AZOTOBACTER AND *AZOSPIRILLUM* INOCULANTS FOR NITROGEN ECONOMY IN VEGETABLE CULTIVATION

By

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THESIS
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DEDICATED TO

A SPECIAL FRIEND FOR
LIMITLESS HELP, SUPPORT, FRIENDSHIP
AND AFFECTION

DECLARATION

I hereby declare that this thesis entitled "***Azotobacter* and *Azospirillum* inoculants for nitrogen economy in vegetable cultivation**" 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 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 "***Azotobacter* and *Azospirillum* inoculants for nitrogen economy in vegetable cultivation**" is a record of research work done independently by Mr. ARUNKUMAR. S (94-11-40) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

The greatest challenge before man kind in the 21st century is to produce sufficient food for growing population. Eventhough we have succeeded to some extent to meet this demand by cultivating high yielding crop varieties and using chemical fertilizers, modern agriculture has got its own problems as well. 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 attention is given to reverse this situation by popularising the concepts of organic farming and integrated nutrient management practices. In the latter technology, the emphasis is to reduce the use of chemical fertilizers by substituting it with organic manures and biofertilizers, without affecting crop productivity.

The use of organic manures and biofertilizers for the cultivation of vegetables is becoming more and more widely accepted. Organic manures such as FYM, poultry manure and vermicompost and microbial biofertilizers particularly that of *Rhizobium, Azotobacter* and *Azospirillum* are extensively used for this purpose. The effectiveness of these ecofriendly inputs are however better expressed in an integrated nutrient management practice. The farmers are benefited in two different ways by adopting this practice viz ., significantly low input of mineral fertilizers and enhanced shelf life of harvested produce.

The main objective of present investigation was to develop an integrated nutrient management practice for three of the most commonly cultivated vegetables in Kerala namely amaranthus, brinjal and chilli. Organic manures in the form of FYM and vermicompost and biofertilizers in the form of *Azospirillum* and *Azotobacter* along with chemical fertilizers were used for this purpose.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Sustainable agriculture is a method of farming to produce adequate food without much adverse effect on soil productivity (Kandaswamy, 1992). Biofertilizers and organic manures are widely used by farmers for this purpose. It also stimulates soil microbial action like biological nitrogen fixation and microbial solubilisation of phosphates (Balasubramani, 1972).

Srivastava (1985) observed that the application of organic manures also resulted in increased organic carbon content, total nitrogen and available phosphorus and potassium status of soil.

Prasad and Singh (1984) found that the use of *Azospirillum* alone produced better growth response equivalent to that of 30 kg N ha^{-1} in rice. Investigating the effect of *A. lipoferum* inoculation in rice Nayak *et al.* (1986) observed that it not only increased tiller numbers but also resulted in early reproductive growth of rice. Purushothaman (1988) reported that root surface area of rice plants inoculated with *Azospirillum* was significantly greater than in uninoculated plant. They also concluded that this increase in root surface area was more pronounced along with the application of 50 and 75 kg N ha^{-1} than at 100 kg N ha^{-1}.

Kapulnic *et al.* (1981) studied the effect of *Azospirillum* inoculation on wheat, sorghum and *Panicum* and observed that inoculation with *A. brasilense* resulted in significant increase in plant height in all the three crops. In wheat this was 38.2 cm as against 31.2 cm in control treatment. in sorghum and *Panicum* these were 23.3 and 18.8 cm and 20.2 and 19.3 cm respectively. There was also earlier heading in all the three crops.

Rai and Gaur (1982) reported that grain yield of wheat at 0, 40 and 80 kg N ha^{-1} was 1260, 2370 and 2960 kg ha^{-1} as against the yield of 2070, 3110 and 4150 kg ha^{-1} in similar treatments receiving *Azospirillum* inoculation. The dry straw yield was 1780, 3240 and 3690 kg ha^{-1} respectively as against 2110, 3820 and 4890 kg ha^{-1} in inoculated plots. The uptake of nitrogen by grain and straw at 0, 40, and 80 kg N ha^{-1} amounted to 33.0, 59.8 and 79.9 kg ha^{-1} as compared to 57.6, 67.4 and 111.9 kg ha^{-1} in similar treatments receiving biofertilizer inoculation. Millet and Feldman (1984) also reported yield increase in wheat due to *Azospirillum* inoculation at medium and high levels of nitrogen feritilisation.

Patel *et al.* (1990) observed that in *Setaria*, *Azosprirllum* seedling dip alone could not increase the grain yield. But when it was combined with nitrogen, 10 and 20 kg ha^{-1}, it gave significantly higher yield over control treatment. This treatment was also on par with 40 kg N ha^{-1} alone.

Hadas and Okon (1987) reported that there were significant increases in root length (35 %), root dry weight (50 %) and total leaf area of 18 day old tomato seedlings due to *Azospirillum* inoculation. Bashan *et al.* (1989) suggested that the contribution of *A. brasilense* to growth of tomato seedlings was in fact not due to nitrogen fixation. Using Nif^- and Nif^+ strains of *A. brasilense* they found that both the wild type and Nif^- strains significantly increased the height of tomato seedlings upto 25 percent over uninoculated control. Analysis of root colonisation also revealed a similar pattern in root colonisation. They also observed that in *Azospirillum* treated brinjal seedlings, the plant height was significantly increased from 11.2 to 15.3 mm as compared to uninoculated treatment. There was also significant increase in dry weight of foliage and number of leaves per plant (7.3 to 10.4) due to *Azospirillum* inoculation. Further there was also significant increase in population of *Azospirillum* (5.4×10^5 CFU per g of fresh roots) in inoculated treatments.

Dhanalakshmi and Pappiah (1995) reported that the *Azospirillum* treated tomato seeds had the highest germination percentage, shoot and root length, vigour index, fresh and dry weight of seedlings, number of primary and secondary roots and better rate of establishment under field conditions as compared to untreated control treatment. They also observed that application of only 75 percent fertilizer nitrogen (112.5 kg N ha^{-1}) along with *Azospirillum* inoculation through seed and soil treatments increased plant height and number of secondary branches formed in tomato. In these treatments early flowering to the extent of 5 days with highest number of flowers, fruit set and maximum yield were also obtained.

Balasubramani and Pappiah (1995) found that seed and soil treatment of bhindi with *Azospirillum* along with 30 kg N ha^{-1} (75 % of recommended dose) recorded the highest yield of 17.5 tonnes as compared to only 9.6 t for the control treatment. Rajasekhar *et al.* (1995) also got better yield in bhindi from plants treated with *Azospirillum* + FYM and inorganic fertilizers.

Obliswamy *et al.* (1976) reported that application of *Azotobacter* could reduce 25 percent of fertilizer nitrogen applied to paddy without affecting the yield. Wani *et al.* (1976) also reported yield increase in cv Suhasini with the application of 120 kg nitrogen + 70 kg P_2O_5 + 50 kg K_2O along with seed inoculation of *Azotobacter*. However, Muskey (1977) found that eventhough seed inoculation with *Azotobacter* increased paddy yield by 12 percent the application of 50 kg nitrogen per hectare decreased the effectiveness of seed inoculation.

Badawy and Amer (1974) reported that seed inoculation of wheat with *A. chroococcum* was effective in increasing yield in cultivated sandy soil. Ishac *et al.* (1986) also studied the effect of seed inoculation of wheat with *Azotobacter* and concluded that inoculation conjugated with half nitrogen (75 kg N ha^{-1}) in the presence of organic manures brought about same yield as in full dose of nitrogen under same conditions. The beneficial effect of *Azotobacter* inoculation on growth and yield of wheat were attributed to high nitrogen uptake by inoculated plants. The use of organic manures was also found to stimulate microbial activity in the rhizosphere. Lekshminarayana *et al.* (1992) also reported from their two year field experiments that *Azotobacter* inoculation increased plant height, number of tillers, ear length and number of spikes in wheat. They also found that these responses were more when the inoculation was carried out along with 60 kg N ha^{-1}.

Singh *et al.* (1979) got significant increase in maize yield due to combined application of fertilizer nitrogen and *Azotobacter* inoculation. Meshram and Shinde (1982) and Martinez- Toledo *et al.* (1986) also reported that in maize *Azotobacter* inoculation was economically most efficient at lower doses of nitrogen especially in combination with organic manures.

Mehrotra and Lehri (1971) while studying the effect of *Azotobacter* inoculation in vegetable crops reported that when brinjal, tomato or cabbage roots were dipped in a slurry of lignite based inoculant at transplanting, the yield were increased. In brinjal this lead to 42 percent increase in yield while in tomato and cabbage these were 29 and 45 percent respectively.

Lehri and Mehrotra (1972) also obtained varying yield increases in cabbage and brinjal with *A. chroococcum* inoculation. These were 26 to 45 and 15 to 62 percent for cabbage and brinjal respectively. Badaway and Imam (1975) reported that seed inoculation of cabbage, cauliflower and onion with *Azotobacter* significantly increased the plant growth. However the yield differences were not significant. Iswaran (1975) got higher yield in cabbage when 5 week old seedlings were pelletted with *A. chroococcum* and dicalcium phosphate.

Dibut *et al.* (1995b) reported that in onion, treatment with dilute *A. chroococcum* preparation at 5 l ha^{-1} immediately after sowing increased plant population by 33 to 62 percent depending on variety. The plant height, leaf number, bulb diameter and dry weight increased by 26, 36, 72 and 175 percent respectively.

Mohandas (1987) found that combined inoculation of tomato with *A. vinelandii* and *Glomus fasciculatum* under field conditions resulted in significant increase in leaf area, shoot dry weight, nitrogen and phosphorus content and yield. Dibut *et al.* (1995a) and Gupta *et al.* (1995) also reported that in tomato, soil inoculation with *A. chroococcum* increased seed germination by 33 to 46 percent besides reducing the period between sowing and transplanting by 5 to 7 days. Soil inoculation also increased the number of flowers and fruits. The net yield was increased by 38 and 60 percent respectively in winter and spring sowings.

In a study on optimum level of poultry manure requirement for cauliflower, Singh *et al.* (1970) observed progressive increase in growth and yield of cauliflower when the dosage was increased from 0 to 169.6 q ha^{-1}. Morelock and Hall (1980) compared the effect of broiler litter applied at different levels (0 to 8 t ha^{-1}) along with the application of commercial fertilizers ($N_{10}P_{20}K_{10}$) at 250 to 750 lb $acre^{-1}$ on field grown tomato plant. Marketable fruit yield was found to increase with broiler litter application. Abusaleha (1981) reported that in bhindi early flowering and highest yield of 18.02 t ha^{-1} were obtained with the application of half nitrogen through ammonium sulphate and half through poultry manure.

Subbiah *et al.* (1983) reported that yield of brinjal was significantly influenced by levels of FYM (0, 12.5, 25.0 and 37.5 t ha^{-1}) but not by the levels of fertilizers (0, 50, 100 and 150 percent of recommended dose). Application of 12.5 t ha^{-1} FYM produced highest yield of 54.28 t ha^{-1}. In lettuce (Anez and Tavira, 1984) observed that application of poultry manure at 0, 20 and 40 m^3 ha^{-1} either as entire basal dose or in split doses increased the yield from 0.66 to 0.88 and 0.90 kg per plant respectively. Jose *et al.* (1988) reported that in brinjal 50 kg nitrogen as poultry manure and 50 kg nitrogen as urea resulted in highest yield of 51 t ha^{-1}.

Hilman and Suwandi (1989) found that sheep manure when applied at the rate of 30 t ha^{-1} gave highest yield of 1.05 kg per plant in tomato cultivar Gondol.

Meena Nair and Peter (1990) reported highest yield in chilli with 15 t FYM + 75:40:25kg NPK ha^{-1} in the three seasons tried when compared to FYM alone or inorganic fertilizers alone.

Sharma and Bhalla (1995) also reported that an integrated nutrient management practice gave maximum yield of 86.04 q ha^{-1} in bhindi, which was 13.3 percent higher over recommended dose of fertilizer alone.

Senapathy *et al.*(1985) reported that the application of vermicompost resulted in higher grain yield in paddy besides significant increase in straw yield and root biomass production. Similarly, Sacirage and Dzelecov (1986) obtained 1 to 68 percent increase in dry matter yields in cabbage due to application of 4, 6 and 8 kg m^{-2} of vermicompost.

Ismail *et al.* (1991) got increased number of flowers and fruits in water melon grown in vermicompost.

Shuxin (1991) reported 30-50 percent increase in plant growth with 10 percent increase in height and effective tillering in sugarcane due to vermicompost application.

Desai (1993) observed that the yield of *Capsicum* in vermicompost treated plot was comparable to that of chemical fertilizer application.

Dharmalingam (1995) got 16 percent increase in yield in soybean over non pelletted seeds due to vermicompost pelleting.

Luchnik (1975) reported that the use of organic manures resulted in high sugar and vitamin-C content which resulted in better keeping quality of cabbage. Similarly, Kansal *et al.* (1981) reported increased shelf life of spinash leaves due to application of 20 t FYM ha^{-1}.

Meir-ploegen and Lehri (1981) studied the quality of different food plants grown with composts from biogenic waste. NPK fertilizers, composted FYM and commercial organic fertilizers were used for comparison. They found that storage quality and contents of desirable nutrients such as vitamin-C and sugar were improved in compost treatments.

Shanmugavelu (1989) and Lumpkin (1990) reported better keeping quality for tomato due to application of FYM.

Montagu and Gosh (1990) found that fruit colour of tomato was significantly increased as a result of application of organic manure of animal origin.

MATERIALS AND METHODS

MATERIALS AND METHODS

The study on "*Azotobacter* and *Azospirillum* inoculants for nitrogen economy in vegetable cultivation" was done at College of Agriculture, Vellayani, Thiruvananthapuram during 1994-96 with following technical programme.

1. Isolation of native strains of *Azospirillum* and *Azotobacter*
2. Pot trial in Completely Randomized Design with three replications each using different levels of nitrogen along with *Azospirillum* or *Azotobacter* inoculation and vermicompost or FYM as organic manure supplement.
3. Field evaluation of promising treatments from pot trials to develop an integrated nutrient management practice for amaranthus, brinjal and chilli.

Isolation of *Azospirillum*

Root samples of amaranthus (*Amaranthus tricolor*. L), brinjal (*Solanum melongena*. L) and chilli (*Capsicum frutescens*. L) were collected at random from the Instructional farm of the College of

Agriculture, Vellayani. *Azospirillum* sp. was isolated by enrichment culture technique using nitrogen free semi-solid malate agar medium.

Nitrogen free semi-solid malate agar medium (Baldani and Doberiner, 1980)

Malic acid	-	5.00 g
K_2HPO_4	-	0.50 g
$MgSO_4$	-	0.20 g
Na Cl	-	0.10 g
Trace element solution	-	2.00 ml
Alcaholic solution of bromothymol blue (5%)	-	2.00 ml
Iron EDTA (1.6 w/w aquous)	-	4.00 ml
Vitamin solution	-	4.00 ml
Agar	-	1.75 g
Distilled water	-	1000.00 ml

pH 6.8

Trace element solution

Na_2SO_4	-	200 mg
$MnSO_4.H_2O$	-	280 mg

H_3PO_4	-	280 mg
$ZnSO_4.7H_2O$	-	24 mg
$CuSO_4$	-	8 mg
Distilled water	-	200 ml

Iron EDTA

Dissolve 26.1 g of EDTA in 1 N KOH solution and 24.9 g of $FeSO_4$ was added to this. The volume was made upto 1 litre. The solution was kept overnight to produce a stable complex for further use.

Vitamin solution

Biotin	-	10 mg
Pyridoxine	-	20 mg
Distilled water	-	100 ml

A vertical semi-solid gel was prepared by dispensing 5 ml of the above medium in 10 ml screw capped test tubes and sterilized in an autoclave at 121^0C for 15 minutes. Healthy rootlets from each plant sample were initially separated and washed gently with tap water to remove adhering soil particles. These were then cut into small bits of 1.0 cm length and surface sterilized with ethyl alcohol for 30 seconds and then washed repeatedly with sterile water. They were then gently crushed using a glass rod and placed aseptically just below the surface of nitrogen free semi-solid agar medium, by using a sterile inoculation needle. These tubes were then incubated at 30 ± 2^{0}C in an incubator.

The presence of microaerobic nitrogen fixing bacterium was detected by the development of a pale dense sub surface pellicle. Such cultures were further purified by repeated transfer to fresh nitrogen free semi-solid malate agar medium until a clear distinct sub-surface pellicle was formed in each tube. These were then streaked on potato infusion agar medium.

Potato infusion agar medium (Baladani and Dobereiner, 1980)

Potato	-	200.0 g
Maleic acid	-	2.5 g
KOH	-	2.0 g
Sucrose	-	2.5 g
Vitamin solution	-	1.0 ml
Alcaholic solution of bromothymol blue	-	2.0 ml
Agar	-	15.0 g

Distilled water - 1000.0 ml

pH 7.0

Potato infusion broth was prepared by boiling 200.0 g of pealed and sliced potatoes for 30 minutes in 200 ml water and filtering the broth through a piece of clean cotton. The remaining nutrient components were added to this filtrate. After making up the volume to 1000 ml and adding the required quantity of agar, the medium was sterilized in an autoclave at 121^{0}C for 15 minutes.

The different isolates were streaked on this medium and incubated for 48 hours at 30 ± 2^{0}C in an incubator. Isolated colonies showing typical wrinkled character of *Azospirillum* were selected and transferred to nitrogen free semi-solid agar medium to observe the characteristic sub-surface pellicle formation. Such cultures were maintained on malate agar slants supplemented with 0.3 % NH_4Cl for further studies.

Mass production of *Azospirillum*

Mass production of *Azospirillum* was done in modified malate broth of following composition

Malic acid	-	5.0 g
K_2HPO_4	-	0.5 g
$MgSO_4 . 7H_2O$	-	0.2 g
Na Cl	-	0.1 g
Trace element solution	-	2.0 ml
Iron EDTA	-	4.0 ml
Vitamin solution	-	4.0 ml
KOH	-	4.0 g
NH_4 Cl	-	3.0 g
Distilled water	-	1000.0 ml
pH 6.8		

The sterile liquid medium in 1000 ml conical flasks were inoculated with the pure *Azospirillum* culture and incubated for 72 hours. This broth culture with a population of 10^9 / ml was mixed with finely powdered and sterile wood charcoal powder of particle size 106 μ sieve at the rate of 40 - 50 per cent of its water holding capacity for further use as a carrier based inoculum of *Azospirillum*.

Isolation of *Azotobacter*

Jensen's nitrogen free agar medium was used for the isolation of *Azotobacter* by soil dilution and plating technique.

Jensen's nitrogen free agar (Jensen 1942)

Sucrose	-	20.0 g
K_2HPO_4	-	1.0 g
$MgSO_4.7H_2O$	-	0.5 g
Na Cl	-	0.5 g
$FeSO_4$	-	0.1 g
$CaCO_3$	-	2.0 g
Agar	-	15.0 g
Distilled water	-	1000.0 ml
pH 7.2		

Mass production of *Azotobacter*

Jensen's nitrogen free broth was used for mass production of carrier based inoculum of *Azotobacter*. An identified stock culture of *A. chroococcum* from the Microbiology section of Department of Plant Pathology, College of Agriculture, Vellayani was used for this purpose.

Crop / Variety

The amaranthus variety Arun, brinjal variety SM- 6 (Surya) and chilli variety Jwalamukhy were used both for pot as well as field trials.

Manures and fertilizers

Farm yard manure (FYM), vermicompost (VEC), urea, mussoriephos and muriate of potash were used as organic manures and chemical fertilizers.

Pot culture experiment

The pot culture experiment was laid out in CRD with twenty different treatments. The treatments consisted of biofertilizer application along with four different levels of nitrogen and FYM or VEC as primary source of organic manure. The experiments were replicated thrice.

Biofertilizers

Azospirillum - AS

Azotobacter - AB

Organic manures

Farm yard manure - FYM

Vermicompost - VEC

Nitrogen levels

25 % of recommended dose - N_1

50 % of recommended dose - N_2

75 % of recommended dose - N_3

100 % of recommended dose - N_4

The different treatment combinations for amaranthus, brinjal and chilli were as follows.

N_1 FYM + AS	N_1 VEC + AS
N_2 FYM + AS	N_2 VEC + AS
N_3 FYM + AS	N_3 VEC + AS
N_4 FYM + AS	N_4 VEC + AS
N_1 FYM + AB	N_1 VEC + AB
N_2 FYM + AB	N_2 VEC + AB
N_3 FYM + AB	N_3 VEC + AB
N_4 FYM + AB	N_4 VEC + AB
N_1 FYM - AS / AB	N_3 FYM - AS / AB
N_2 FYM - AS / AB	**N_4 FYM - AS / AB**

Soil and sand in the ratio of 2:1 was used as potting mixture. Earthern pots were filled with the potting mixture at the rate 13 kg per pot. The organic manures (FYM / VEC) and chemical fertilizers were applied following the Package of Practice recommendations of Kerala Agricultural University (1993) for amaranthus, brinjal and chilli.

Crop	Fertilizer recommendation (kg NPK / ha)	Recommended dose of FYM (t / ha)
Amaranthus	50 : 50 : 50	50
Brinjal and chilli	75 : 40 : 25	25

For amaranthus nitrogen was applied in three split doses. One half as basal dose at the time of transplanting along with organic manures and full doses of phosphorus and potash. The remaining half of nitrogen was applied in two split doses at 30 and 45 days after transplanting (DAT).

For brinjal and chilli, half doze of nitrogen, potash and full dose of phosphorus and organic manures were applied as basal dose at the time of transplanting. One fourth of nitrogen and half of potash were applied 20 to 25 DAT. The remaining one fourth of nitrogen was given 50 DAT.

The *Azospirillum* and *Azotobacter* were given both by seedling dip method and by direct incorporation into potting mixture at the rate of 5 kg / ha. In the seedling treatment, the roots of amaranthus, brinjal and chilli were dipped in a water slurry of carrier based inoculum of appropriate biofertilizer (1kg in 5 litre of water) for 20 minutes prior to transplanting.

Amaranthus, brinjal and chilli were grown for a period of 90 days giving regular irrigation. The biometric observations recorded were

Plant height

Plant height was recorded on 60 DAT. Height was measured in cm from ground level to tip of top most leaf.

Number of branches

Total number of branches were counted on 60 DAT.

Flowering time

The time taken for flower initiation was calculated from the date of transplanting.

Root biomass

After final harvest, plants were carefully uprooted and gently washed with water to remove adhering soil particles. These were dried to a constant weight in a drying oven and root biomass (g) was estimated by using electronic balance.

Leaf area index

Leaf area was recorded only for amaranthus by using a leaf area meter. The leaf area index was calculated using the formula

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Spacing}}$$

Number of fruits

The total number of fruits of brinjal and chilli at the time of harvest was recorded.

Yield

In amaranthus, the plants were cut on 60 DAT and fresh weight of shoot portion (g) was recorded. In brinjal and chilli, total weight (g) of fruits harvested were taken as yield.

Field experiment

The treatments from pot trials which gave maximum yield along with *Azospirillum* or *Azotobacter* inoculation were used for further field evaluation. VEC treatments which produce maximum yield in amaranthus, brinjal and chilli were also selected for field evaluation. These treatments were further duplicated with the use of VEC only at 50 percent of the recommended level for FYM as organic manure. These additional treatments were included since VEC was used as a new source of organic manure for the cultivation of above vegetable crop.

The different treatment combinations in the main field for amaranthus, brinjal and chilli were as follows

Amaranthus	Brinjal	Chilli
T_1 N_3 FYM + AS	T_1 N_3 FYM + AS	T_1 N_1 FYM + AS
T_2 N_3 FYM + AB	T_2 N_3 FYM + AB	T_2 N_1 FYM + AB
T_3 N_3 VECF + AS	T_3 N_2 VECF + AS	T_3 N_4 FYM + AS
T_4 N3 VECF + AB	T_4 N_2 VECF + AB	T_4 N_4 VECF + AS
T_5 N_3 VECH + AS	T_5 N_4 VECF + AS	T_5 N_4 VECF + AB
T_6 N_3 VECH + AB	T_6 N_2 VECH + AB	T_6 N_4 VECH + AS
T_7 N_4 FYM - BF	T_7 N_4 VECH + AS	T_7 N_4 VECH + AB
T_8 N_4 VECF - BF	T_8 N_4 FYM - BF	T_8 N_4 FYM - BF
T_9 N_4 VECH - BF	T_9 N_4 VECF - BF	T_9 N_4 VECF - BF
	T_{10} N_4 VECH - BF	T_{10} N_4 VECH - BF

N_1 : 25 % of recommended level — FYM : Farm Yard Manure

N_2 : 50 % of recommended level — VECF : Vermicompost (full dose)

N_3 : 75% of recommended level — VECH : Vermicompost (half dose)

N_4 : 100 % of recommended level — BF : Biofertilzer

Design of field experiment

Design - RBD

Replication - 3

Number of treatments - 9 or 10 depending upon the crop

Gross plot size - 2.3 x 2.1 m

Net plot size - 2.0 x 1.8 m

Spacing

Amaranthus - 30 x 15 cm

Brinjal - 60 x 75 cm

Chilli - 45 x 45 cm

Lay out

Amaranthus

T_9	T_2	T_6	7_3	T_7	T_4	T_5	T_8	T_1

T_8	T_1	T_6	T_9	T_3	T_4	T_2	T_7	T_5

T_2	T_9	T_1	T_5	T_6	T_8	T_7	T_3	T_4

Brinjal

T_8	T_1	T_6	T_9	T_3	T_4	T_2	T_7	T_5	T_{10}

T_{10}	T_3	T_2	T_6	T_4	T_7	T_9	T_5	T_8	T_1

T4	T_9	T_1	T_6	T_3	T_8	T_2	T_7	T_{10}	T_5

Chilli

T_{10}	T_2	T_6	T_9	T_3	T_7	T_4	T_5	T_8	T_1

T_2	T_9	T_1	T_5	T_6	T_8	T_7	T_3	T_{10}	T_4

T_8	T_1	T_9	T_6	T_4	T_3	T_2	T_7	T_5	T_{10}

Biofertilizer application

This was done both by seedling dip at the time of transplanting and by direct field application as per the method described earlier.

Observations

The observations on plant height, number of branches, leaf area index (for amaranthus), number of fruits (for brinjal and chilli) and yield were taken as per the methods described earlier. Five plants were randomly selected from each plot and the final data were recorded as the mean of three replications for each treatment.

Keeping quality of fruits

The harvested fruits from each treatment and replication were kept at room temperature for 10 days. The number of days the fruits remained healthy without any spoilage was taken as the main criterion to assess the keeping quality of harvested fruits of brinjal and chilli.

Estimation of microbial population

Total bacteria, fungi and actinomycetes along with *Azospirillum* and *Azotobacter* in soil samples collected from each treatment were enumerated by soil dilution and plate technique using appropriate medium. For *Azospirillum* and *Azotobacter* nitrogen free malate agar and Jensen's nitrogen free agar were used. Soil extract agar, Martin's Rose Bengal agar and Kenknight's media of following composition were used for enumeratiing bacteria, fungi and actenomycetes at dilution of 10^{-6} and 10^{-4} dilutions respectively. Soil samples collected from each plot before raising amaranthus, brinjal and chilli served as control treatment.

Soil extract agar (Allen, 1957)

Glucose	-	1.0 g
K_2HPO_4	-	0.5 g
Soil extract	-	100.0 ml
Agar	-	15.0 g
Water	-	900.0 ml
pH		6.8 - 7.0

Soil extract was prepared by autoclaving 1 kg of garden soil with one litre of water. The filtered and cooled extract was used for preparation of medium.

Martin's Rose Bengal agar (Martin, 1950)

Dextrose	-	10.0 g
Peptone	-	5.0 g
KH_2PO_4	-	1.0 g
$MgSO_4.7H_2O$	-	0.5 g
Rose Bengal	-	1 part in 30000 parts of medium
Agar	-	15.0 g
Distilled water	-	1000.0 ml
Streptomycin solution (10%)	-	3.0 ml

Kenknight's medium (Subba Rao, 1986)

Dextrose	-	1.0 g
KH_2PO_4	-	0.1 g
$NaNO_3$	-	0.1 g
K Cl	-	0.1 g
Mg $SO_4.7H_2O$	-	0.1 g
Agar	-	15.0 g
Distilled water	-	1000.0 ml

Statistical analysis

The data of pot trial experiments were analysed by the method described by Snedecor and Cochran (1967) for the analysis of variance of completely randomised design.

The data of field trials were subjected to analysis of variance (ANOVA) described by Panse and Sukhatme (1967).

RESULTS

RESULTS

The influence of different microbial inoculants such as *Azospirillum* and *Azotobacter* and organic manures such as farm yard manure and vermicompost and four different levels of nitrogen on growth and yield of amaranthus, brinjal and chilli were studied both under pot culture and field conditions. The *Azospirillum* isolate from chilli which had a faster rate of growth was used for mass production of carrier based inoculum. However in the case of *Azotobacter*, since no crop speicific isolate was obtined, an identified culture of *A. chroococcum* was uniformly used for the preparation of carrier based inoculum. The beneficial effects of different treatments were assessed in relation to the control (N_4 FYM-AS/AB) maintained as per the existing Package of Practices recommendations of Kerala Agricultural University.

Pot trial

Amaranthus

Effect of *Azospirillum* inoculation

Plant height

There were significant differences among the treatments on plant height. It was maximum (61.7 cm) in the treatment combination of N_3

Table 1. Effect of *Azospirillum* inoculation on plant growth in amaranthus (60 DAT) under pot culture condition.

Treatments	Plant height (cm)	Number of branches	Flowering time (DAT)
N_1 FYM + AS	54.0	8.0	38.0
N_2 FYM + AS	41.7	7.7	47.0
N_3 FYM + AS	61.7	6.7	49.7
N_4 FYM + AS	35.7	4.7	39.0
N_1 VEC + AS	31.0	6.0	43.0
N_2 VEC + AS	38.0	4.7	40.0
N_3 VEC + AS	29.0	4.7	43.6
N_4 VEC + AS	29.3	6.3	47.7
N_1 FYM - AS	41.3	6.3	36.3
N_2 FYM - AS	44.3	6.7	35.7
N_3 FYM - AS	34.0	6.7	38.0
N_4 FYM - AS	33.0	4.7	45.3
CD (0.05)	10.2	NS	4.2

FYM+AS as compared to 33.0 cm in control (Table 1). The plant height in N_1 FYM+AS was statistically on par with the best treatment.

Number of branches

There were no significant differences between the treatments on number of branches formed in amaranthus (Table 1). Maximum number of branches (8.0) was in N_1 FYM+AS treatment.

Flowering time

Flowering time was significantly delayed to the extent of 49.7 DAT in N_3 FYM+AS treatment (Table 1) as compared to 35.7 DAT in N_2 FYM-AS and 45.3 DAT in control.

Root biomass, leaf area index and yield

The increase in root biomass (16.6 g), leaf area index (2.4) and yield 146.7 g) were uniformly high and significant in N_3 FYM+AS treatment (Table 2, Fig. 1). The leaf area index in N_1 FYM+AS (2.2) and N_2 FYM+AS (1.8) and yield in N_2 FYM+AS (140.7 g) and N_4 FYM+AS (130.0 g) were statistically on par with the best treatment. In two of the treatments without *Azospirillum* inoculation such as N_1 FYM-AS and N_2 FYM-AS similar results were obtained.

Table 2. Effect of *Azospirillum* inoculation on root biomass, leaf area and yield of amaranthus under pot culture condition.

Treatments	Root biomass (g)	Leaf area Index	Yield* (g)
N_1 FYM + AS	6.1	2.2	100.0
N_2 FYM + AS	10.3	1.8	140.7
N_3 FYM + AS	16.6	2.4	146.7
N_4 FYM + AS	8.8	1.3	130.0
N_1 VEC + AS	4.9	1.4	80.7
N_2 VEC + AS	5.5	1.2	85.0
N_3 VEC + AS	7.8	1.2	96.0
N_4 VEC + AS	5.0	1.7	89.3
N_1 FYM - AS	7.6	1.5	118.0
N_2 FYM - AS	13.6	1.4	133.3
N_3 FYM - AS	5.6	1.5	98.3
N_4 FYM - AS	4.5	1.0	63.3
CD (0.05)	2.0	0.6	38.0

* Total of two cuttings

Effect of *Azotobacter* inoculation

Plant height

There were significant differences between treatments on plant height. It was maximum (58.7 cm) in the treatment combination N_3 FYM+AB as compared to 33.3 cm in control (Table 3). The plant height in N_1 FYM+AB was statistically on par with the best treatment.

Number of branches

There were no significant differences between treatments (Table 3). Maximum number of branches (7.7) were noticed in the treatment combination N_1 FYM+AB.

Flowering time

Flowering time was delayed to the extent of 46.7 DAT in N_2VEC+AB (Table 3). But this was not significantly different from control.

Root biomass, leaf area index and yield

The root biomass of 13.6 g was maximum in the N_2FYM-AB treatment (Table 4; Fig. 1; Plate. 1). The increase in root biomass in

Table 3. Effect of *Azotobacter* inoculation on plant growth in amaranthus (60 DAT) under pot culture condition.

Treatments	Plant height (cm)	Number of branches	Flowering time (DAT)
N_1 FYM + AB	50.3	7.7	37.7
N_2 FYM + AB	44.3	7.3	38.7
N_3 FYM + AB	58.7	6.3	40.0
N_4 FYM + AB	33.0	7.3	39.0
N_1 VEC + AB	37.7	6.7	37.7
N_2 VEC + AB	28.3	5.7	46.7
N_3 VEC + AB	34.0	6.3	38.0
N_4 VEC + AB	39.7	7.0	37.7
N_1 FYM - AB	41.3	6.3	36.3
N_2 FYM - AB	44.3	6.7	35.7
N_3 FYM - AB	34.0	6.7	38.0
N_4 FYM - AB	33.3	4.7	45.3
CD (0.05)	12.6	NS	4.5

treatments such as N_2 FYM+AB (13.3 g) and N_3 FYM+AB (12.4 g) were statistically on par with N_2 FYM-AB.

Leaf area index and yield were high in N_3 FYM+AB treatment. These were 2.0 and 150.0 g respectively (Table 4). The treatment effects in N_1 FYM+AB (2.0), N_2 FYM+AB (2.0) and N_4 FYM+AB (1.6) for leaf area index and N_2 FYM+AB (138.3 g) and N_4 FYM+AB (133.3 g) for yield among biofertilizer treatments were on par with N_3FYM+AB. Similar results were also obtained in N_1FYM-AB and N_2FYM-AB treatments.

Effect of organic manure and biofertilizer application on growth and yield of amaranthus

In general, plant height, root biomass, leaf area index and yield were significantly high in treatments using FYM (Table 5). However, no such differences were observed between *Azospirillum* and *Azotobacter* application except for flowering time which was significantly delayed in *Azospirillum* treatments.

Table 4. Effect of *Azotobacter* inoculation on root biomass, leaf area index and yield of amaranthus under pot culture condition.

Treatments	Root biomass (g)	Leaf area Index	Yield* (g)
N_1 FYM + AB	8.0	2.0	111.7
N_2 FYM + AB	13.3	2.0	138.3
N_3 FYM + AB	12.4	2.0	150.0
N_4 FYM + AB	9.1	1.6	133.3
N_1 VEC + AB	5.5	0.9	96.0
N_2 VEC + AB	5.3	1.2	98.3
N_3 VEC + AB	5.9	1.3	113.3
N_4 VEC + AB	6.1	1.0	103.3
N_1 FYM - AB	7.6	1.5	118.0
N_2 FYM - AB	13.6	1.4	133.3
N_3 FYM - AB	5.6	1.5	98.3
N_4 FYM - AB	4.5	1.0	63.3
CD (0.05)	2.3	0.6	36.3

*Total of two cuttings

Fig. 1 Effect of organic manure and biofertilizer application on root biomass production in amaranthus

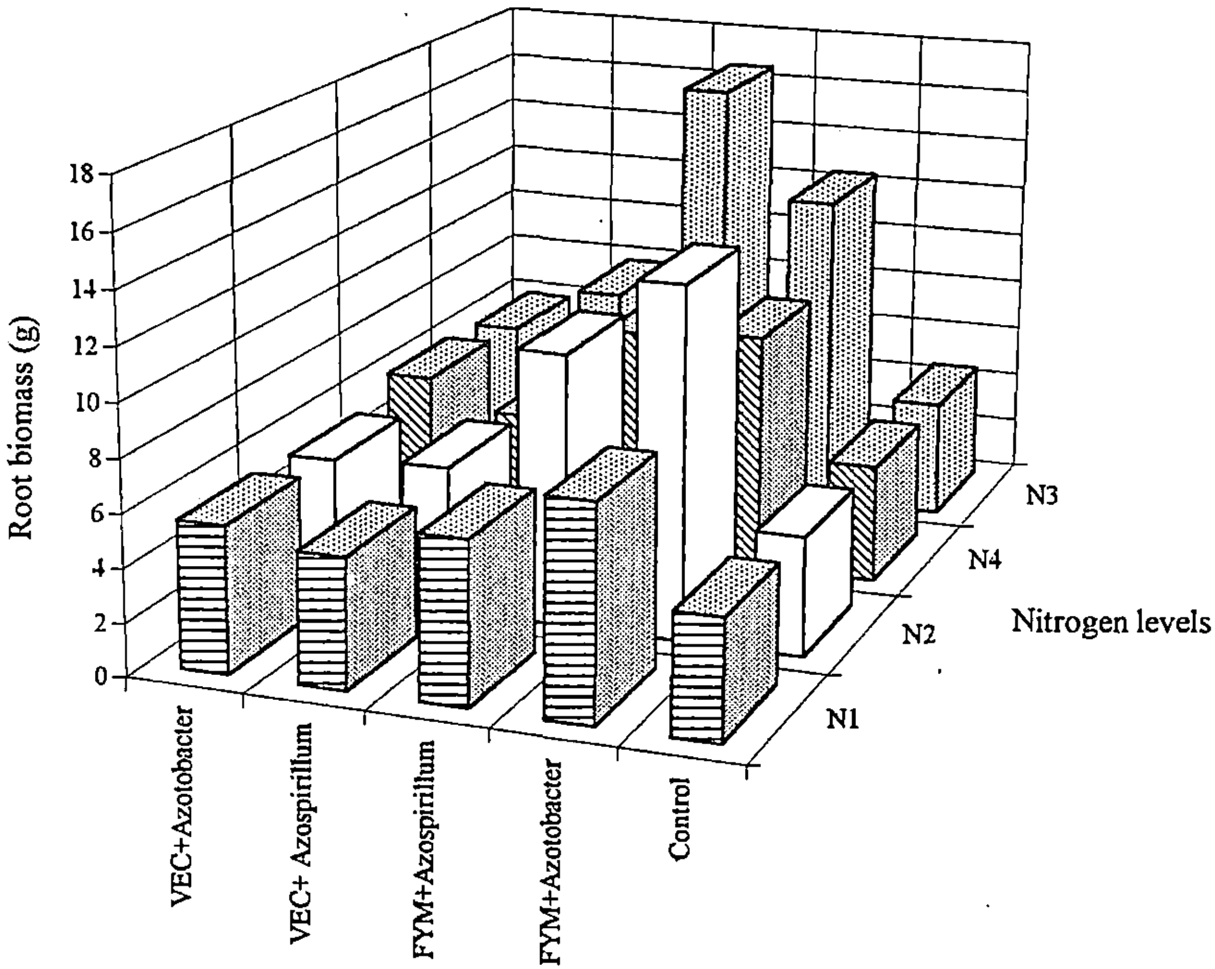


Table 5. Effect of organic manure and biofertilizer application on growth and yield of amaranthus

Treatments	Plant height (cm)	Flowering time (DAT)	Root biomass (g)	Leaf area Index	Yield (g)
FYM	47.5	41.1	10.6	1.9	131.3
VEC	33.4	41.8	5.8	1.2	95.3
CD (0.05)	4.4	NS	1.4	0.2	16.4
AS	40.0	43.5	8.1	1.7	108.5
AB	40.8	39.4	8.2	1.5	118.2
CD (0.05)	NS	1.8	NS	NS	NS

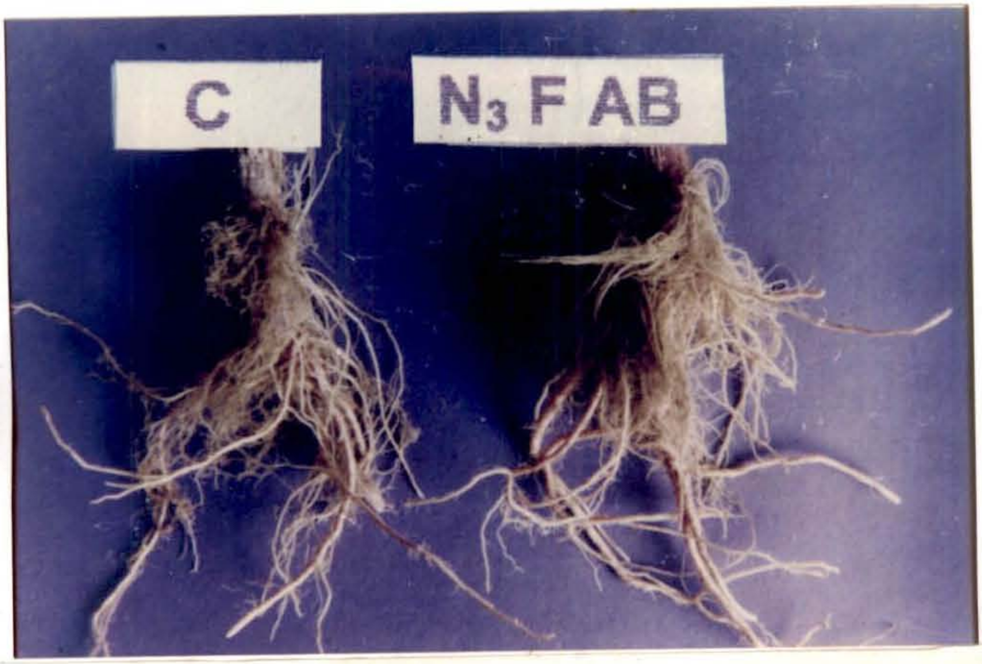


Plate 1 Effect of *Azotobacter* inoculation on root biomass production in amaranthus under pot culture condition.

N_3 - 75 % of fertilizer Nitrogen

F[redacted] - Farm Yard Manure

AB - *Azotobacter*

Brinjal

Effect of *Azospirillum* inoculation

Plant height

There were significant differences among the treatments on plant height. It was maximum (48.7 cm) in the treatment combination N_4 FYM+AS as compared to 35.7 cm in control (Table 6; Plate. 2). The plant heights in N_3 FYM+AS (47.7 cm), N_1 FYM+ AS (41.3 cm), N_2 FYM+AS (40.3 cm), N_1 VEC+AS (40.3 cm) and N_2 VEC+AS (39.0 cm) were statistically on par with the best treatment. A similar result was also obtained in N_2 FYM-AS.

Number of branches

There were significant difference among the treatments in number of branches formed in brinjal (Table 6). Maximum number (4.7) was in N_2 FYM-AS. None of the other treatments were statistically on par with the above treatment.

Flowering time

The onset of flowering in brinjal was not significantly affected by different treatments (Table 6). However, earlier flowering to the extent of 37.7 DAT was observed in N_4VEC+AS treatment.

Table 6. Effect of *Azospirillum* inoculation on plant growth in brinjal (60 DAT) under pot culture condition.

Treatments	Plant height (cm)	Number of branches	Flowering time (DAT)
N_1 FYM + AS	41.3	3.3	43.0
N_2 FYM + AS	40.3	3.3	41.0
N_3 FYM + AS	47.7	3.3	44.0
N_4 FYM + AS	48.7	3.0	44.3
N_1 VEC + AS	40.3	2.3	43.7
N_2 VEC + AS	39.0	2.3	45.0
N_3 VEC + AS	33.0	2.3	41.0
N_4 VEC + AS	32.7	2.0	37.7
N_1 FYM - AS	35.0	2.7	41.0
N_2 FYM - AS	40.7	4.7	42.0
N_3 FYM - AS	34.7	3.3	45.7
N_4 FYM - AS	35.7	2.3	41.3
CD (0.05)	10.0	1.3	NS

Root biomass

Root biomass of 7.2 g was significantly high in N_4 FYM+AS (Table 7; Fig. 2). The root biomass production in treatments such as N_3 FYM+AS (6.7 g), N_2 FYM-AS (5.6) and N_1 VEC+AS (6.0 g) were statistically on par with the best treatment.

Number of fruits and yield

The number of fruits formed (6.0) and the net yield (158.1 g) were significantly high in N_3 FYM+AS (Table 7). The number of fruits in N_2 FYM+AS formed and yield in N_2 FYM-AS were statistically on par with the above treatment.

Effect of *Azotobacter* inoculation

Plant height

There were significant differences between treatments on plant height in brinjal. It was maximum (52.0 cm) in N_2 FYM+AB (Table 8; Plate. 3). Plant height in N_4 FYM+AB (45.0 cm) was also statistically on par with the above treatment.

Table 7. Effect of *Azospirillum* inoculation on root biomass and yield of brinjal under pot culture condition.

Treatments	Root biomass (g)	Number of fruits	Yield (g)
N_1 FYM + AS	3.8	2.3	72.3
N_2 FYM + AS	3.4	4.7	73.8
N_3 FYM + AS	6.7	6.0	158.1
N_4 FYM + AS	7.2	3.7	81.1
N_1 VEC + AS	6.0	2.3	61.4
N_2 VEC + AS	5.1	1.3	52.8
N_3 VEC + AS	5.1	3.0	75.4
N_4 VEC + AS	5.0	2.7	81.9
N_1 FYM - AS	3.6	2.1	45.0
N_2 FYM - AS	5.6	3.3	120.3
N_3 FYM - AS	3.7	3.0	95.7
N_4 FYM - AS	4.5	2.3	60.4
CD (0.05)	1.9	2.1	53.2

Plate 2

Effect of *Azospirillum* inoculation on plant growth in brinjal under pot culture condition

C - Control

N_3 - 75 percent fertilizer nitrogen

F - Farm Yard Manure

AS - *Azospirillum*

Plate 3

Effect of *Azotobacter* inoculation on plant growth in brinjal under pot culture condition.

C - Control

N_3 - 75 percent fertilizer nitrogen

F - Farm Yard Manure

AB - *Azotobacter*


C
N3 F AS


C
N3 F AB

Table 8. Effect of *Azotobacter* inoculation on plant growth in brinjal (60 DAT) under pot culture condition.

Treatments	Plant height (cm)	Number of branches	Flowering time (DAT)
N_1 FYM + AB	35.0	3.3	40.7
N_2 FYM + AB	52.0	5.3	42.3
N_3 FYM + AB	38.3	4.0	43.0
N_4 FYM + AB	45.0	3.7	40.7
N_1 VEC + AB	30.7	1.3	44.3
N_2 VEC + AB	32.7	1.3	43.3
N_3 VEC + AB	36.3	2.7	44.0
N_4 VEC + AB	32.0	1.3	45.0
N_1 FYM - AB	35.0	2.7	41.0
N_2 FYM - AB	40.7	4.7	42.0
N_3 FYM - AB	34.7	3.3	45.7
N_4 FYM - AB	35.7	2.3	41.3
CD (0.05)	10.8	3.2	NS

Table 9. Effect of *Azotobacter* inoculation on root biomass and yield of brinjal under pot culture condition.

Treatments	Root biomass (g)	Number of fruits	Yield (g)
N_1 FYM + AB	4.8	2.3	58.9
N_2 FYM + AB	6.3	4.3	69.6
N_3 FYM + AB	7.7	4.0	118.4
N_4 FYM + AB	7.9	4.3	90.0
N_1 VEC + AB	5.3	1.3	40.8
N_2 VEC + AB	5.6	1.3	66.5
N_3 VEC + AB	4.0	1.3	61.4
N_4 VEC + AB	6.6	3.3	49.9
N_1 FYM - AB	3.6	2.7	45.0
N_2 FYM - AB	5.6	3.3	120.3
N_3 FYM - AB	3.7	3.0	95.7
N_4 FYM - AB	4.5	2.3	60.4
CD (0.05)	2.1	2.1	NS

Number of branches

Maximum number of branches (5.3) was recorded in N_2 FYM+AB (Table 8) followed by N_2 FYM-AB (4.7)

Flowering time

There were no significant differences between treatments on the onset of flowering in brinjal (Table 8).

Root biomass

Root biomass of 7.9 g was found to be significantly high in N_4 FYM+AB treatment (Table 9; Fig. 2). The increase in root biomass in N_2 FYM+AB (6.3 g), N_3 FYM+AB (7.7 g) and N_4 VEC+AB (6.6 g) were statistically on par with above treatment.

Number of fruits and yield

The number of fruits formed (4.3) was maximum in N_2 FYM+AB and N_4 FYM+AB treatments (Table 9). But this was not significantly different from control.

There were no significant differences between treatments in net yield of brinjal. Maximum yield of 120.3 g was in N_2 FYM-AB (Table 9) followed by 118.4 g in N_3 FYM+AB.

Fig. 2 Effect of organic manure and biofertilizer application on root biomass production in brinjal

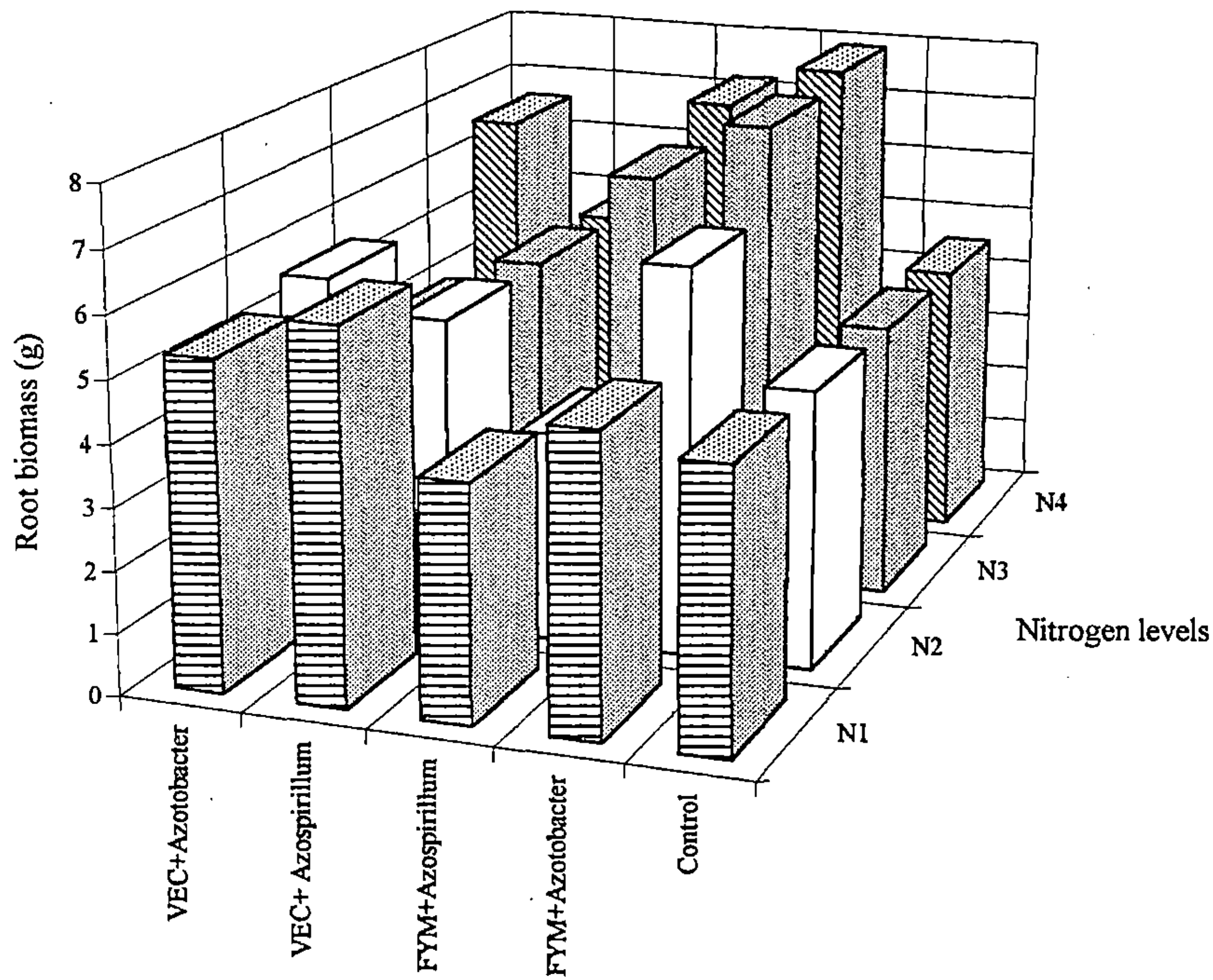


Table 10 Effect of organic manure and biofertilizer application on growth and yield of brinjal

Treatments	Plant height (cm)	Number of branches	Root biomass (g)	Number of fruits	Yield (g)
FYM	41.6	3.6	6.0	6.0	90.3
VEC	35.4	2.1	5.3	5.3	61.3
CD (0.05)	3.6	0.8	NS	NS	19.8
AS	37.4	2.8	5.3	5.3	82.1
AB	39.6	2.9	6.0	6.0	69.5
CD (0.05)	NS	NS	NS	NS	NS

Effect of organic manure and biofertilizer application on growth and yield of brinjal

In general, plant height, number of branches and yield were significantly high in pots were FYM was used as organic manure (Table 10). However , significant yield differnce was not recorded in treatments receiving *Azospirillum* and *Azotobacter*.

Chilli

Effect of *Azospirillum* inoculation

Plant height

There were no significant differences between treatments on plant height in chilli (Table 11; Plate. 4). It was maximum (49.7 cm) in N_3 FYM+AS.

Number of branches

Significant differences were recorded in the number of branches formed in chilli among the different treatments. The number of branches formed was maximum in N_4 VEC+AS (26.0) (Table 11). But it was not significantly superior to control treatment. The number of branches formed in most of the other treatments except N_3 FYM+AS, N_1 VEC+AS,

Table 11. Effect of *Azospirillum* inoculation on plant growth in Chilli (60 DAT) under pot culture condition.

Treatments	Plant height (cm)	Number of branches	Flowering time (DAT)
N_1 FYM + AS	42.0	24.3	39.3
N_2 FYM + AS	40.0	20.0	39.0
N_3 FYM + AS	49.7	15.0	39.3
N_4 FYM + AS	47.7	18.0	41.7
N_1 VEC + AS	26.7	8.0	41.7
N_2 VEC + AS	40.3	15.0	39.3
N_3 VEC + AS	44.0	14.7	39.0
N_4 VEC + AS	46.7	26.0	39.7
N_1 FYM - AS	42.0	21.7	39.0
N_2 FYM - AS	39.0	25.7	38.7
N_3 FYM - AS	41.7	25.0	41.3
N_4 FYM - AS	38.7	17.7	41.3
CD (0.05)	NS	9.6	NS

N_2 VEC+AS and N_3 VEC+AS were statistically on par with the best treatment.

Flowering time

There were no significant differences between treatments on the onset of flowering in chilli (Table 11). Earlier flowering (38.7 DAT) was observed in N_2 FYM-AS treatment. Maximum variation among the treatments was only 2.6 days.

Root biomass

Root biomass of 9.6 g was significantly high in N_4 FYM+AS as compared to only 3.0 g in the control (Table 12; Fig. 3). The treatment effect in N_4 VEC+AS (9.3 g) was statistically on par with above treatment.

Number of fruits and yield

The number of fruits formed (27.3) and net yield (135.6 g) were significantly high in N_4 VEC+AS (Table 12). The number of fruits formed in N_2 FYM+AS (17.7) and N_4 FYM+AS (18.7) and yield in N_4 FYM+AS (88.7) and N_3 VEC+AS (90.2) were statistically on par with the best treatment. A similar result was also obtained in N_2 FYM-AS and N_3 FYM-AS treatments.

Table 12. Effect of *Azospirillum* inoculation on root biomass and yield of Chilli under pot culture condition.

Treatments	Root biomass (g)	Number of fruits	Yield (g)
N_1 FYM + AS	4.8	16.7	68.6
N_2 FYM + AS	4.1	17.7	70.5
N_3 FYM + AS	6.7	17.0	66.4
N_4 FYM + AS	9.6	18.7	88.7
N_1 VEC + AS	4.3	9.0	39.4
N_2 VEC + AS	3.7	10.7	39.4
N_3 VEC + AS	4.8	12.7	90.2
N_4 VEC + AS	9.3	27.3	135.6
N_1 FYM - AS	3.9	12.3	67.5
N_2 FYM - AS	5.6	10.7	93.4
N_3 FYM - AS	4.4	19.7	93.5
N_4 FYM - AS	3.0	11.7	39.9
CD (0.05)	2.7	9.8	50.0

Plate 4 Effect of *Azospirillum* inoculation on plant growth in chilli under pot culture condition.

N_4 - 100 % of fertilizer nitrogen

V[redacted] - Vermicompost

AS - *Azospirillum*

Table 13. Effect of *Azotobacter* inoculation on plant growth in Chilli (60 DAT) under pot culture condition.

Treatments	Plant height (cm)	Number of branches	Flowering time (DAT)
N_1 FYM + AB	36.3	27.3	39.7
N_2 FYM + AB	47.0	31.3	41.7
N_3 FYM + AB	36.7	14.7	37.7
N_4 FYM + AB	51.0	20.7	41.3
N_1 VEC + AB	39.0	13.7	42.0
N_2 VEC + AB	33.3	14.3	38.7
N_3 VEC + AB	33.7	16.7	41.7
N_4 VEC + AB	52.7	21.0	41.0
N_1 FYM - AB	42.0	21.7	39.0
N_2 FYM - AB	39.0	25.7	38.7
N_3 FYM - AB	41.7	25.0	41.3
N_4 FYM - AB	38.7	17.7	41.3
CD (0.05)	NS	10.7	NS

Effect of *Azotobacter* inoculation

Plant height

There were no significant differences between treatments on plant height in chilli (Table 13). Maximum plant height of 52.7 cm was in N_4 VEC+AB treatment.

Number of branches

The number of branches formed (31.3) was significantly high in N_2 FYM+AB treatment (Table 13). However, this was on par with the treatments N_1 FYM+AB (27.3), N_4 FYM+AB (20.7) and N_4 VEC+AB (21.0).

Flowering time

There were no significant differences between treatments on the onset of flowering in chilli (Table 13). When the chilli plants in the N_3 FYM+AB treatment flowered 37.7 DAT, therein N_1VEC+AB took 42 days for flowering.

Root biomass

The root biomass of was significantly high in N_4 FYM+AB (9.6 g) (Table 14; Fig. 3).

Number of fruits and yield

The number of fruits formed 21.0 was significantly high in N_4 VEC+AB treatment. The treatment effect in N_1 FYM+AB (19.0), N_2 FYM+AB (14.0), N_4 FYM+AB (13.0) and N_1 VEC+AB (14.3) were statistically on par with the best treatment. A similar result was also obtained in N_3 FYM-AB treatment. However, there were no significant differences between treatments on yield in chilli (Table 14). The maximum yield of 107.6 g was obtained in N_4 VEC+AB treatment.

Effect of organic manure and biofertilizer application on growth and yield of chilli

In general, the number of branches formed and root biomass were significantly high with the use of FYM as organic manure (Table 15). However, no significant differences were observed between *Azospirillum* and *Azotobacter* treatments.

Field trial

Amaranthus

The best treatment combinations from pot trials viz., N_3 FYM+AS and N_3 FYM+AB along with corresponding vermicompost treatment and the additional treatment with vermicompost applied at the rate of 50

Table 14. Effect of *Azotobacter* inoculation on root biomass and yield of Chilli under pot culture condition.

Treatments	Root biomass (g)	Number of fruits	Yield (g)
N_1 FYM + AB	2.9	19.0	82.2
N_2 FYM + AB	4.1	14.0	78.4
N_3 FYM + AB	6.4	4.3	26.5
N_4 FYM + AB	9.6	13.0	58.2
N_1 VEC + AB	3.8	14.3	65.2
N_2 VEC + AB	4.0	12.3	62.3
N_3 VEC + AB	5.5	12.0	77.8
N_4 VEC + AB	4.0	21.0	107.6
N_1 FYM - AB	3.9	12.3	67.8
N_2 FYM - AB	5.6	10.7	93.4
N_3 FYM - AB	4.4	19.7	93.5
N_4 FYM - AB	3.0	11.7	39.9
CD (0.05)	1.8	8.3	NS

Fig. 3 Effect of organic manure and biofertilizer application on root biomass production in chilli

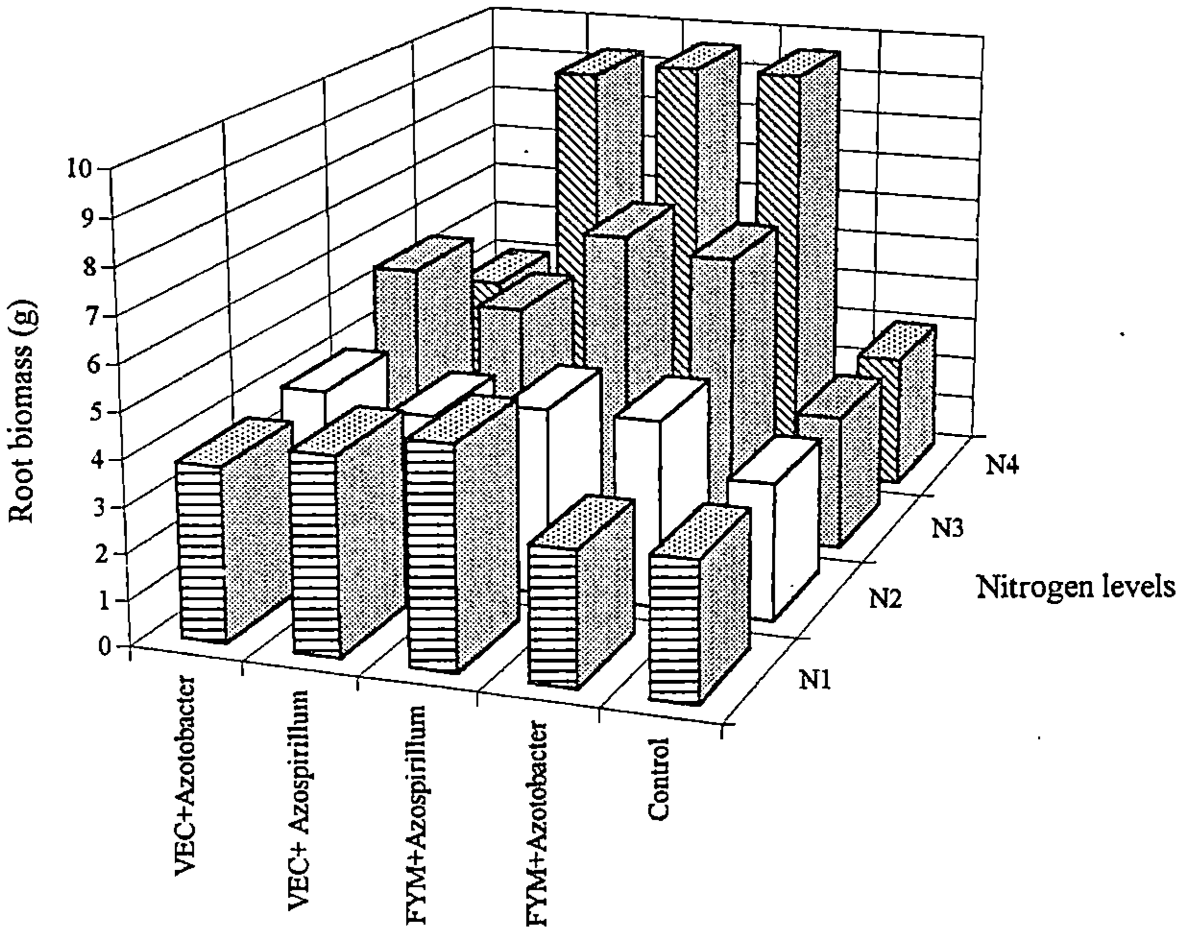


Table 15 Effect of organic manure and biofertilizer application on growth and yield of chilli

Treatments	Plant height (cm)	Number of branches	Root biomass (g)	Number of fruits	Yield (g)
FYM	43.8	21.4	6.0	15.0	67.4
VEC	39.5	16.2	4.9	14.9	77.2
CD (0.05)	NS	3.8	0.9	NS	NS
AS	42.1	17.6	5.9	16.2	74.8
AB	41.2	20.0	5.0	13.8	69.8
CD (0.05)	NS	NS	NS	NS	NS

percent of FYM were evaluated under field condition. Package of Practices recommendation of Kerala Agricultural University (1993) for amaranthus (N_4 FYM-BF) served as control.

Effect of application of organic manures and biofertilizers on growth and yield of amaranthus

Plant height

This was significantly high in N_3 FYM+AB (95.7 cm) as compared to 79.5 cm in the control (Table 16). Plant height in most of the remaining treatments except in N_3 VECH+AB, N_4 FYM-BF and N_4 VECH-BF were statistically on par with the best treatment.

Number of branches

There were no significant differences between treatments on the number of branches formed in amaranthus (Table 16). Maximum number of branches (9.4) were in N_4 VECF-BF treatment.

Flowering time

There were no significant differences between treatments on the on set of flowering in amaranthus. The delay was maximum in N3 VECH+AB (57.7 DAT) treatment (Table 16).

Table 16. Effect of organic manure and biofertilizer application on plant growth in amaranthus (60 DAT) under field condition.

Treatments	Plant height (cm)	Number of branches	Flowering time (DAT)
N_3 FYM + AS	90.9	8.7	55.0
N_3 FYM + AB	95.7	9.3	55.7
N_3 VECF + AS	88.6	8.0	53.7
N_3 VECF + AB	89.9	7.8	56.7
N_3 VECH + AS	86.1	8.2	52.0
N_3 VECH + AB	83.8	7.7	57.7
N_4 FYM - BF	79.5	8.7	55.7
N_4 VECF - BF	90.7	9.4	52.7
N_4 VECH - BF	71.7	8.3	56.0
CD (0.05)	10.5	NS	NS

Plate. 5

Effect of *Azospirillum* inoculation on plant growth in amaranthus under field condition.

C - Control

N_3 - 75 percent fertilizer nitrogen

V - Vermicompost

AS - *Azospirillum*

Plate. 6

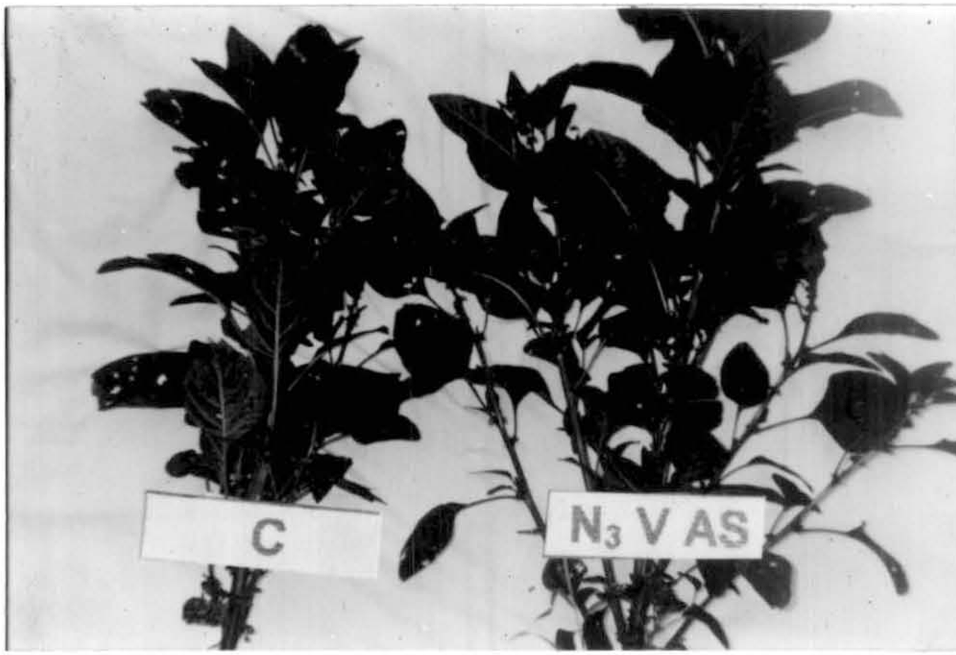
Effect of *Azotobacter* inoculation on plant growth in amaranthus under field condition.

C - Control

N_3 - 75 percent fertilizer nitrogen

F - Farm Yard Manure

AB - *Azotobacter*


C
N_3 V AS


C
N_3 F AB

Leaf area index and yield

There were no significant differences between treatments for leaf area index and yield in amaranthus. Maximum leaf area index and yield were in N_3 FYM+AB treatment (Table 17; Fig 4, 5 and 6; Plate 5 and 6). These were 23.9 and 8.3 kg respectively.

Estimation of microbial population

There were significant differences between treatments in microbial population (Table 18). Total count of bacteria and fungi were high in N_3 FYM+AS treatment. These were 17 x 10^6 and 13.7 x 10^4 respectively. However, there were no significant differences between treatments in the number of actinomycetes. The survival of *Azospirillum* and *Azotobacter* were more in N3 VECF+AS and N3 VECF+AB treatments. These were 12.3 x 10^3 and 15.7 x 10^3 respectively.

Brinjal

The best treatment combinations from pot trials, N_3 FYM+AS and N_3 FYM+AB, N_2 VECF+AB and N_4 VECF+AS were selected for field trial. Corresponding to the best vermicompost treatments two treatments with 50 percent of vermicompost were also included

Table 17. Effect of organic manure and biofertilizer application on leaf area index and yield in amaranthus under field condition.

Treatments	Leaf area Index	Yield per plot (kg)
N_3 FYM + AS	19.8	6.7
N_3 FYM + AB	23.9	8.3
N_3 VECF + AS	19.4	7.3
N_3 VECF + AB	18.6	6.2
N_3 VECH + AS	16.1	5.7
N_3 VECH + AB	18.5	6.3
N_4 FYM - BF	17.0	6.6
N_4 VECF - BF	21.9	6.3
N_4 VECH - BF	18.3	5.7
CD (0.05)	NS	NS

Fig 4 Effect of organic manure and biofertilizer application on plant height and yield in amaranthus under field condition

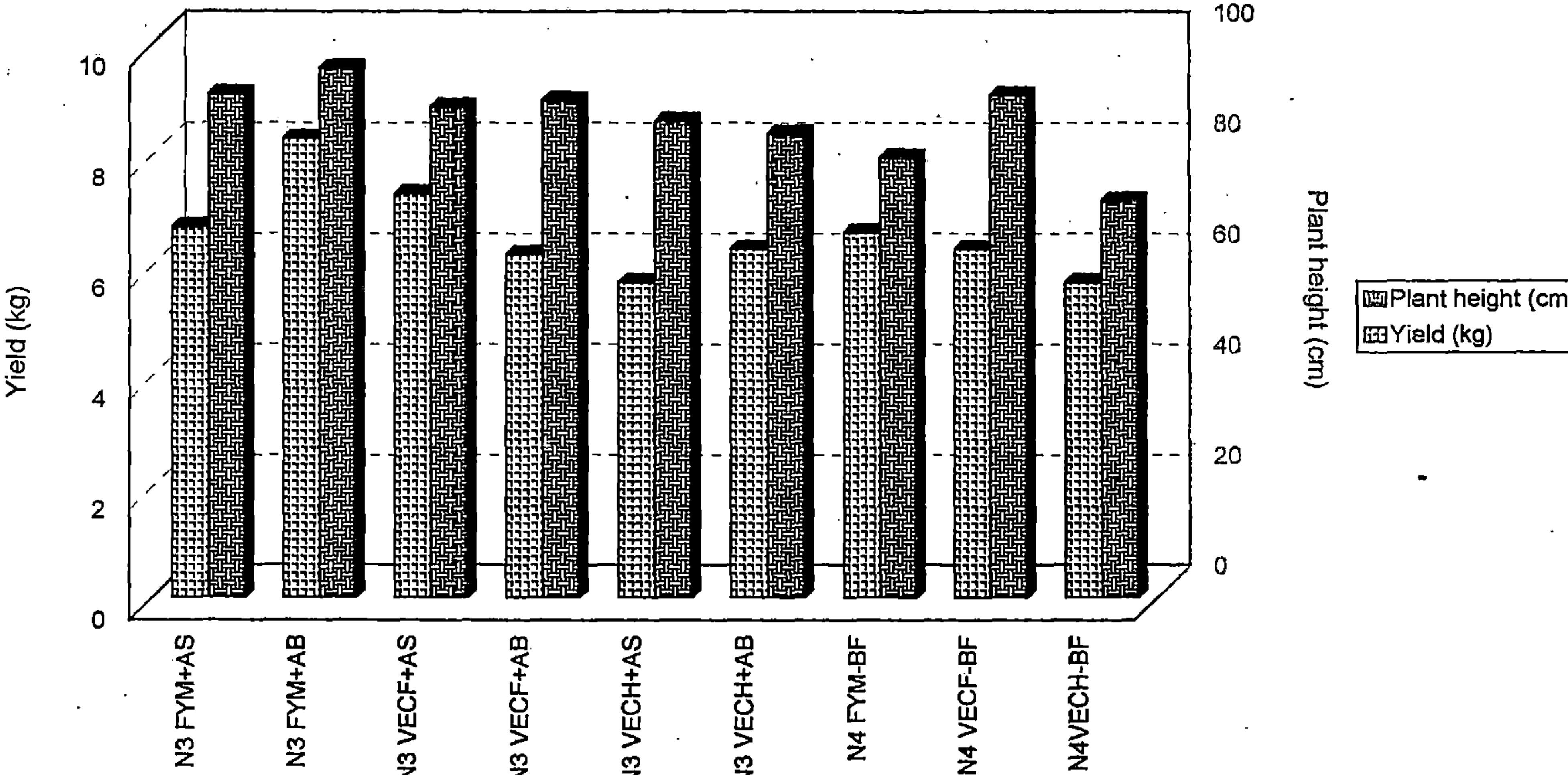


Fig 5 Effect of organic manure and biofertilizer application on number of branches and yield of amaranthus under field conditions

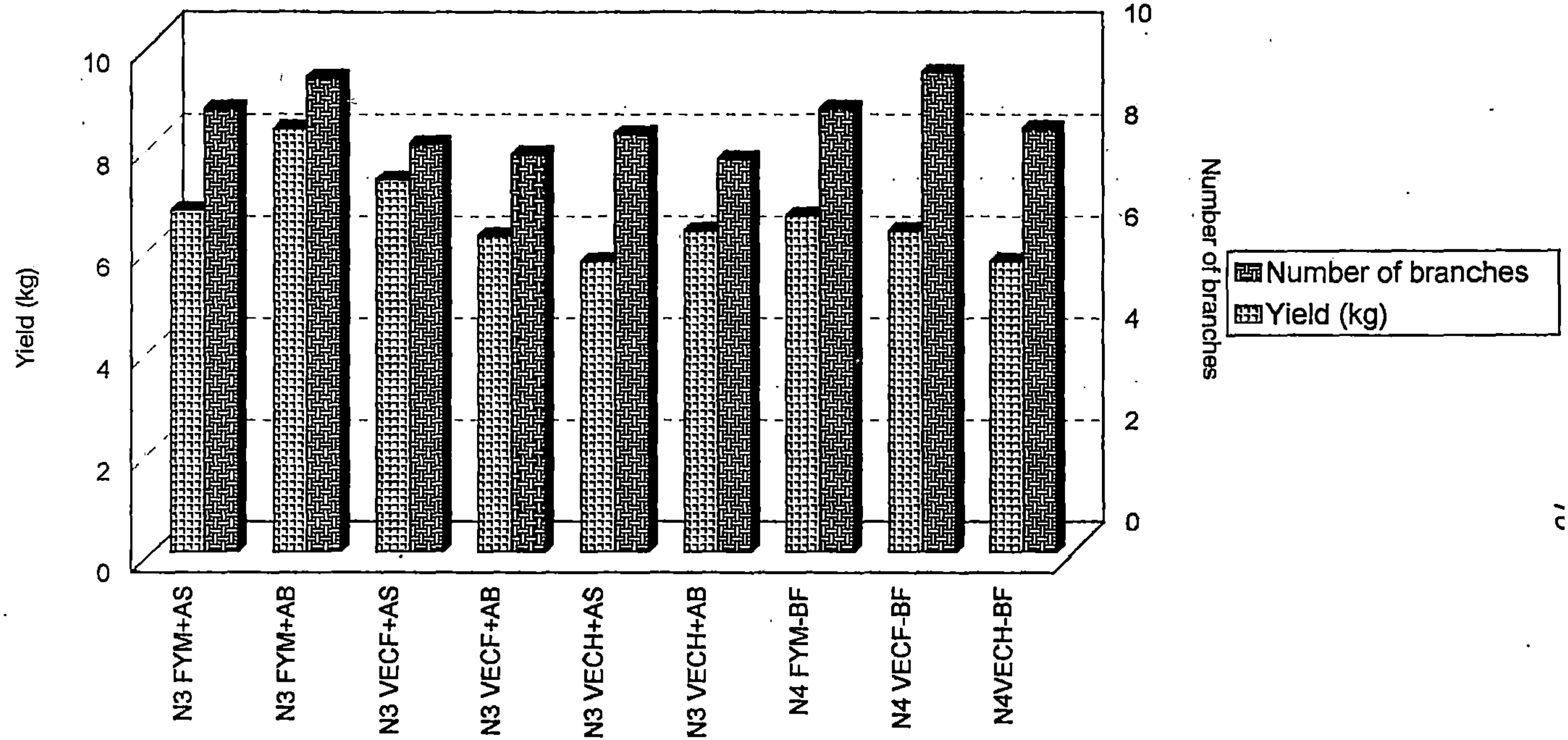


Fig 6 Effect of organic manure and biofertilizer application on leaf area and yield in amaranthus under field condition

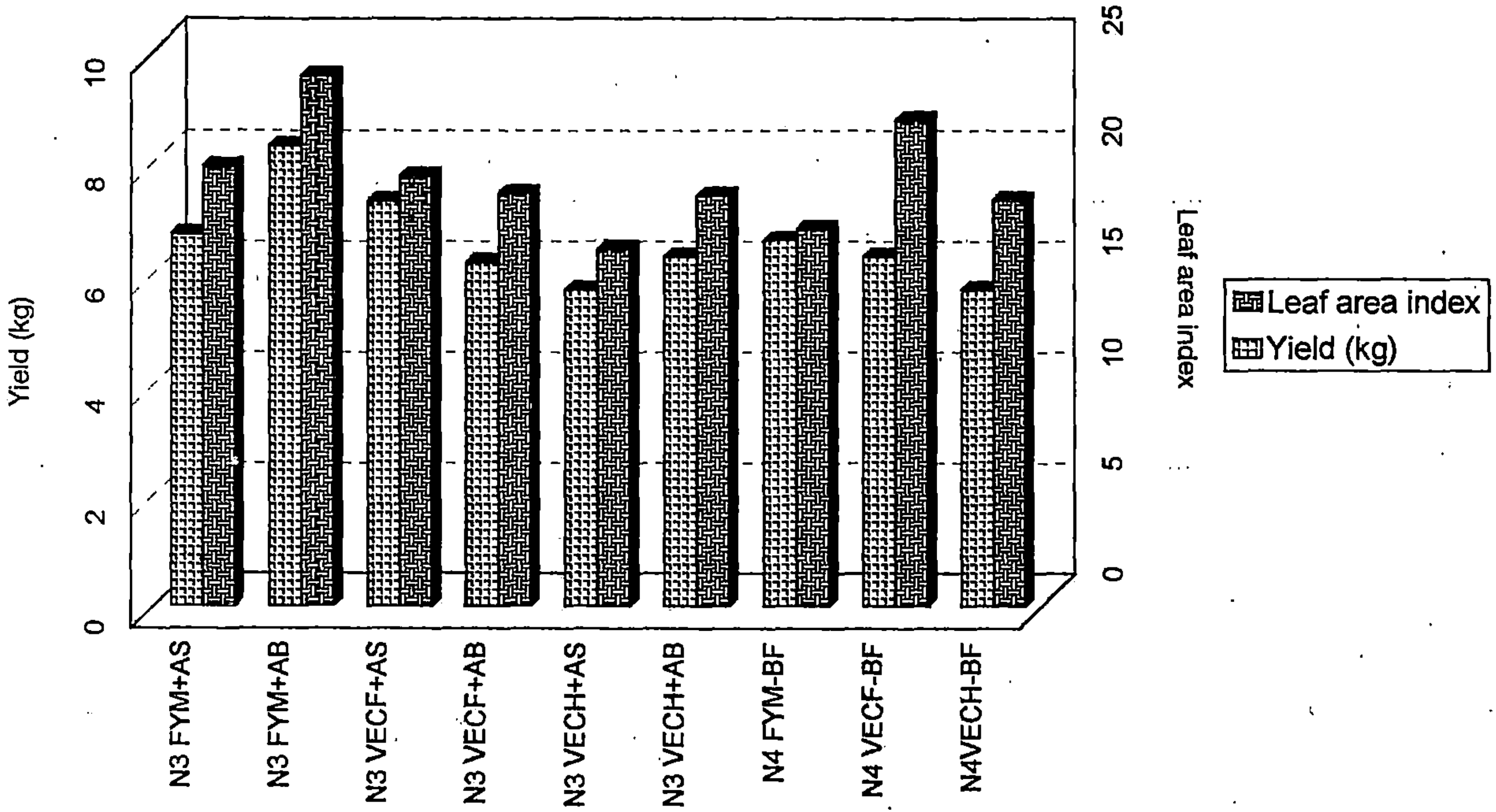


Table 18. Estimation of microbial population before and after cultivation of amaranthus

A. Before cultivation

	Bacteria (10^6)	Fungi (10^4)	Actinomy -cetes (10^4)	Azospirillum (10^3)	Azotobacter (10^3)
	6.0	4.0	9.0	-	3.0
B. After cultivation					
N_3 FYM + AS	17.0	13.7	19.7	10.3	7.3
N_3 FYM + AB	11.7	9.7	17.0	5.3	12.0
N_3 VECF + AS	11.7	7.7	21.7	12.3	8.3
N_3 VECF + AB	9.3	6.0	20.0	5.7	15.7
N_3 VECH + AS	10.7	11.7	17.7	8.7	7.3
N_3 VECH + AB	7.3	9.7	19.3	4.3	10.3
N_4 FYM - BF	13.0	8.3	15.3	4.0	5.7
N_4 VECF - BF	10.7	10.3	21.0	6.3	8.3
N_4 VECH - BF	7.3	9.0	18.0	4.0	7.7
CD (0.05)	2.7	2.7	NS	3.0	2.5

Effect of application of organic manures and biofertilizers on growth and yield of brinjal

Plant height

There were no significant differences between treatments on plant height in brinjal (Table 19). The maximum height of 67.5 cm was in the treatment combination of N_3 FYM+AB.

Number of branches

There were no significant differences between treatments on number of branches formed in brinjal (Table 19). Maximum number of branches (9.1) were in N_3 FYM+AB treatment.

Flowering time

The onset of flowering in brinjal was not significantly different in various treatments (Table 19). Early flowering (36.0 DAT) was observed in N_3 FYM+AS, N_4 VECF+AS and N_4 VECH+AS treatments.

Number of fruits

There were no significant differences between treatments on number of fruits formed in brinjal (Table 20). Maximum number of fruits (7.1) were in N_3 FYM+AB treatment.

Table 19. Effect of organic manure and biofertilizer application on plant growth in brinjal (60 DAT) under field condition.

Treatments	Plant height (cm)	Number of branches	Flowering time (DAT)
N_3 FYM + AS	55.0	7.7	36.0
N_3 FYM + AB	67.5	9.1	38.0
N_2 VECF + AB	57.9	6.5	37.0
N_2 VECH + AB	54.6	7.6	41.0
N_4 VECF + AS	54.7	6.9	36.0
N_4 VECH + AS	55.0	7.6	36.0
N_4 FYM - BF	56.5	6.8	40.3
N_4 VECF - BF	58.4	8.2	43.0
N_4 VECH - BF	53.7	7.4	43.0
CD (0.05)	NS	NS	NS

Table 20. Effect of organic manure and biofertilizer application on yield of brinjal under field condition.

Treatments	Number of fruits	Yield per plot (kg)
N_3 FYM + AS	4.5	2.5
N_3 FYM + AB	7.1	3.6
N_2 VECF + AB	5.9	2.6
N_2 VECH + AB	4.8	2.2
N_4 VECF + AS	5.5	3.3
N_4 VECH + AS	5.5	3.3
N_4 FYM - BF	3.7	2.0
N_4 VECF - BF	5.5	3.0
N_4 VECH - BF	3.5	1.3
CD (0.05)	NS	NS

Fig 7 Effect of organic manure and biofertilizer application on plant height and yield of brinjal under field conditions

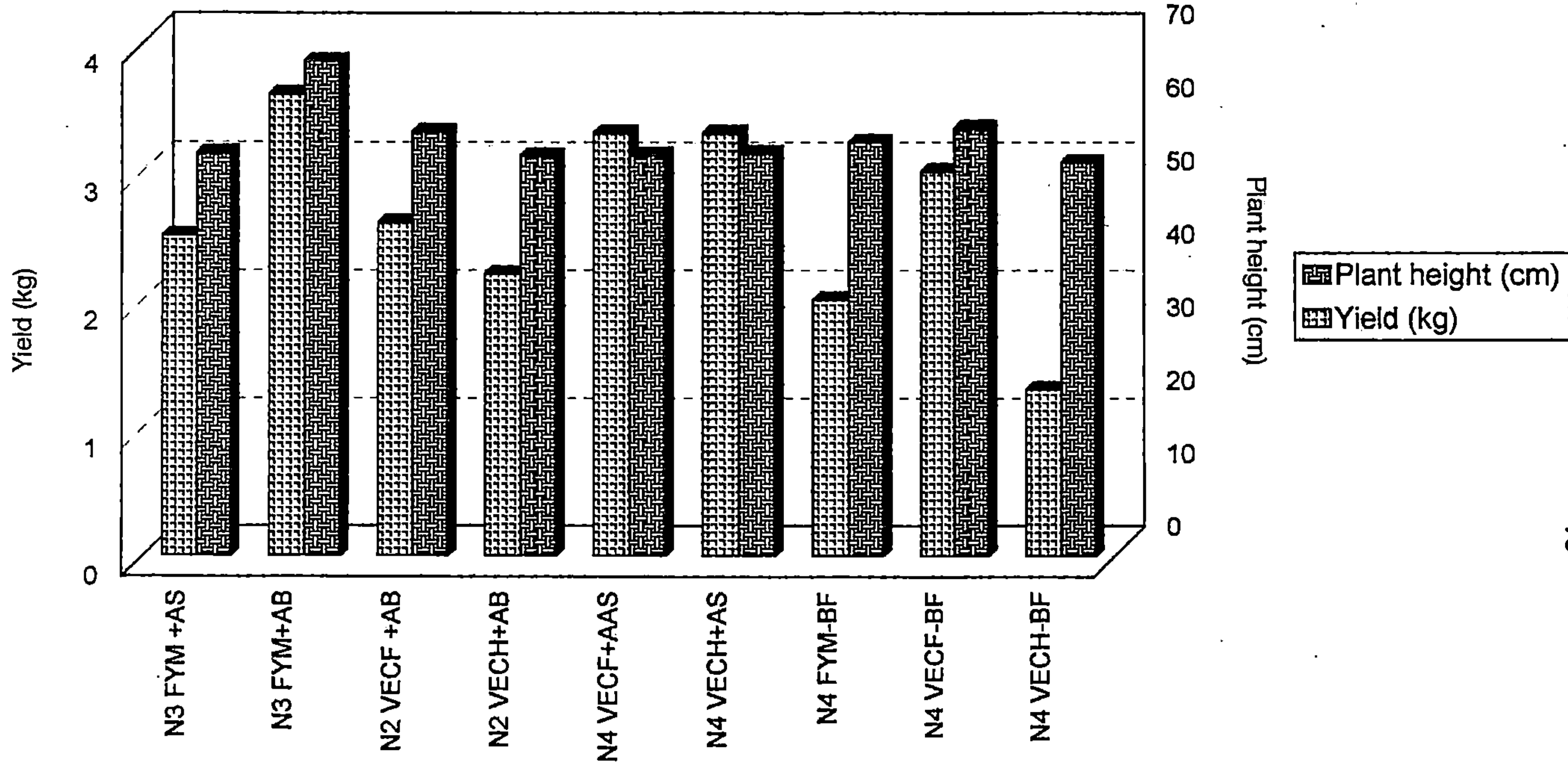
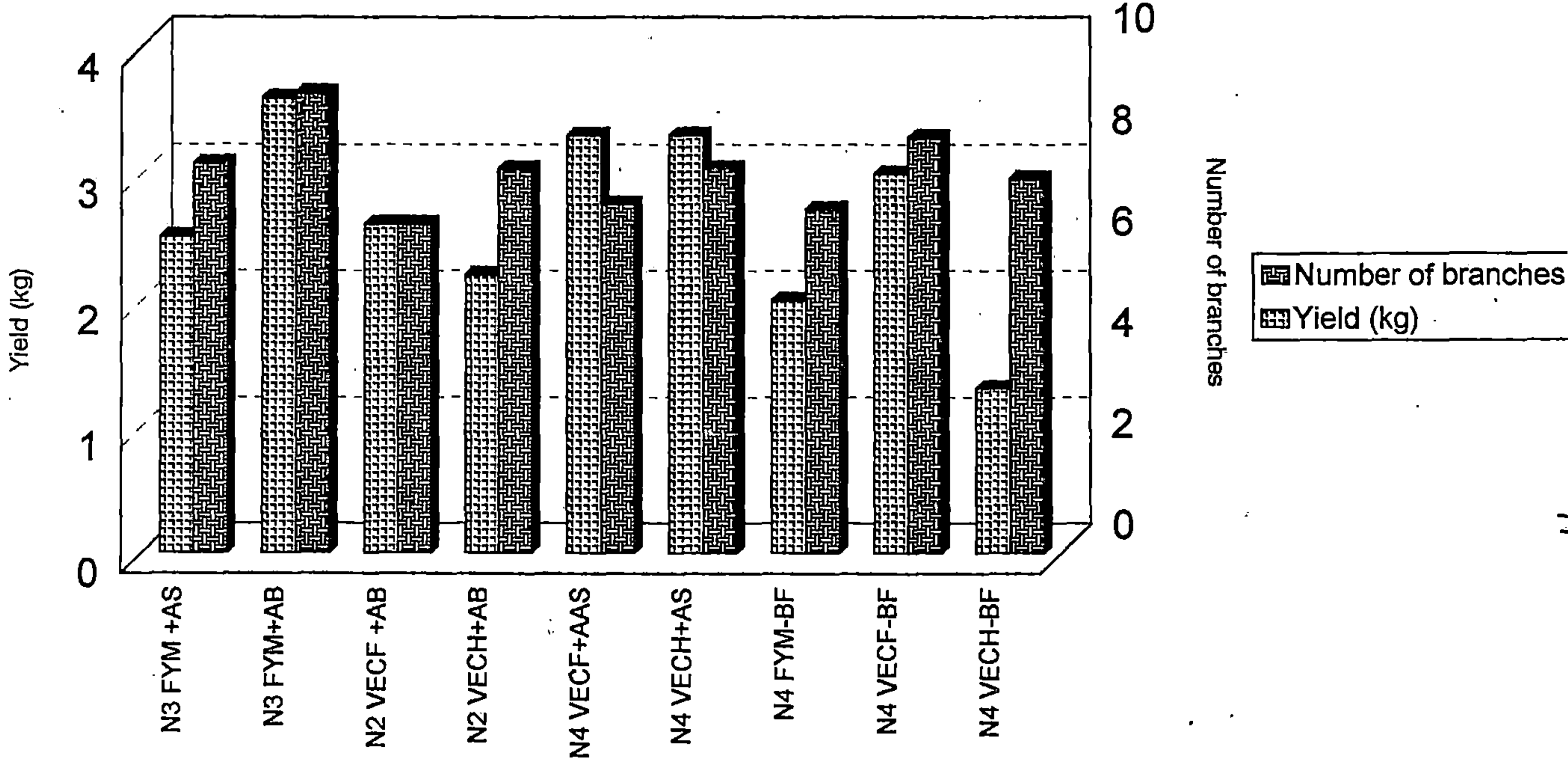


Fig 8 Effect of organic manure and biofertilizer application on number of branches and yield of brinjal under field condition



Yield

There were no significant differences between treatments on yield of brinjal (Table 20; Fig. 7 and 8). Maximum yield of 3.6 kg was obtained in the treatment combination of N_3 FYM+AB.

Estimation of microbial population

There were significant differences between treatments in microbial population (Table 21). The total count of fungi, actinomycetes, *Azospirillum* and *Azotobacter* after harvest were significantly high in N_4 VECH+AS for fungi (12.7×10^4), N_2 VECF+AB for actenomycetes (20.0×10^4) and *Azotobacter* (10.0×10^3) and N_4 VECF+AS for *Azospirillum* (8.0×10^3). However there were no significant differences between treatments for total bacteria which was maximum (13.0×10^6) in the treatment combination of N_4 VECF+AS.

Keeping quality of fruits

There were significant differences between treatments in improving the keeping quality of brinjal due to organic manure and biofertilizer application. It was maximum (6.7 days) for fruits harvested from combination of N_2 VECF+AB treatment (Table 22; Fig. 9). The treatment

Table 21. Estimation of microbial population before and after cultivation of brinjal under field condition.

A. Before cultivation

	Bacteria (10^6)	Fungi (10^4)	Actinomycetes (10^4)	Azospirillum (10^3)	Azotobacter (10^3)
	6.0	4.0	9.0	-	3.0

B. After cultivation

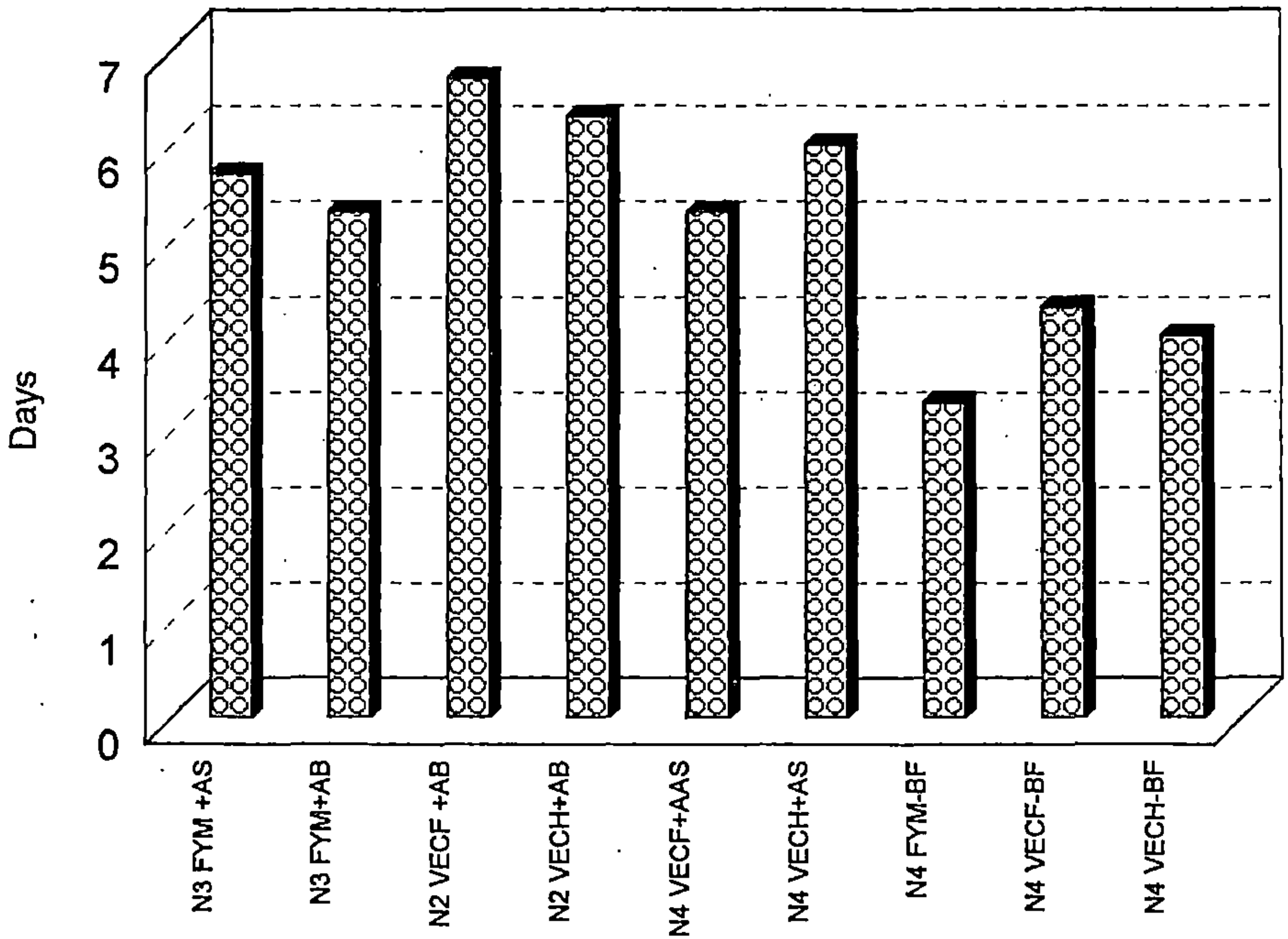
N_3 FYM + AS	12.7	12.0	15.7	5.3	3.7
N_3 FYM + AB	10.3	11.7	12.3	6.3	8.0
N_2 VECF + AB	8.3	11.0	20.0	4.3	10.0
N_2 VECH + AB	9.3	11.7	16.7	4.0	7.3
N_4 VECF + AS	13.0	9.7	14.7	8.0	6.3
N_4 VECH + AS	11.0	12.7	13.3	6.0	7.7
N_4 FYM - BF	11.3	7.0	14.3	2.3	3.7
N_4 VECF - BF	11.7	8.3	18.3	3.3	5.3
N_4 VECH - BF	10.3	10.0	14.3	2.7	3.7
CD (0.05)	NS	2.1	3.1	2.1	1.9

Table 22. Effect of organic manure and biofertilizer application on keeping quality of brinjal

Treatment	Keeping quality*
N_3 FYM + AS	5.7
N_3 FYM + AB	5.3
N_2 VECF + AB	6.7
N_2 VECH + AB	6.3
N_4 VECF + AS	5.3
N_4 VECH + AS	6.0
N_4 FYM - BF	3.3
N_4 VECF - BF	4.3
N_4 VECH - BF	4.0
CD (0.05)	1.3

* Number of days from harvest.

Fig 9 Effect of organic manure and biofertilizer application on keeping quality of brinjal fruits



effect in N_3FYM+AS, N_2 VECH+AB and N_4 VECH+AS were statistically on par with best treatment.

Chilli

The best treatments from pot trials such as N_4 FYM+AS and N_1 FYM+AB among FYM treatments and N_4 VEC+AS and N_4 VEC+AB from vermicompost treatments along with the corresponding 50 percent dosage of vermicompost treatments were selected for field trial.

Effect of application of organic manures and biofertilizers on growth and yield of chilli

Plant height

There were no significant differences between treatments on plant height in chilli (Table 23). It was maximum (42.6 cm) in N_4 VECF+AS treatment.

Number of branches

There were no significant differences between treatments on the number of branches formed in chilli (Table 23). It was maximum (6.5) in N_4 FYM-BF followed by (6.0) in N_4 VEC+AB treatment.

Table 23. Effect of organic manure and biofertilizer application on plant growth in Chilli (60 DAT) under field condition.

Treatments	Plant height (cm)	Number of branches	Flowering time (DAT)
N_1 FYM + AS	35.3	5.9	23.7
N_1 FYM + AB	39.9	5.7	25.3
N_4 FYM + AS	42.5	5.5	29.7
N_4 VECF + AS	42.6	5.7	28.3
N_4 VECF + AB	40.6	6.0	26.7
N_4 VECH + AS	34.5	5.5	36.0
N_4 VECH + AB	35.7	4.9	31.0
N_4 FYM - BF	40.1	6.5	28.3
N_4 VECF - BF	39.3	5.3	25.7
N_4 VECH - BF	36.1	6.2	25.7
CD (0.05)	NS	NS	NS

Table 24. Effect of organic manure and biofertilizer application on yield of Chilli under field condition.

Treatments	Number of fruits	Yield per plot (kg)
N_1 FYM + AS	44.9	2.6
N_1 FYM + AB	45.5	2.6
N_4 FYM + AS	41.4	2.7
N_4 VECF + AS	39.8	3.4
N_4 VECF + AB	34.4	2.8
N_4 VECH + AS	50.1	2.8
N_4 VECH + AB	40.1	3.0
N_4 FYM - BF	38.2	2.5
N_4 VECF - BF	48.3	3.0
N_4 VECH - BF	49.2	2.5
CD (0.05)	NS	NS

Fig 10 Effect of organic manure and biofertilizer application on plant height and yield of chilli under field condition

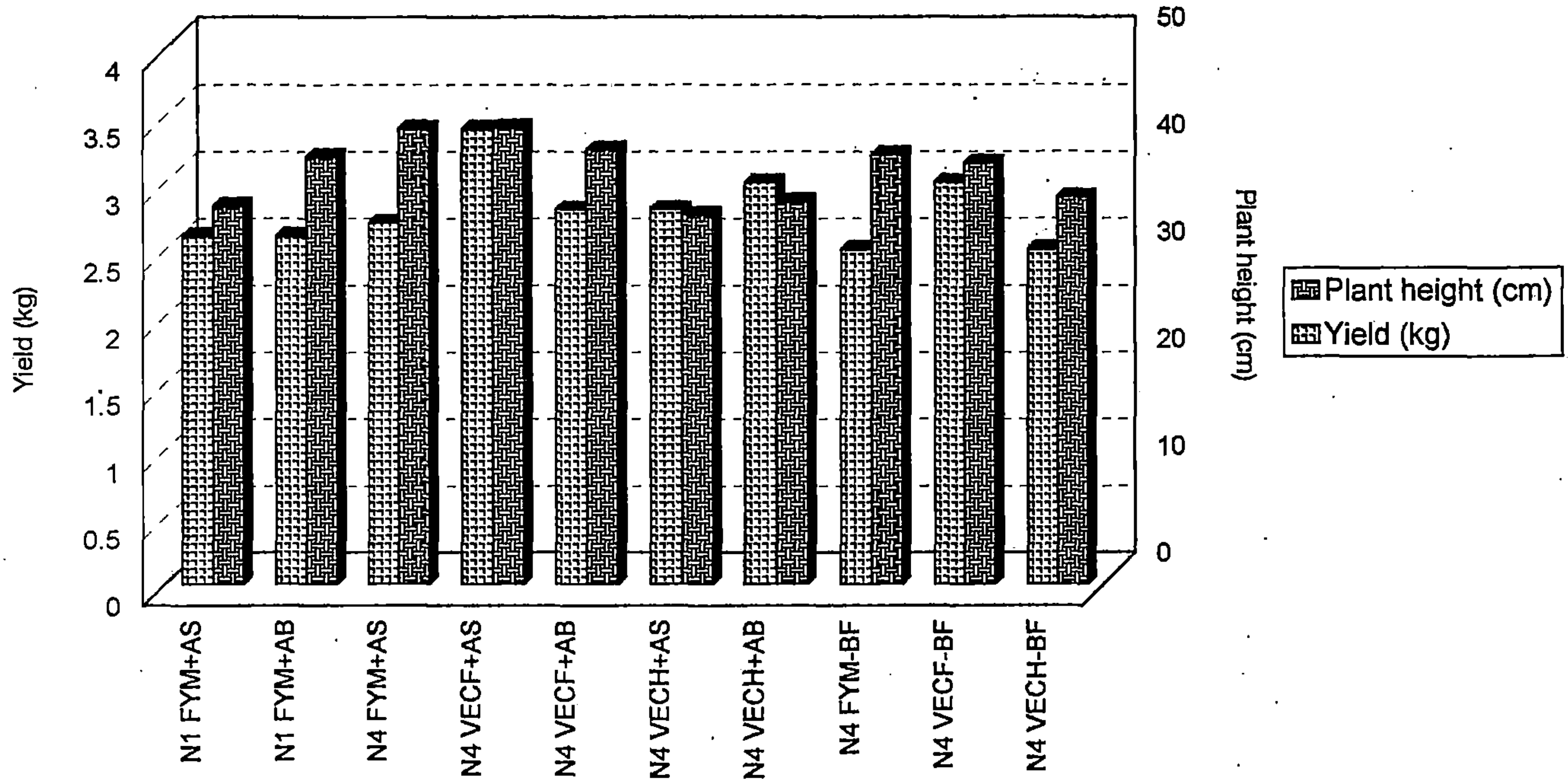
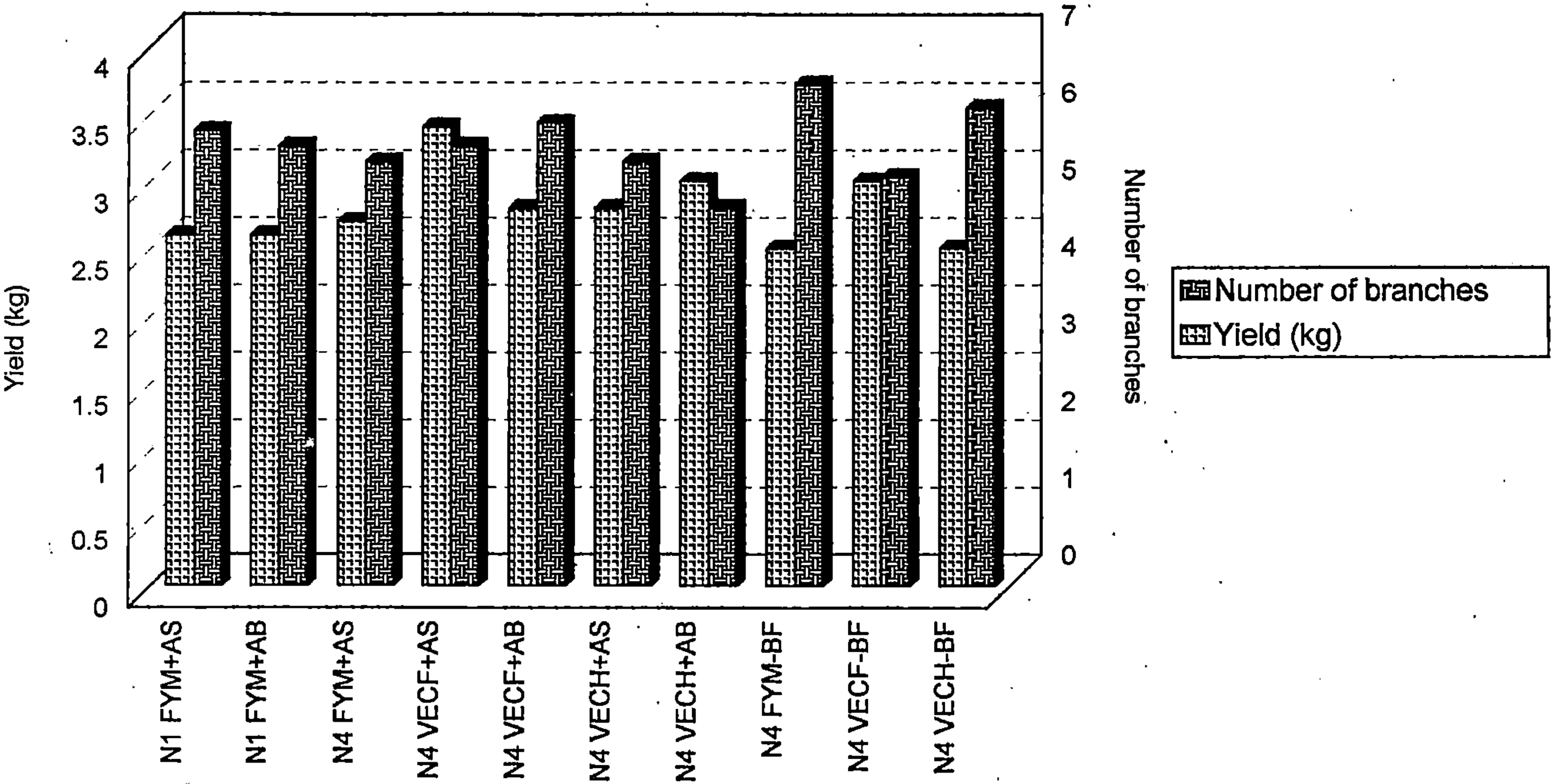


Fig 11 Effect of organic manure and biofertilizer application on number branches and yield of chilli under field condition



Flowering time

The onset of flowering in chilli was not significantly affected by various treatments (Table 23). Earlier flowering (23.7 DAT) was observed in N_1 FYM+AS treatment.

Number of fruits

There were no significant differences between treatments on the number of fruits formed in chilli (Table 24). It was maximum (50.1) in N_4 VECH+AS treatment.

Yield

There were no significant differences between treatments on net yield of chilli (Table 24). The maximum yield 3.4 kg was obtained in N_4 VECF+AS treatment.

Estimation of microbial population

There were significant differences between treatments in population of different microorganisms except fungi estimated after harvest of crop under field condition. The bacterial population of 12.7×10^6 was significantly high in N_4 VECF+AS treatment (Table 25). Similarly the

Table 25. Estimation of microbial population before and after cultivation of Chilli.

A. Before cultivation

	Bacteria (10^6)	Fungi (10^4)	Actinomycetes (10^4)	Azospirillum (10^3)	Azotobacter (10^3)
	6	4	9	-	3

B. After cultivation

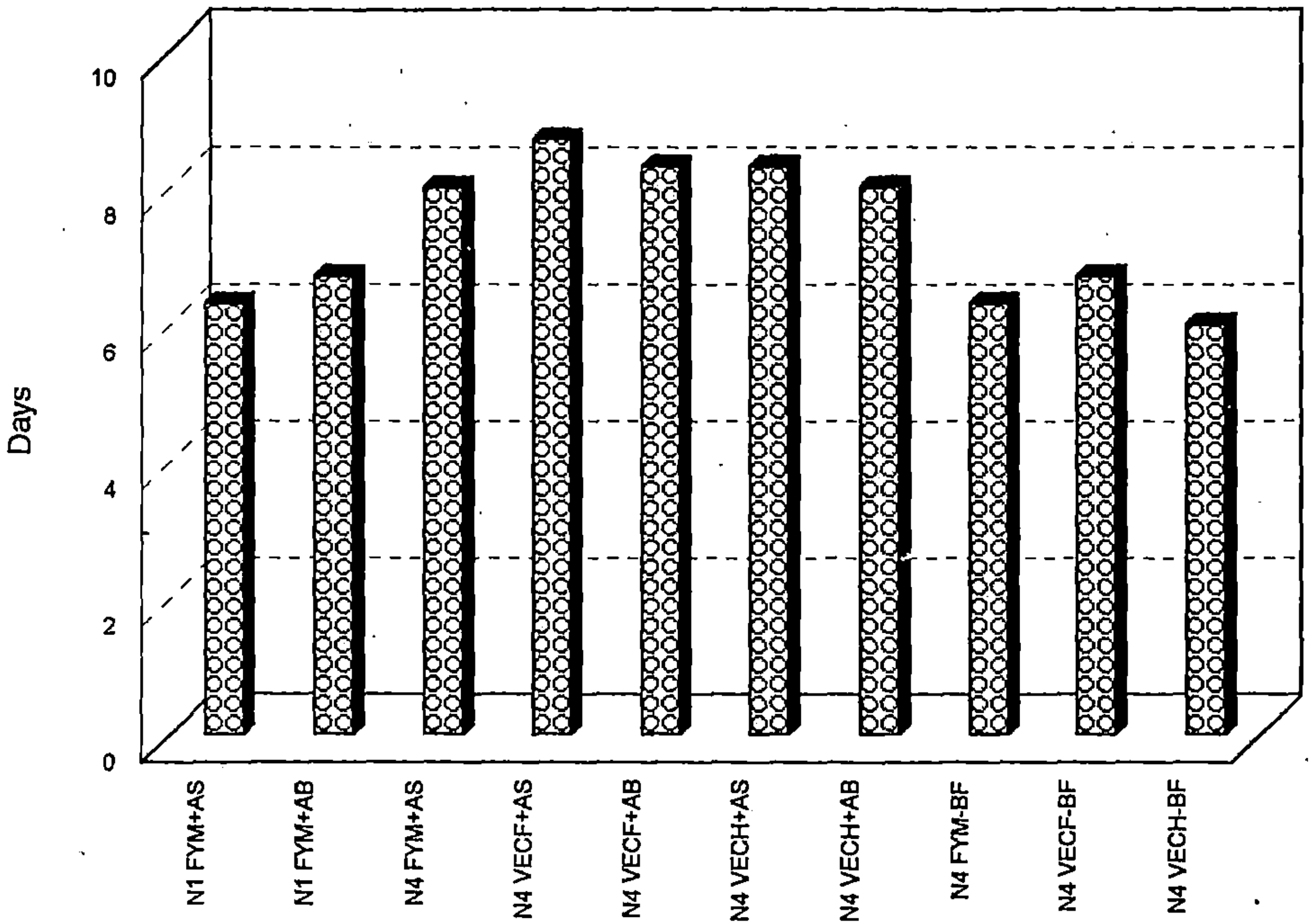
	Bacteria (10^6)	Fungi (10^4)	Actinomycetes (10^4)	Azospirillum (10^3)	Azotobacter (10^3)
N_1 FYM + AS	8.0	7.7	13.0	9.0	4.7
N_1 FYM + AB	8.3	9.0	16.0	3.7	13.7
N_4 FYM + AS	12.3	5.3	17.0	11.3	5.0
N_4 VECF + AS	12.7	7.0	16.7	11.7	7.3
N_4 VECF + AB	12.0	6.3	17.3	5.7	15.7
N_4 VECH + AS	12.0	6.3	18.0	13.0	6.0
N_4 VECH + AB	8.3	7.3	14.0	4.7	10.7
N_4 FYM - BF	9.0	6.0	15.0	2.0	4.0
N_4 VECF - BF	10.7	7.7	12.3	2.3	6.3
N_4 VECH - BF	9.7	7.0	12.7	2.0	4.7
CD (0.05)	2.6	NS	3.5	2.3	2.5

Table 26. Effect of organic manure and biofertilizer application on keeping quality of chilli.

Treatment	Keeping quality*
N_1 FYM + AS	6.3
N_1 FYM + AB	6.7
N_4 FYM + AS	8.0
N_4 VECF + AS	8.7
N_4 VECF + AB	8.3
N_4 VECH + AS	8.3
N_4 VECH + AB	8.0
N_4 FYM - BF	6.3
N_4 VECF - BF	6.7
N_4 VECH - BF	6.0
CD (0.05)	0.8

* Number of days from harvest.

Fig 12 Effect of organic manure and biofertilizer application on keeping quality of chilli fruits



number of actinomycetes (18.0×10^4) and *Azospirillum* (13.0×10^3) were significantly high in N_4 VECH+AS treatment. A similar result was obtained for *Azotobacter* (15.7×10^3) in N_4 VECF+AB treatment.

Keeping quality

There were significant differences between treatments in keeping quality of chilli (Table 26). It was maximum (8.7 days) in fruits harvested from N_4VECF+AS treatment. The keeping quality of fruits from treatments such as N_4 VECF+AB (8.3), N_4 VECH+AS (8.3), N_4 VECH+AB (8.0) and N_4 FYM+AS (8.0) were statistically on par with the best treatment.

DISCUSSION

DISCUSSION

Many developing countries including India have succeeded to attain near self sufficiency in food production. This was possible with the introduction of certain new concepts in agriculture such as cultivation of high yielding crop varieties, use of chemical fertilizers and the introduction of adequate facilities for regular irrigation. However such a success with green revolution had its own problems especially due to the extensive use of chemical fertilizers and plant protection chemicals which lead to serious instances of environmental pollution and much faster deterioration in many desirable soil properties. It was in this context, the concept of total organic farming began to gain much acceptance in many developed countries. Unfortunately this technology does not appear to be immediately suitable for developing countries like India with an anticipated population of nearly one billion or more by 2000 AD. Under such condition, what is important is to popularise an integrated nutrient management practice for crop production where equal importance will be given not only for organic manures but also for chemical fertilizers and biofertilizers. The present research was envisaged to develop such a nutrient management practice for three of the commonly cultivated vegetables in Kerala viz., amaranthus, brinjal and chilli. Another important objective was to evaluate the suitability of using vermicompost as a substitute for FYM which is often in short supply in Kerala.

Two sets of experiments consisting pot and field trials were conducted. The inputs were FYM and vermicompost as organic manures, *Azospirillum* and *Azotobacter* as diazotrophic biofertilizers and NPK fertilizers as per the package of practices recommendations of Kerala Agricultural University (1993) for amaranthus, brinjal and chilli. In the pot trials, four levels of nitrogen such as 25 (N_1), 50 (N_2), 75 (N_3) and 100 (N_4) per cent of the recommended level for amaranthus, brinjal and chilli were also tried. This was done to explore the possibility of reducing the application of fertilizer nitrogen by the combined use of FYM or vermicompost along with *Azospirillum* or *Azotobacter* treatment. The best treatment for each crop based on yield were selected for further field evaluation.

In the pot experiments, the treatment effects were more or less uniform in amaranthus with the application of FYM as organic manure along with *Azospirillum* or *Azotobacter* inoculation. The increase in plant height (61.7 cm), delay in flowering time (49.7 DAT), root biomass (16.6 g), leaf area index (2.4) and yield (146.7 g) were significantly high in N_3

FYM+AS treatment (Table 1 and 2, Fig. 1). However, with the use of *Azotobacter,* such increases were obtained only in plant height and root biomass (Table 3 and 4, Fig. 1; Plate. 1). Leaf area index (2.0) and yield (150.0 g) were also maximum in the N_3 FYM+AB treatment. In general, the application of vermicompost as organic manure did not result in any significant increase in any of plant growth parameters studied in amaranthus.

In brinjal while the yield parameters such as number of fruits (6.0) formed and net yield (158.1 g) were significantly high in N_3 FYM+AS treatment, plant height (48.7 cm) and root biomass (7.2 g) were significantly more in the treatment combination of N_4 FYM+AS (Table 6 and 7, Fig. 2; Plate. 2). On the other hand, in *Azotobacter* treatment, the plant height (52.0 cm), number of branches formed (5.3) and root biomass (7.9 g) were significantly high in N_2 FYM+AB and N_4 FYM+AB treatments respectively (Table 8 and 9, Fig. 2). But there were no significant differences between treatments in the yield which was maximum in N_2 FYM-AB (120.0 g) followed by N_3 FYM+AB (118.3 g) treatment. The number of fruits formed (4.3) were maximum in N_2 FYM+AB and N_4 FYM+AB treatments.

Unlike in amaranthus and brinjal, plant growth responses were more or less uniform due to application of FYM or vermicompost in chilli. In *Azospirillum* treatment, the number of branches (26.0), number of fruits formed (27.3) and yield (135.6 g) were significantly high in N_4 VEC+AS treatment (Table 11 and 12; Plate. 4). A similar response was obtained with FYM only in root biomass (9.6 g) production (Table 12, Fig. 3). In *Azotobacter* treatment also, a similar response was obtained. The number of fruits formed (21.0) and yield (107.6 g) were however maximum in N_4 VEC+AB treatment.

When the data was analysed for individual effect of biofertilizer and organic manure application, it was found that there were no significant differences between treatments due to application of either *Azospirillum* or *Azotobacter* (Table 5, 10 and 15). The only exception was in the onset of flowering in amaranthus which was significantly delayed due to *Azospirillum* application (Table 5). On the otherhand, FYM application resulted in significant increase in most of the plant growth characters. Thus in amaranthus, plant height, root biomass, leaf area index and yield were significantly high with the use of FYM as organic manure when compared to vermicompost. In brinjal also the crop response was more especially with regard to production of branches and yield due to FYM application. In chilli such a result was obtained only in the number of branches produced and root biomass.

The beneficial effects of biofertilizer application in enhancing plant growth are reported earlier also. These include enhanced root biomass production in wheat (Hadas and Okon, 1985) and rice (Purushothaman, 1988), plant height in sorghum and *Panicum* (Kapulnik *et al.*, 1981), increase in leaf number and dry weight of foliage in brinjal (Bashan *et al.*, 1989) and improved seed germination with better percentage increase in shoot and root length in tomato (Dhanalakshmi and Pappiah, 1995). Application of different forms of organic manures are also found to improve growth in many crop plants. Thus it was observed that the use of organic manures such as poultry manure in cauliflower (Singh *et al.*, 1970) and lettuce (Anez and Tavira, 1984), sheep manure in tomato (Hilman and Suwandi, 1989), FYM in brinjal (Subbiah *et al.*, 1983) and chilli (Meena Nair and Peter, 1990) and vermicompost in paddy (Senapathy *et al.*, 1985), cabbage (Sacirage and Dzelier, 1985), watermelon (Ismail *et al.*, 1991), sugarcane (Shuxin, 1991) and *Capsicum* (Desai, 1993) resulted in better plant growth and yield.

Under field conditions, there were no significant differences between treatments. The only exception was in plant height of amaranthus which was significantly high in N_3 FYM+AB treatment (Table 16; Plate. 6). In both amaranthus and brinjal, yield responses were also more in N3 FYM+AB treatment. Thus the leaf area index of 23.9 and net yield of 8.7 kg in amaranthus (Table 16 and 17; Fig. 4, 5 and 6) and the number of fruits formed (7.1) and net yield of 3.6 kg in brinjal (Table 19 and 20; Fig. 7 and 8) were maximum in the above treatment. But in chilli, the yield responses were more in the treatment combination of *Azospirillum* and vermicompost. The average number of fruits and net yield of 50.1 and 3.4 kg respectively were maximum in N_4VECH+AS and N_4VECF+AS treatments (Table 23 and 24; Fig.10 and 11).

The beneficial effect of combined application of organic manure and biofertilizer resulting in 25 to 30 per cent economy in the use of fertilizer nitrogen are reported earlier also in many cereals and vegetables such as brinjal and tomato (Mehrotra, 1972 and Iswaran, 1975), rice (Obliswamy *et al.*, 1976), maize (Meshram and Shende, 1982 and Martinez-Toledo *et al.*, 1988), wheat (Rai and Gaur, 1982, Ishac *et al.*, 1986 and Lekshminarayana *et al.*, 1992) and bhindi (Balasubramaniam and Pappiah, 1995 and Rajasekhar *et al.*, 1995).

Flowering time was another important parameter studied during this investigation. Eventhough there were no significant differences between treatments in amaranthus, this was delayed maximum in the N_3 VEC H+AB treatment as compared to control without biofertilizer application. These were 57.7 and 52.7 to 56.0 DAT respectively (Table 16). In brinjal and chilli on the other hand, early flower initiation was observed in N3 FYM+AS (36.0 DAT), N4 VEC F+AS (36.0 DAT) and N4 VEC H+AS (36.0 DAT) treatments and in N1 FYM+AS (23.7 DAT) treatment respectively. At the same time in the control treatments without biofertilizer application, the onset of flowering varied from 40.3 to 43.3 in brinjal and 25.7 to 28.3 in chilli (Table 19 and 23). Early flower initiation due to organic manure and biofertilizer application have been observed in crops such as bhindi (Abusaleha,. 1981), rice (Nayak *et al.*, 1986), watermelon (Ismail *et al.*, 1991), wheat (Lekshminarayana *et al.*, 1992) and tomato (Dhanalakshmi and Pappiah, 1995 and Dibut et al, 1995).

In both brinjal and chilli the use of vermicompost as organic manure had a significant effect on keeping quality of harvested fruits. In brinjal the fruits remained undamaged at room temperature for an average of 6.7 days in N_2VECF+AB treatment (Table 22 and Fig. 9). In chilli, such a response was obtained till 8.7 days in fruits harvested from N_4VECF+AS treatment (Table 26 and Fig. 12). In the corresponding control treatments, this ranged from 3.3 to 4.3 in brinjal and 6.3 to 6.6 in chilli. It was interesting to observe that in all other treatments involving an integrated nutrient management practice, the keeping quality of harvested brinjal and chilli fruits were relatively higher. This varied from 5.3 to 6.3 in brinjal and from 6.3 to 8.3 in chilli. Higher sugar and vitamin-C content in fruits raised under partial or total organic farming are reported to be responsible for this phenomenon (Luchnik, 1975; Kansal *et al.*, 1981; Shanmugavelu, 1989; Lumpkin, 1990 and Montagu and Gosh, 1990).

The application of organic manures also had a favourable effect on rhizosphere microbial population in all the three crops. In amaranthus the number of bacteria (17.0 x 10^6), fungi (13.7 x 10^4) were significantly high in N_3FYM+AS treatment. The *Azospirillum* and *Azotobacter* population were more in N_3VECF+AS and N_3VECF+AB treatments respectively (Table 18). In brinjal and chilli such responses were high due to vermicompost application (Table 21 and 25). This may be due to the relatively higher number of bacteria, fungi and actinomycetes present in vermicompost at the time of field application.

The lack of significant crop response under field conditions is not unusual since the treatment effects were compared with a control which had a full compliment of NPK fertilizers and organic manures as per the package of practices recommendations. The main objective of this study was to find out how far an integrated nutrient management practice will be useful for the cultivation of vegetables such as amaranthus, brinjal and chilli in Kerala. This is because, in Kerala, the soil conditions are not entirely suitable for effective use of biofertilizers alone for crop production. Certain soil factors such as acidic pH and relatively very poor organicmatter content often adversely affect the efficacy of biofertilizer application. Such problems can be rectified only by resorting to liming and periodical application of organic manures. However, since the cost of lime is very high, it has become uneconomical to apply it on a large scale to correct the pH imbalance of soil. This problem can be solved to some extent by adequate use of organic manures which will not only improve the nutritional status of soil but will also help different microorganisms including bacteria like *Azospirillum* and *Azotobacter* to survive better in such soils. This alone can ensure some degree of economy in the use of chemical fertilizers. Hence there is great scope for integrated nutrient management practice for crop production in Kerala. A definite trend towards achieving this goal was observed during this investigation when it was found that it was possible to achieve at least 20 to 25 per cent economy in the use of fertilizer nitrogen, by adopting this technology for the cultivation of vegetables such as amaranthus, brinjal and chilli.

SUMMARY

SUMMARY

The study on *Azotobacter* and *Azospirillum* inoculants for nitrogen economy in vegetable cultivation was carried out at College of Agriculture, Vellayani, Thiruvananthapuram during 1994-96. Two sets of experiments consisting of pot and field trials were conducted for this purpose.

Pot culture experiments with amaranthus showed that, plant height (61.7 cm), root biomass (16.6 g), leaf area index (2.4) and yield (146.7 g) were significantly high in the treatment combination of *Azospirillum* inoculation along with FYM and 75 percent fertilizer nitrogen application (N_3FYM+AS). Flowering time was also significantly delayed in this treatment.

Among *Azotobacter* treatments also plant height (58.7 cm), leaf area index (2.0) and yield (150.0 g) were significantly high in the treatments receiving 75 percent nitrogen along with FYM and *Azotobacter* inoculation (N_3FYM+AB).

When the individual effect of organic manures and biofertilizers were studied, no significant differences were obtained between the two biofertilizer treatments except for some delay in flowering due to *Azospirillum* inoculation. At the same time FYM was found superior to vermicompost in inducing better plant height, root biomass production, leaf area index and yield in amaranthus.

As regard to the individual effect of organic manure and biofertilizer application, no significant differences were observed between *Azospirillum* and *Azotobacter* treatments.

The selected treatments from pot culture experiments were evaluated under field conditions for all the three crops.

In amaranthus, maximum yield (8.3 kg) was obtained in N_3FYM+AB treatment. This treatment also showed a significant increase in plant height (95.7 cm) over the control treatment. The number of branches formed (9.3) and leaf area index (23.9) were also maximum in this treatments. But flowering time was delayed to the extent of 66.7 DAT in N_3VECF+AB treatment. The total count of bacteria (17.0×10^6) and fungi (13.7×10^4) were significantly high in N_3FYM+AS treatment. The population of *Azospirillum* (12.3×10^3) and *Azotobacter* (15.7×10^3) were significantly high in N_3VECF+AS and N_3VECF+AB treatments respectively.

In brinjal, plant height (67.5 cm), number of branches (9.1), number of fruits (7.1) and yield (3.6 kg) were maximum in N_3FYM +AB treatment. Early flowering to the extent of 36.0 DAT was observed in the treatments such as N_3FYM+AS, N_4VECF+AS and N_4VECH+AS.

The total count of fungi, actinomycetes, *Azospirillum* and *Azotobacter* were significantly high in N_4VECH+AS, N_2VECF+AB and

As in amaranthus, in brinjal significant increase in yield was obtained in the treatment combination of *Azospirillum* inoculation along with FYM and 75 percent fertilizer nitrogen (N_3FYM+AS). The plant height (48.7 cm) and root biomass production (7.2 g) were however more in N_4FYM+AS treatment.

Among the *Azotobacter* treatments, no significant differences were observed between treatments in yield of brinjal. It was maximum (118.4 g) in the treatment receiving *Azotobacter* inoculation along with FYM and 75 percent fertilizer nitrogen (N_3FYM+AB).

In brinjal also the application of FYM had favourable effects in most of the plant growth and yield parameters. At the same time as observed in amaranthus there were no significant differences between *Azospirillum* and *Azotobacter* treatments.

In chilli, the number of branches formed (26.0), number of fruits (27.3) and yield (135.6 g) were significantly high in treatment combination of *Azospirillum* inoculation along with vermicompost and full dose of fertilizer nitrogen. Similarly among *Azotobacter* treatments, plant height (52.7 cm) and yield (107.6 g) were maximum in the treatment receiving *Azotobacter* inoculation along with vermicompost and 100 percent fertilizer nitrogen (N_4VEC+AB). Here also no significant differences were observed between treatments in the flowering time of chilli.

N_4VECF+AS respectively. The keeping quality of the fruits were significantly high (6.7 days) in N_3VECF+AB treatments.

In chilli, plant height (42.6 cm) and yield (3.4 kg) were maximum in N_4VECF+AS treatments. The number of fruits formed were maximum in N_4VECH+AS treatments. However, early flowering to the extent of 23.7 days was observed in N_1FYM+AS.

The population of bacteria (12.7 x 10^6) and *Azotobacter* (15.7 x 10^3) significantly high in N_4VECF+AS treatments. Similarly population of actinomycetes (18.0 x 10^4) and *Azospirillum* (13.0 x 10^3) were significantly high in N_4VECH+AS treatments. The keeping quality of chilli upto 8.7 days was significantly high in N_4VECF+AS treatment.

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ABSTRACT

AZOTOBACTER AND *AZOSPIRILLUM* INOCULANTS FOR NITROGEN ECONOMY IN VEGETABLE CULTIVATION

By

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ABSTRACT OF THESIS
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ABSTRACT

The study on *Azotobacter* and *Azospirillum* inoculants for nitrogen economy in vegetable cultivation was conducted at College of Agriculture, Vellayani, Thiruvananthapuram during 1994-1996. Two sets of experiments consisting of pot and field trials were conducted for this purpose.

Pot culture experiments with amaranthus showed that, plant height, root biomass, leaf area index and yield were significantly high in the treatment combination of *Azospirillum* inoculation along with FYM and 75 percent fertilizer nitrogen (N_3FYM+AS). Flowering time was also significantly delayed in this treatment.

Among *Azotobacter* treatments also plant height, leaf area index and yield were significantly high in the treatment receiving 75 percent nitrogen along with FYM and *Azotobacter* inoculation (N_3FYM+AB).

In brinjal while *Azospirillum* inoculation along with 75 percent nitrogen and FYM (N_3FYM+AS) could significantly increase yield and

increase plant height and root biomass production, there were no significant difference among *Azotobacter* treatments on yield.

In chilli also *Azospirillum* treatment coupled with vermicompost and 100 percent nitrogen (N_4VEC+AS) was significantly increasing number of branches, number of fruits and yield. Whereas there were no significant differences among *Azotobacter* treatments on yield of chilli.

When the individual effect of organic manure and biofertilizer application for all the three crops were studied, no significant differences were obtained between two biofertilizer treatments except for some delay in flowering time in amaranthus due to *Azospirillum* inoculation. But FYM application had favorable effects in most of the plant growth and yield parameters of all the three crops.

The selected treatments from pot culture experiments were evaluated under field conditions for all the three crops.

Maximum yield for amaranthus was obtained in *Azotobacter* treatment with FYM and 75 percent fertilizer nitrogen (N_3FYM+AB), which also had a significant increase in plant height.

For brinjal, the *Azotobacter* treatment receiving FYM and 75 percent nitrogen (N_3FYM+AB) produced maximum plant height, number of branches, number of fruits and yield. But keeping quality of fruits was significantly high in *Azotobacter* treatment with full dose of vermicompost and 75 percent fertilizer nitrogen (N_3VECF+AB).

For chilli, *Azospirillum* treatment receiving full dose of vermicompost and 100 percent nitrogen (N_4VECF+AS) produced maximum yield which also has got maximum plant height. Keeping quality of fruits was also significantly high in this treatment.

The population of bacteria, fungi, actinomycetes, *Azospirillum* and *Azotobacter* were significantly high in most of the treatments receiving either *Azospirillum* or *Azotobacter* inoculants and organic manure supplements.