Dry matter production was increased in all stages except 30 DAT, by the application of 100 per cent organic source. Among the various organic manures tried, poultry manure recorded the highest DMP at 60 and 75 DAT.

Time to 50 per cent flowering was lowered when the nutrients are applied 100 per cent as organic source. Significantly lowered value for time to 50 per cent flowering was recorded by the plants treated with poultry manure. Among the control treatments the plots received POP without FYM recorded more number of days to reach 50 per cent flowering. Number of flowers and fruits were significantly higher in plots received nutrients as organic and inorganic sources in 1:1 ratio. Poultry manure treated plots produced more number of flowers and fruits when compared to that of neem cake and biogas slurry. Azospirillum inoculation increased the number of flowers and fruits per plant when compared to plots which received no Azospirillum. Per cent fruit set was significantly higher in plants which received organic and inorganic nitrogen sources in 1:1 ratio. Among the organic manures tried, poultry manure recorded the maximum fruit set percentage.

Marketable fruit yield per ha was maximum for the treatments receiving organic and inorganic sources in 1:1 ratio. Among the various organic manures poultry manure recorded the maximum marketable fruit yield per ha as compared to the control treatments. The same trend was noticed in harvest index also. The interaction effects of various treatments showed that the treatment receiving 50 per cent chemical fertilizer and 50 per cent neem cake had the maximum marketable fruit yield per ha.

Keeping quality of the fruits was increased the poultry manure application. Among the different sources of nitrogen, the treatments receiving organic and inorganic sources of 1:1 ratio helped the fruits to remain fresh for a longer period. Among the control treatments, plots receiving POP with FYM produced fruits which have maximum keeping quality.

When organic and inorganic sources were applied in 1:1 ratio the yield per harvest was maximum in all the harvests. Among the three different types of organic manures, poultry manure recorded maximum yield per harvests than the control treatments. Interaction effect of various treatments showed that when *Azospirillum* was applied along with poultry manure recorded the maximum yield per harvest.

The uptake and concentration of plant nitrogen was highest for treatments receiving organic and inorganic sources in 1:1 ratio. The uptake and content of plant P and K were highest when nutrients were applied as 100 per cent organic manure. Among the different types of organic manures neem cake recorded the maximum content and uptake of nitrogen while poultry manure recorded maximum content and uptake of P and K. *Azospirillum* application increased the content and uptake of P and K when compared to control treatments.

Interaction effect of various treatments showed that what ever be the type of organic manure, when organic and inorganic sources were applied in 1:1 ratio and content and uptake of N, P and K were higher. Azospirillum inoculation increased the content and uptake of N and P when applied along with neemcake.

Significant increase in soil N status was recorded by the treatments receiving organic and inorganic manures in 1:1 ratio. Among the different types of organic manures, poultry manure recorded the highest N and P status of soil.

Maximum net profit (Rs. 290397.5) and benefit cost ratio (3.42) registered by the treatments receiving organic and inorganic sources at 1:1 ratio. Among the different types of organic manures, poultry manure registered the highest (Rs. 306862.5) and benefit cost ratio (3.57).

The present study revealed that an integrated application of organic and inorganic sources was beneficial for increasing the yield and improving the keeping quality of brinjal. Among the various types of organic manures tried, poultry manure proved best in increasing the yield.

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APPENDIX

APPENDIX I

Weather data for the crop period - weekly averages
(July 1998 - November 1998)

Period	Max. Temp. (°C)	Min. Temp. (°C)	Relative humidity (%)	Rainfall (mm)	Evaporation (mm)
July 1 - July 7	30.30	23.63	80.21	0.029	1.81
July 8 - July 14	30.39	28.41	82.99	2.77	6.80
July 15 - July 21	28.83	23.89	85.79	4.00	2.71
July 22 - July 28	29.19	23.91	86.07	1.57	3.46
July 29 - Aug 4	29.59	24.84	85.71	0.70	3.13
Aug 5 - Aug 11	30.07	24.24	83.00	2.77	3.56
Aug 12 - Aug 18	30.74	24.83	81.93	0.31	3.80
Aug 19 - Aug 25	29.01	26.80	87.50	16.74	2.21
Aug 26 - Sep 1	30.19	24.17	82.29	0.04	3.59
Sep 2 - Sep 8	29.96	24.13	83.14	8.69	3.80
Sep 9 - Sep 15	29.75	23.97	85.29	13.46	3.06
Sep 16 - Sep 22	25.97	24.03	88.21	7.54	3.73
Sep 23 - Sep 29	28.71	23.50	84.93	15.00	2.61
Sep 30 - Oct 6	29.60	24.16	86.57	0.94	2.96
Oct 7 - Oct 13	28.24	23.21	94.29	51.91	1.94
Oct 14 - Oct 20	30.20	23.70	83.50	5.69	3.60
Oct 21 - Oct 27	30.54	23.70	81.64	—	4.01
Oct 28 - Nov 3	30.07	23.04	81.86	2.54	2.86
Nov 4 - Nov 10	28.77	23.39	89.14	41.57	2.20
Nov 11 - Nov 17	30.07	23.10	82.71	7.43	3.30
Nov 18 - Nov 24	30.57	23.07	78.36	—	3.57

INTEGRATED NUTRIENT MANAGEMENT IN BRINJAL
(*Solanum melongena* L.)

By

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ABSTRACT OF THE THESIS
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ABSTRACT

An experiment was conducted at the Instructional Farm, Vellayani during the period from July to November, 1998. The objective of the experiment was to study the combined effect of organic manures, chemical fertilizers and biofertilizers on the productivity and quality of brinjal and to assess the possibility of substitution of fertilizers by organic manures and biofertilizers. Two sources of nitrogen, three types of organic manures, one Azospirillum treatment and two control treatments were tried in the experiment.

The result of the study showed that growth characters viz., plant height, number of leaves and branches and LAI were significantly increased by poultry manure application. Integrated application of organic and inorganic sources recorded significantly higher values for all the growth characters.

Yield attributes like time to 50 per cent flowering was considerably lowered by the application of 100 per cent organic source and by the poultry manure treatments. Poultry manure treated plots showed maximum number of flowers and fruits leading to maximum fruit set percentage. Marketable fruit yield per ha was found to be maximum for treatments receiving organic and inorganic sources at 1:1 ratio and for poultry manure applied plots. The same trend was noticed in keeping quality of fruits at ambient temperature.

The economics of cultivation revealed that whatever be the type of organic manure used, when it is applied along with chemical source in 1:1 ratio the net returns and benefit cost ratio were maximum.