ORGANIC NUTRITION IN OKRA
(Abelmoschus esculents)

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Declaration

I here declare that this thesis entitled **"ORGANIC NUTRITION IN OKRA *(Abelmoschus esculents)*"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"ORGANIC NUTRITION IN OKRA *(Abelmoschus esculents)*"** is a record of research work done independently by Smt. Asha.K. Raj, 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

mm	-	Millimetre
cm	-	Centimetre
mg	-	Milligram
g	-	Gram
kg	-	Kilogram
l	-	Litre
lb	-	Pound
q	-	Quintal
t	-	Ton
ha	-	Hectare
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
DAH	-	Days after harvest
DAS	-	Days after sowing
Fig.	-	Figure
DMP	-	Dry matter production
et al.	-	And others
Rs.	-	Rupees
CD	-	Critical difference
SE	-	Standard error
CV	-	Cultivar
no	-	Number
min.	-	Minute
AICVP	-	All India Co-ordinated Vegetable Improvement Project

Introduction

1. INTRODUCTION

India has achieved food security and now there is an urgent need for providing health security to our population. This can be achieved through balanced diet of which vegetables form the most important component. But in India vegetable cultivation is not yet properly developed and there is a wide gap between the percapita availability of vegetables (135g day^{-1}) and minimum requirement of vegetables (285g day^{-1}). By 2000 A.D the requirement of vegetables will be 110 MT (Ministry of Agriculture, 1994). Hence we must increase the production to meet the requirements of our growing population. Supply of optimum quantity and type of nutrition is the most important of all agronomical operations so as to improve yield. But with the indiscriminate use of fertilizers and chemicals there is increasing risk of health hazards. Intensive agriculture with the indiscriminate use of chemicals has brought about adverse effects on soil structure, soil microflora, quality of water, food, fodder and feed materials (Raj *et al.*, 1996). Since the vegetables are mostly consumed fresh or only partially cooked, they should be devoid of residual effect of chemical fertilizers. In this context organic sources of nutrients can act as an alternative to the costlier, environmental damaging and energy intensive chemical inputs. Organic nutrition for vegetables will enable the farmers to produce superior quality vegetables devoid of toxic residues. More over organically grown vegetables are preferred for their flavour, taste, nutritive value and extended shelf life.

Among vegetables bhindi occupies an important place on account of its tender green fruits. In addition to its role as vegetable it has economic and medicinal importance too (CSIR,1959). These are relished for the high mucilage content and are used in soups and stews. Nadkarni (1954) reported that okra has emollient , diuretic, cooling and aphrodisiac actions and is found serviceable in fevers, catarrhal attacks and dysentery. Since bhindi is considered as an important vegetable crop of Kerala, this study has been proposed in bhindi.

India has vast potential of manurial resources. Farm yard manure and poultry manure are the most commonly used manures in our country. But inadequacy is the main bottleneck in popularising the use of organic manures. The gap between the demand and supply of organic manures can be narrowed down considerably by composting the organic wastes available in the farm. But compost is bulky and low in major plant nutrient contents and the conventional method of composting is time consuming. Various technologies are available for the production of superior quality compost in less time. Microbial inoculation and addition of phosphorous help to improve the nutrient status and reduce the composting time. Extensive studies conducted in this regard at IARI have shown that inoculation with *Azotobacter chroococcum* and phosphate solubilising microorganisms improved the manurial value of compost (Sadasivam *et al.*, 1981). Also phosphate addition increased the rate of decomposition and nitrogen conservation (Poincelot,1975). The result of this study will help to develop appropriate technology to convert agricultural waste into nutrient rich organic manure and this type of organic recycling is more valid in the days to come since the concept of organic farming is in the anvil.

Organic nutrition relies upon efficient recycling of animal manures such as farmyard manure, poultry manure, green manures, oil cakes, composts etc. FYM, the most commonly used organic manure is a good source of both macro as well as micronutrients. Poultry manure with its low C:N ratio and good nutrient value suits well for all crops especially vegetables (Jose *et al.*,1988). Its higher efficiency is due to the large quantities of easily mineralisable nitrogen.Non-edible oilcakes such as neem cake is rich in plant nutrients (Mercykutty *et al.*, 1983). They are valued much due to their alkaloid content which inhibit the nitrification process in soils which inturn help to improve nitrogen use efficiency in crops. Use of green manure helps to increase the yield of crops by 15-20per cent and also improves the quality of produce (Thampan,1993). Improvement of the physico-chemical and biological properties of soil adds the merit of organic manures.

Now a days the practice of using biofertilizers as a partial substitute for chemical fertilizers is gaining much momentum. Biofertilizers are preparations containing microorganisms in sufficient number helping plant growth and nutrition and show no deleterious effects either on soil health or environment. Azospirillum is an associative symbiotic nitrogen fixing bacteria having high potential for nitrogen fixation. They produce growth promoting hormones also. Response of vegetable crops to Azospirillum inoculation was reported by several workers like Dart (1986), Wam and Konde (1986), Balakrishnan (1988) and Subbiah (1990).

With this background the study was undertaken with the following objectives.

1. To assess the effect of dual application of microbes and phosphate sources on the quality of compost.

2. To standardize an organic nutrient schedule for bhindi using farm yard manure, poultry manure, green leaf, neem cake, enriched compost and Azospirillum.

3. To work out the economics of various nutrient sources and to arrive at the best economic nutrient schedule for organic bhindi.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In recent years there had been a welcome awareness for ecofriendly organic products. Sustainable and ecofriendly agriculture, which minimizes the use of harmful energy intensive inputs, is achievable through the use of organic and biofertilisers. Organic nutrition in vegetables is specially important as they provide quality foods which are very important for providing health security to people. Among the various organic sources, compost is a potential organic manure which can be prepared in small farm holdings, with family labour. Microbial inoculation and addition of phosphatic fertilizers help to improve nutrient value of compost.

The present study is aimed to find out the effect of dual application of microbes and phosphate sources on the quality of compost and to standardize an organic nutrient schedule for bhindi. The available literature relating to the above topic is reviewed here under.

2.1. Effect of microbial inoculation and phosphate sources on composting period and quality of compost.

The conventional method of composting takes a long time to produce quality compost. In order to hasten the process and to improve the quality of end product, the material to be composted is inoculated with microbes such as cellulolytic, lignolytic, nitrogen fixing and phosphate solubilising organisms. Addition of sources of nitrogen and phosphorus may also be desirable when the materials to be composted lack much of these elements.

The effect of various microbial inoculants and phosphate sources on the quality of compost and the time taken for composting is reviewed here under.

2.1.1. Time taken for composting

Davey (1953) and Wilde (1958) reported that, inoculation with *Coprinus ephemerus*, a cellulose decomposer, and addition of nitrogen, phosphate and potassium salts to the composting material hastened the production of saw dust compost.

Phosphate addition to the compost increased the rate of decomposition and nitrogen conservation (Dhar *et al.*, 1955 and Poincelot, 1975).

Gaur *et al.* (1982) reported that the use of mesophilic cellulolytic fungi in the preparation of plant residue compost, reduced the composting period by one month. In the preparation of Jamun leaves compost the decomposition was hastened due to inoculation with *Aspergillus sp.* (Bharadwaj and Gaur, 1985). They also reported that due to increased microbial population, nitrogen fixing and phosphorus solubilising process get accelerated and the compost become ready for use within four months.

Rasal *et al.* (1985) reported that enrichment of sugarcane trash compost with effective cellulolytic fungi, nitrogen fixing bacteria, phosphorus solubilising organisms and rock phosphate resulted in hastening the composting process and the compost became ready for use within four months. Inoculated compost had low C:N ratio and high amount of N and P as compared to uninoculated compost.

Mathur *et al.* (1986) reported that addition of microbial inoculants reduced the composting period by four weeks. It has been demonstrated by Halsall (1993) that combined inoculation with cellulolytic or ligno cellulolytic fungi and diazotrophic bacteria can increase the rate of straw degradation. Thakur and Sharma (1998) observed that the decomposition of compost was accelerated when enriched with rockphosphate and Azotobacter.

2.1.2. Quality aspects

Improvement in the quality of compost, due to phosphate addition and microbial inoculation has been reported by many workers.

Addition of rock phosphate or bonemeal to farm composting materials was found to be useful in increasing the solubility of phosphoric acid in rock phosphate and dicalcium phosphate. Nearly 50 to70 percent of P_2O_5 were made soluble, and they were readily absorbed by plants (Acharya,1954).

Compost charged with varying levels of mussorie rock phosphate with and without pyrite at different time intervals showed that after 160 days of incubation the release of citricacid and water soluble P was significantly higher with higher dose of phosphate as compared to lower dose (Mathur *et al* ., 1980). Sadasivam *et al* . (1981) found that inoculating rock phosphate amended compost with culture of Azotobacter and P solubilising strain of Aspergillus increased the N and humus content. Kapoor *et al.* (1983) observed that inoculation of Azotobacter into already decomposed material increased N content. They also found that composting with rock phosphate significantly increased citrate soluble P and this was further increased on inoculation with Aspergillus.

Mathur and Debanath (1983) observed that incorporation of rock phosphate improved the quality of compost by increasing the contents of citrate soluble phosphorus, nitrogen, calcium, magnesium and micronutrients. Bharadwaj and Gaur (1985) reported that due to increased microbial population, nitrogen fixing and phosphorus solubilising process get accelerated and the compost become ready for use within four months with low C:N ratio and high N and P content in the enriched and inoculated compost.

.Mathur *et al.* (1986) reported that addition of microbial inoculants improved the fertilizer value of paddy straw rock phosphate compost. Hajra (1988) noticed that inoculation with microbial cultures and rock phosphate favourably affected the quality of compost. Bidan chandra (1992) found that the enrichment of compost with *Azotobacter chroococcum*, rock phosphate, N, pyrite and P solubilising cultures of Bacillus and Penicillium significantly increased dry matter yield of rice and blackgram and also N and P uptake. Zachariah (1995) reported that the enrichment of compost with N fixing Azospirillum and P solubilising microorganisms along with one percent rock phosphate had a significant effect on the nutrient content.

Thakur and Sharma (1998) studied the effect of rock phosphate addition and Azotobacter inoculation on N and P transformations during composting. Inoculation with Azotobacter increased NH_4^+, NO_3^- and total N contents and decreased water soluble P and C:N ratio. Rock phosphate enrichment accelerated decomposition, conserved N and improved N mineralization. Phosphorus from rock phosphate was solubilized during composting and transformed into available forms.

2.2. Effect of organic manures on soil properties

Addition of organic manures like farmyard manure, poultry manure, green manures, oil cakes, compost etc improve soil physical, chemical and biological properties and there by enhance the productivity of soil.

The favourable effect of farmyard manure application on the structural properties of the soil were observed by several investigators. (Biswas *et al* ., 1969 and Muthuvel *et al.*, 1982). Loganathan (1990) reported that application of organic amendments viz. saw dust, groundnut, shell powder, coir dust and FYM, each at 2.5 and 5 t ha^{-1} improved the soil physical characteristics like infiltration rate, total porosity and hydraulic conductivity of red soil with hard pan.

Olsen *et al.* (1970) reported that addition of manures increased the soil P^H. Farmyard manure application resulted in lowest acidity due to the decrease in exchangeable and soluble Al in the soil (Nambiar, 1994 and Patiram, 1996).

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.

Srivastava (1985) observed that the application of organic manures resulted in increased organic carbon content, total N and available P and K status of soil. Badanur *et al.* (1990) reported that available phosphorus content of soil was significantly increased with the incorporation of subabul, sunhemp loppings and farmyard manure. Connell *et al.* (1993) found that the composted municipal solid waste application in soil increased the status of available nitrogen content. More (1994) reported that addition of farm wastes and organic manures increased the status of available nitrogen and available phosphorus of the soil.

2.3. Effect of organic nitrogen sources on growth, yield and quality of crops with special reference to vegetables

Organic manures have been time-tested materials for improving the fertility and productivity of soils. Role of various organic amendments in improving the growth, yield and quality of crops are reviewed here under.

Stalin *et al.* (1993) observed the best germination and seedling growth in silver oak pretreated with organic manure and various combinations of Azospirillum and Phosphobacter.

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

Increase in the yield of chilli, bhindi, tomato and brinjal by organic manure application was reported by Gaur *et al.* (1984).

Organic manures like FYM, compost, oilcakes, green leaf, poultry manure etc improve the yield as well as quality of vegetable crops like tomato, onion, gourds, chillies etc. 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).

2.3.1. Effect of farmyard manure on growth, yield and quality of crops

Application of FYM resulted in higher vegetative mass, dry weight, plant height and rate of dry matter increment per unit leaf area of capsicum (Cerna, 1980 and Valsikova and Ivanic, 1982). They also reported that application of chemical fertilizers in the absence of FYM retarded the formation of vegetative organs and subsequently the reproductive organs and has resulted in lower flower production. Arun kumar(1997) reported that in amaranthus FYM application was found to be superior to vermicompost in inducing better plant height, root biomass production, leaf area index and yield. Joseph (1998) observed that in snake gourd, growth characters viz. weight of the root $plant^{-1}$ and dry matter production ha^{-1} were highest in FYM treated plants as compared to poultry manure or vermicompost treated plants.

Subbaih *et al.* (1983) reported that the yield of brinjal was significantly influenced by levels of FYM (0, 12.5, 25.0 and 37.5t ha^{-1}) but not by the levels of fertilizers (0, 50, 100 and 150 percent of recommended dose). In the long term field experiment for 7 years at Jalandhar, Sharma *et al.* (1988) revealed that FYM was more effective in increasing tuber yield of potato than green manuring with dhaincha. 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 per plant in tomato. From studies at different places it was found that FYM to supply 100 kg P_2O_5 ha^{-1}, about 30 t ha^{-1} not only met P and K needs of the crop but also kept the potato yield level at a higher level than the combined use of P and K fertilizers (Sud and Grewal, 1990). Minhas and Sood (1994) reported that FYM application significantly increased crop yield. Joseph (1998) reported that in snake gourd yield attributing characters viz. length, weight and number of fruits per plant were highest in FYM treated plants as compared to poultry manure or vermicompost treated plants.

Kansal *et al.* (1981) reported that application of 20 t FYM ha^{-1} increased the ascorbic acid content in spinach leaves.

2.3.2. Effect of poultry manure on growth, yield and quality of crops.

A study on optimum level of poultry manure requirement for cauliflower by Singh *et al.* (1970) revealed progressive increase in growth and yield of cauliflower when the dose was increased from 0 to 169.6 q ha^{-1}. Singh *et al.* (1973) reported that, in potato, poultry manure application exhibited better response than FYM on yield and growth attributes. Anitha (1997) reported that, in chilli various growth attributes like plant height, number of branches and DMP were better with poultry manure application as compared to FYM or vermicompost.

Morelock and Hall (1980) compared the effects of broiler litter applied at different rates (0-8 t $acre^{-1}$) with a preplanning application of commercial fertilizer (N_{10} P_{20} k_{10}) at 280-840 kg ha^{-1} on field grown tomato plants. Marketable fruit yield was found to increase with broiler 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 poultrymanure In lettuce, poultry manure applied at 0, 20 and 40 kg ha^{-1} either as entire basal dose or in splits increased the yield from 0.66 to 0.81 and 0.90 kg $plant^{-1}$ (Anez and Tavira, 1984). Jose *et al.* (1988) observed that plants supplied with 50 kg N as poultry manure and 50 kg nitrogen as urea recorded the highest yield of brinjal fruits (51 t ha^{-1}) followed by plants supplied with 50 kg N as pigmanure and 50 kg as urea. Poultry manure treated chilli plants showed better yield and yield attributing characters as compared to FYM and vermicompost application (Anitha, 1997).

Application of poultry manure showed a slight increase in ascorbic acid content of cauliflower. The highest vit C. content was obtained in the curds supplied with 169.6 q ha^{-1} of poultry manure

(Singh *et al.* 1970). He also reported that the protein content of potato gradually increased with higher levels of poultry manure. Anitha (1997) reported that chilli plants treated with poultry manure recorded the maximum ascorbic acid content of fruit as compared to vermicompost and control treatment. Joseph (1998) observed that, in snake gourd, poultry manure treated plants recorded the highest crude protein content and lowest crude fibre content as compared to that of FYM and vermicompost treated plants.

2.3.3.Effect of oilcakes on growth, yield and quality of crops.

Increase in plant height of bhindi due to oilcake application was reported by Singh and Sitaramaiah (1963). Chinnaswamy (1967) observed better growth in tomato plants with the application of FYM and groundnut cake in organic mixture. Application of commercial sea weed concentrate (kalpak 66) at dilution of 1:500 to the foliage at regular interval or once to the soil improved the growth of glass house tomato plants (Featon by –Smith and Staden, 1983). Whenever it was applied it brought about significant improvement in root growth due to reduction in root-knot nematode. Jain and Hasan (1986) in a field experiment found that the oilcakes increased the chlorophyll content of leaves and neemcake 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 oilcakes tried were karanj, mahua, mustard and neemcake. The maximum plant height of 70.77 cm was recorded in the treatment receiving neemcake @ 50 q ha^{-1} followed by mustard cake at its higher dose.

Jiro Asano (1984) reported that the crops of egg plant, cabbage, tomato, radish and lettuce harvested from the rapeseed cake applied plot produced higher yield than the crop from inorganic fertilizer alone treated plot. Shanmugavelu (1987) observed that application of mahua cake, castor cake, and neemcake @ 500 kg ha^{-1} one day prior to transplanting of tomato, increased the fruit yield by 31.7, 27.8 and 9.0 percent, respectively over control. Anon (1990) reported that application of neemcake @ 1 t ha^{-1} before planting gave maximum yield in ginger. In the review of soil and fertilizer management for vegetable production in Bangladesh, Islam and Haque (1992) mentioned the application of oilcakes as an organic manure during land preparation to brinjal, chilli and bhindi for getting higher yield. Som *et al.* (1992) while studying the influence of organic manures on growth and yield of brinjal found that maximum fruit length and diameter were recorded by mahua cake and neemcake applied @ 50 q ha^{-1} respectively. Mahua cake recorded highest number of fruits of 11.68 per plant. 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 the yield of betel vine. Among the various sources tried viz. neem cake, karanj cake, neemcake + urea and urea alone, application of N through neemcake produced significant response in increasing the yield.

Sahrawat and Mukherjee (1977) reported that application of karanj seed cake or mahua cake improved the grain protein content in rice.

2.3.4. Effect of green manures on growth, yield and quality of crops

In a field experiment conducted at TamilNadu Agricultural University, Coimbatore application of sunhemp @ 12.5 t ha^{-1} to rice enhanced dry matter production and nutrient uptake, when applied in combination with superphosphate or mussorie rock phosphate (Srikantan, 1987). A trial with promising green manure crop during the pre-rice season in 1988 and 1989 at Coimbatore revealed highest biomass production by dhaincha at 30, 45 and 60 DAS (Palaniappan and Siddeswaran, 1990).

Varadarajan and Sanyasi Raju (1956) studied the effect of different green leaf manures on rice. Green leaves of Glyricidia, Pongamia, Thespesia, Calotropis, Delonix and Croton were incorporated to supply 45 kg N ha^{-1}. Performance was compared with 45 kg N as ammonium sulphate per hectare. Croton leaves gave higher yield than leaves of other species and nearly equalled the yield with ammonium sulphate. Srikantan (1987) recorded higher grain yield in rice crop with the incorporation of green manure as compared to control. Chellamuthu and Kothandaraman (1988) recorded that green manure application increased the grain yield of both rice crops in a rice-rice-pulse system. Patil and Kulkarni (1988) reported that incorporation of 5 t ha^{-1} of subabul leaves gave sorghum yield which was on par with that obtained with recommended fertilizer dose. Sharma (1991) reported that potato after sunhemp yielded 1.5 t ha^{-1} more than potato after fallow. Green manuring increases the yield of crops to an extent of 15 to 20 percent compared to non green manuring (Thampan, 1993).

Green manures were found to improve the quality of rice, compared to ammonium sulphate. Green manured rice contained more protein, phosphoric acid and potash (Murthy, 1978). Enhanced availability of iron upon green manuring has been reported by Takker and Nayyar (1986). Thampan (1993) reported that application of green manure crops improved the quality of food grains and fruits. Vitamin and protein contents of rice have been found to be increased by green manuring of rice crop.

2.3.5. Effect of enriched compost on growth, yield and quality of crops

Banerjee and Das (1988) reported that the application of enriched compost improved the growth attributes of potato as compared to uninoculated control. Hajra *et al*. (1992) reported that application of enriched compost significantly increased the dry matter yield of rice-rice- blackgram as compared to that of control. Application of Eudrillus compost inoculated with both Azospirillum and P solubilising organisms had the highest plant height, more number of leaves and highest shoot : root ratio (Zachariah, 1995)

Garg *et al*. (1971) reported an increase in the yield of rice, wheat, sugarcane and cotton due to the application of FYM and compost. In bhindi, the application of water hyacinth at the rate of 25t ha^{-1} along with bonemeal 75 kg ha^{-1} under soil surface six weeks of sowing recorded significantly higher yield (112.6 q ha^{-1}) as compared to control (48 q ha^{-1}) (Verma and Verma, 1974). Singh (1985) found that phosphocompost prepared by enrichment with rockphosphate was as good as that of single super phosphate in microplot field experiments taking mung bean and wheat as test crop. Mishra and Banagar (1986) also emphasized that the P enriched compost was comparable to single super phosphate in crop response and P uptake. Banerjee and Das (1988) reported that application of enriched compost produced more tuber yield in potato as compared to uninoculated control. Murillo *et al*. (1989) were of the opinion that successive application of city waste compost to tomato in a green house experiment, resulted in increased yield. Application of Eudrillus compost enriched with both Azospirillum and phosphorus solubilising organisms to chilli plants gave maximum per plant yield as compared to uninoculated compost (Zachariah, 1995). Stoffella and Graetz (1996) reported that the total tomato yield was larger in plots amended with sugarcane filter cake compost as compared to control plots without compost. Green pepper plots amended with compost gave higher marketable yields than unamended plots, regardless of zero or 50 percent of a standard growers fertilizer was used (Roe *et al.* 1997). After the final pepper harvest cucumber was subsequently sown in the same plots. Plots amended with compost gave higher marketable yields than those without, regardless of fertilizer rate.

Verma and Verma (1974) reported that application of water hyacinth @ 25t ha^{-1} along with bonemeal 75 kg ha^{-1} to bhindi, resulted in higher protein content of bhindi fruits as compared to control treatment. Studies conducted by Meier-Ploeger and Lehri (1989) revealed that tomato plants grown with compost produced fruits with higher vit. C content. Stoffella and Graetz (1996) reported that the mean fruit size of tomato was larger in plots amended with sugarcane filter cake compost (224 mt ha^{-1}) as compared to control plots without compost. In the case of cucumber and green pepper, the plots amended with compost gave higher marketable yields than those without, regardless of fertilizer rate (Roe *et al.*1997).

2.4. Effect of organic manures on keeping quality of produce

Considerable scientific data were generated recently to show that produce obtained from organic farming is nutritionally superior with good taste, lustre and better keeping qualities.

Luchnik (1975) reported that the use of organic manures resulted in high sugar and Vit C content which resulted in better keeping quality of cabbage. Similarly Kansal *et al.* (1981) reported increased shelf life of spinach leaves due to application of 20t FYM ha^{-1}. Yoshida *et al.* (1984) found that fertilization with bone and rapeseed meals produced firm fruits with most cohesiveness, chewingness and uniform thickness at top and bottom of tomato fruits. 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 (Kerala Agricultural University, 1987). Meier- Ploeger and Lehri (1989) studied the quality of tomato plants grown with compost from biogenic waste. NPK fertilizers, composted FYM and commercial organic fertilizers were used for comparison. They found that storage quality and content of desirable nutrients such as vitamin C and sugar of fruits were improved in compost treatments. Shanmugavelu (1989) pointed out that the application of a combination of FYM and inorganic mixture was the best for firmness, storage life and keeping quality of tomatoes for a long time. The better storage life of spinach grown with organic manure was found to be associated with lower free aminoacid content, lower level of nitrate accumulation and higher protein N to nitrate N (Lampkin, 1990). Joseph (1998) reported that shelf life of snake gourd grown with organic residues is much higher as compared to that grown with fertilizers.

2.5. Effect of organic manures on nutrient uptake

Organic manures play a very important role in enhancing the uptake of nutrients by plants.

Gaur and Mukherjee (1979) observed that nitrogen uptake by groundnut crop in straw amended plots was 100 percent more than in the control. Significant increases in crop yield and N uptake in maize were obtained by using cereal straw and neemcake in the proportion of 3:1 (Gaur and Mathur, 1979). Concentration of potassium in seedling tissues of vegetable crops like snap bean, cucumber, radish and tomato increased progressively as the levels of mushroom spent compost increased (Sherry Hsiao – Lei Wang *et al.*, 1984). Mishra and Banagar (1986) emphasised that the P enriched compost was comparable to single super phosphate in crop response and P uptake. Green manure incorporation in rice resulted in 10 to12 percent better utilization of P and K (Srikantan and Palaniappan, 1990). Hajra *et al.* (1992) observed that application of enriched city compost, enhanced the N and P uptake in rice and blackgram as compared to control treatment. Application of FYM was beneficial in enhancing the uptake of phosphorus by potato and maize (Minhas and Sood ,1994). Zachariah (1995) reported that in chilli application of Eudrillus compost inoculated with both Azospirillum and P solubilising organisms increased the uptake of N and P significantly than control. Anitha (1997) observed the better uptake of N in poultry manure treated plants as compared to control.

2.6. Effect of nitrogen levels on the growth, yield and quality of vegetables.

2.6.1. Effect on growth characters.

Increase in plant height with increasing levels of nitrogen in bhindi was reported by several workers [Singh and Singh (1965), Chauhan and Gupta (1973) and Subramonian (1980)]. Increase in nitrogen levels resulted in a sequential increase in plant height in chilli as noted by Srinivas (1983). Sajitharani (1993) showed that the maximum plant height of 106.75 cm (90 DAS) was at the higher level of nutrients (330:110:220 kg NPK ha^{-1}) in bhindi. Anitha (1997) reported that plant height of chilli increased significantly with increased levels of nitrogen.

But Singh (1979) observed no significant difference in plant height of bhindi by increasing the nitrogen dose from 75 to 150 kg ha^{-1}.

Increased LAI with increasing levels of nitrogen had been reported by several workers. Subramonian (1980) reported that increasing levels of nitrogen significantly increased the LAI both at 30 and 60 DAS. Thomas and Leong (1984) observed that increase in nitrogen application increased the foliar growth and canopy spread in chilli. Nitrogen enhanced the expansion of leaves which in turn increased the LAI in amaranthus (Rajan, 1991).

Verma *et al.* (1970) observed no effect on the number of leaves in bhindi by increasing fertilizer nitrogen from 90 to120 kg ha^{-1}.

The significant influence of nitrogen on drymatter production was reported by several workers. Subramonian (1980) observed that in bhindi crop DMP was increased with increasing levels of nitrogen up to 60 kg N ha^{-1} though the statistical significance was observed only up to 30 kg N ha^{-1}. Rajendran (1981) reported that the total DMP at 60 DAS and at harvest increased with increasing levels of nitrogen in pumpkin. Hedge (1987) observed that increase in nitrogen application increased the DMP in chilli through higher LAI and crop growth rate. Sajitharani (1993) observed that the dry matter content of plants increased with increasing levels of nutrients, recording the maximum value at 330:110:220 kg NPK ha^{-1} in bhindi crop. Shirley (1996) observed maximum DMP in chilli with drip irrigation and at higher levels of nutrients.

In general various growth characters showed positive response to the increased levels of nitrogen.

2.6.2. Effect on yield attributes and yield.

Kamalanathan *et al* . (1970) reported delayed maturity in bhindi with increasing levels of nitrogen. Shrestha (1983) in a study to find out the effect of spacing and nitrogen fertilization in bhindi variety Pusa sawani found that nitrogen fertilization advanced the first harvest by 4 to 6 days compared with control receiving no nitrogen. Subhani *et al* . (1990) reported that, 120 kg ha^{-1} nitrogen recorded minimum time for 50 percent flowering in chilli. Sajitharani (1993) showed that plants supplied with highest level of nutrients (330:110:220 kg NPK ha^{-1}) took about 42 days for flowering while those supplied with the lowest level of nutrients (50:8:30 kg NPK ha^{-1}) took only 38 days in the case of bhindi. In general delayed flowering was observed due to nitrogen application.

Verma *et al* . (1970) reported that in bhindi the number of fruits per plant increased with increasing levels of nitrogen up to 90 kg ha^{-1}. Shrestha (1983) found that in bhindi pod yield was highest from plots receiving 60 kg N ha^{-1}. Similar results have been reported by Majanbu *et al* . (1985) and Lenka *et al* . (1989).

But Gupta and Rao (1979) reported that in bhindi application of nitrogen above 100 kg ha^{-1} did not affect the number of fruits per hectare significantly.

Balasubramoni (1988) reported that in bhindi nitrogen application showed significant increase in fruit length with increasing levels. Lenka *et al* . (1989) in a study in bhindi with 4 levels of nitrogen (0,50,75 and 100 kg ha^{-1}) observed that all the levels were on par with respect to length of bhindi fruits.

Chandrasekharan (1965) found that highest level of nitrogen showed a decrease in the length of fruits over lower levels.

Saimbhi and Padda (1970) observed increased yield in okra with nitrogen fertilization up to 134 kg N ha^{-1} in sandy loam soils. Tomar and Rathore (1988) found that yield of bhindi was highest in plants which received 75 kg N ha^{-1}. Sajitharani (1993) showed that highest level of nutrients (330:110:220 kg NPK ha^{-1}) recorded the highest per plant yield of 2.7 kg in bhindi. Anitha (1997) reported that in chilli, yield parameters like number of flowers $plant^{-1}$, fruits $plant^{-1}$, fruit girth, fruit length and total fruit yield were better under higher levels of nitrogen as compared to lower levels.

2.6.3. Effect of nitrogen on quality

Subramonian (1980) found that application of nitrogen at the highest level (60 kg ha^{-1}) increased the protein content of fruits. He also reported that nitrogen at the rate of zero and 30 kg ha^{-1} were on par as far as protein content was concerned.

Chandrasekharan (1965) found that nitrogen at 75 lb and 100 lb per acre increased the crude protein content while 125 lb nitrogen per acre reduced the crude protein.

Paraminder Singh *et al.* (1986) showed that vitamin C content in chilli was increased with enhanced levels of nitrogen and the response was linear up to 90 kg ha^{-1}. Irene Vethamoni (1988) found that in bhindi application of 55 kg N ha^{-1} recorded the highest ascorbic acid content of fruits followed by the decreasing levels of nitrogen. Balasubramoni (1988) reported that the application of 30 kg N ha^{-1} gave highest ascorbic acid content. Sajitharani (1993) showed that the highest level of nutrients (330:110:220 kg NPK ha^{-1}) recorded the highest ascorbic acid content of 24.48 mg per 100 g^{-1} of fresh weight of bhindi fruit which was on par with 220:73:146 kg NPK ha^{-1}. She also reported that crude fibre content of fruits significantly decreased and ascorbic acid content increased with higher level of nutrients.

Anitha (1997) reported maximum ascorbic acid content in chilli fruit with the highest level of nitrogen.

Mani and Ramanathan (1982) reported that crude fibre content of bhindi fruit was significantly decreased by nitrogen fertilization. Application of 80 kg N ha^{-1} recorded least crude fibre content of 12.91 percent as against 14.2 percent with zero level of nitrogen. Balasubramoni (1988) reported least crude fibre content in bhindi fruits with 30 kg ha^{-1}.

2.6.4. Effect of nitrogen on nutrient uptake by crops

Singh *et al.* (1970) reported that nitrogen application increased the utilization of phosphorus in cauliflower. Asif and Greig (1972) found that in bhindi application of nitrogen increased nitrogen content but decreased phosphorus content. Joseph (1982) observed that in chilli total uptake of nitrogen was increased significantly by increased levels of nitrogen.The beneficial effect of higher levels of nutrients in increasing the uptake of nitrogen has been reported by Dolkova *et al.* (1986), Hedge (1988), Saji john (1989) and Sajitharani (1993). Anitha (1997) reported that application of higher levels of nitrogen increased the nitrogen and potassium uptake by plants.

2.7. Effect of Azospirillum on growth, yield and quality of vegetables.

Significant improvement in growth, yield and quality of vegetables by Azospirillum inoculation has been reported in various crops.

2.7.1. 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 inturn result in better establishment of plant seedling and subsequent growth (Tien *et al.*, 1979 and Govindan and Purushothaman, 1984). Hadas and Okon (1987) reported that there was significant increase in root length (3.5%), root dry weight (50%) and total leaf area of 18 days old tomato seedlings due to Azospirillum inoculation.

Manib *et al.* (1979) reported increased dry weight of tomato plants by 5 to12 percent due to inoculation of Azospirillum.

Wam and Konde (1986) reported that performance of Azospirillum was better at lower dose of nitrogen. Soil and foliage application of Azospirillum not only increased the root biomass but also the shoot biomass and plant height in bhindi (Parvatham *et al* ., 1989). Bashan *et al* . (1989) observed that in Azospirillum treated tomato 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. In knolkhol, Azospirillum inoculation resulted in increased leaf area and plant height (Chattoo *et al* ., 1997).

2.7.2. Effect on yield attributes and yield

Cohen *et al* . (1980) obtained increased yield for a wide range of tropical and temperate crops by Azospirillum inoculation. Azospirillum inoculation was known to increase the yield of crops by 5 to 20 percent with savings of 40 percent of the recommended dose of nitrogen (Dart, 1986).

The mechanism 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 biological nitrogen fixation, development and branching of roots, production of plant growth hormones, enhancement on uptake of nutrients, improved water status of plants, increased nitrate reductase activity in plants and production of antibacterial and antifungal compounds (Okon, 1985 ; Pandey and Kumar, 1989 and Wani, 1990).

Subbiah (1991) reported that in okra, application of 50 percent of the recommended dose of N and soil application of Azospirillum had beneficial effect on yield and N use efficiency besides saving up to 50 percent of recommended N. Dhanalakshmi and Pappiah (1995) reported that 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 uninoculated plants.

Okon and Gonzalaz (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 region. The results showed significant increases in yield of the order of 5-30 percent.

2.7.3. Effect on quality parameters

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, drymatter and vitamin C contents in cabbage, cauliflower and tomato. (Subbiah, 1990; Kalyani *et al* ., 1992 and Jeevajohti *et al* ., 1993). Chattoo *et al* . (1997) observed that, in knolkhol Azospirillum inoculation markedly increased growth, yield and quality attributes over control. There was a nonsignificant increase in drymatter and vitamin C over control.

Azospirillum treated tomato plants gave fruits with high total soluble solids(8.46 %) and ascorbic acid content(32.91 mg 100 g^{-1}fruit) (Kumaraswamy and Madalageri, 1990).

2.7.4. Effect of Azospirillum inoculation on nutrient uptake

Sarig *et al.* (1988) reported that Azospirillum inoculation enhanced the uptake of NO_3, NH_4, phosphorus and potassium in plants as compared to uninoculated plants. Boddey *et al.* (1986) using N-15 labelled $(NH_4)SO_4$ as a source of nitrogen fertilizer to wheat plants observed high quantity of N-15 in inoculated than in uninoculated plants. Pacovsky *et al.* (1986) observed an increase in P and other nutrient concentration in the foliage of Azospirillum inoculated sorghum plants. Parvatham *et al.* (1989) noted better uptake of N and P in bhindi due to Azospirillum inoculation. Subbiah (1991) observed that soil application of Azospirillum to bhindi crop had beneficial effect on N,P and K uptake as compared to uninoculated plants. Anitha (1997) reported that Azospirillum inoculation improved N,P and K uptake in chilli as compared to no inoculation.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled " Organic nutrition in okra *(Abelmoschus esculentus)*" was taken up at College of Agriculture, Vellayani during July 1997 to May 1998. The study was aimed to find out the effect of dual application of phosphate sources and microbial inoculants on the quality of compost and to standardize an organic nutrient schedule for bhindi.

Two successive experiments namely standardisation of agro-techniques for enriching compost and organic nutrient scheduling in okra were conducted to achieve the objectives envisaged.

The details on the materials used and methods adopted are presented in this chapter.

3.1. Standardisation of agro-techniques for enriching compost

Agro-techniques for enriching compost were standardised on the basis of the duration of composting and the nutrient status of the composted materials.

Preparation of enriched compost

Composting was done in pits of 2x1 x 0.75 m size. The materials were chopped to 5-7 cm size and mixed with cowdung-soil-slurry in the ratio 70:20:10 (waste:cowdung:soil). Rock phosphate and bonemeal were added as per the treatments. These materials were filled in the pit and covered with thin layer of mud. Adequate moisture level of 60 per cent by wet weight was maintained by watering regularly. Fortnighly turning was given for proper aeration.

After 45 days Azotobacter and Phosphobacter were inoculated @ 1 kg per ton of material and again plastered with mud (Thampan, 1993). Occassionally the mud plaster was removed and the compost maturity was visually observed. When the compost was ready by its physical appearance such as the development of dark brown to black colour with uniformly disintegrated structure, watering was stopped. After ripening and curing the compost was removed.

Preparation of ordinary compost

For making ordinary compost, the raw materials used and the procedure followed were same as in the case of enriched compost.But here no organic supplements and microbial inoculants were added. The materials were chopped to 5-7 cm size and mixed with cowdung-soil-slurry in the ratio 70:20:10 (waste:cowdung:soil). These materials were filled in the pit and covered with thin layer of mud. Regular watering and fortnightly turning was given. Occassionally the mud plaster was removed and the compost maturity was visually observed. After completion of composting the mud plaster was carefully removed.

For both ordinary and enriched compost the time taken for composting was recorded. Samples of air dried compost were gently powdered and were subjected to chemical analysis.

3.1.1. Season and weather conditions

The experiment was conducted during July to October 1997. The data on various weather parameters viz. weekly rainfall, minimum and maximum temperature and relative humidity during the composting period are presented in Appendix. I and are graphically represented in Fig.1.

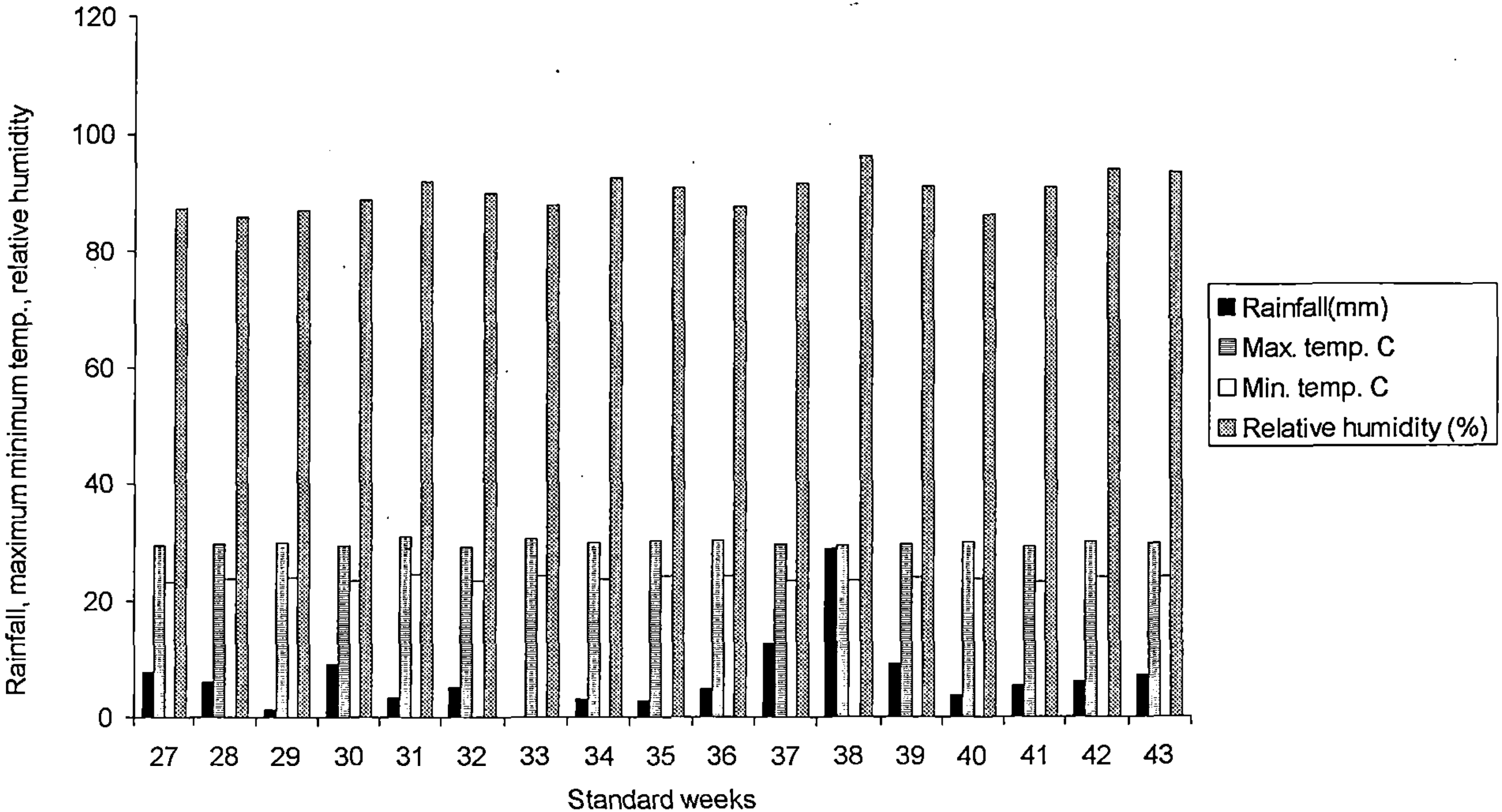


Fig.1. Weather data during the composting period

3.1.2. Materials

To ensure uniformity of raw materials banana leaves and culm along with dried cowdung were used for composting. Mussorie rock phosphate, bonemeal, Azotobacter and Phosphobacter (obtained from Microbiology Section, College of Agriculture, Vellayani) were added as per the treatments.

Materials	Chemical composition (%)		
	N	P_2O_5	K_2O
Cowdung	0.49	0.19	0.51
Banana leaves and culm	0.55	0.46	0.69
Mussorie rockphosphate	--	20.00	--
Bonemeal	3.43	24.80	--

3.1.3. Methods

Design and layout

The experiment was laid out in randomised block design with three replications. The layout plan is given in Fig.2.

Treatments

C_1 – Ordinary composting (uninoculated and unamended compost)

C_2 – 5 per cent rockphosphate + Azotobacter + Phosphobacter

C_3 – 10 per cent rockphosphate + Azotobacter + Phosphobacter

C_4 – 20 per cent rockphosphate + Azotobacter + Phosphobacter

C_5 – 5 per cent bonemeal + Azotobacter + Phosphobacter

C_6 – 10 per cent bonemeal + Azotobacter + Phosphobacter

C_7 – 20 per cent bonemeal + Azotobacter + Phosphobacter

C_8 – Ordinary composting + Azotobacter

C_9 – Ordinary composting + Phosphobacter.

3.1.4. Observations

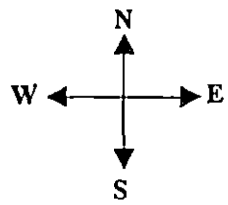
Duration of composting

The time taken for composting for different treatments was recorded based on the physical appearance (development of dark brown to black colour with uniformly disintegrated structure) and the C:N ratio. C:N ratio below 20 is indicative of an acceptable maturity in the finished product (Inbar *et al.*, 1990).

Quality of compost

Compost samples were analysed for total nitrogen, C : N ratio, total phosphorus and total potassium following standard analytical procedures (Jackson, 1973). Quality of compost was assessed based on the nutrient composition of the composted material and the C:N ratio.

Fig. 2. LAYOUT PLAN OF COMPOST



C_3	C_8	C_5	C_6	C_1	C_9	C_2	C_4	C_7	Replication I
C_2	C_7	C_4	C_6	C_5	C_8	C_3	C_9	C_1	Replication II
C_7	C_3	C_8	C_1	C_4	C_5	C_9	C_6	C_2	Replication III

3.2. Organic nutrient scheduling in okra.

3.2.1. Experimental site

The experiment was carried out in the Instructional Farm attached to the College of Agriculture, Vellayani situated at 8.5^0 N latitude, 76.9^0 E longitude at an altitude of 29m above mean sea level.

3.2.2. Soil

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

3.2.3. Cropping history of the field

The experimental area was previously cropped with a bulk crop of bhindi.

3.2.4. Season

The experiment was conducted during January to May 1998. The crop was raised as summer crop.

3.2.5. Weather conditions

The data on various weather parameters viz. weekly rainfall, maximum and minimum temperature and relative humidity during the cropping period are presented in Appendix II and are graphically represented in Fig.3. The mean maximum and minimum temperature,

Table 3.1. Soil characteristics of the experimental site

A. Physical composition

Sl. No.	Fraction	Content in soil (%)	Method
1.	Coarse sand	36.35	Bouyoucos Hydrometer method (Bouyoucos, 1962)
2.	Fine sand	15.00	
3.	Silt	17.50	
4.	Clay	30.00	

B. Chemical composition

Sl. No.	Parameter	Content ($kg\ ha^{-1}$)	Rating	Method
1	Available N	434.62	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
2	Available P_2O_5	39.21	High	Bray colorimetric method 1 (Jackson, 1973)
3	Available K_2O	122.35	Low	Ammonium acetate method (Jackson, 1973)
4	P^H	4.80	Acidic	P^H meter with glass electrode (Jackson, 1973)

mean rainfall and mean relative humidity ranged from 31.66 ^{o}C to 34.3 ^{o}C, 22.36 ^{o}C to 26.6 ^{o}C, from zero to 4.71 mm and from 82.29 to 96.57 per cent respectively. In general the conditions were favourable for the satisfactory growth of the crop.

3.2.6. Materials

3.2.6.1. Variety

Okra variety *Arka anamika*, identified as a superior variety at national level by the AICVIP workshop during 1990, was the test crop used for the study. It was evolved by crossing *Abelmoschus esculentus* with *Abelmoschus tetraphyllus* var. *tetraphyllus* and is resistant to yellow vein mosaic virus. Yield potential of *Arka anamika* varies from 17.5 to 25 t ha^{-1} depending upon the season.

The seed was obtained from the Department of Olericulture, College of Horticulture, Vellanikkara.

3.2.6.2. Manures and fertilizers

Farmyard manure (0.42%N, 0.25%P_2O_5, 0.46% K_2O), poultry manure (2.86%N, 2.64% P_2O_5, 2.2% K_2O), neem cake (5.1%N, 1.0% P_2O_5, 1.51% K_2O), green leaf (3.74% N, 0.52% P_2O_5 ,0.96% K_2O), enriched compost (2.78% N, 4.66% P_2O_5, 1.12% K_2O) and ash (1.12% K_2O) were used as organic sources and urea (46%N), mussorie rock phosphate (20% P_2O_5) and muriate of potash (60% K_2O) as the inorganic sources for N, P and K respectively.

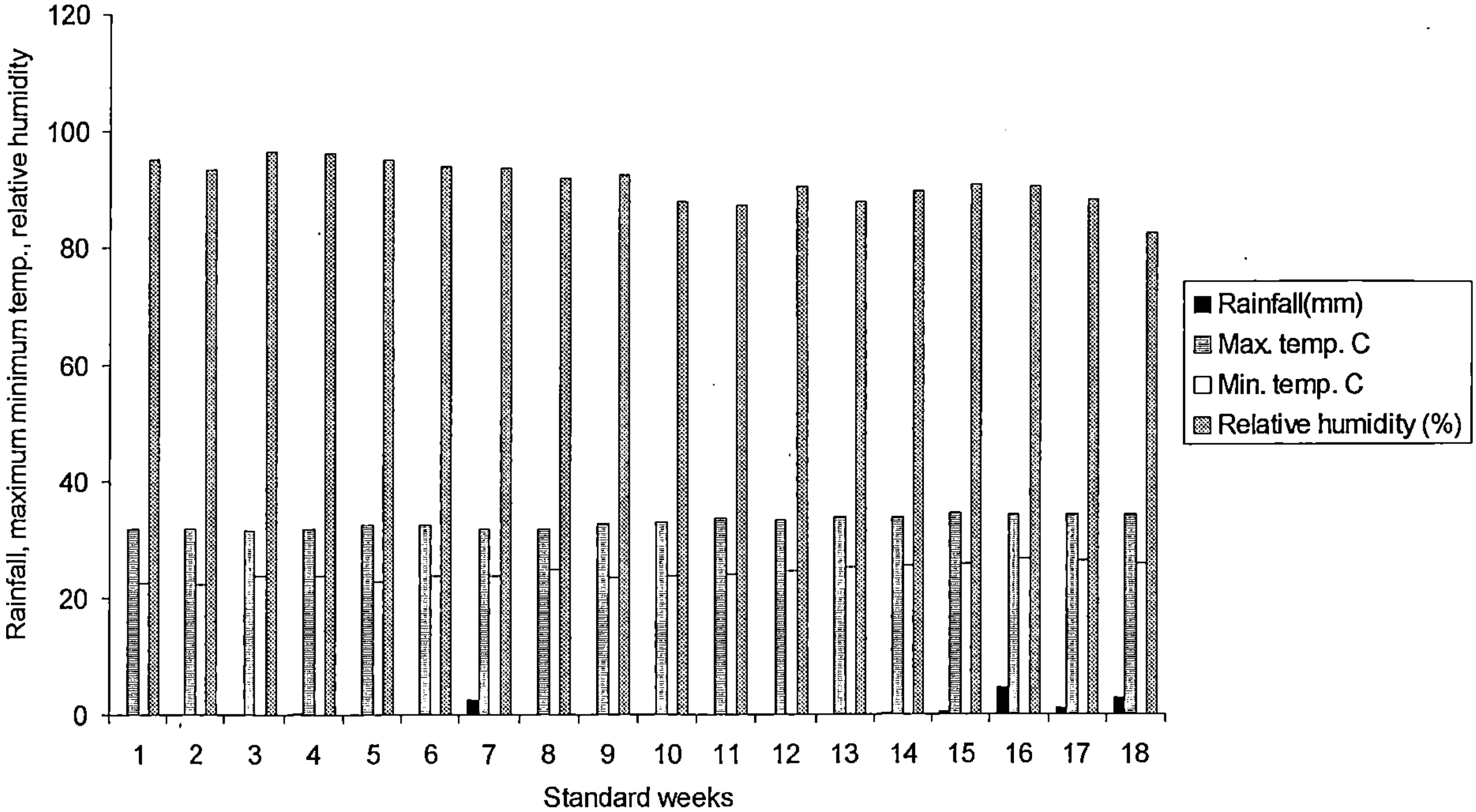


Fig. 3. Weather data during the cropping period

3.2.7. Methods

3.2.7.1. Design and treatments

The experiment was laid out as a 5x3x2+1 factorial experiment in randomised block design with three replications and 31 treatment combinations as detailed below. The layout plan is shown in Fig.4.

Treatments

The treatments consisted of combinations of nitrogen sources, nitrogen levels and microbial inoculants.

Levels of nitrogen (N)

N_1—50 per cent of package of practices (POP) recommended dose

N_2—100 per cent of POP recommended dose

N_3—150 per cent of POP recommended dose

Sources of nitrogen (S)

S_1—Farmyard manure (FYM) alone

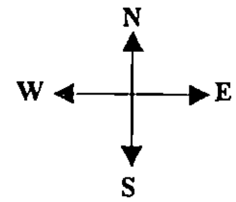
S_2—FYM + poultry manure (PM) in (1:1 ratio)

S_3—FYM + neem cake (NC) in (1:1 ratio)

S_4—FYM + green leaf (GL) in (1:1 ratio)

S_5—FYM + enriched compost (EC) in (1:1 ratio)

Fig . 4. LAYOUT PLAN OF CROP



RI

T_{17}	T_{31}	T_{24}	T_{18}	T_{22}	T_{21}	T_{14}	T_{5}	T_{1}	T_{13}	T_{29}	T_{16}	T_{23}	T_{15}	T_{7}	T_{12}	T_{19}	T_{30}	T_{8}	T_{26}	T_{20}	T_{9}	T_{28}	T_{3}	T_{11}	T_{27}	T_{25}	T_{6}	T_{10}	T_{4}	T_{2}

RII

T_{4}	T_{18}	T_{16}	T_{13}	T_{20}	T_{8}	T_{1}	T_{3}	T_{11}	T_{15}	T_{2}	T_{17}	T_{5}	T_{12}	T_{14}	T_{24}	T_{30}	T_{21}	T_{10}	T_{26}	T_{23}	T_{7}	T_{19}	T_{27}	T_{25}	T_{9}	T_{31}	T_{6}	T_{29}	T_{28}	T_{22}

RIII

T_{1}	T_{26}	T_{14}	T_{17}	T_{4}	T_{22}	T_{28}	T_{11}	T_{13}	T_{8}	T_{25}	T_{7}	T_{10}	T_{2}	T_{5}	T_{3}	T_{20}	T_{9}	T_{15}	T_{12}	T_{30}	T_{16}	T_{24}	T_{19}	T_{23}	T_{18}	T_{29}	T_{21}	T_{27}	T_{31}	T_{6}

T_1	–	$S_1N_1A_o$	T_6	–	S_1N_3A	T_{11}	–	$S_2N_3A_o$	T_{16}	–	S_3N_2A	T_{21}	–	$S_4N_2A_o$	T_{26}	–	S_5N_1A
T_2	–	S_1N_1A	T_7	–	$S_2N_1A_o$	T_{12}	–	S_2N_3A	T_{17}	–	$S_3N_3A_o$	T_{22}	–	S_4N_2A	T_{27}	–	$S_5N_2A_o$
T_3	–	$S_1N_2A_o$	T_8	–	S_2N_1A	T_{13}	–	$S_3N_1A_o$	T_{18}	–	S_3N_3A	T_{23}	–	$S_4N_3A_o$	T_{28}	–	S_5N_2A
T_4	–	S_1N_2A	T_9	–	$S_2N_2A_o$	T_{14}	–	S_3N_1A	T_{19}	–	$S_4N_1A_o$	T_{24}	–	S_4N_3A	T_{29}	–	$S_5N_3A_o$
T_5	–	$S_1N_3A_o$	T_{10}	–	S_2N_2A	T_{15}	–	$S_3N_2A_o$	T_{20}	–	S_4N_1A	T_{25}	–	$S_5N_1A_o$	T_{30}	–	S_5N_3A

T_{31} – POP recommendation

(1:1 ratio represents half of the N supplied through FYM and the remaining half through the other organic manure. Basal dose of organic manure is supplied through FYM for all treatments).

Microbial inoculation (A)

A_O – Control (no inoculation)

A -- Azospirillum

Absolute control – Package of Practices Recommendation of Kerala Agricultural University. (50: 8: 25 kg ha^{-1} NPK + 12 t FYM ha^{-1})

All treatments were given diluted cow's urine spray (10 times dilution) at fortnightly interval.

Phosphorus and potassium nutrients were supplied through organic manures and ash.

3.2.7.2. Field culture

Land preparation

The experimental field was dug twice, stubbles removed, clods broken and the field was laid out into blocks and plots of 2.4m x 1.2m size.

Manure and fertilizer application

Manures and fertilizers were applied as per the schedule of treatments. Quantity of various organic manures were computed on the basis of the nitrogen content (single nutrient basis) before the application of manures. Organic manures and Azospirillum were mixed with FYM and applied as basal dressing. In absolute control plots, entire dose of phosphorus and potassium and half of the recommended dose of nitrogen were applied as chemical fertilizer at the time of sowing and the remaining dose one month after sowing.

Seeds and sowing

Two seeds were dibbled in each pit at a depth of 3-4 cm and at a spacing of 60cm x 30cm. Gap filling was done in a week followed by thinning two weeks later so as to retain one plant pit^{-1}.

After cultivation

The crop was irrigated and weeded as and when needed. Top dressing was done one month after sowing along with the intercultural operations.

Plant protection

Only organic chemicals were used for plant protection. Repeated sprayings (4 times at the interval of 15 days) of neem kernal emulsion (neem kernal based EC containing azadiractin 0.15%) @ 4ml $litre^{-1}$ was done against shoot and fruit borer, night feeders and other pests for getting satisfactory fruit yield. Fortnightly spraying of diluted cow's urine also acted as a repellent and was effective in controlling the pests to some extent.

Harvesting

The fruits were harvested at vegetable maturity stage on alternate days as judged by visual observations. A total of 20 harvests were taken over the entire cropping period.

3.2.7.3. Observations

Four sample plants were selected after eliminating the border rows in each plot and the following observations were recorded.

3.2.7.3.1. Germination percentage

The number of seeds germinated per plot on the 8^{th} day after sowing was recorded and expressed in percentage.

3.2.7.3.2. Height of the plant

The height of plants were measured from the base to the growing tips and expressed in cm at monthly intervals.

3.2.7.3.3. Leaf Area Index (LAI)

LAI was worked out at 30 DAS and 60 DAS. Area of all the leaves produced per plant was recorded using LI – 3100 leaf area meter and LAI was worked out by the formula suggested by Watson (1952).

LAI = Leaf area / Land area

3.2.7.3.4. Days to 50 per cent flowering

The number of days taken for 50 per cent of the plant population to flower in each treatment was recorded.

3.2.7.3.5. Dry matter production and partitioning

The fruits at each harvest and the plants at final harvest were seperately chopped and ovendried to constant weight at $80 \pm 5\ ^0c$.

The dry weight of fruits and shoot were seperately recorded, expressed in g $plant^{-1}$ and later converted to kg ha^{-1}.

3.2.7.3.6. Fruits per plant

The per plant fruit number was calculated from the total number of fruits harvested from the observation plants.

3.2.7.3.7. Length of fruits

Length of the fruits harvested from the observation plants in each harvest was measured, mean worked out and expressed in cm.

3.2.7.3.8. Weight of fruits

Weight of green fruits obtained per plant was recorded, mean worked out and expressed in g $fruit^{-1}$.

3.2.7.3.9. Fruit yield per plant

Fruit yield was computed by adding the weights of fruits of each harvest and is expressed in g $plant^{-1}$.

3.2.7.3.10. Total fruit yield

Weight of the fruits from the 20 harvests were totalled up at the end of the cropping season and was converted into per hectare yield.

3.2.7.3.11. Shelf life

The harvested fruits from each treatment and replication were kept at room temperature for 8 days. The keeping quality was assessed as per visual observations (number of days the fruits remained healthy without any spoilage) and crude fibre content.

3.2.7.4. Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The air dried samples were analysed for available nitrogen, available P_2O_5 and available K_2O as per the standard analytical methods described by Jackson (1973).

3.2.7.5. Plant analysis

Plant samples were analysed for N, P and K after final harvest. The plant and fruit samples were separately chopped and dried in an air oven at $80 \pm 5\ ^0c$ till constant weights were achieved. Samples were then passed through a 0.5mm mesh in a Wiley mill. Nitrogen content was estimated using microkjeldhal method, phosphorus content using vanado molybdophosphoric yellow colour method and potassium content using flame photometer (Jackson, 1973).

3.2.7.5.1. Nutrient uptake

The total uptake of N, P and K were calculated as the product of percentage content of nutrients in the plant samples and dry weight and expressed in kg ha^{-1}.

3.2.7.5.2. Ascorbic acid content of fruit

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

3.2.7.5.3. Crude protein content

The percent of crude protein was calculated by multiplying the percentage of nitrogen in the fruits by the factor 6.25 (Simpson *et al.*, 1965).

3.2.7.5.4. Crude fibre content

Crude fibre content was determined by the A.O.A.C method (1960).

3.2.7.6. Economics of production

The economics of production was worked out considering all aspects of cost of cultivation and the income derived from the treatments. It was calculated as per the norms and rates fixed by the Instructional Farm, College of Agriculture, Vellayani.

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

Benefit cost ratio = Gross income / Cost of cultivation

3.2.7.7. Statistical analysis

The data relating to each character in the experiment was analysed using the analysis of variance technique as applied to randomised block design described by Cochran and Cox (1965). Where the effects were found to be significant critical differences were calculated for effecting comparison among the means. Correlation studies were also carried out between yield and yield attributes.

RESULTS

4. RESULTS

An investigation was conducted to find out the effect of dual application of microbes and phosphate sources on the quality of compost and to standardize an organic nutrient schedule for bhindi. Two successive experiments as detailed below were conducted to achieve the objectives envisaged.

1. Standardisation of agro-techniques for enriching compost.

2. Organic nutrient scheduling in okra.

The data on various observations were statistically analysed and presented in this chapter.

4.1. Standardisation of agro-techniques for enriching compost.

4.1.1. C:N ratio of composts as influenced by microbial inoculation and supply of phosphate sources.

Table 4.1 gives the C:N ratio of different matured composts.

The lowest C:N ratio (13.71) was recorded by compost enriched with 20per cent bonemeal and microbial inoculants. This was on par with the treatment C_4 (20% rockphosphate + Azotobacter + Phosphobacter) which recorded C:N ratio of 14.23. The maximum C:N ratio of 19.35 was recorded by ordinary compost

C:N ratio showed a decreasing trend with the increase in the levels of phosphate sources. Compost treated with microbial inoculants and varying levels (5%, 10% and 20%) of bonemeal and rock phosphate recorded the C:N ratio of 15.54 (C_5), 14.32 (C_6), 13.71 (C_7) and 15.76 (C_2), 14.88 (C_3) and 14.23 (C_4) respectively.

C:N ratio of composts treated with Azotobacter alone (C_8) and Phosphobacter (C_9) were statistically on par.

4.1.2. Time taken for composting

Mean data on time taken for composting are presented in Table 4.1.

The data reveals that the time taken for composting was significantly influenced by various treatments. The minimum number of days (82.33) were taken by the compost enriched with 20 percent bonemeal , Azotobacter and Phosphobacter (C_7) and this was on par with treatment C_4 which took 84.66 days for maturity. The maximum number of days (120) for compost maturity was taken by ordinary compost (uninoculated and unamended).

The application of increased levels of phosphate sources (5%, 10% and 20% bonemeal and rock phosphate) resulted in decreasing the composting period considerably. Compost treated with varying levels of bonemeal and microbial inoculants matured earlier as compared to the respective levels of rock phosphate, even though the statistical difference was insignificant.

Compost inoculated with Azotobacter alone took 95.33 days and Phosphobacter alone took 98 days for maturing and statistically they were on par.

Table 4.1. Ripening period and quality of compost as influenced by phosphorus sources and microbial inoculants.

Treatments	C:N ratio	Time taken for composting (days)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
C_1 [OC]	19.35	120	0.52	0.48	0.73
C_2 [5% RP + MI]	15.76	93	0.85	1.66	0.83
C_3 [10% RP + MI]	14.88	89.67	1.24	3.48	0.86
C_4 [20% RP + MI]	14.23	84.66	1.63	4.63	0.93
C_5 [5% BM + MI]	15.54	90.67	0.96	1.71	0.84
C_6 [10% BM + MI]	14.32	85.66	1.72	3.53	0.92
C_7 [20% BM + MI]	13.71	82.33	2.78	4.66	1.12
C_8 [OC + Azotobacter]	15.83	95.33	0.81	0.8	0.81
C_9 [OC + Phosphobacter]	16.11	98	0.72	1.06	0.79
SE	0.191	1.010	0.016	0.021	0.012
CD [0.05]	0.573	3.03	0.048	0.062	0.037

OC- Ordinary compost
RP- Rock phosphate
MI- Microbial inoculants (Azotobacter and Phosphobacter)
BM- Bone meal

4.1.3. Nutrient composition of composts as influenced by microbial inoculation and phosphate sources.

Table 4.1 gives the mean values of major nutrients contained in different composts

Nitrogen

Significant differences were obtained in the nitrogen content of enriched and ordinary composts

The maximum nitrogen content (2.78%) was observed in compost enriched with 20 percent bonemeal, Azotobacter and Phosphobacter and was significantly superior to all other treatments. Ordinary compost (uninoculated and unamended) recorded the least value of 0.52 per cent and was significantly inferior to all other treatments.

Increased levels of phosphate sources increased the nitrogen content of compost. Each higher level was significantly superior to the next lower level. Also compost treated with varying levels of bonemeal and microbial inoculants showed higher nitrogen contents as compared to the respective levels of rockphosphate and microbial inoculants. The corresponding values were 2.78 per cent (C_7), 1.63 per cent (C_4), 1.72 per cent (C_6), 1.24 per cent (C_3) 0.96 per cent (C_5) and 0.85 per cent (C_2).

Compost treated with Azotobacter alone recorded significantly higher nitrogen content (0.81%) and was superior to compost treated with Phosphobacter alone.

Phosphorus

Table 4.1 showed that the phosphorus content of enriched compost was significantly higher than that of ordinary compost.

The maximum phosphorus content of 4.66 per cent was recorded by treatment C_7 (20% bonemeal and microbial inoculants) and was comparable with C_4 (20% rock phosphate + microbial inoculants) which recorded 4.63 per cent. The minimum phosphorus content of 0.48 per cent was observed in C_1 (ordinary compost). The compost enriched with 5 percent and 10 per cent and microbial inoculants recorded phosphorus content of 1.71 per cent and 3.53 per cent respectively and was statistically on par with the corresponding levels of rockphosphate and microbial bonemeal.

Among the various microbial inoculants Phosphobacter alone treated compost (C_9) registered significantly higher phosphorus content (1.06%) as compared to Azotobacter alone treated compost (0.81%).

Potassium

Table 4.1 gives the potassium content of different composts.

The maximum potassium content (1.12%) was observed in compost treated with 20 per cent bonemeal and microbial inoculants. All other treatments were significantly inferior with the least value recorded by ordinary compost (0.73%). Compost treated with 20 per cent rockphosphate and microbial inoculants (C_4) recorded the potassium content of 0.93 per cent and was on par with C_6 (10% bonemeal and microbial inoculants) which registered potassium content of 0.92 per cent.

Among various microbial inoculants compost treated with Azotobacter (C_8) alone recorded the potassium content of 0.81 per cent and was on par with C_9 (0.79%).

4.2. Organic nutrient scheduling in okra

4.2.1. Growth characters

4.2.1.1. Germination percentage

Germination percentage as recorded on the 8^{th} DAS is given in Table 4.2.

The data revealed that the germination percentage was significantly influenced by various nitrogen sources. Treatment S_3 (FYM + neem cake) recorded the maximum germination percentage of 93.4 per cent and was on par with S_4 and S_2, but significantly superior to other treatments. The lowest germination percentage of 81.6 per cent was recorded by S_5 (FYM + enriched compost) and was on similar lines with POP recommendation and treatment S_1 (FYM alone).

Effect of nitrogen levels and microbial inoculation on germination percentage was non significant.

Effect of interaction between nitrogen sources (S) and nitrogen levels (N) was significant. S_3 N_3 recorded the highest germination percentage of 96.88 per cent and was on par with S_4 N_2, S_1 N_1, S_3 N_2, S_3N_1, S_4 N_1, S_2 N_1, and S_2N_2 (88.54 %) and was significantly superior to other treatments. Lowest value of 78 per cent was recorded by S_5 N_2 (Table 4.2a).

Table 4. 2.Effect of sources of nitrogen, levels of nitrogen and microbial inoculation on germination percentage on 8th DAS.

Treatments	Germination percentage (%)
Nitrogen sources	
S_1 (FYM alone)	87.5
S_2 (FYM+PM)	88.19
S_3 (FYM+NC)	93.40
S_4 (FYM+GL)	90.63
S_5 (FYM + EC)	81.59
SE	2.10
CD (0.05)	5.95
Nitrogen levels (kg ha^{-1})	
N_1 (50)	89.38
N_2 (100)	87.71
N_3 (150)	87.71
SE	--
CD (0.05)	--
Microbial inoculation	
A_0 (control)	89.03
A (Azospirillum)	87.5
SE	--
CD (0.05)	--
T_{31} [Absolute control – POP recommendation]	83.33

Wherever F values are significant CD values are given in the Table

Table 4.2a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on germination percentage on 8th DAS.

Germination percentage (%)					
Treatments	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation.	
Nitrogen sources	Nitrogen levels			Microbial inoculation.	
	N_1	N_2	N_3	Ao	A
S_1	93.75	84.38	84.38	90.28	84.72
S_2	89.58	88.54	86.46	86.81	89.58
S_3	90.63	92.71	96.88	93.06	93.75
S_4	90.63	94.79	86.46	92.36	88.89
S_5	82.29	78.13	84.38	82.64	80.56
SE	3.65	3.65	3.65	2.98	2.98
CD (0.05)	10.3	10.3	10.3	8.42	8.42

	Germination percentage (%)	
Treatments	Nitrogen levels x Microbial inoculation	
Nitrogen levels	Microbial inoculation.	
	Ao	A
N_1	89.17	89.58
N_2	87.08	88.33
N_3	90.83	84.58
SE	--	--
CD (0.05)	--	--

In the interaction effect between S x A (nitrogen sources x microbial inoculation) which was significant, treatment S_3 A recorded the maximum germination (93.75 percent) and was on line with other treatments except S_5 A_0 and S_5 A which registered significantly lower values.

Interaction effect between nitrogen levels and microbial inoculation was non significant.

4.2.1.2. Plant height

The data on mean plant height recorded at 30 and 60 DAS is presented in Table 4.3.

Different sources of nitrogen caused significant variation in plant height at all growth stages. At 30 DAS treatment S_2 (FYM + poultry manure) recorded the maximum plant height of 16.12 cm and was on line with S_4 (FYM + green leaf). The lowest height of 11.75 cm was recorded by T_{31} (POP recommendation) which was on par with S_5 and significantly inferior to all other sources. At 60 DAS S_4 (57.7 cm) and S_2 (55.41 cm) recorded comparable plant height, which were significantly superior to other sources.

At all growth stages nitrogen levels had influenced plant height significantly. At 30 DAS N_3 recorded the maximum plant height (16.94 cm) and was significantly superior to other two levels. The lowest plant height of 12.26 cm was observed in treatment N_1 and was significantly inferior to treatment N_2. At 60 DAS also each higher level was significantly superior to the next lower level.

Azospirillum inoculation resulted in a non significant increase in plant height at all growth stages.

Table 4.3. Effect of nitrogen sources, nitrogen levels and microbial inoculation on plant height at 30 DAS and 60 DAS.

Treatments	Height (cm)	
	30 DAS	60 DAS.
Nitrogen sources		
S_1 (FYM alone)	13.88	47.37
S_2 (FYM + PM)	16.12	55.41
S_3 (FYM + NC)	14.09	46.74
S_4 (FYM +GL)	15.89	57.71
S_5 (FYM +EC)	12.35	39.29
SE	0.46	1.92
CD (0.05)	1.31	5.42
Nitrogen levels (kg ha^{-1})		
N_1 (50)	12.26	39.16
N_2 (100)	14.19	45.86
N_3 (150)	16.94	62.89
SE	0.36	1.49
CD (0.05)	1.01	4.2
Microbial inoculation		
Ao (control)	14.3	48.25
A (Azospirillum)	14.63	50.35
SE	--	--
CD (0.05)	--	--
T_{31} [Absolute control-POP recommendation]	11.75	35.9

Table 4. 3a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on plant height at 30 DAS and 60 DAS.

Treatments	Height (cm) 30 DAS					Height (cm) 60 DAS				
	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation		Sources of nitrogen x Levels of nitrogen			Sources of nitrogen x Microbial inoculation.	
Nitrogen sources	Levels of nitrogen			Microbial inoculation		Levels of nitrogen			Microbial inoculation	
	N_1	N_2	N_3	A_O	A	N_1	N_2	N_3	A_O	A
S_1	12.1	13.44	16.08	13.67	14.07	39.1	43.11	59.88	46.8	47.9
S_2	13.45	16.41	18.48	15.99	16.24	43.5	53.6	69.1	53.26	57.55
S_3	11.76	13.03	17.48	13.83	14.35	35.21	39.02	65.99	44.8	48.67
S_4	13.59	15.98	18.11	15.82	15.97	47.17	57.03	68.9	56.69	58.7
S_5	10.38	12.1	14.57	12.19	12.51	30.8	36.5	50.53	39.69	38.89
SE	0.80	0.80	0.80	0.65	0.65	3.32	3.32	3.32	2.71	2.71
CD (0.05)	2.27	2.27	2.27	1.84	1.84	9.4	9.4	9.4	7.67	7.67

Treatments	Height (cm) 30 DAS		Height (cm) 60 DAS	
	Levels of nitrogen x Microbial inoculation		Levels of nitrogen x Microbial inoculation	
Levels of nitrogen	Microbial inoculation		Microbial inoculation	
	A_O	A	A_O	A
N_1	12.05	12.47	37.98	40.34
N_2	13.75	14.63	43.36	48.36
N_3	17.1	16.79	63.42	62.35
SE	0.51	0.51	2.10	2.10
CD (0.05)	1.43	1.43	5.94	5.94

Interaction effect between nitrogen sources and nitrogen levels was significant at all growth stages. Treatment S_2 N_3 recorded the maximum plant heights of 18.48 cm and 69.12 cm at 30 DAS and 60 DAS respectively and was on par with S_4 N_3 at both the stages (Table 4.3a).

The S x A interaction effect was significant. At 30 DAS treatment S_2 A recorded the maximum plant height (16.24 cm) and was on line with S_2 A_0, S_4 A and S_4 A_0. All the other treatments were significantly inferior with the lowest plant height being 12.19 cm recorded by S_5 A_0. At 60 DAS, S_4 A recorded the maximum height (58.72 cm) and was comparable with S_2 A (57.55 cm), S_4 A_0 (56.69 cm), and S_2 A_0 (53.26 cm) (Table 4.3a).

In the interaction between nitrogen levels and microbial inoculation, treatment N_3 A_0 recorded the maximum height of 17.1 cm and 63.42 cm at 30 and 60 DAS respectively and was on par with N_3 A. All the other treatments were significantly inferior.

4.2.1.3. Leaf Area Index (LAI)

LAI recorded at 30 and 60 DAS are presented in Table 4.4. In general the leaf area index of bhindi was significantly influenced by nitrogen sources. At 30 DAS, S_4 (FYM + green leaf) recorded the highest LAI of 0.807 and was significantly superior to other sources. The lowest LAI of 0.62 was observed on treatment S_3 (FYM + neem cake) and was on line with T_{31} and S_1. S_5 and S_2 recorded the intermediate values. At 60 DAS, the LAI values increased and the mean values ranged from 1.32 (S_1) to 1.53 (S_4).

Nitrogen levels influenced LAI significantly. Both at 30 DAS and 60 DAS each higher level was significantly superior to the next lower level. The values ranged from 0.604 (N_1) to 0.801 (N_3) and 1.234 (N_1) to 1.599 (N_3) for 30 DAS and 60 DAS respectively.

Table 4.4. Effect of sources of nitrogen, levels of nitrogen and microbial inoculation on leaf area index (LAI) at 30 DAS and 60 DAS

Treatments	LAI at 30 DAS	LAI at 60 DAS
Nitrogen sources		
S_1 (FYM alone)	0.650	1.324
S_2 (FYM + PM)	0.707	1.407
S_3 (FYM + NC)	0.623	1.369
S_4 (FYM + GL)	0.807	1.527
S_5 (FYM + EC)	0.742	1.452
SE	0.022	0.041
CD (0.05)	0.061	0.117
Nitrogen levels (kg ha^{-1})		
N_1(50)	0.604	1.234
N_2(100)	0.718	1.411
N_3(150)	0.801	1.599
SE	0.017	0.032
CD (0.05)	0.048	0.09
Microbial inoculation		
A_O (control)	0.704	1.411
A (Azospirillum)	0.711	1.421
SE	--	--
CD (0.05)	--	--
T_{31} (Absolute control-POP recommendation)	0.672	1.332

Wherever F values are significant CD values are given in the Table.

Table 4.4a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on leaf area index (LAI) at 30 DAS and 60 DAS.

Treatments	LAI (30 DAS)					LAI (60 DAS)				
	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation		Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
Nitrogen sources	Nitrogen levels			Microbial inoculation		Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A	N_1	N_2	N_3	A_0	A
S_1	0.577	0.666	0.733	0.648	0.669	1.19	1.32	1.46	1.32	1.33
S_2	0.609	0.693	0.819	0.721	0.693	1.22	1.37	1.63	1.44	1.38
S_3	0.568	0.646	0.654	0.619	0.626	1.21	1.38	1.52	1.35	1.38
S_4	0.646	0.856	0.92	0.7898	0.825	1.32	1.54	1.72	1.49	1.57
S_5	0.62	0.728	0.879	0.743	0.742	1.24	1.45	1.67	1.46	1.45
SE	0.038	0.038	0.038	0.031	0.031	0.072	0.072	0.072	0.058	0.058
CD (0.05)	0.106	0.106	0.106	0.087	0.087	0.202	0.202	0.202	0.165	0.165

Treatments	LAI (30 DAS)		LAI (60 DAS)	
	Nitrogen levels x Microbial inoculation		Nitrogen levels x Microbial inoculation	
Nitrogen levels	Microbial inoculation		Microbial inoculation	
	A_0	A	A_0	A
N_1	0.597	0.610	1.24	1.23
N_2	0.709	0.727	1.39	1.44
N_3	0.806	0.796	1.61	1.59
SE	0.024	0.024	0.045	0.045
CD (0.05)	0.067	0.067	0.128	0.128

Azospirillum inoculation resulted in a nonsignificant increase in the LAI with respect to no inoculation.

Interaction between nitrogen sources and nitrogen levels, nitrogen sources and microbial inoculation, and nitrogen levels and microbial inoculation were significant at all growth stages (Table 4.4a). In S x N interaction S_4 N_3 recorded maximum and significant LAI at 30 DAS (0.920) and 60 DAS (1.72). Treatments S_5N_3, S_4N_2, S_2N_3 behaved similarly with S_4N_3 at both the stages.

S x A interaction effect showed that S_4A recorded maximum and significant LAI at all stages and was on par with treatments S_4A_0, S_5A_0 and S_5A. Other treatments were significantly inferior. The LAI values ranged from 0.619 (S_3A_0) to 0.825 (S_4A) at 30 DAS and from 1.32 (S_1A_0) to 1.57 (S_4A) at 60 DAS.

In N x A interaction N_3A_0 recorded the maximum values of 0.806 at 30 DAS and 1.61 at 60 DAS. Treatment N_3A also behaved similarly, but other treatments were significantly inferior.

4.2.1.4. Drymatter production (DMP) and partitioning at the stage of final harvest

Shoot dry weight (stem + leaf)

Shoot dry weight recorded at the time of final harvest is given in Table 4.5.

Shoot dry weight was significantly influenced by nitrogen sources and nitrogen levels. Among various nitrogen sources, S_3 (FYM + neem cake) recorded the maximum and significant shoot dry weight of 1454.68 kg ha^{-1} and was comparable with treatments S_4, S_5

and S_2. Treatments S_1 and T_{31} (POP recommended dose) recorded lower values and was significantly inferior to other treatments.

Shoot dry weight increased significantly with each successive increase in levels of nitrogen. The values ranged from 898.58 kg ha^{-1} (N_1) to 1781.29 kg ha^{-1} (N_3)

Effects of Azospirillum inoculation and various interactions on shoot dry weight were non-significant.

Fruit dry weight

Dry weight of fruits produced upto the stage of final harvest is given in Table 4.5.

Fruit dry weight was nonsignificantly influenced by various nitrogen sources.

Effect of nitrogen levels on fruit dry weight was significant. Each higher level was significantly superior to the next lower level. The values ranged from 1104.45 kg ha^{-1} (N_1) to 1996.74 kg ha^{-1} (N_3).

Azospirillum inoculation resulted in a nonsignificant increase in fruit dry weight than the control. Various interaction effects on fruit dry weight were nonsignificant.

Table 4.5. Effect of nitrogen sources , nitrogen levels and microbial inoculation on shoot dry weight, fruit dry weight and total dry matter production (DMP) at harvest.

Treatments	Shoot dry weight [kg ha^{-1}]	Fruit dry Weight [kg ha^{-1}]	DMP [kg ha^{-1}]
Nitrogen sources			
S_1 (FYM alone)	1189.62	1529.03	2719.12
S_2 (FYM + PM)	1348.65	1632.67	2982.13
S_3 (FYM + NC)	1454.68	1644.06	3099.01
S_4 (FYM + GL)	1377.83	1501.52	2888.61
S_5 (FYM + EC)	1370.48	1558.63	2929.07
SE	59.13	--	--
CD (0.05)	167.26	--	--
Nitrogen levels (kg ha^{-1})			
N_1 (50)	898.58	1104.45	2003.05
N_2 (100)	1364.87	1618.35	2984.17
N_3 (150)	1781.29	1996.74	3783.59
SE	45.81	47.25	87.26
CD (0.05)	129.56	133.63	246.79
Microbial inoculation			
A_0 (control)	1305.93	1552.24	2862.08
A (Azospirillum)	1390.57	1594.12	2985.13
SE	--	--	--
CD (0.05)	--	--	--
T_{31} (Absolute control-POP recommendation)	1259.62	1538.36	2797.99

Total drymatter production (DMP)

Table 4.5 gives the DMP at the time of final harvest.

The influence of nitrogen sources on total drymatter production was nonsignificant.

Different levels of nitrogen N_1, N_2 and N_3 differed significantly among one another. The values ranged from 2003.05 kg ha^{-1} (N_1) to 3783.59 kg ha^{-1} (N_3).

The effects of Azospirillum inoculation and various interactions on DMP was nonsignificant.

4.2.2. Yield attributes and yield.

4.2.2.1. Days to 50 percent flowering

Mean number of days taken for 50 percent flowering are given in Table 4.6.

Different sources of nitrogen significantly influenced the time of 50 percent flowering. Earliest flowering was observed in treatment S_4 (FYM + green leaf) which took only 41 days. Treatment S_1 and S_3 completed 50 percent flowering within 42 days and T_{31} (POP recommendation) and S_5 (FYM + enriched compost) took a maximum of about 44 days.

Nitrogen levels and microbial inoculation had no significant effect on the days to 50 percent flowering.

Interaction effects of S x N and S x A were significant (Table 4.6a.).

Table 4. 6. Effect of sources of nitrogen, levels of nitrogen and microbial inoculation on time of 50 percent flowering and number of fruits plant^{-1}.

Treatments	Time of 50 percent flowering	Number of fruits plant^{-1}
Nitrogen sources		
S_1 (FYM alone)	42.12	10.97
S_2 (FYM + PM)	41.77	11.77
S_3 (FYM + NC)	41.77	11.89
S_4 (FYM + GL)	40.8	10.44
S_5 (FYM + EC)	43.52	11.28
SE	0.35	0.42
CD (0.05)	0.98	1.19
Nitrogen levels [kg ha^{-1}]		
N_1(50)	41.97	7.93
N_2(100)	42.15	11.69
N_3(150)	41.89	14.19
SE	--	0.33
CD (0.05)	--	0.75
Microbial inoculation		
A_0 (control)	41.89	11.02
A (Azospirillum)	42.11	11.52
SE	--	--
CD (0.05)	--	--
T_{31} [Absolute control-POP recommendation]	43.8	11.77

Table 4. 6a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on time of 50 percent flowering.

Time of 50 percent flowering					
Treatments	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
Nitrogen sources	Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A
S_1	41.62	42.79	41.95	42.48	41.76
S_2	40.3	42.38	42.65	40.96	42.6
S_3	42.43	42.28	40.62	41.84	41.71
S_4	41.3	39.67	41.43	40.41	41.19
S_5	44.18	43.6	42.79	43.78	43.27
SE	0.60	0.60	0.60	0.49	0.49
CD (0.05)	1.70	1.70	1.70	1.39	1.39

	Time of 50 percent flowering	
Treatments	Nitrogen levels x Microbial inoculation	
Nitrogen levels	Microbial inoculation	
	A_0	A
N_1	42.25	41.69
N_2	42.04	42.25
N_3	41.39	42.38
SE	0.38	0.38
CD (0.05)	--	--

In S x N interaction, treatment $S_4 N_2$ was the superior most (39.67 days) followed by S_2N_1 (40.3 days) and S_3N_3 (40.62 days) which were on par . S_5N_1 took the maximum number of days (44.18 days) for 50 percent flowering and was on line with S_5N_2, S_1N_2, S_5N_3 and S_2N_3.

In the interaction between nitrogen sources and microbial inoculation treatment S_4A_0 (40.41 days) recorded early flowering compared to all other treatments.

N x A interaction effect appeared to be nonsignificant.

4.2.2.2. Fruits per plant

The mean number of fruits recorded per plant is shown in Table 4.6.

Various nitrogen sources significantly influenced the number of fruits produced per plant. Treatment S_3 (FYM + neem cake) produced the maximum number of fruits (11.89) and was on line with all other treatments except S_4 (FYM + green leaf) whose production was the lowest (10.44).

Nitrogen levels N_1, N_2 and N_3 also showed significant variations. Each higher level was significantly superior to the next lower level and the values ranged from 7.93 (N_1) to 14.19 (N_3) fruits per plant.

Fruit production was non significantly increased by Azospirillum inoculation.

Interaction between nitrogen sources and nitrogen levels (S x N), nitrogen sources and microbial inoculation (S x A), and nitrogen levels and microbial inoculation (N x A) were significant (Table 4.6b.).

Table 4. 6b. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on number of fruits plant^{-1}

Number of fruits plant^{-1}					
Treatments	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
Nitrogen sources	Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A
S_1	7.88	11.65	13.37	10.69	11.24
S_2	7.81	10.99	16.51	11.63	11.89
S_3	8.5	12.85	14.35	11.57	12.23
S_4	7.51	10.6	13.2	9.87	11.00
S_5	7.95	12.38	13.52	11.34	11.22
SE	0.73	0.73	0.73	0.59	0.59
CD (0.05)	2.05	2.05	2.05	1.68	1.68

	Number of fruits plant^{-1}	
Treatments	Nitrogen levels x Microbial inoculation	
Nitrogen levels	Microbial inoculation	
	A_0	A
N_1	7.73	8.12
N_2	11.28	12.11
N_3	14.05	14.32
SE	0.50	0.50
CD (0.05)	1.30	1.30

In S x N interaction, $S_2 N_3$ with the maximum number of fruit production of 16.51 was significantly superior to all other treatments and $S_4 N_1$ (7.5) was the most inferior one.

In S x A interaction, S_3A produced the maximum number of fruits per plant (12.23). All other treatments behaved similarly with S_3A, except S_4A_0 which showed the least value of 9.87 fruits per plant.

In the interaction between nitrogen levels and microbial inoculation, N_3A recorded the maximum number of fruits (14.32), just followed by N_3A_0 (14.05), while N_1A_0 recorded the minimum production of 7.73 fruits per plant.

4.2.2.3. Fruit weight

The data on mean weight of fruits presented in Table 4.7 revealed the significant influence of nitrogen sources and nitrogen levels on fruit weight.

Among the various nitrogen sources, S_4 (FYM + green leaf) recorded the maximum and significant fruit weight (32.15 g) as compared to others. Plants treated with FYM alone (S_1) recorded the lowest fruit weight of 20.78 g and was almost similar to T_{31}, S_5 and S_2 treatments.

Fruit weight increased significantly with the incremental doses of nitrogen. Fruit weights were 20.24 g, 24.13 g and 30.8 g for N_1, N_2 and N_3 respectively.

Table 4. 7. Effect of sources of nitrogen, levels of nitrogen and microbial inoculation on weight of fruit and length of fruit.

Treatments	Weight of fruit (g)	Length of fruit (cm)
Nitrogen sources		
S_1 (FYM alone)	20.78	14.79
S_2 (FYM + PM)	22.72	15.52
S_3 (FYM + NC)	26.53	15.55
S_4 (FYM + GL)	32.15	16.39
S_5 (FYM + EC)	23.12	14.01
SE	0.42	0.46
CD (0.05)	4.47	1.20
Nitrogen levels (kg ha^{-1})		
N_1 (50)	20.24	14.08
N_2 (100)	24.13	15.32
N_3 (150)	30.81	16.36
SE	0.33	0.36
CD (0.05)	3.46	0.926
Microbial inoculation		
A_0 (control)	24.45	15.23
A (Azospirillum)	25.66	15.28
SE	--	--
CD (0.05)	--	--
T_{31}(Absolute control-POP recommendation)	23.62	14.3

Table 4. 7a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on weight of fruit and length of fruit.

Treatments	Weight of fruit (g)					Length of fruit (cm)				
	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation		Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
Nitrogen sources	Nitrogen levels			Microbial inoculation		Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A	N_1	N_2	N_3	A_0	A
S_1	16.53	20.38	25.41	20.83	20.72	13.58	14.47	16.32	14.72	14.85
S_2	18.30	21.32	28.55	22.50	22.94	14.31	16.33	15.92	15.57	15.47
S_3	18.90	26.00	34.68	25.48	27.57	14.19	15.25	17.22	15.59	15.52
S_4	28.48	32.7	35.25	30.71	33.58	15.63	16.55	17.0	16.58	16.21
S_5	18.99	20.22	30.15	22.74	23.5	12.7	14	15.33	13.69	14.33
SE	0.73	0.73	0.73	0.59	0.59	0.73	0.73	0.73	0.60	0.60
CD (0.05)	7.74	7.74	7.74	6.32	6.32	2.07	2.07	2.07	1.69	1.69

Treatments	Weight of fruit (g)		Length of fruit (cm)	
	Nitrogen levels x Microbial inoculation		Nitrogen levels x Microbial inoculation	
Nitrogen levels	Microbial inoculation		Microbial inoculation	
	A_0	A	A_0	A
N_1	18.89	21.59	13.95	14.22
N_2	24.09	24.16	15.37	15.26
N_3	30.38	31.24	16.37	16.35
SE	0.46	0.46	0.46	0.46
CD (0.05)	4.89	4.89	1.31	1.31

Fruit weight was increased non significantly by Azospirillum inoculation (25.66 g) than control (24.45 g). S x N interaction showed significant effect. Fruit weight was maximum (35.25 g) for $S_4 N_3$ which was on par with $S_3 N_3$, $S_4 N_2$, $S_5 N_3$, S_2N_3 and $S_4 N_1$(28.48) and significantly superior to other treatments (Table 4.7a).

In S x A interaction S_4A recorded the maximum fruit weight of 33.58 g and was on similar lines with $S_4 A_0$ and S_3A, but significantly superior to other treatments. S_1A recorded the lowest fruit weight of 20.72 g.

N x A interaction effect was also significant. N_3A recorded the maximum fruit weight (31.24 g), just followed by N_3A_0 (30.38g). N_1A_0 recorded the least value of 18.89 g.

4.2.2.4. Fruit length

The data on mean length of fruit is presented in Table 4.7.

Various nitrogen sources influenced fruit length significantly. Plants supplied with FYM and green leaf (S_4) produced longest fruits (16.39 cm) and was on par with S_3 (FYM + neem cake) and S_2 (FYM + poultry manure). Treatments S_1, T_{31} (POP recommendation) and S_5 (FYM + enriched compost) recorded shorter fruit length and was significantly inferior to other treatments.

Effect of nitrogen levels was also significant. Each higher level was significantly superior to the next lower level. The fruit length varied from a minimum of 14.08 cm (N_1) to a maximum of 16.36 cm for N_3.

Azospirillum inoculation registered a non significant increase in fruit length over control.

Effect of various interactions on fruit yield was significant. In S x N interaction S_3N_3 recorded the highest fruit length (17.22 cm) and was comparable with all other treatments except S_1N_2, S_2N_1, S_3N_1, S_5N_2, S_1N_1 and S_5N_1 which recorded significantly lower values ranging from 12.7 to14.47 cm (Table 4.7a).

In the interaction between nitrogen sources and microbial inoculation, S_4A_0 recorded the maximum fruit length of 16.58 cm and the minimum value of 13.69 cm by S_5 A_0.

In N x A interaction, N_3A_0 recorded the highest fruit length of 16.37 cm and was on line with all other treatments except N_1A (14.22 cm) and N_1A_0 (13.95 cm).

4.2.2.5. Fruit yield per plant

The data presented in Table 4.8 revealed the significant influence of nitrogen sources, nitrogen levels, and microbial inoculation on yield per plant.

Among the various nitrogen sources combined application of FYM and neem cake on equivalent nitrogen basis (S_3) recorded the maximum per plant productivity (271.3 g) followed by S_4 (253.46 g) and S_2 (226.17 g). Treatment S_1 (FYM alone) recorded the lowest yield.

Significant variations were noticed among nitrogen levels. N_3 was the most superior (341.64 g) followed by N_2 (237.58 g) and N_1 (115.8 g).

Azospirillum inoculation showed significantly higher yield (240.96 g) than control (222.39 g).

Table 4.8. Effect of sources of nitrogen, levels of nitrogen and microbial inoculation on fruit yield plant^{-1} and fruit yield hectare^{-1}.

Treatments	Fruit yield plant^{-1} (g)	Fruit yield hectare^{-1} (q)
Nitrogen sources		
S_1 (FYM alone)	190.56	105.9
S_2 (FYM + PM)	226.17	135.38
S_3 (FYM + NC)	271.30	158.48
S_4 (FYM + GL)	253.46	152.78
S_5 (FYM + EC)	216.90	126.71
SE	9.53	6.37
CD (0.05)	26.96	18.02
Nitrogen levels (kg ha^{-1})		
N_1(50)	115.81	64.78
N_2(100)	237.58	134.77
N_3 (150)	341.64	208.0
SE	7.38	4.94
CD (0.05)	20.88	13.96
Microbial inoculation		
A_0 (control)	222.39	129.74
A (Azospirillum)	240.96	141.97
SE	6.03	4.03
CD (0.05)	17.05	11.39
T_{31} (Absolute control-POP recommendation)	207.44	115.7

Table 4.8a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on fruit yield plant^{-1} and fruit yield ha^{-1}.

Treatments	Fruit yield plant^{-1} (g)					Fruit yield (q ha^{-1})				
	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation		Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
Nitrogen sources	Nitrogen levels			Microbial inoculation		Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A	N_1	N_2	N_3	A_0	A
S_1	105.26	189.3	277.1	181.65	199.5	58.4	105.26	154.03	100.96	11.83
S_2	112.3	196	370.2	221.12	231.2	62.68	117.57	225.9	132.53	138.24
S_3	126.9	291.97	395.1	254.2	288.4	70.58	162.1	242.75	150.04	166.92
S_4	115.5	288.7	356.2	241.5	265.4	64.5	165.37	228.4	142.29	163.27
S_5	119.13	221.9	309.7	213.5	220.34	67.7	123.55	188.89	122.86	130.57
SE	16.51	16.51	16.51	13.48	13.48	11.04	11.04	11.04	9.01	9.01
CD (0.05)	46.69	46.69	46.69	38.12	38.12	31.2	31.2	31.2	25.5	25.5

Treatments	Fruit yield plant^{-1} (g)		Total fruit yield (q ha^{-1})	
	Nitrogen levels x Microbial inoculation		Nitrogen levels x Microbial inoculation	
Nitrogen levels	Microbial inoculation		Microbial inoculation	
	A_0	A	A_0	A
N_1	108.69	122.9	60.55	69.02
N_2	223.43	251.7	125.44	144.098
N_3	335.06	348.21	203.22	212.79
SE	10.44	10.44	6.98	6.98
CD (0.05)	29.53	29.53	19.74	19.74

All the interactions had significant influence on yield per plant. In the interaction between nitrogen sources and nitrogen levels (S x N), S_3N_3 recorded the maximum yield (395.1 g) and was on par with S_2N_3 , S_4N_3 and S_5N_3 but significantly superior to other treatments. S_1N_1 recorded the lowest yield (105.26 g) (Table 4.8a).

In S x A interaction, S_3A recorded the highest yield (288.4 g) and behaved commonly with S_4A and S_3A_0. Rest of the treatments were significantly inferior with the lowest value recorded by S_1A_0 (181.65 g).

In N x A interaction, N_3A recorded the highest yield (348.21 g) followed by N_3A_0 (335.06 g). N_1A_0 (108.69 g) recorded the lowest yield.

4.2.2.6. Total fruit yield

The data on the yield of fruits are presented in Table 4.8.

Nitrogen sources, nitrogen levels and microbial inoculation significantly influenced the fruit yield of bhindi. Among various nitrogen sources, S_3 (FYM + neem cake) recorded the highest fruit yield of 158.48 q and was on par with S_4 (FYM + green leaf) and significantly superior to other treatments. Lowest productivity of 105.9 q was recorded by S_1 (FYM alone) and was on line with T_{31} (POP recommendation).

Fruit yield increased significantly with increasing levels of nitrogen. The corresponding values recorded were 64.78 q, 134.77 q and 208 q for N_1, N_2 and N_3.

Azospirillum inoculation registered significantly higher fruit yield (141.97 q) than control (129.74 q)

The interaction effects of S x N, S x A and N x A on total fruit yield were significant. In S x N interaction S_3N_3 recorded the maximum fruit yield of 242.75 q and was on par with S_4N_3 and S_2N_3, but significantly superior to other treatments. The lowest fruit yield was recorded by S_1N_1 (58.4 q ha^{-1}) (Table 4.8a).

In S x A interaction, S_3A recorded the maximum fruit yield of 166.92 q and S_1A_0 recorded the minimum (100.96 q)

In the interaction between nitrogen levels and microbial inoculation, N_3A recorded the maximum fruit yield of 212.79 q ha^{-1} followed by N_3A_0 (203.22 q ha^{-1}). Rest of the treatments were significantly inferior and the least value was recorded by N_1A_0. (60.55 q).

4.2.3. Quality aspects

4.2.3.1. Crude protein content in fruit

The data on crude protein content of fruits are presented in Table 4.9.

The effect of nitrogen sources, nitrogen levels and microbial inoculation on crude protein content in fruits was significant. Among various nitrogen sources, S_2 (FYM + poultry manure) recorded the maximum and significant crude protein content of 17.92 per cent. S_3 and S_4 showed intermediate values. S_1 (FYM alone) recorded the lowest value and was significantly inferior to other nitrogen sources and the present package recommendation.

Nitrogen levels also influenced crude protein content in fruits significantly. Each higher level was significantly superior to the next lower level. The corresponding values recorded were 16.10 per cent, 17.67 per cent and 19.32 per cent for N_1, N_2 and N_3 respectively.

Table 4. 9. Effect of nitrogen sources, nitrogen levels and microbial inoculation on crude protein content and ascorbic acid content of fruits.

Treatments	Crude protein content [%]	Ascorbic acid content [mg 100 g^{-1} fresh fruit]
Nitrogen Sources		
S_1 (FYM alone)	17.04	21.49
S_2 (FYM + PM)	17.92	21.78
S_3 (FYM + NC)	17.88	21.82
S_4 (FYM + GL)	17.86	21.80
S_5 (FYM + EC)	17.78	21.85
SE	0.005	0.009
CD (0.05)	0.014	0.025
Nitrogen levels		
N_1 (50)	16.10	19.50
N_2 (100)	17.67	22.11
N_3 (150)	19.32	23.64
SE	0.004	0.007
CD (0.05)	0.011	0.019
Microbial inoculation		
A_0 (control)	17.66	21.72
A (Azospirillum)	17.73	21.78
SE	0.003	0.006
CD (0.05)	0.009	0.016
T_{31} (Absolute control, POP recommendation)	17.37	21.71

Table 4. 9a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation crude protein content and ascorbic acid content of fruit.

Treatments	Crude Protein content (%)					Ascorbic acid content (mg 100 g^{-1} fresh fruit)				
	Nitrogen sources x nitrogen levels			Nitrogen sources x Microbial inoculation		Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
Nitrogen source	Nitrogen levels			Microbial inoculation		Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A	N_1	N_2	N_3	A_0	A
S_1	15.39	16.98	18.76	16.97	17.11	19.29	21.67	23.52	21.46	21.53
S_2	16.27	17.94	19.56	17.89	17.95	19.52	22.21	23.61	21.74	21.82
S_3	16.33	17.85	19.45	17.85	17.90	19.58	22.20	23.67	21.78	21.85
S_4	16.30	17.85	19.42	17.82	17.89	19.53	22.22	23.65	21.77	21.83
S_5	16.22	17.74	19.39	17.86	17.81	19.57	22.25	23.74	21.82	21.89
SE	0.009	0.009	0.009	0.007	0.007	0.015	0.015	0.015	--	--
CD (0.05)	0.025	0.025	0.025	0.020	0.020	0.043	0.043	0.043	--	--

Treatments	Crude protein content (%)		Ascorbic acid content (mg 100 g^{-1} fresh fruit)	
	Nitrogen levels x Microbial inoculation		Nitrogen levels x Microbial inoculation	
Nitrogen levels	Microbial inoculation		Microbial inoculation	
	A_0	A	A_0	A
N_1	16.00	16.20	19.42	19.58
N_2	17.66	17.68	22.08	22.15
N_3	19.32	19.32	23.65	23.62
SE	0.006	0.006	0.010	0.010
CD (0.05)	0.016	0.016	0.027	0.027

Azospirillum inoculation registered significantly higher crude protein content (17.73%) than the control (17.66%).

Various interactions also influenced crude protein content significantly. In the interaction between nitrogen sources and nitrogen levels S_2N_3 recorded the maximum value (19.56%) and S_1N_1 registered the minimum value (15.39%) of crude protein content (Table 4.9a).

In SxA interaction S_2A recorded the highest crude protein content of 17.95 percent and S_1A_O recorded the lowest value of 16.97 percent.

In NxA (nitrogen sources x microbial inoculation) interaction, N_3A_o and N_3A recorded the maximum and significant crude protein content (19.32%). All other treatments were significantly inferior.

4.2.3.2. Ascorbic acid content in fruits.

Table 4.9 gives the mean value of ascorbic acid content in fruits.

Ascorbic acid content in fruits was significantly influenced by various nitrogen sources. S_5 (FYM + enriched compost) recorded significantly higher ascorbic acid content (21.85 mg $100g^{-1}$ fruit) than other sources. The lowest value of 21.49 mg $100g^{-1}$ fruit was recorded by S_1.

The effect of nitrogen levels was also significant. N_3 the highest level of nitrogen recorded the highest ascorbic acid content of 23.64 mg $100g^{-1}$ of fresh weight of fruit. N_1 recorded the lowest value of 19.50 mg $100g^{-1}$ fresh weight of fruit and was significantly inferior to all other levels.

Azospirillum inoculation registered significantly higher ascorbic acid content (21.78 mg $100g^{-1}$ fruit) than the control (21.72 mg $100g^{-1}$ fruit)

The interaction effect between nitrogen sources and nitrogen levels (SxN) and nitrogen levels and microbial inoculation (NxA) were also significant (Table 4.9a).

In SxN interaction, S_5N_3 recorded the maximum value (23.74 mg $100g^{-1}$ fruit) and S_1N_1 registered the minimum value (19.29 mg $100g^{-1}$ fruit). In NxA interaction N_3A_0 recorded the highest value (23.65mg $100g^{-1}$ fruit) and was comparable with N_3A. The least value was showed by N_1Ao (19.42 mg $100g^{-1}$ fruit).

The SxA interaction effect was nonsignificant.

4.2.3.3. Crude fibre content of fruits

The data on crude fibre content of fruits recorded on 1st, 5th and 8th day after harvest are presented in Table 4.10. The data reveals that the crude fibre content increased with the increase in the days after harvest.

Various nitrogen sources had influenced crude fibre content of fruits significantly on 1st, 5th and 8th day after harvest. On the 1st day after harvest S_5 (FYM + enriched compost) recorded the lowest crude fibre content of 10.59 percent and was on par with S_3. On the 5th day S_3 recorded the lowest value and was on par with S_5 and S_4. On the 8th day S_3 recorded the least value of 13.45 percent. Plants supplied with POP recommended dose of nutrients showed the highest crude fibre content from 1st day (11.87%) to the 8th day (14.84%) and was significantly inferior to all other treatments.

Table 4. 10. Effect of nitrogen sources, nitrogen levels and microbial inoculation on crude fibre content of fruits at 1st, 5th and 8th day after harvest (DAH)

Treatments	Crude fibre content (%)		
	1st DAH	5th DAH	8th DAH
Nitrogen sources			
S_1 (FYM alone)	11.46	12.90	14.21
S_2 (FYM + PM)	11.22	12.86	13.99
S_3 (FYM + NC)	10.60	12.66	13.45
S_4 (FYM + GL)	10.68	12.72	13.71
S_5 (FYM + EC)	10.59	12.67	13.65
SE	0.007	0.026	0.005
CD (0.05)	0.021	0.073	0.014
Nitrogen levels			
N_1 (50)	13.09	14.35	15.28
N_2 (100)	10.76	12.92	13.95
N_3 (150)	8.87	11.02	12.18
SE	0.006	0.020	0.004
CD (0.05)	0.016	0.056	0.011
Microbial inoculation			
A_0 (control)	10.92	12.80	13.87
A (Azospirillum)	10.90	12.73	13.73
SE	0.005	0.016	0.003
CD (0.05)	0.013	0.046	0.009
T_{31} (Absolute control, POP recommendation)	11.87	13.09	14.84

Table 4.10a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on crude fibre content of fruits at 1st and 5th day after harvest.

Treatments	Crude fibre content (%) at 1st DAH					Crude fibre content (%) at 5th DAH				
Nitrogen sources	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation		Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
	Nitrogen levels			Microbial inoculation		Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A	N_1	N_2	N_3	A_0	A
S_1	13.61	11.55	9.21	11.50	11.41	14.33	13.15	11.22	12.90	12.90
S_2	13.42	11.13	9.12	11.23	11.21	14.44	13.05	11.11	12.90	12.82
S_3	12.79	10.37	8.65	10.63	10.57	14.36	12.72	10.88	12.73	12.58
S_4	12.90	10.48	8.66	10.66	10.69	14.31	12.92	10.94	12.75	12.70
S_5	12.73	10.30	8.73	10.59	10.58	14.32	12.75	10.93	12.70	12.64
SE	0.013	0.013	0.013	0.010	0.010	0.044	0.044	0.044	--	--
CD (0.05)	0.036	0.036	0.036	0.029	0.029	0.126	0.126	0.126	--	--

Treatments	Crude fibre content (%) at 1st DAH and 5th DAH			
Nitrogen levels	Nitrogen levels x Microbial inoculation		Nitrogen levels x Microbial inoculation	
	A_0	A	A_0	A
N_1	13.13	13.05	14.33	14.37
N_2	10.77	10.76	13.02	12.82
N_3	8.87	8.88	11.04	10.99
SE	0.008	0.008	0.028	0.028
CD (0.05)	0.023	0.023	0.079	0.079

Table 4. 10 b. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on crude fibre content of fruit at 8th DAH

Crude fibre content (%) at 8th DAH					
Treatments	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
Nitrogen sources	Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A
S_1	15.49	14.64	12.51	14.29	14.14
S_2	15.38	14.05	12.55	14.11	13.88
S_3	14.87	13.69	11.79	13.65	13.25
S_4	15.28	13.79	12.07	13.69	13.74
S_5	15.38	13.58	12.00	13.63	13.67
SE	0.008	0.008	0.008	0.007	0.007
CD (0.05)	0.024	0.024	0.024	0.019	0.019

	Crude fibre content (%)	
Treatments	Nitrogen levels x Microbial inoculation	
Nitrogen levels	Microbial inoculation	
	A_0	A
N_1	15.39	15.17
N_2	14.03	13.87
N_3	12.20	12.16
SE	0.005	0.005
CD (0.05)	0.015	0.015

Different levels of nitrogen showed significant influence on the crude fibre content of fruits on 1^{st} ,5^{th} and 8^{th} day after harvest. The crude fibre content increased with decreasing levels of nutrients and was maximum at the lowest level of nitrogen.

Azospirillum inoculation resulted in a significant decrease in crude fibre content as compared to control

The effect of various interactions on crude fibre content was also significant. In the interaction between nitrogen sources and nitrogen levels, S_3N_3 recorded the least crude fibre content of 8.65 percent, 10.88 percent and 11.79 percent on 1^{st}, 5^{th} and 8^{th} day after harvest respectively. S_5N_3 and S_4N_3 showed intermediate values where as all the other treatments were significantly inferior (Table 4.10a, 4.10b).

The SxA interaction effect was significant only at 1^{st} and 8^{th} day after harvest. On both the days S_3A recorded the least crude fibre content and S_1A_0 the maximum.

In NxA (nitrogen levels x microbial inoculation) interaction N_3A_o and N_3A recorded comparable and least crude fibre content on all the days and were significantly superior to all other treatments.

4.2.3.4. Keeping quality

The influence of various treatments on keeping quality is presented in Table 4.11.

The effect of nitrogen sources, nitrogen levels and microbial inoculation on keeping quality of fruits were significant. Among the various nitrogen sources combined application of FYM and neemcake (S_3) produced fruits with the best keeping quality (5.68 days) and this was on par with S_5 (FYM + enriched compost). But the plants treated with POP recommended dose (12t FYM + 50:8:25 kg ha^{-1} NPK through fertilizers) produced fruits with least keeping quality of 4.58 days and was significantly inferior to all other nitrogen sources.

The influence of nitrogen levels on keeping quality was also significant. Incremental doses of nitrogen resulted in the extended shelf life of fruits. Highest level of nitrogen N_3 produced fruits with the best keeping quality (6.75 days) followed by N_2 (5.2 days) and N_1 (4.49 days) and each level differed significantly among one another.

Azospirillum inoculation resulted in a significant improvement in the keeping quality of fruits (5.54 days) as compared to control (5.43 days)

Various interaction effects on keeping quality were also significant. In SxN interaction (nitrogen sources x nitrogen levels), S_3N_3 produced fruits with the maximum keeping quality (7.02 days) and was on par with S_5N_3 (7 days). All other treatments were significantly inferior with the least shelf life of 4.4 days recorded by S_1N_1 and was comparable with S_2N_1 and S_5N_1 (Table 4.11a).

In SxA interaction (nitrogen sources x microbial inoculation) S_3A produced fruits with the best keeping quality of 5.78 days. All other treatments were significantly inferior with the lowest value recorded by S_1N_1.

In NxA interaction N_3A produced fruits with the best keeping quality (6.77 days) and was on similar lines with N_3A_o (6.73 days). N_1A_o was the most inferior treatment.

Table 4.11. Effect of nitrogen sources, nitrogen levels and microbial inoculation on keeping quality of fruits.

Treatments	Keeping quality (days)
Nitrogen sources	
S_1 (FYM alone)	5.17
S_2 (FYM+PM)	5.37
S_3 (FYM+NC)	5.68
S_4 (FYM+GL)	5.54
S_5 (FYM+EC)	5.65
SE	0.02
CD (0.05)	0.05
Nitrogen levels (kg ha^{-1})	
N_1 (50)	4.49
N_2 (100)	5.20
N_3 (150)	6.75
SE	0.01
CD (0.05)	0.04
Microbial inoculation	
A_0 (control)	5.43
A (Azospirillum)	5.54
SE	0.01
CD (0.05)	0.03
T_{31} (Absolute control-POP recommendation)	4.58

Wherever F values are significant CD values are given in the Table

Table 4.11a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on keeping quality of fruits

Keeping quality (days)					
Treatments	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
Nitrogen sources	Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A
S_1	4.40	4.78	6.34	5.12	5.23
S_2	4.44	5.07	6.59	5.29	5.45
S_3	4.64	5.40	7.02	5.59	5.78
S_4	4.50	5.29	6.82	5.53	5.55
S_5	4.47	5.48	7.00	5.62	5.68
SE	0.03	0.03	0.03	0.02	0.02
CD (0.05)	0.08	0.08	0.08	0.07	0.07

	Keeping quality (days)	
Treatments	Nitrogen levels x Microbial inoculation	
Nitrogen levels	Microbial inoculation	
	A_0	A
N_1	4.42	4.56
N_2	5.14	5.27
N_3	6.73	6.77
SE	0.02	0.02
CD (0.05)	0.05	0.05

4.2.4. Nutrient uptake

4.2.4.1. Uptake of nitrogen by plant (excluding fruit)

The data on uptake of nitrogen by plants are presented in Table 4.12.

The nitrogen uptake was influenced significantly by various nitrogen sources and nitrogen levels. Among nitrogen sources application of FYM and neem cake (S_3) recorded significantly higher nitrogen uptake (35.13 kg ha^{-1}) and was on par with S_5 and S_2. Other treatments were significantly inferior and the lowest value was given by treatment S_1 (27.85 kg ha^{-1})

There was a progressive increase in the uptake of nitrogen by plants due to increase in nitrogen levels. N_3 recorded the maximum uptake of 42.16 kg ha^{-1} and N_1 the minimum uptake of 20.32 kg ha^{-1}

The nitrogen uptake was increased non significantly by Azospirillum inoculation (31.92 kg ha^{-1}) than control (31.08 kg ha^{-1})

The interaction effect of nitrogen sources and nitrogen levels on nitrogen uptake was significant. S_2N_3 recorded the highest uptake of 48.24 kg ha^{-1} and was comparable with S_3N_3 and S_5N_3. S_1N_1 recorded the lowest nitrogen uptake of 18.79 kg ha^{-1} (Table 4.12a).

The SxA and NxA interaction effect on nitrogen uptake was nonsignificant.

Table 4.12. Effect of nitrogen sources, nitrogen levels and microbial inoculation on N, P and K uptake by plants (excluding fruit)

Treatments	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
Nitrogen sources			
S_1 (FYM alone)	27.85	4.55	25.76
S_2 (FYM + PM)	32.23	4.77	30.02
S_3 (FYM + NC)	35.13	4.70	31.23
S_4 (FYM + GL)	29.81	4.57	29.98
S_5 (FYM + EC)	32.50	4.78	30.22
SE	1.42	--	0.40
CD (0.05)	4.01	--	1.13
Nitrogen levels (kg ha^{-1})			
N_1 (50)	20.32	2.48	18.38
N_2 (100)	32.02	4.58	29.44
N_3 (150)	42.16	6.96	40.51
SE	1.10	0.16	0.31
CD (0.05)	3.11	0.45	0.88
Microbial inoculation			
A_0 (control)	31.08	4.55	28.57
A (Azospirillum)	31.92	4.80	30.32
SE	--	--	0.25
CD (0.05)	--	--	0.72
T_{31} (Absolute control-POP recommendation)	29.85	3.15	28.62

Table 4. 12a. Interaction effect of nitrogen sources and nitrogen levels on N, P and K uptake by plants (excluding fruit)

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})		
	Nitrogen sources x Nitrogen levels			Nitrogen sources x Nitrogen levels		
Nitrogen sources	Nitrogen levels			Nitrogen levels		
	N_1	N_2	N_3	N_1	N_2	N_3
S_1	18.79	26.11	38.64	2.99	4.47	6.20
S_2	20.08	28.36	48.24	2.36	4.16	7.79
S_3	21.67	38.05	45.67	2.31	4.97	6.82
S_4	21.22	31.38	36.82	2.39	4.12	7.20
S_5	19.86	36.23	41.42	2.34	5.18	6.81
SE	2.46	2.46	2.46	0.36	0.36	0.36
CD (0.05)	6.95	6.95	6.95	1.009	1.009	1.009

Treatments	Potassium uptake (kg ha^{-1})		
Nitrogen sources	Nitrogen sources x Nitrogen levels		
	Nitrogen levels		
	N_1	N_2	N_3
S_1	17.42	23.81	36.05
S_2	19.34	26.83	43.89
S_3	18.43	34.04	41.23
S_4	18.71	28.32	42.92
S_5	17.99	34.20	38.48
SE	0.70	0.70	0.70
CD (0.05)	1.97	1.97	1.97

4.2.4.2. Uptake of phosphorus by plants (excluding fruit)

The data given on Table 4.12 shows the phosphorus uptake by plants.

Various nitrogen sources and Azospirillum inoculation did not show any significant influence on phosphorous uptake.

Nitrogen levels significantly influenced the phosphorus uptake by plants. Each higher level was significantly superior to the next lower level. Maximum uptake was observed in N_3 (6.96 kg ha^{-1}) and least in N_1 (2.48 kg ha^{-1}).

Interaction effect between nitrogen sources and nitrogen levels was significant and S_2N_3 recorded the highest phosphorus uptake of 7.79 kg ha^{-1} S_3N_1 (2.31 kg ha^{-1}) recorded the lowest uptake.

The interaction effect between nitrogen sources and microbial inoculation and nitrogen levels and microbial inoculation were nonsignificant.

4.2.4.3. Uptake of potassium by plants (excluding fruits)

The data on potassium uptake by plants are presented in Table 4.12.

Effect of nitrogen sources, nitrogen levels and microbial inoculation on potassium uptake was significant. Among nitrogen sources, S_3 recorded the highest uptake of 31.32 kg ha^{-1} followed by S_5. S_1 (FYM alone) recorded the lowest potassium uptake of 25.76 kg ha^{-1} and was significantly inferior to all nitrogen sources including POP recommendation.

Among the nitrogen levels N_3 recorded the maximum uptake (40.51 kg ha^{-1}) followed by N_2 and N_1 and these nitrogen levels differed significantly among one another.

Azospirillum inoculation significantly increased the potassium uptake by plants (30.32 kg ha^{-1}) over control (28.57 kg ha^{-1}).

Interaction effect between nitrogen sources and nitrogen levels was significant (Table 4.12a). S_2N_3 recorded the highest potassium uptake (43.98 kg ha^{-1}) and was on similar lines with S_4N_2. S_1N_1 recorded the minimum uptake value (17.42 kg ha^{-1}).

The interaction effect between nitrogen sources and microbial inoculation and nitrogen levels and microbial inoculation on potassium uptake were nonsignificant.

4.2.4.4. Uptake of nitrogen in fruits

The data on nitrogen uptake by fruits are presented in Table 4.13.

Nitrogen sources significantly influenced the nitrogen uptake by fruits. S_2 (FYM + poultry manure) recorded the highest N uptake of 47.81 kg ha^{-1} and was on similar lines with S_3 and S_5. All other sources were significantly inferior.

Among nitrogen levels N_3 recorded the maximum uptake of 61.57 kg ha^{-1} followed by N_2 and N_1 and these nitrogen levels differed significantly among one another.

Nitrogen uptake was nonsignificantly increased by Azospirillum inoculation(45.94 kg ha^{-1}) than control (44.58 kg ha^{-1}).

Table 4.13. Effect of nitrogen sources, nitrogen levels and microbial inoculation on N, P and K uptake by fruits

Treatments	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
Nitrogen sources			
S_1 (FYM alone)	42.63	9.78	35.17
S_2 (FYM + PM)	47.81	10.79	38.16
S_3 (FYM + NC)	47.65	10.31	37.65
S_4 (FYM + GL)	42.60	9.33	33.01
S_5 (FYM +EC)	45.61	10.28	35.59
SE	0.80	0.34	0.96
CD (0.05)	2.25	0.95	2.72
Nitrogen levels (kg ha^{-1})			
N_1 (50)	28.39	6.79	24.7
N_2 (100)	45.83	10.29	36.00
N_3 (150)	61.57	13.22	47.04
SE	0.62	0.26	0.75
CD (0.05)	1.74	0.73	2.11
Microbial inoculation			
A_0 (control)	44.58	9.87	34.96
A (Azospirillum)	45.94	10.33	36.87
SE	--	--	0.61
CD (0.05)	--	--	1.72
T_{31} (Absolute control-POP recommendation)	42.75	9.68	34.3

Table 4. 13a. Interaction effect of nitrogen sources and nitrogen levels on N, P and K uptake by fruits

Treatments / Nitrogen sources	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})		
	Nitrogen sources x Nitrogen levels			Nitrogen sources x Nitrogen levels		
	Nitrogen levels			Nitrogen levels		
	N_1	N_2	N_3	N_1	N_2	N_3
S_1	27.84	43.74	56.29	6.74	10.28	12.33
S_2	27.78	44.01	71.66	6.77	9.96	15.65
S_3	29.98	51.13	61.83	7.00	11.14	12.80
S_4	27.39	41.60	58.80	6.32	9.03	12.62
S_5	28.94	48.64	59.25	7.08	11.05	12.71
SE	0.79	0.79	0.79	0.58	0.58	0.58
CD (0.05)	2.25	2.25	2.25	1.64	1.64	1.64

Treatments / Nitrogen sources	Potassium uptake (kg ha^{-1})		
	Nitrogen levels		
	N_1	N_2	N_3
S_1	24.23	37.23	44.04
S_2	25.54	34.28	54.68
S_3	25.55	40.05	47.35
S_4	23.48	31.41	44.15
S_5	24.72	37.06	45.00
SE	1.67	1.67	1.67
CD (0.05)	4.71	4.71	4.71

Interaction effect of nitrogen sources and nitrogen levels was significant (Table 4.13a). The maximum uptake was recorded by S_2N_3 (71.66 kg ha^{-1}) and the minimum by S_4N_1 (27.39 kg ha^{-1}).

All other interaction effects were nonsignificant.

4.2.4.5. Uptake of phosphorus in fruits

The data on phosphorus uptake in fruits are presented in Table 4.13.

Various nitrogen sources significantly influenced phosphorus uptake. The maximum uptake was recorded by S_2 (10.79 kg ha^{-1}) and was on par with S_3 and S_5. All other sources were significantly inferior.

Phosphorus uptake was significantly influenced by different nitrogen levels. Each higher level was significantly superior to the next lower level.

Azospirillum inoculation registered a nonsignificant increase in phosphorus uptake (10.33 kg ha^{-1}) than control (9.87 kg ha^{-1}).

In the interaction effect between nitrogen sources and nitrogen levels which was significant the maximum uptake was recorded by S_2N_3 (15.65 kg ha^{-1}) and the minimum by S_4N_1 (6.32 kg ha^{-1}).

The effect of interaction between nitrogen sources and microbial inoculation and nitrogen levels and microbial inoculation were nonsignificant.

4.2.4.6. Uptake of potassium in fruits.

The data on potassium uptake in fruits are presented in Table 4.13.

The uptake of potassium was significantly influenced by nitrogen sources. S_2 recorded the maximum uptake and was on par with S_3 and S_5. All other sources were significantly inferior.

The influence of nitrogen levels on potassium uptake was also significant There was a progressive increase in the uptake of potassium with incremental doses of nitrogen.

Azospirillum inoculation resulted in a significant increase in potassium uptake (36.87 kg ha^{-1}) than control (34.96 kg ha^{-1}).

In the interaction between nitrogen sources and nitrogen levels S_2N_3 recorded the maximum uptake (54.68 kg ha^{-1}) and was significantly superior to other treatments (Table 4.13a).

All other interaction effects were nonsignificant.

4.2.5. Available nutrient status of soil

4.2.5.1. Available nitrogen

Table 4.14 gives the data on the mean available nitrogen content in the soil after the experiment.

Available nitrogen content of the soil after the experiment was significantly influenced by nitrogen sources nitrogen levels and microbial inoculation. Among nitrogen sources S_3 recorded the maximum value of 389.03 kg ha^{-1}. All other treatments were significantly inferior and the lowest value of 362.60 kg ha^{-1} was registered by S_1 which inturn was on line with T_{31} (POP recommendation).

In the case of nitrogen levels each higher level was significantly superior to the next lower level. The values ranged from 303.37 kg ha^{-1} (N_1) to 458.81 kg ha^{-1} (N_3).

Azospirillum inoculation registered significant increase in available soil N content (376.41 kg ha^{-1}) than the control (374.29 kg ha^{-1}).

In the interaction effect between nitrogen sources and nitrogen levels which was significant S_3N_3 recorded the maximum value of 475.22 kg ha^{-1} and S_1N_1 recorded the minimum value (Table 4.14a).

The SxA interaction effect was also significant S_3A recorded the maximum value of 389.59 kg ha^{-1} and was on par with S_3A_o but significantly superior to other sources. S_5A_o recorded the minimum value of 360.53 kg ha^{-1}.

The interaction between nitrogen levels and microbial inoculation was nonsignificant.

4.2.5.2. Available phosphorus

The data on available phosphorus content of the soil after the experiment are given in Table 4.14.

Various nitrogen sources affected available phosphorus content significantly. S_5 (FYM + enriched compost) reported the maximum value (46.83 kg ha^{-1}) and was on similar lines with S_2. Other sources were significantly inferior with the lowest value of 38.47 kg ha^{-1} recorded by T_{31} (POP recommendation).

The nitrogen levels N_1,N_2 and N_3 differed significantly among themselves. Available phosphorus content was 36.77 kg ha^{-1}, 43.96 kg ha^{-1} and 48.65 kg ha^{-1} respectively for N_1,N_2 and N_3.

The effect of Azospirillum inoculation was nonsignificant.

The SxN interaction effect was significant. S_5N_3 recorded the highest available phosphorus content (54.03 kg ha^{-1}) and was on par with S_2N_3. S_3N_1 recorded the least value (Table 4.14b).

All other interaction effects were nonsignificant.

4.2.5.3. Available potassium

Table 4.14 gives the available potassium content of the soil after the experiment.

Available potassium content of the soil was significantly influenced by nitrogen sources. S_1 recorded the maximum value of 155.25 kg ha^{-1} and the minimum value of 145.28 $kgha^{-1}$ was given by T_{31} (POP recommendation).

Nitrogen levels significantly influenced the available potassium content. The corresponding values for N_1 ,N_2 and N_3 were 133.86, 146.62 and 172.78 kg ha^{-1}.

In the interaction between nitrogen sources and nitrogen levels which was significant, S_1N_3 recorded the highest value (179.44 kg ha^{-1}) and S_4N_1 the lowest (Table 4.14b).

Table 4. 14. Effect of nitrogen sources, nitrogen levels and microbial inoculation on available nitrogen, phosphorus and potassium status of soil after the experiment.

Treatments	Nitrogen ($kg\ ha^{-1}$)	Phosphorus ($kg\ ha^{-1}$)	Potassium ($kg\ ha^{-1}$)
Nitrogen sources			
S_1 (FYM alone)	362.60	41.58	155.25
S_2 (FYM + PM)	382.19	46.58	151.66
S_3 (FYM + NC)	389.03	39.02	149.11
S_4 (FYM + GL)	377.34	41.63	148.64
S_5 (FYM + EC)	365.59	46.83	150.78
SE	0.63	0.14	0.48
CD (0.05)	1.79	0.39	1.34
Nitrogen levels ($kg\ ha^{-1}$)			
N_1 (50)	303.37	36.77	133.86
N_2 (100)	363.86	43.96	146.62
N_3 (150)	458.81	48.65	172.78
SE	0.49	0.11	0.37
CD (0.05)	1.39	0.29	1.04
Microbial inoculation			
A_0 (control)	374.29	43.06	151.14
A (Azospirillum)	376.41	43.19	151.04
SE	0.40	--	--
CD (0.05)	1.13	--	--
T_{31} (Absolute control-POP recommendation)	363.03	38.47	145.28

Table 4. 14a. Interaction effect of nitrogen sources, nitrogen levels and microbial inoculation on available nitrogen status of soil after the experiment.

	Nitrogen (kg ha^{-1})				
Treatments	Nitrogen sources x Nitrogen levels			Nitrogen sources x Microbial inoculation	
Nitrogen sources	Nitrogen levels			Microbial inoculation	
	N_1	N_2	N_3	A_0	A
S_1	282.91	352.62	452.27	361.09	364.10
S_2	314.46	370.51	461.59	379.83	384.54
S_3	314.79	377.08	475.22	388.47	389.59
S_4	299.47	370.62	461.93	381.51	373.17
S_5	305.23	348.49	443.05	360.53	370.65
SE	1.01	1.01	1.01	0.89	0.89
CD (0.05)	3.09	3.09	3.09	2.53	2.53

Table 4. 14b.Interaction effect of nitrogen sources and nitrogen levels on available phosphorus and potassium status of soil after the experiment.

Treatments	Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	Nitrogen sources x Nitrogen levels			Nitrogen sources x Nitrogen levels		
Nitrogen sources	Nitrogen levels			Nitrogen levels		
	N_1	N_2	N_3	N_1	N_2	N_3
S_1	35.74	43.17	45.83	135.18	151.13	179.44
S_2	39.31	46.97	53.39	134.42	146.85	173.71
S_3	33.08	39.86	44.14	133.02	144.82	169.49
S_4	36.16	42.89	45.84	132.94	144.16	168.80
S_5	39.57	46.90	54.03	133.76	146.15	172.44
SE	0.24	0.24	0.24	0.82	0.82	0.82
CD (0.05)	0.67	0.67	0.67	2.33	2.33	2.33

The effects of Azospirillum inoculation and all other interactions on available potassium content were nonsignificant.

4.2.6. Correlation studies

Correlation coefficient of yield and dry matter production with all growth, yield and quality parameters were worked out and is presented in Table 4.15.

The results showed that all the parameters were positively correlated with yield and all the correlation coefficients were statistically significant except in the case of time of 50 per cent flowering, potassium uptake by shoot and crude fibre content of fruits.

Per plant fruit yield showed the highest degree of correlation with yield (r = 0.96). There was also significant correlation between yield and DMP (0.92), yield and shoot dry weight (0.91), yield and fruits $plant^{-1}$ (0.89), yield and N uptake by fruit (0.89), and yield and crude protein content (0.89).

DMP was positively and significantly correlated with all characters except that of time of 50 per cent flowering and crude fibre content of fruit. The highest degree of correlation was with shoot dry weight (0.97) followed by number of fruits $plant^{-1}$ (0.967), fruit dry weight (0.94), N uptake by shoot (0.94) and P uptake by shoot (0.94) .

4.2.7. Economics of production.

The data on total cost of production, gross income (returns) ha^{-1}, net returns (profit or loss ha^{-1}) and benefit cost ratio are shown in Table 4.16.

Table 4. 15. Values of simple correlation coefficients

Sl.No.	Characters correlated	Correlation coefficients	
		Yield	DMP
1.	Yield ha^{-1}	1.00**	0.92**
2.	Yield plant^{-1}	0.96**	0.89**
3.	Number of fruits plant^{-1}	0.89**	0.96**
4.	Days to 50 percent flowering	-0.15	-0.03
5.	LAI at 30 DAS	0.57**	0.52**
6.	LAI at 60 DAS	0.67**	0.63**
7.	Weight of fruit	0.57**	0.43**
8.	Length of fruit	0.43**	0.29**
9.	Plant height at 30 DAS	0.60**	0.52**
10.	Plant height at 60 DAS	0.67**	0.56**
11.	Shoot dry weight	0.91**	0.97**
12.	Fruit dry weight	0.87**	0.94**
13.	Total DMP at harvest	0.92**	1.00**
14.	N uptake by fruit	0.89**	0.90**
15.	P uptake by fruit	0.86**	0.92**
16.	K uptake by fruit	0.88**	0.92**
17.	N uptake by shoot	0.86**	0.94**
18.	P uptake by shoot	0.91**	0.94**
19.	K uptake by shoot	- 0.16	0.88**
20.	Crude protein content of fruit	0.89**	0.84**
21.	Ascorbic acid content	0.86**	0.84**
22.	Crude fibre content	-0.88	-0.84
23.	Keeping quality of fruits	0.87**	0.80**
24.	Soil nitrogen after harvest	0.88**	0.82**
25.	Soil phosphorus after harvest	0.66**	0.68**
26.	Soil potassium after harvest	0.79**	0.78**

** Significant at 1% level

DMP - Dry matter production

The data showed that among various nitrogen sources application of FYM + neemcake (S_3) registered the maximum profit of Rs. 42120.5 ha^{-1} and was on par with that recorded by FYM + green leaf (Rs. 39215.5 ha^{-1}) and FYM + poultry manure (Rs. 29625.5 ha^{-1}). The minimum profit of Rs. 11357.5 ha^{-1} was recorded by the plants treated with FYM alone (S_1). The profit registered by other nitrogen sources were, Rs. 21183.5ha^{-1} (FYM + enriched compost) and Rs. 21015 ha^{-1} (POP recommendation of Kerala Agricultural University).

Increase in profit was noticed due to the increase in nitrogen levels. Maximum profit was registered by N_3 level (Rs. 66977.5 ha^{-1}) followed by N_2 (Rs. 28032 ha^{-1}). But the application of lowest level of nitrogen resulted in a loss of Rs. 8969.5 ha^{-1}.

Azospirillum inoculation showed higher profit (Rs. 32352 ha^{-1}) than control (Rs. 25059 ha^{-1}) eventhough statistically they were on par.

In the case of benefit cost ratio application of FYM + neemcake (S_3) recorded the maximum value of 1.80 and FYM alone (S_1) recorded the minimum value of 1.22. Among nitrogen levels N_3 recorded the maximum value of 2.16 and N_1 recorded the minimum of 0.81. Azospirillum inoculation registered higher benefit cost ratio (1.61) than control (1.47).

Table 4.16. Effect of nitrogen sources, nitrogen levels and microbial inoculation on economics of production

Treatments	Cost of production ha^{-1} (Rs.)	Returns ha^{-1} (Rs.)	Net returns ha^{-1} (profit or loss) (Rs.)	Benefit cost (B:C) ratio
Nitrogen sources				
S_1 (FYM alone)	52182.5	63540	11357.5	1.22
S_2 (FYM + PM)	51602.5	81228	29625.5	1.57
S_3 (FYM +NC)	52967.5	95088	42120.5	1.80
S_4 (FYM +GL)	52452. 5	91668	39215.5	1.75
S_5 (FYM +EC)	54842.5	76026	21183.5	1.39
SE			5288.79	
CD (0.05)			14958.95	
Nitrogen levels (kg ha^{-1})				
N_1 (50)	47837.5	38868	-8969.5	0.81
N_2 (100)	52830	80862	28032	1.53
N_3 (150)	57822.5	124800	66977.5	2.16
SE			4096.68	
CD(0.05)			11587.15	
Microbial inoculation				
A_0 (control)	52785	77884	25059	1.47
A (Azospirillum)	52830	85182	32352	1.61
SE			3344.92	
CD(0.05)			9460.87	
T_{31} (Absolute control - POP recommendation)	48405	69420	21015	1.43

DISCUSSION

5. DISCUSSION

An experiment was conducted to find out the effect of microbial inoculation and phosphate sources on ripening period and quality of compost, and to standardize an organic nutrient schedule for bhindi by comparing the effects of various nitrogen sources, nitrogen levels and Azospirillum inoculation on growth, yield and quality of bhindi.

The results obtained from this study are briefly discussed in this chapter

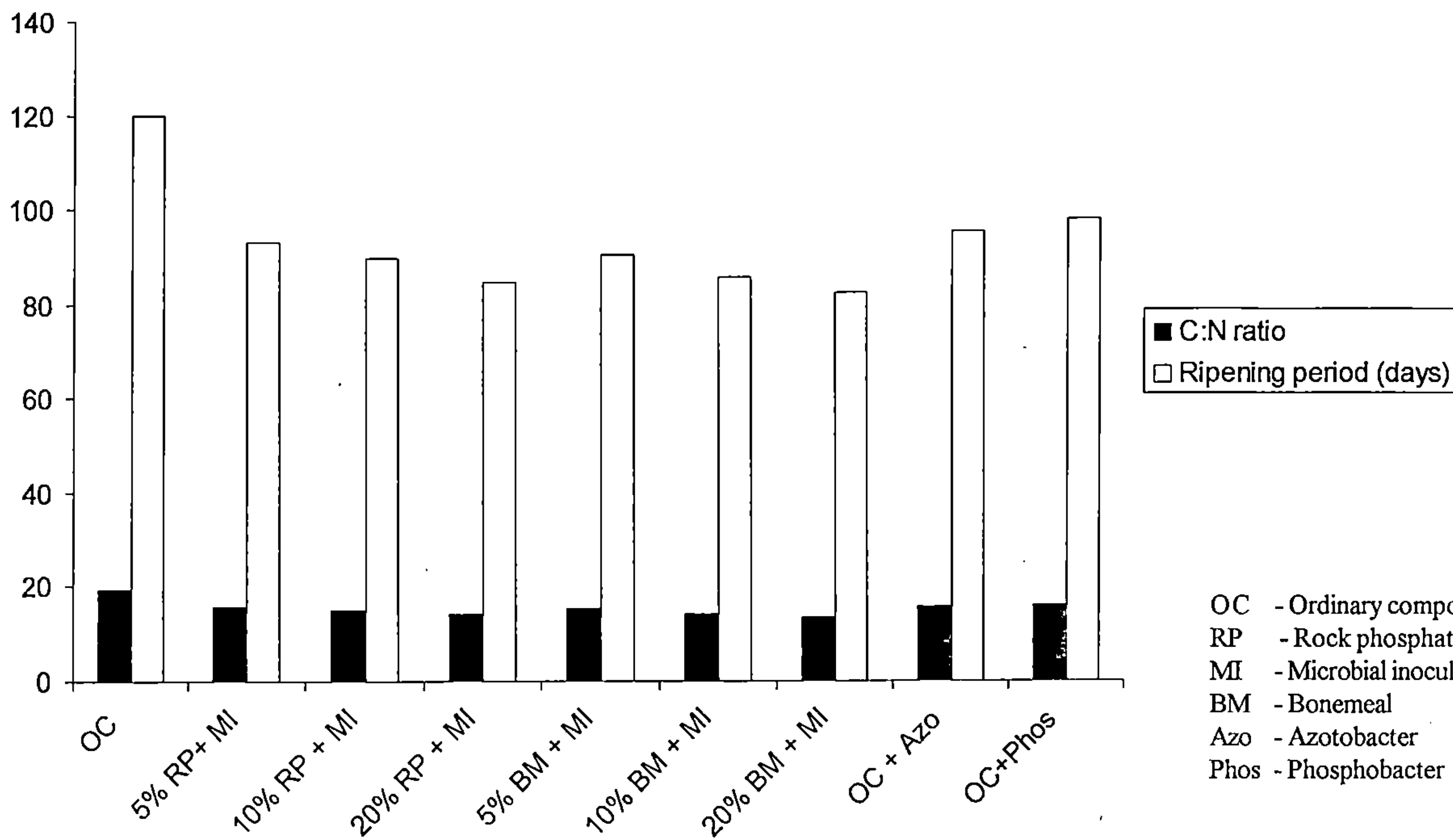
5.1. Standardisation of agro-techniques for enriching compost

Two handicaps common to all bulky organic manures are their low nutrient content and large volume. Various technologies are available to upgrade the nutrient content of compost and to hasten the composting process, so that materials of better quality can be obtained in less time. The present investigation aims to find out the effect of microbial inoculants and phosphate sources on the quality and ripening period of compost.

5.1.1. Effect of microbial inoculants and phosphate sources on C:N ratio of compost and time taken for composting

C:N ratio

The data given on Table 4.1 show the significant influence of various treatments on C:N ratio of compost. Substantial reduction took place in the C:N ratio of various enriched composts as compared to ordinary compost.



OC - Ordinary compost
RP - Rock phosphate
MI - Microbial inoculants
BM - Bonemeal
Azo - Azotobacter
Phos - Phosphobacter

Fig. 5. Effect of phosphate sources and microbial inoculants on C:N ratio and ripening period of compost.

The lowest C:N ratio (13.71) was recorded by the compost treated with 20 per cent bonemeal and microbial inoculants (Azotobacter + Phosphobacter) and this was 41.13 percent lower than ordinary compost (Fig.5). The lower values of C:N ratio in inoculated and enriched compost suggest that microorganisms played a significant role in hastening the process of decomposition. As composting proceeds the microflora use the carbon for energy and the nitrogen for cell building. The C:N ratio narrows down with time since the nitrogen remains in the system while some of the carbon is released as CO_2 (Gaur and Sadasivan, 1993). Nitrogen fixing bacteria indirectly help in decreasing C:N ratio by making available more nitrogen from added organic matter (Lee, 1985; Jambakar, 1991 and Shinde *et al.*, 1992). Thus inoculation with Azotobacter, a nitrogen fixing bacteria might have resulted in reducing the C:N ratio of inoculated compost as compared to the uninoculated one.

The C:N ratio showed a decreasing trend with the addition of phosphate sources like rock phosphate and bonemeal. This may be due to increased loss of organic carbon in the presence of phosphate sources which further conserved the nitrogen. Improved nitrogen conservation due to phosphate addition had been reported by Poincelot (1975). As compared to the varying levels of rockphosphate, the corresponding levels of bonemeal were found to be more effective in reducing the C:N ratio of the compost. This may be due to the fact that, unlike rockphosphate which contains only phosphorus, bonemeal contains 3 to 4 per cent nitrogen in addition to phosphorus, which might have resulted in increasing the nitrogen and reducing the C:N ratio of compost.

Time taken for composting

The results showed that the ripening period of compost was considerably reduced due to microbial inoculation and phosphate addition as compared to ordinary compost. Compost treated with 20 per cent bonemeal and microbial inoculants matured at the earliest (82.33 days) where as the ordinary compost took the maximum period of 120 days for maturity.

The process of decomposition is carried out by a group of active micro organisms which break down the cellulolytic material and hasten the process of composting (Kalokar *et al.*, 1976). The activities of these micro organisms are greatly affected by the food materials available in the substrate, which are utilized by the micro organisms for their body build up and multiplication (Rasal *et al.*, 1985). Inoculation of compost with Azotobacter and addition of phosphate sources like rock phosphate and bonemeal improved the nitrogen content of the substrate which was utilized by the microorganisms for growth and multiplication. Due to this increased microbial population composting, nitrogen fixing and phosphorus solubilising process got accelerated and the compost became ready for use within a short time. Similar observations of accelerated decomposition due to microbial inoculation and phosphate addition was reported by Mathur *et al.* (1986) and Thakur and Sharma (1998).

5.1.2. Nutrient composition of composted material

Nitrogen

The data given in Table 4.1 bring out the fact that microbial inoculation and phosphate addition favourably affected the quality of compost. Total nitrogen content of various enriched composts varied

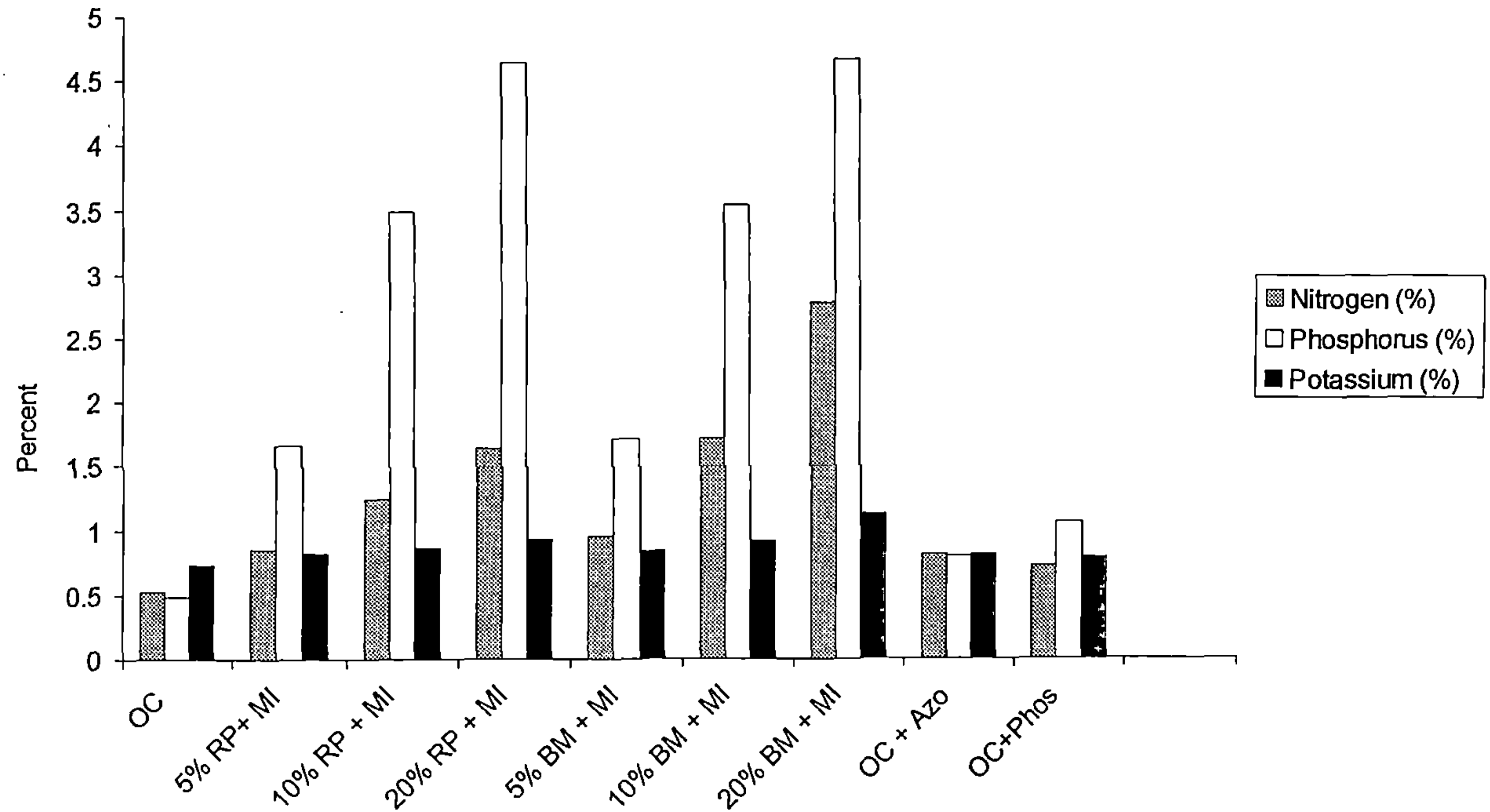


Fig. 6. Effect of phosphate sources and microbial inoculants on nutrient composition of compost.

within the range of 0.72 per cent (C_9) to 2.78 per cent (C_7) in comparison to 0.52per cent in the control. An appreciable amount of nitrogen was enriched by microbial inoculants. The enrichment increased progressively when microbial inoculants were supplemented with phosphate sources such as rockphosphate or bone meal. Also increased levels of phosphate sources resulted in an increase in the total nitrogen content of the finished compost (Fig.6).

Azotobacter being a nitrogen fixing bacteria, fixes atmospheric nitrogen, which in turn increases the nitrogen content of composts. In addition to that microorganisms produce various organic acids which are capable of stimulating the mineralisation of various nutrients. Addition of phosphate sources such as rock phosphate and bonemeal have accelerated decomposition, conserved nitrogen and improved nitrogen mineralisation (Thakur and Sharma, 1998). All these factors might have resulted in improving the nitrogen content of the enriched compost as compared to that of ordinary compost. Increased nitrogen conservation due to rockphosphate addition was reported by several workers (Dhar *et al.*, 1955 and Poincelot, 1975). Shinde *et al.* (1985) reported that the nutrient status of the compost can be improved by enriching compost with nitrogen fixing and P solubilising organisms. Hajra (1988) observed a variation within the range of 1.18 to 1.82 percent in the total nitrogen content of the enriched compost in comparison to 0.97per cent in the control. Inoculation with Azotobacter and P solubilising organisms in the presence of one percent rockphosphate is a beneficial input to obtain a good quality compost rich in N (Tiwari, 1989).

Compost treated with varying levels of bonemeal showed higher nitrogen content as compared to the respective levels of rock phosphate. This was because in addition to phosphorus bonemeal contained about 3.4 per cent N which might have resulted in enriching the nitrogen content of the compost, where as rock phosphate contained only phosphorus and no nitrogen.

Phosphorus

The results showed that the phosphorus content of various enriched composts was significantly higher than that of ordinary compost. The maximum phosphorus content of 4.66 per cent was recorded by the compost treated with 20 per cent bonemeal, Azotobacter and Phosphobacter and was comparable with C_4 (20% rock phosphate + Azotobacter + Phosphobacter) which recorded 4.63 per cent. Ordinary compost registered the minimum value of 0.48 per cent.

Organic amendments such as rockphosphate and bonemeal are rich sources of phosphorus. Bonemeal contained 24 per cent P_2O_5 and rock phosphate analysed 20 per cent P_2O_5, there by contributing to the phosphorus enrichment in the amended composts. As the level of organic amendments increased the phosphorus content of the compost also increased.

Subha Rao (1983) and Gaur (1990) reported that a group of heterotrophic microorganisms are known to have the ability to solubilise inorganic phosphorus from insoluble sources. The solubilisation of phosphorus by these microorganisms is attributed to excretion of organic acids like citric, glutamic, succinic, lactic, oxalic, glyoxalic, maleic, fumaric, tartaric and Ketobutyric acids (Subba Rao, 1983 and Gaur, 1988). Due to the acidic condition, phosphorus from rock phosphate and bonemeal applied in the compost gets solubilised and compost become enriched. Also these microorganisms weather rockphosphate and tricalcium phosphate by decreasing the particle size (Gaur, 1988). The action of organic acids has been attributed to their ability to form stable complexes with Al^{++}, Ca^{++}, Fe^{++} and Mg^{++}. In addition to P-solubilisation, these microorganisms can mineralise organic P into a soluble form. The P solubilisers also produce fungistatic and growth promoting substances which influence plant growth (Mishustin and Naumova, 1962). An increase in total and citrate soluble phosphorus due to rock phosphate addition and P solubilising culture was observed by Rasal *et al.* (1985). They obtained a phosphorus content of 0.76 percent P_2O_5 for enriched compost while P_2O_5 content of uninoculated compost was only 0.36percent. Gaur (1983) and Tiwari (1989) observed increased phosphorus content in compost enriched with N fixing and P solubilising organisms with one percent rock phosphate. Mathur *et al.* (1980) observed higher release of water soluble and citrate soluble P from compost charged with higher doses of rockphosphate as compared with lower dose.

Potassium

Potassium content in enriched compost increased by 53.4 percent as compared to ordinary compost. The reason for higher potassium content is not known. It might be due to the accelerated mineralisation of organic wastes by microbial activity.

5.2. Organic nutrient scheduling in okra

Performance of okra as influenced by various nitrogen sources.

The treatments included organic nitrogen sources such as FYM alone (S_1), FYM + poultry manure (S_2), FYM + neem cake (S_3), FYM + green leaf (S_4) and FYM + enriched compost (S_5), applied on equivalent nitrogen basis. The performance of these organic sources was compared with that of the package of practices (POP) recommendation [12 t FYM + 50:8:25 kg ha^{-1} NPK through chemical fertilizers] of Kerala Agricultural University.

Organic manures Vs POP recommendation

The result of this experiment showed that all treatments except FYM alone (S_1) were superior to the POP recommendation in their response to growth, yield and quality of okra.

The average germination percentage registered by organic manure application was 88.26 percent. But it was only 83.33 percent for POP recommendation. In the case of plant height, organic manure treated plants showed an increase of 23.15 percent and 37.33 percent over POP recommendation at 30 and 60 DAS respectively. Similarly LAI and DMP were comparatively higher for organic manure application. The beneficial effect of organic amendments in increasing the growth parameters were reported by Zhang *et al.* (1988), Almazov and Kholuyaka (1990), Pushpa (1996) and Anitha (1997).

Not only the growth parameters, the yield and yield attributes were also significantly improved by organic manure application. Days to 50 percent flowering was lowered by organic manure application (42 days) as compared to that of POP recommendation (43.8 days). Respective values for fruit weight and fruit length were 25.06g and 15.25cm for organic manure application and 23.62g and 14.3 cm for POP recommendation. Per hectare yield was significantly higher for organic amendment treated plants (135.85 q ha^{-1}) than that of POP recommendation (115.7q ha^{-1}). Similar results of increased plant growth and yield of tomato by the application of organic amendments were reported by Gianquinto and Borin (1990).

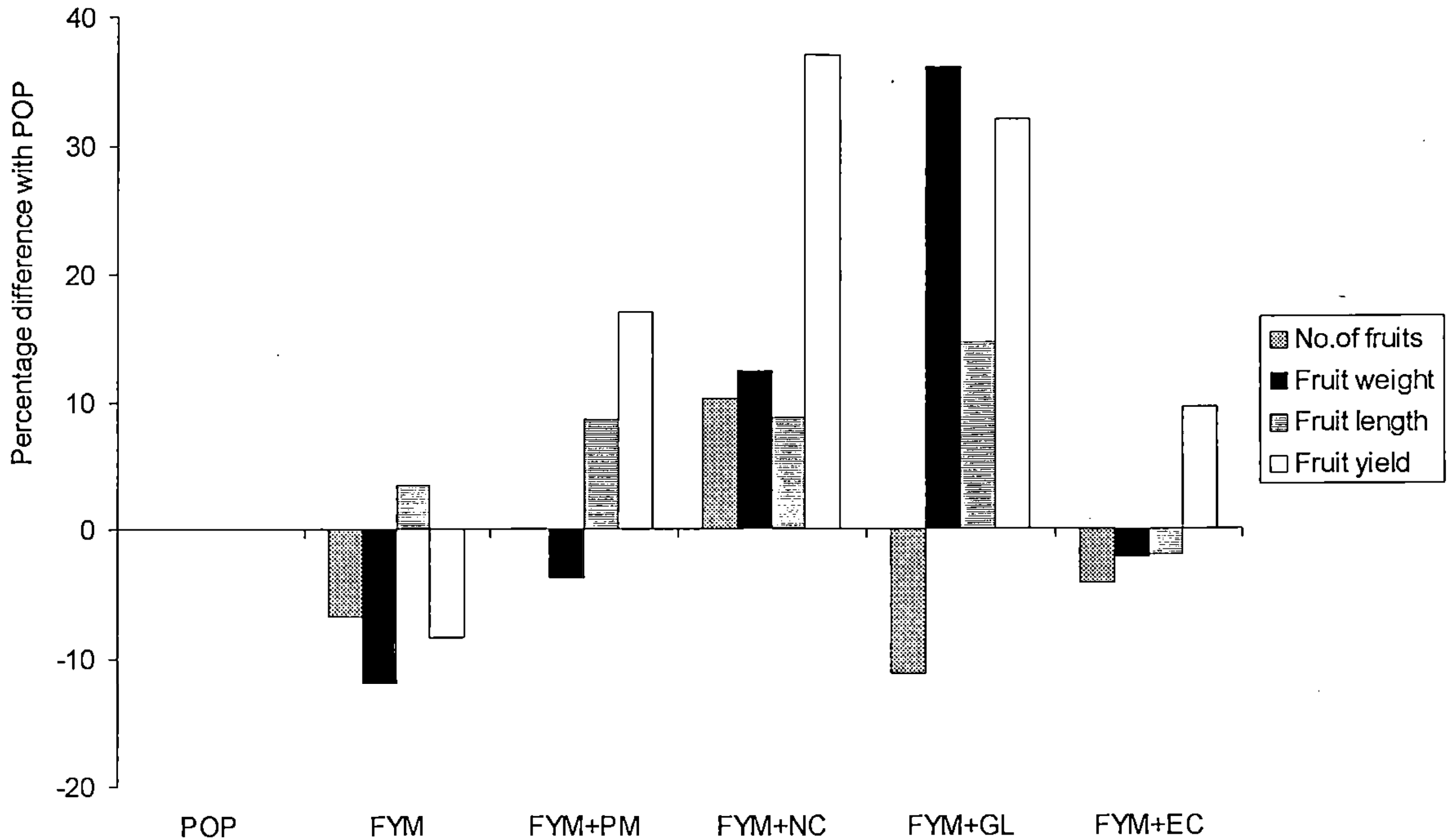


Fig . 7. Effect of nitrogen sources on number of fruits plant $^{-1}$, fruit weight, fruit length and fruit yield ha^{-1}

This better expression of growth and yield parameters noticed in the study may be due to the multidynamic role played by organic amendments. 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). Nitrogen fixation and P solubilisation are also improved due to the increased microbiological activity in organic matter amended soil. All these factors might have resulted in enhancing nutrient availability in the soil treated with organic manures alone.

This 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 of crops for organic manure application was 76.76 kg ha^{-1}, 14.67 kg ha^{-1} and 65.35 kg ha^{-1} respectively, where as the corresponding values for POP recommendation was only 72.6 kg ha^{-1}, 12.83 kg ha^{-1} and 62.92 kg ha^{-1}. Thus the better uptake of nutrients might have resulted in the better performance of bhindi supplied with organic manures alone.

In POP recommendation, a part of the nutrients was supplied through FYM and the remaining through chemical fertilizers. Nitrogen through urea was supplied in two equal split doses, one as basal and the other one month after sowing. 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 crop (Thampan, 1993). In the case of fertilizers especially urea, nutrients mineralise very quickly and are susceptible to leaching losses (Tisdale *et al.*, 1997). Thus quick mineralisation and leaching losses might have resulted in declining the nutrient availability within two months.

Thus the nutrients from FYM and 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. As compared to FYM, organic manures such as neemcake, poultry manure, enriched compost and green leaf are rich in plant nutrients and about 50-80 percent of nutrients are available to the immediate crop. Unlike chemical fertilizers nutrients in organic manures such as neemcake are available slowly within 2 to 3 months according to crop demand and are less susceptible to leaching losses. Hence the crops might have utilized the available nutrients more efficiently and resulted in better growth and yield.

In quality aspects also organic amendments showed significant improvement than POP recommendation. Plants treated with organic manures recorded higher crude protein content (17.68%) and ascorbic acid content (21.74 mg 100 g^{-1} fruit) and lower crude fibre content of fruits (10.91%) as compared to POP recommendation. Increased ascorbic acid content in spinach by the application of organic amendments was reported by Kansal *et al.* (1981). During decomposition, bulky organic manures yield many organic compounds as well as antibiotic substances as inter mediate products. These products on absorption by plants increase their resistance to some diseases and improve the quality of harvested produce (Thampan, 1993). This might be the reason for improved fruit quality in organic manure treated plants as compared to POP recommendation.

The better ascorbic acid content in organic manure treated plants might have further helped in improving the keeping quality of fruits (5.48 days) as compared to fertilizer treated plants (4.58 days). Fruits with high vitamin C content is associated with good keeping quality due to the effective antioxygenic property of ascorbic acid. Also decreased crude fibre content might have improved the tenderness of the fruits.

In addition to this better keeping quality might also be due to the high K uptake in organic manure treated plants as compared to that of inorganic manures. Fritz and Habben (1972) reported that K fertilizers increase the durability of the fruit by lowering the activity of enzymes which breakdown carbohydrate.

The data on available nutrient status of the soil after the experiment show that it was higher in organic manure treated plots as compared to that of POP recommendation. This might be due to the better retension of nutrients in soil due to slow mineralisation and reduced leaching losses of nutrients in organic manures as compared to fertilizers.

Neemcake Vs POP recommendation

There was a significant improvement in growth, yield and quality of bhindi due to the combined application of FYM and neemcake as compared to that of POP recommendation (Fig.7). The increase for various attributes were 30 percent (plant height at 60 DAS), 2.79 per cent (LAI at 60 DAS), 10.76 per cent (DMP), 36.97 per cent (yield ha^{-1}) and 2.94 per cent (crude protein content of fruit). Similar reports on improved growth and yield due to neemcake application was reported by Som *et al.* (1992) in brinjal.

Neemcake is a concentrated organic manure rich in plant nutrient contents. In addition to nutrients, it possess some alkaloids like nimbin, nimbidin and certain sulphur compounds, which have nitrification inhibiting properties. As a result neemcake acts like a slow releasing nitrogenous fertilizers, by inhibiting the nitrification process of soil and nutrients are available within a period of 2-3 months according to the crop demand. Thus apart from the nutrient content in neemcake, the retention capacity of nutrients especially nitrogen to a prolonged period and its balanced availability might have resulted in producing better yield due to neemcake application as compared to POP recommendation.

Green leaf manure Vs POP recommendation

Plants supplied with green leaf manure showed significant response with respect to growth, yield and quality of bhindi as compared to the plants supplied with POP recommended dose of nutrients. Plant height at 60 DAS (57.71cm), LAI at 30 DAS (0.807) and 60 DAS (1.53) and fruit weight (32.15g) were highest for green leaf treated plants. Green manured plants recorded 32.05 percent increase in yield as compared to that of POP recommendation (Fig.7).

Green manure crops undergo rapid decomposition on incorporation into the soil. This is accompanied by the release of nitrogen along with other nutrients in available forms. These nutrients are easily absorbed by the plants and undergo rapid vegetative growth. This might be the reason for the better height and higher LAI recorded by the plants treated with green manures. This better vegetative growth, leaf number and leaf area might have helped the plants to tap more solar radiation and to form more photosynthates. Thus the increased production, translocation and assimilation of photosynthates in fruits have resulted in increasing the fruit weight. This increased fruit weight have further contributed to the increment in the overall yield.

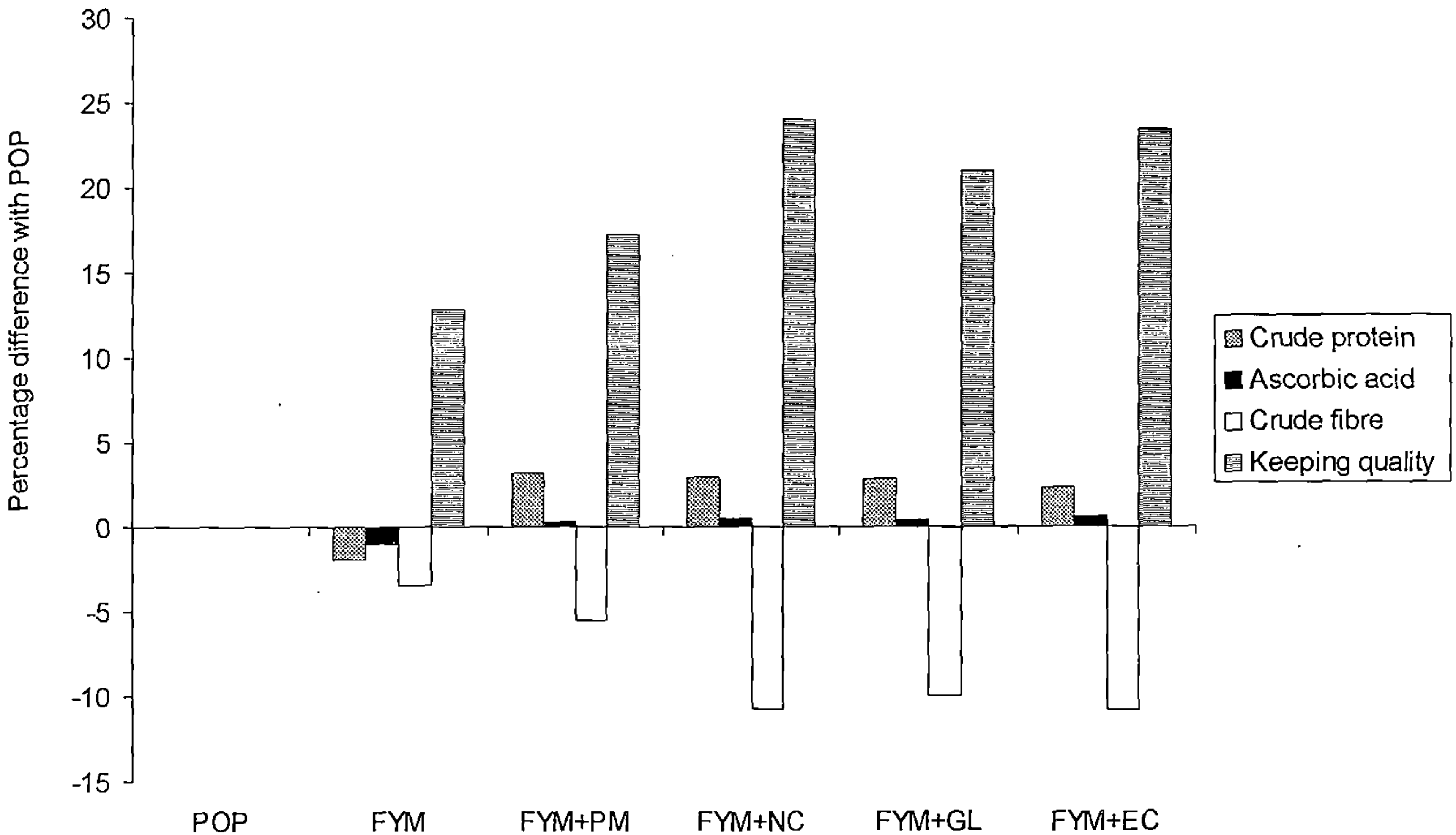


Fig. 8. Effect of nitrogen sources on crude protein content, ascorbic acid content, crude fibre content and keeping quality of fruit

Poultry manure Vs POP recommendation

Performance of bhindi was better under poultry manure application as compared to POP recommendation. Growth attributes like plant height at 60 DAS (55.41 cm), LAI at 60 DAS (1.407), DMP (2982.13 kg ha^{-1}), yield attributes like fruit length (15.52cm) and yield ha^{-1} (135.38 q ha^{-1}) were higher for poultry manure treated plants.

Poultry manure is a good source of nutrients, particularly for vegetable production. In this manure, 60 percent of the nitrogen is present as uric acid 30 percent as more stable organic nitrogen forms and balance as mineral nitrogen (Srivastava, 1988). The uric acid N readily changes into ammoniacal form of nitrogen. Singh *et al.* (1973) attributed higher efficiency of poultry manure to its narrow C:N ratio and comparatively higher content of readily mineralisable N.

Enriched compost Vs POP recommendation

Plants treated with enriched compost produced higher yields (126.71 q ha^{-1}) than that of the plants treated with POP recommended dose of nutrients (115.7 q ha^{-1}), even though the statistical difference was insignificant. Various growth attributes and yield attributes were also comparable. But in the case of quality aspects compost treated plants showed significant superiority over POP recommendation. Crude protein and ascorbic acid content were higher and crude fibre content was lower as compared to that of the plants treated with POP recommendation.

Enriched compost is a good source of both macro and micro nutrients. Also compost improve soil organic matter content, water and nutrient retension in soil and reduce leaching losses (Dick and Mc coy, 1993). Application of compost improve the soil properties, increase crop production and improve crop quality (Papavizas and Lumsden, 1980; Yang *et al.*, 1996). Thus application of compost might have improved soil properties and nutrient availability and there by crop growth and yield. Improvement in fruit quality might be due to the presence of certain plant growth hormones in compost, which was produced due to Azotobacter and Phosphobacter. Mishustin and Naumova (1962) reported that P solubilisers prouduce fungistatic and growth promoting substances which influence plant growth.

Farm yard manure alone Vs POP recommendation

The result of the study showed that plants treated with FYM alone (treatment S_1) recorded lower fruit yield (105.9q ha^{-1}) as compared to that of the plants treated with POP recommended dose of nutrients (115.7q ha^{-1}) even through the statistical difference was insignificant. Various growth, yield and quality attributes were comparable.

5.2.2. Comparative performance of various organic nitrogen sources with respect to the growth, yield and quality of okra.

Organic manures compared in this study were farmyard manure, poultry manure, neemcake, greenleaf and enriched compost.

The result of the study showed that neem cake mixed with FYM was superior to all other organic manures on equivalent nitrogen basis. Plants treated with neemcake (S_3) recorded the maximum yield of 158q ha^{-1} and was 49.65 percent higher as compared to that of FYM alone (S_1), which was the most inferior treatment in the study (Fig. 7).

Neemcake is a concentrated organic manure with N,P and K content of 5.1per cent, 1.0per cent, and 1.51per cent respectively. In addition to these nutrient elements, it contains some alkaloids like nimbin, nimbidin and certain sulphur compounds, which have nitrification inhibiting properties. As a result neemcake acts like a slow releasing nitrogenous fertilizer, by inhibiting the nitrification process of soil and nutrients are available within a period of 2-3 months (which is in line with the duration of the test crop) according to the crop demand.

The result of the study showed that the neemcake treated plants recorded the highest germination percentage of 93.40 percent. This might be due to the optimum supply of nitrogen at the time of germination. Dry matter production was also maximum (3099 kg ha^{-1}) as compared to other manures. Neemcake provided continuous and steady supply of nitrogen, which might have more efficiently been utilized by the crop there by resulting in increased DMP at the time of final harvest. Similar findings were reported by Sathianathan (1982) in cassava, Apurbasarkar (1987) in jute and Muniram *et al.* (1987) in Japanese mint.

The plant height and leaf area index due to neemcake application was lower as compared to other organic manures. This might be due to the slow release of nitrogen resulting in slow initial growth. But due to the continuos supply of nutrients during the full growth period of the crop, the growth progressively improved with better shoot weight, leaf longevity and fruit production thereby resulting in the maximum DMP at the time of final harvest.

The maximum number of fruits plant^{-1} (11.89) was also recorded by neemcake treated plants. Som *et al.* (1992) reported similarly in brinjal. This might be due to the increased availability of nutrients in sufficient quantities at critical stages of growth. Neemcake behaved as a slow releasing nitrogenous fertilizer by inhibiting nitrification, might have checked the leaching , denitrification and runoff losses of nitrogen and thereby increased the availability of nitrogen for producing maximum number of fruits.

Thus the production of more number of fruits had finally resulted in improving the overall yield of the crop. Table 4.15 showed a positive correlation between number of fruits plant^{-1} and yield.

Thus apart from the nutrient content in neemcake, the retension capacity of nutrients especially nitrogen to a prolonged period and its balanced availability might have resulted in producing better yield due to neemcake application as compared to other organic manures.

Green leaf (Glyricidia) treated plants produced comparable yield (152.78 q ha^{-1}) as that of neemcake.

The green manure crops are high in water soluble constituents, nitrogen (3.74percent) and minerals, but are comparatively low in cellulose and lignin. Therefore on incorporation into the soil green manures undergo rapid decomposition and mineralisation, and the nutrients are available within a period of 6-8 weeks. These nutrients are easily absorbed by the plants an undergo rapid vegetative growth. This might be the reason for the better height and higher LAI recorded by the plants treated with green manures. As compared to other organic manures, green manure treated plants recorded the highest LAI of 0.807 and 1.527 at 30 DAS and 60 DAS respectively.

With respect to the yield attributes green manure treated plants recorded the maximum fruit weight of 32.15 g. This is 54.7 per cent higher as compared to that recorded by FYM alone treated plants. The better leaf number and leaf area had helped the plants to tap more solar radiation and form more photosynthates. Thus the increased production, translocation and assimilation of photosynthates in fruits has resulted in increasing the fruit weight. This increased fruit weight had further contributed to the increment in the overall yield. A positive correlation (0.57) was observed between fruit weight and yield.

Yield produced by poultry manure treated plants (135.38 q ha^{-1}) was on par with that of green leaf treated plants.

Poultry manure is a good source of nutrients particularly for vegetable production .In poultry manure 60 per cent of nitrogen is present as uric acid, which readily changes into ammoniacal form of nitrogen which become available to the plant immediately and thereby increase growth and yield of the plant (Smith, 1950). Another factor contributing to the higher yield with poultry manure might be its higher P_2O_5 content (Singh and Srivasthava, 1970). Singh *et al.* (1973) attributed higher efficiency of poultry manure to its narrow C:N ratio and comparatively higher content of readily mineralisable nitrogen.

FYM + enriched compost recorded comparatively lower yield (126.71 q ha^{-1}). The lowest yield of 105.9 q ha^{-1} was recorded by FYM alone (S_1).

Thus the better performance of neemcake, greenleaf and poultry manure as compared to that of FYM and enriched compost could be attributed to the low C:N ratio of the former as compared to that of the latter. C:N ratio of neemcake, greenleaf and poultry manure varied within the range of 3to10, whereas C:N ratio of enriched compost was 13.71 and that of FYM was 15.5. The amounts of nitrogen released from different manure sources have been related to both their total nitrogen content (Rees *et al.*, 1993) and C:N ratios (Frankenberger and Abdelmagid, 1985). The higher the total nitrogen content of the amendment, the greater its restorative ability. The performance of enriched compost was superior as compared to that of FYM but inferior to other organic manures. Inspite of high nitrogen content in enriched compost, the inferior performance might be due to the high C:N ratio, which reduced the mineralisation of nutrients and inturn their availability. Also FYM was not as effective as other organic manures with respect to the performance of bhindi. This was probably due to low nitrogen content and high C:N ratio. Due to high C:N ratio, the nutrients contained in FYM mineralised very slowly and about 30 percent nitrogen, one sixth of phosphoric acid and more than one half of the potash alone were available to the immediate crop. Due to the decreased nutrient availability plant growth and yield declined.

Effect on quality aspects

The data given on Table 4.9 showed that the crude protein content of fruit was highest (17.92 %) in poultry manure treated plants. Similar trend was reported by Singh *et al.* (1973) and Sujatha and Krishnappa (1995) in potato. Poultry manure contained 60 percent of its nitrogen as uric acid and this is converted to ammoniacal form and the same could be absorbed by the plants in a better way at the reproductive stage of the crop resulting in better crude protein content.

With respect to the ascorbic acid content of fruits plants treated with enriched compost recorded the highest value (21.85 mg 100g fruit^{-1}) and was on par with that of neemcake treated plants (Fig.8). In case of enriched compost, which was inoculated with microorganisms, the increase in ascorbic acid content might be due to the increased efficiency of microbial inoculants to fix atmospheric nitrogen and secrete growth promoting hormones which accelerated physiological processes like synthesis of carbohydrates and vitamins. This result corroborates with the findings of other workers in different crops (Balakrishnan, 1988; Kumaraswamy and Madalageri, 1990; Kalyani *et al.*, 1992). In the case of neem cake the high ascorbic acid content could be explained by the slow dissolution and mineralisation of nitrogen there by causing a steady and longer availability from these resources.

In the case of crude fibre content lower values were given by enriched compost and neemcake. Production of growth hormones might have decreased the crude fibre content in enriched compost. In neemcake increased nitrogen uptake might have resulted in increasing the succulence and there by decreasing crude fibre content. In case of enriched compost the production of growth hormones might have improved the quality and decreased the crude fibre content .

Keeping quality

Among organic sources the combined application of FYM and neemcake produced fruits with best keeping quality (5.68 days) and this was on par with that of enriched compost. This might be due to the high ascorbic acid content and lower crude fibre content of fruits treated with neem cake and enriched compost. Fruits with high vitamin C content is associated with good keeping quality due to the effective antioxygenic property of ascorbic acid. Similar reports on improved keeping quality of tomato due to compost application had been reported by Meier – Ploeger and Lehri (1989)

Nutrient uptake by crops as influenced by organic nitrogen sources.

Total nitrogen uptake by plants (shoot + fruit) was highest in neemcake treated plants (82.78 kg ha^{-1}) as compared to other organic manures (Fig.9) . The highest nitrogen uptake might be due to the better nitrogen availability in the soil. Due to the presence of certain alkaloids, neemcake inhibited the population of *Nitrosomonas sp.* there by reducing the nitrification. Thus they behaved as a slow releasing nitrogenous fertilizer and checked the leaching, denitrification and runoff losses of nitrogen resulting in an even availability of nitrate nitrogen through out the growth period commensurating with plant needs (Sahrawat and Parmer, 1975). The bitter odoriferous substance namely nimbidin and high amount of sulphur present in neemcake are responsible for reducing the nitrification more efficiently. As a result nitrogen availability in soil increased which inturn 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.

Phosphorus uptake was highest in poultry manure treated plots (15.56 kg ha^{-1}). This might be due to the high phosphorus content and favourable C/P ratio in poultry manure which inturn increased the available phosphorus content in soil. Higher nutrient supplying efficiency of poultry manure was reported by Singh *et al.* (1973).

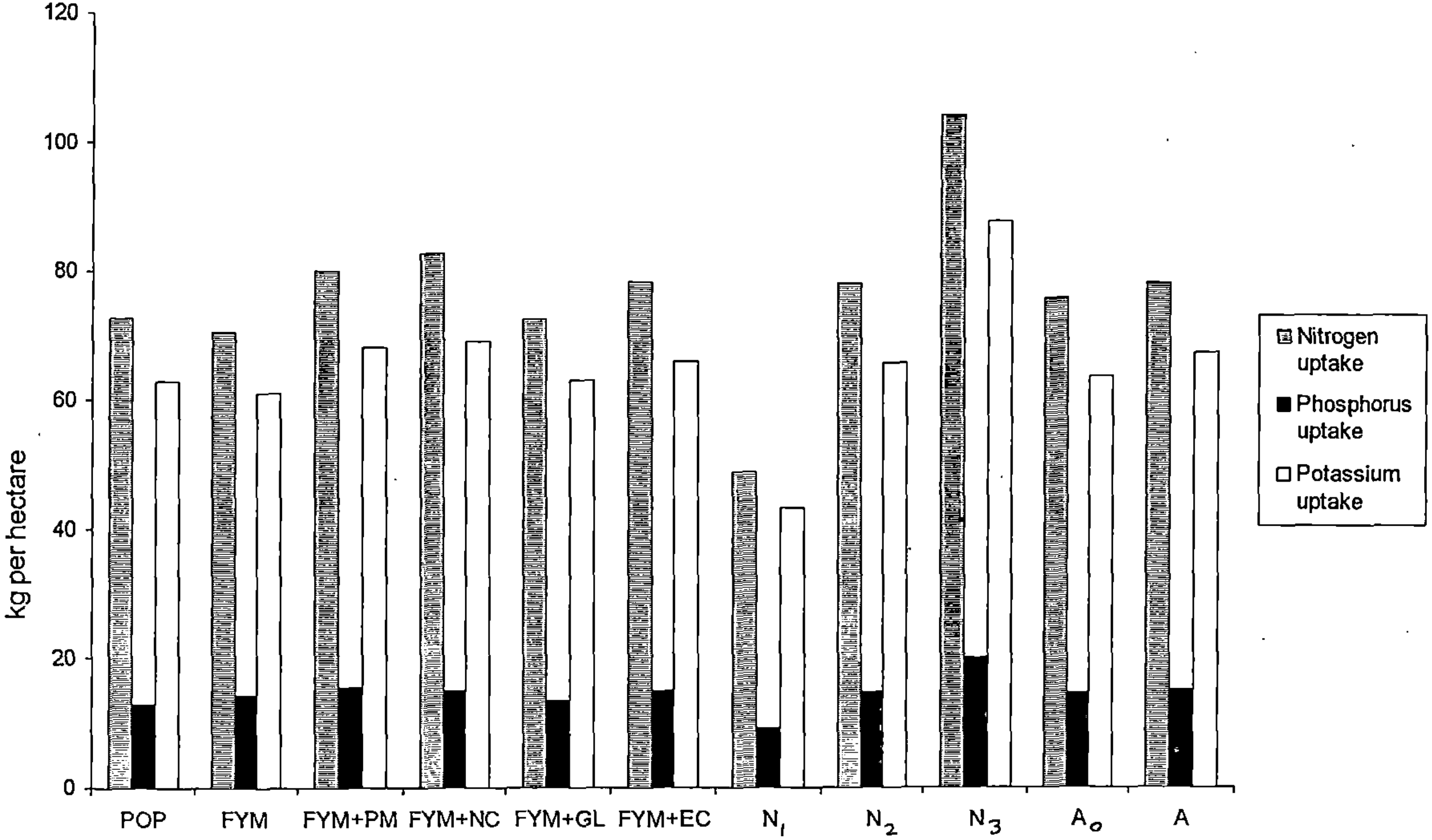


Fig. 9. Effect of nitrogen sources, nitrogen levels and microbial inoculation on nitrogen, phosphorus and potassium uptake by plants

Potassium uptake was highest for neemcake application (68.88 kg ha^{-1}). Neemcake must have provided sufficient quantity of nitrogen through out the growth period resulting in an increased biomass production which might have contributed towards the increased K uptake. The results are in agreement with the findings of Sathianathan (1982) in cassava and Shivaprakash (1991) in mulberry.

This better uptake of nutrients might have resulted in better expression of growth, yield attributes and finally the yield. A positive correlation was observed between yield and N and P uptake.

Available nutrient status of soil after the experiment

Available nitrogen in the soil after the experiment was highest (389.03 kg ha^{-1}) in neemcake treated plots as compared to other manures. This might be due to the fact that neemcake acted as efficient nitrification inhibitor there by conserving more nitrogen, resulting in the minimisation of losses of nitrogen through leaching, denitrification and runoff.

Available soil phosphorus after the experiment was highest (46.83 kg ha^{-1}) in enriched compost treated plots. This might be due to the high phosphorus content in enriched compost as compared to other manures.

Potassium content was highest (155.25 kg ha^{-1}) in FYM alone treated plots. This might be due to the high potassium content in FYM.

5.2.3. Effect of nitrogen levels on growth, yield and quality of bhindi (okra)

The treatments included three levels of nitrogen viz. 50 percent (N_1), 100 percent (N_2), and 150 percent (N_3) of POP recommended dose (12t FYM + 50:8.25 kg NPK ha^{-1}) of Kerala Agricultural University supplied through organic manures.

The results of the experiment showed that the growth parameters like plant height, LAI, shoot dry weight, fruit dry weight and total dry matter production increased with increasing levels of nitrogen. The highest level of nitrogen increased plant height by 38.17 percent and 60.59 percent at 30 and 60 DAS respectively. Similar findings were reported by Prabhakar *et al.* (1987), Belichki (1988), Saji John (1989) and Sajitharani (1993).

Nitrogen is a vitally important plant nutrient. An adequate supply of nitrogen is associated with high photosynthetic activity vigorous vegetative growth and a dark green colour (Tisdale *et al.*, 1997). Increased plant height obtained at higher levels of nitrogen could be due to the rapid meristematic activity triggered by plant nutrients especially nitrogen (Crowther, 1935) and the higher rate of metabolic activity coupled with rapid cell division brought about by phosphorus (Bear, 1965). Also nitrogen is the major constituent of chlorophyll, protein and amino acids of which synthesis is accelerated by the increased supply of nitrogen in the soil (Burris, 1957).

LAI also increased from 0.604 (N_1) to 0.801 (N_3) at 60 DAS with the highest level of nitrogen. Russel (1973) reported that as the nitrogen supply increases, the extra protein produced allows the plant leaves to grow larger and hence to have more surface area available for photosynthesis. Thus increased LAI might be due to the enhanced production of leaves and increased longevity of leaves exhibited by plants receiving higher level of nutrients. Steineek (1964) reported that more the available nitrogen, the greater the effect of potassium on the growth of shoot and number of leaves and potassium increases longevity of leaves.

The increase in plant height and LAI due to the better assimilation of nutrients might have helped to increase the DMP from 2003. 05 kg ha^{-1} to 3783.59 kg ha^{-1} by the application of highest level of nitrogen. Similar findings were earlier reported by Pandey *et al.* (1980), Paraminder Singh *et al.*, (1986) and Pandey *et al.* (1992). According to Black (1973) an adequate supply of nitrogen is associated with vigorous vegetative growth in plants.

Number of fruits produced per plant was increased by 78.94 percent by the application of highest level of nitrogen (Fig.10). Increase in nitrogen levels might have increased the production, translocation and assimilation of photosynthates to growing points there by stimulating plants to produce more number of fruits $plant^{-1}$. Similar results were reported by Dolkova *et al.* (1984) and Kaminawar and Rajagopal (1993). Increased application of N, P and K have been reported to increase the number of fruits produced per plant by several workers like Majanbu *et al.* (1985) for nitrogen and potassium and Mishra and Pandey (1987) for phosphorus and potassium.

Fruit length and fruit weight also increased significantly due to nitrogen application. Fruit length increased from 14.08 cm (N_1) to 16.36 cm (N_3) and fruit weight increased from 20.24g (N_1) to 30.81g (N_3). Subramanian (1980) found significant influence of nitrogen on fruit length.

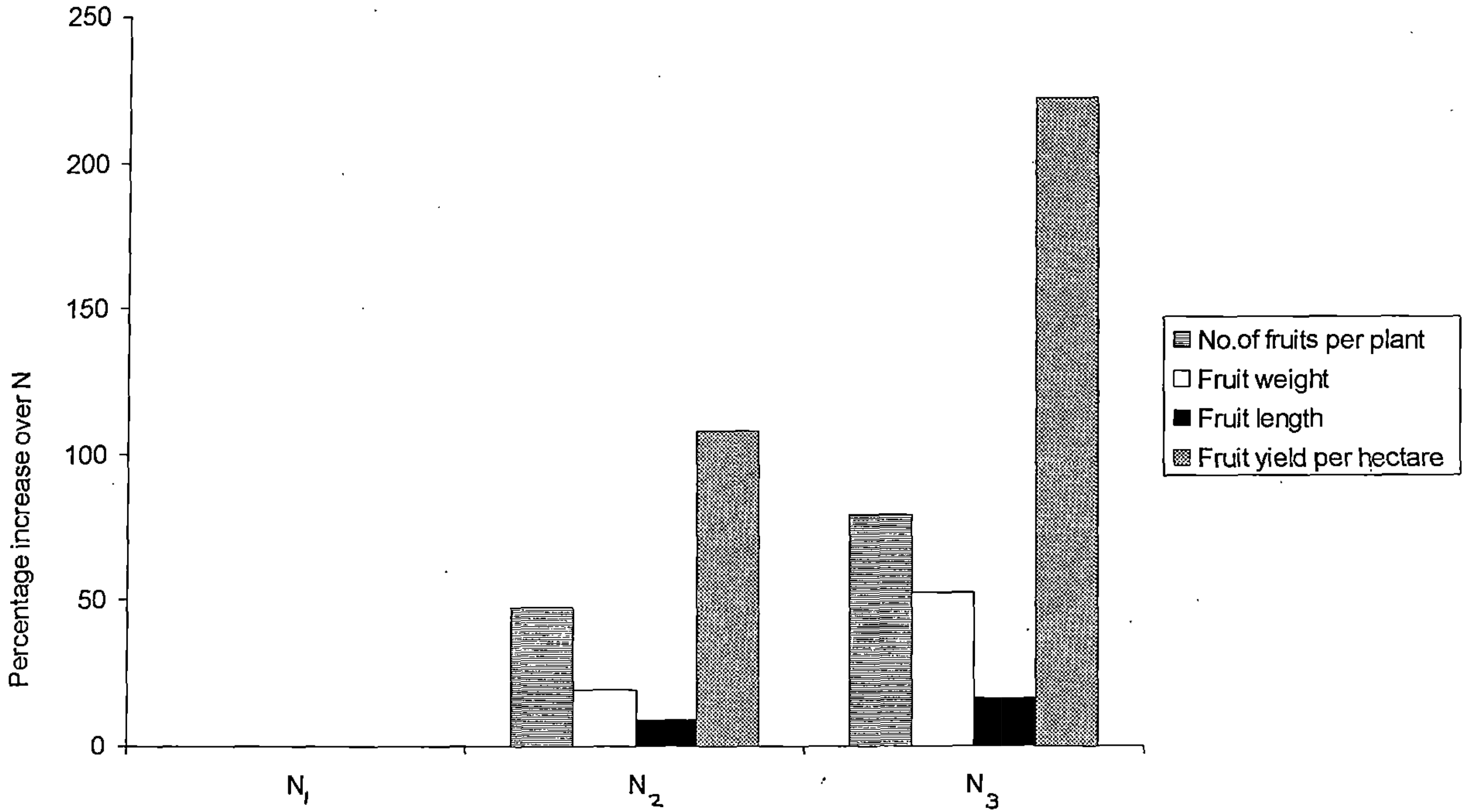


Fig. 10. Effect of nitrogen levels on number of fruits plant^{-1}, fruit weight, fruit length and fruit yield ha^{-1}

Thus the improvement in growth and yield attributes might have resulted in increasing the total fruit yield by the application of highest level of nitrogen. Yield at N_2 level registered 108.04 per cent over N_1 level and yield at N_3 level registered 54.24 per cent over the N_2 level. Similar findings on increased yield with higher levels of nutrients had been reported by Jayaraman and Balasubramanian (1991), Kaminawar and Rajagopal (1993) and Subbiah (1993).

Quality aspects

Crude protein content of fruits was significantly influenced by nitrogen levels (Fig .11). Each higher level was significantly superior to the next lower level and values ranged from 16.01 per cent (N_1) to 19.32 per cent (N_3). The increase in crude protein content due to higher levels of nitrogen might be due to the favourable effect of nitrogen on protein synthesis. These results are in confirmity with the findings of Subramanian (1980)

Effect of nitrogen levels on ascorbic acid content of fruits was also significant. The maximum ascorbic acid content of 23.64 mg 100g fruit^{-1} was recorded by N_3 and this was 21.23 per cent more as compared to N_1 level. Increased ascorbic acid content noticed in the present study might be due to the increase in protein synthesis and enhancement of enzymatic activities for aminoacid synthesis at higher level of nutrients which was instrumental in improving the quality (Shibhila Mary and Balakrishnan, 1990 and Kaminawar and Rajagopal, 1993). Similar results of increased ascorbic acid content with the application of nitrogen, phosphorus and potassium were reported by De *et al.* (1977).

Application of nitrogen exerted a significant influence on crude fibre content of bhindi fruits. Crude fibre content was minimum (8.87%) at the highest level of nitrogen and maximum (13.09%) at lowest level of nitrogen. Increased levels of nitrogen application causing an increase in the succulence of fruit might have decreased the crude fibre content. Hence it could be emphasized that the higher levels of nitrogen improved the quality of bhindi fruits with particular reference to its tenderness. Tiwana *et al* (1975) observed decreased crude fibre content in Napier bajra hybrid fodder due to nitrogen application.

It was also observed that crude fibre content of fruits increased with the advancement in the days after harvest. This might be due to the reduced succulence resulting from the cell wall thickening with the advance in time.

Keeping quality

The results showed that the keeping quality of fruits improved with increased nitrogen application. This might be due to the increased ascorbic acid content and reduced crude fibre content due to the application of higher levels of nitrogen. Fruits with high vitamin C content is associated with good keeping quality due to the effective antioxygenic property of ascorbic acid. Application of higher levels of nitrogen through organic manures has resulted in increased application of potassium also, as organic manures contained P and K in addition to N. The better keeping quality of the fruits might be due to the high K content. Fritz and Habben (1972) reported that K fertilizers increase the durability of the fruit by lowering the activity of enzymes which breakdown carbohydrate.

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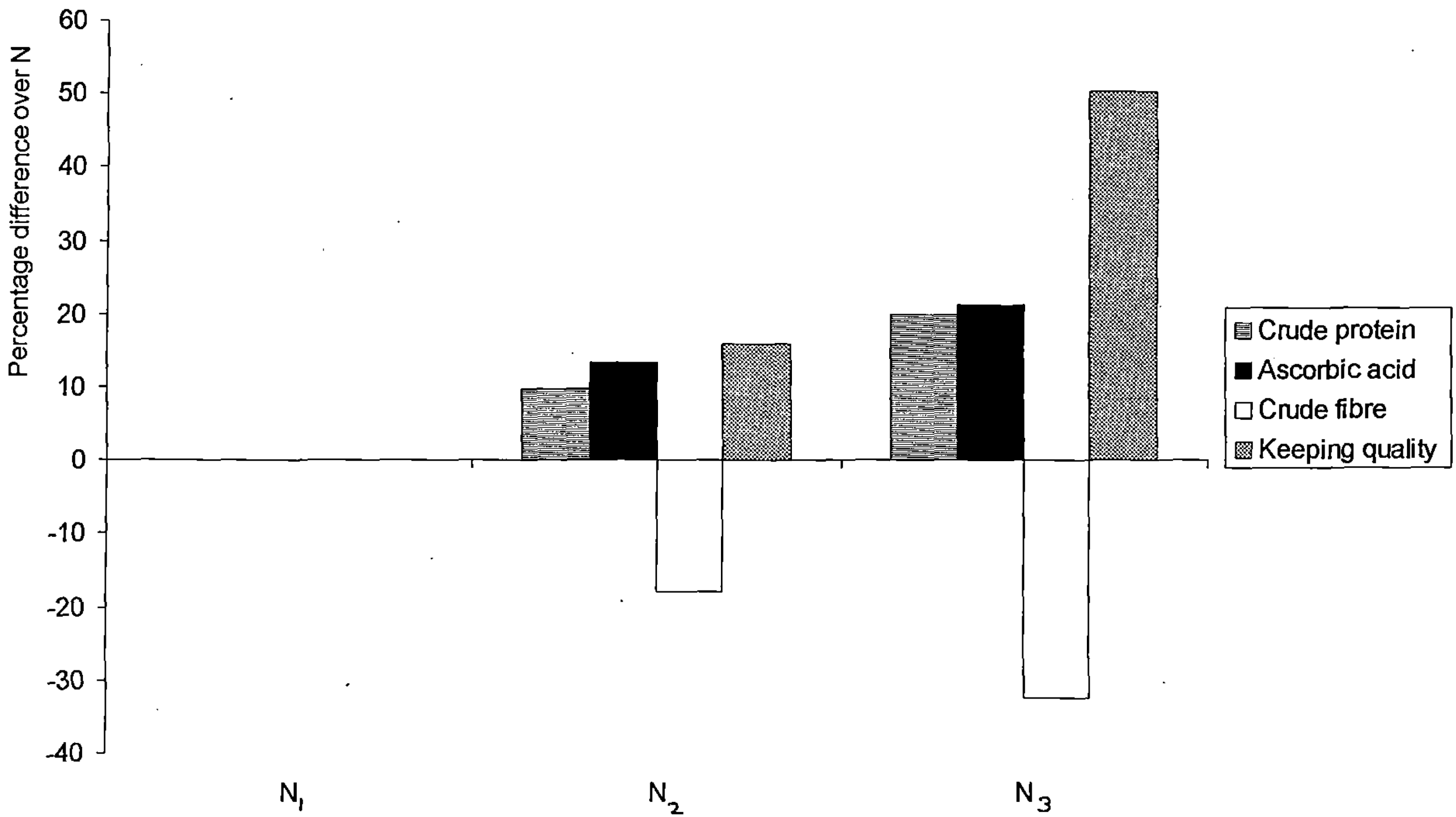

Fig. 11. Effect of nitrogen levels on crude protein content, ascorbic acid content, crude fibre content and keeping quality of fruit.

Nutrient uptake by crops

Nutrient uptake was significantly improved due to the application of increased levels of nitrogen. The highest level of nitrogen (N_3) resulted in the maximum uptake of N, P and K and the percentage increase was 112.9 percent, 177.69 percent and 103.22 percent respectively over the N_1 level. According to Tanaka *et al.*(1964) the nutrient availability is controlled by factors like nutrient availability in soil, nutrient absorption power of roots and rate of increase in dry matter. A stimulated growth under higher levels of nutrient application might have resulted in better proliferation of root system and increased intake efficiency of plants. Also the beneficial effect of higher levels of nutrients in increasing the uptake of nitrogen has been reported by Dolkova *et al.* (1986), Hedge (1988), Saji John (1989) and Sajitharani (1993). Relationship between nitrogen and phosphorus is synergetic in nature. Potassium is required for nitrogen uptake and potassium uptake increased with increasing levels of nitrogen. Nitrogen at higher level recorded maximum potassium uptake. The beneficial effect of higher levels of nutrients in increasing the potassium uptake were reported by Tapia and Dabed (1984) and Subbiah (1994).

The improved nutrient uptake due to increased nitrogen application might have played a positive role in developing a better expression of growth and yield parameters.

Soil analysis

The data on soil analysis revealed that the available nitrogen, phosphorus and potassium content was significantly increased by nitrogen application. This might be due to the direct effect of applied nutrients.

Nitrogen levels Vs POP recommendation.

The results showed that the per hectare yield recorded by the N_2 (134.77 q ha^{-1}) and N_3 (208.0 q ha^{-1}) level of organic manures were higher and yield recorded by N_1 level (64.78 q ha^{-1}) was lower as compared to the yield recorded by the application of POP recommended dose of nutrients (115.7 q ha^{-1}) (Fig.12).

In POP recommendation plants were supplied with 100 kg N, 38 kg P_2O_5 and 40 kg K_2O. But the N_1 level of organic manures supplied only half the quantity of above nutrients, which were insufficient for the satisfactory growth of the crops. This might be the reason for the low yield of plants supplied with N_1 level of organic manures as compared to that of POP recommendation. In the case of N_2 level the amount of nitrogen supplied was the same as that of POP recommendation but the quantity of phosphorus and potassium supplied was much higher. Thus the higher availability of P and K might have resulted in improving the yield.

In the case of N_3 level, 150 kg N was supplied through organic manures which was 50 percent higher than POP recommendation. Thus the increased supply of nutrients might have resulted in producing maximum yield at N_3 level of organic manures.

5.2.4. Effect of Azospirillum inoculation on growth, yield and quality of bhindi

Owing to the energy and cost intensive manufacture of chemical fertilizers, use of microbial inoculants to supplement a part of nitrogen requirement, has attained immense importance.

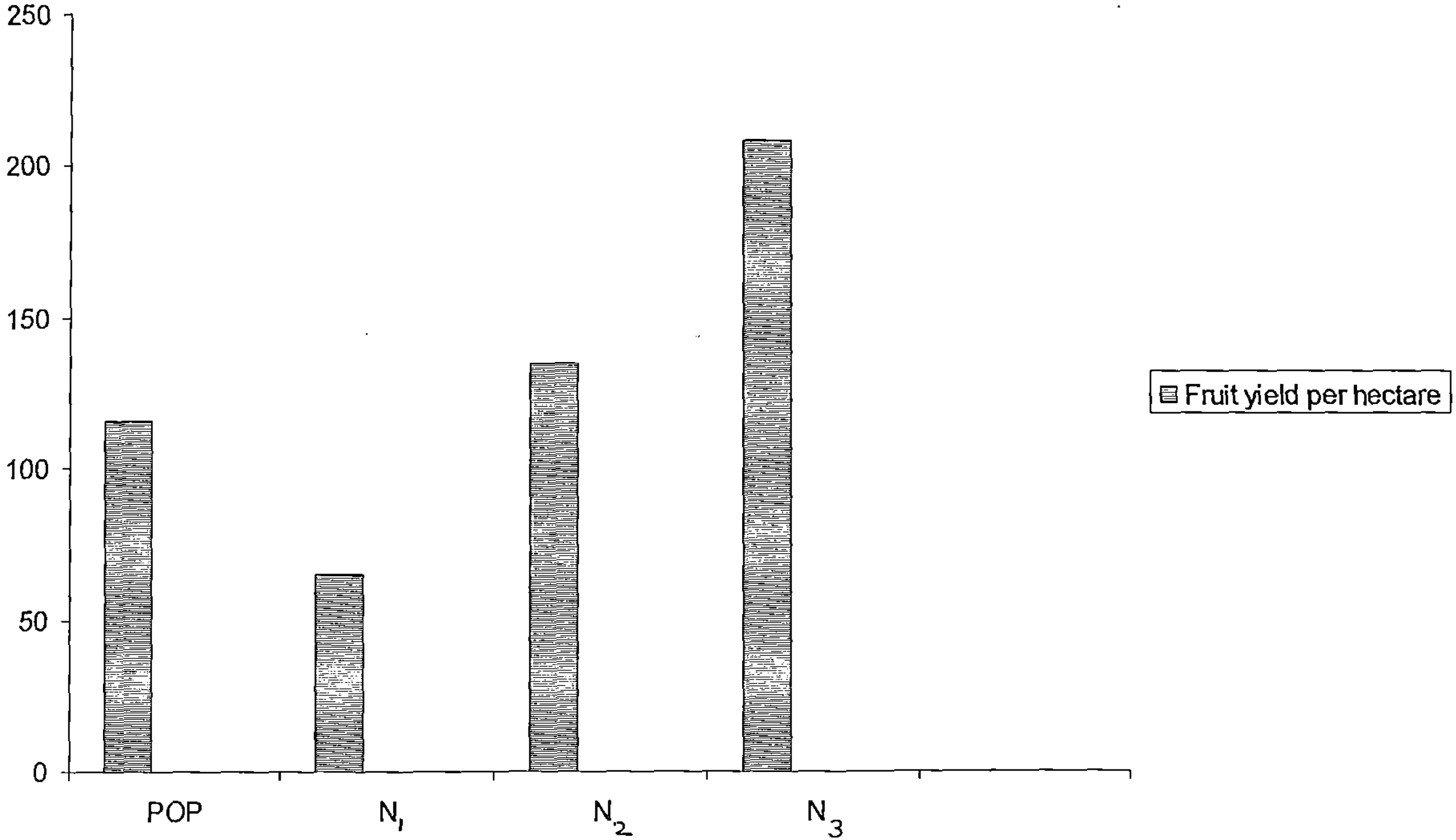

Fig. 12. Nitrogen levels Vs POP recommendation with respect to fruit yield ha^{-1}

These biofertilizers are cost effective as well as environment friendly. Application of Azospirillum inoculants in vegetable crop has been of much significance because they not only fix atmospheric nitrogen but also produce growth promoting and antifungal substance. Azospirillum inoculation is known to increase yield of crops by 5 to 20 percent with saving of nitrogen upto 40 percent of the recommended dose (Dart, 1986). The effect of Azospirillum on growth, yield and quality of bhindi was studied in this experiment.

Azospirillum inoculation had beneficial effect on various growth and yield attributes of bhindi. Total fruit yield was significantly higher for Azospirillum inoculation (141.29 q ha^{-1}) than control (129.74 q ha^{-1}).

Increase in yield by Azospirillum inoculation is a cumulative effect of various positive roles played by Azospirillum. Azospirillum inoculation helps not only in promoting nitrogen fixation but also in the release of various growth promoting agents which might have lead to better root development, better transportation of water, and uptake and deposition of nutrients. Similar observations have also been made by other workers (Mohandas, 1987; Kumaraswamy and Madalageri, 1990; Jeevajohti *et al.*, 1993) in different crops.

Quality aspects

Quality of bhindi fruits showed good response to Azospirillum inoculation. Crude protein content was significantly increased by Azospirillum inoculation (17.73%) as compared to control. This might be due to the increased nitrogen fixation by Azospirillum which inturn had favourable effect on nitrogen uptake and protein synthesis.

Ascorbic acid content of fruits was significantly increased by Azospirillum inoculation (21.78 mg 100g $^{-1}$ fruit) as compared to control. The increase in ascorbic acid content could be due to the increased efficiency of microbial inoculants to fix atmospheric nitrogen and secrete growth promoting substances which accelerated the physiological process like synthesis of carbohydrates. This result corroborates with the findings of other workers on different crops (Balakrishnan, 1988; Kumaraswamy and Madalageri ,1990 and Kalyani *et al.*, 1992).

Azospirillum inoculation had resulted in significant reduction in crude fibre content as compared to untreated plants. This might be due to the increased N fixation by Azospirillum which inturn improved the nitrogen uptake by plants. As a result plant became more succulent and crude fibre content decreased.

Nutrient uptake

The nutrient uptake was also favourably influenced by Azospirillum inoculants. Azospirillum has the ability for better root induction in inoculated plants mainly due to the production of plant growth hormones. As a result such plants are capable of absorbing more and more available nutrients from the soil which inturn results in better establishment of plant seedling and subsequent growth (Tien *et al* ., 1979 and Govindan and Purushothaman, 1984).

Available nutrient status of soil after the experiment

The available nitrogen status of soil in Azospirillum treated plots were higher as compared to control: This might be due to improved N fixation by Azospirillum which inturn increased the nitrogen availability in soil. Significant improvement in K uptake might be due to increase in dry matter yield and K contents in the fruits and plants (Nover *et al.*, 1985).

5.2.5. Interaction effect of nitrogen sources and nitrogen levels on yield of bhindi

Interaction between organic nitrogen sources and nitrogen levels revealed that, application of various organic nitrogen sources at N_3 level recorded higher yields as compared to their N_2 and N_1 levels (Fig.13). S_1N_3 (154.03q ha^{-1}) recorded higher yield than S_1N_2 (105.26q ha^{-1}) and S_1N_1 (58.4 q ha^{-1}). Similarly S_2N_3 (225.9 q ha^{-1}) recorded higher yield than S_2N_2 (117.57 q ha^{-1}) and S_2N_1 (62.68 q ha^{-1}). S_3N_3 recorded 65 percent increase in yield over S_3N_2 which inturn recorded 130 percent increase in yield over S_3N_1. S_4N_3 registered higher yield (228.4 q ha^{-1}) than S_4N_2 (165.37 q ha^{-1}) and S_4N_1 (64.5 q ha^{-1}). In the case of S_5 the values ranged from 67.7 q ha^{-1} (S_5N_1) to 188.89 q ha^{-1} (S_5N_3).

The better performance of organic nitrogen sources at higher levels of nitrogen might be due to the increased supply of nutrients, which inturn stimulated growth resulting in better growth and yield attributes and finally the yield. Singh and Singh (1965), Widham (1966) and Chauhan (1968) have reported the beneficial effect of nitrogen, phosphorus and potash on growth, development and yield of okra. Thus the better supply of these nutrients at higher levels of organic manures as compared to lower levels resulted in better response of bhindi to higher levels of organic manures.

Among treatment combinations combined application of FYM and neem cake (S_3) at N_3 level recorded the maximum yield of 242.75 q ha^{-1} and this was on par with S_4N_3 (228.4 q ha^{-1}) and S_2N_3 (225.9 q ha^{-1}). Yield produced by S_5N_3(188.89 q ha^{-1}) and S_1N_3

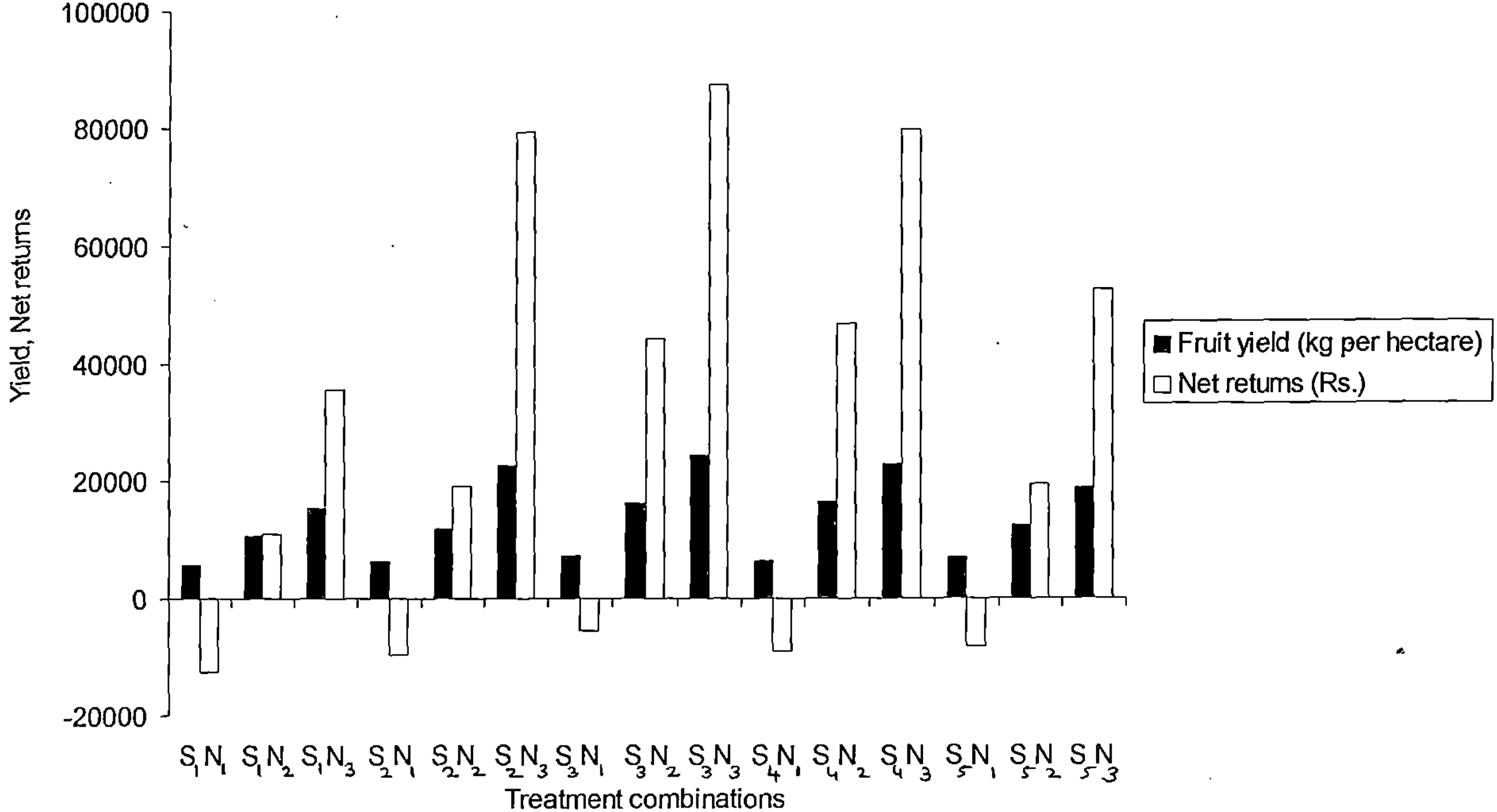

Fig.13. Interaction effect of nitrogen sources and nitrogen levels on fruit yield (kg ha^{-1}) and net returns (Rs.)

(154.03 ha^{-1}) were almost comparable to that of S_4N_2 (165.37 q ha^{-1}) and S_3N_2 (162.1 q ha^{-1}) . The above results showed the superiority of neemcake green leaf and poultry manure over enriched compost and FYM. This might be due to the low C:N ratio of the former as compared to that of the latter. The C:N ratio of neemcake, green leaf and poultry manure varied within the range of 3 to10 where as the C:N ratio of enriched compost was 13.71 and that of FYM was 15.5. The amount of nitrogen released from different manure sources have been related to both their total nitrogen content (Rees *et al.*,1993) and C:N ratios (Frankenberger and Abdelmajid, 1985). Thus the higher nutrient contents and lower C:N ratio in neemcake, green leaf and poultry manure have resulted in better nitrogen availability which further contributed towards better growth and yield.

Application of neemcake (S_3) at various levels N_1, N_2 and N_3 was found to produce superior yield as compared to that of other organic manures at their respective levels. Neemcake is rich in plant nutrients and in addition to that it contains certain alkaloids like nimbin and nimbidin which have nitrification inhibiting properties. As a result neemcake acts like a slow releasing nitrogenous fertilizer, by inhibiting the nitrification process of soil and nutrients are available within a period of 2-3 months according to the crop demand. Thus apart from the nutrient content in neemcake, the retension capacity of nutrients especially nitrogen to a prolonged period and its balanced availability might have resulted in producing better yield due to neemcake application as compared to other organic manures.

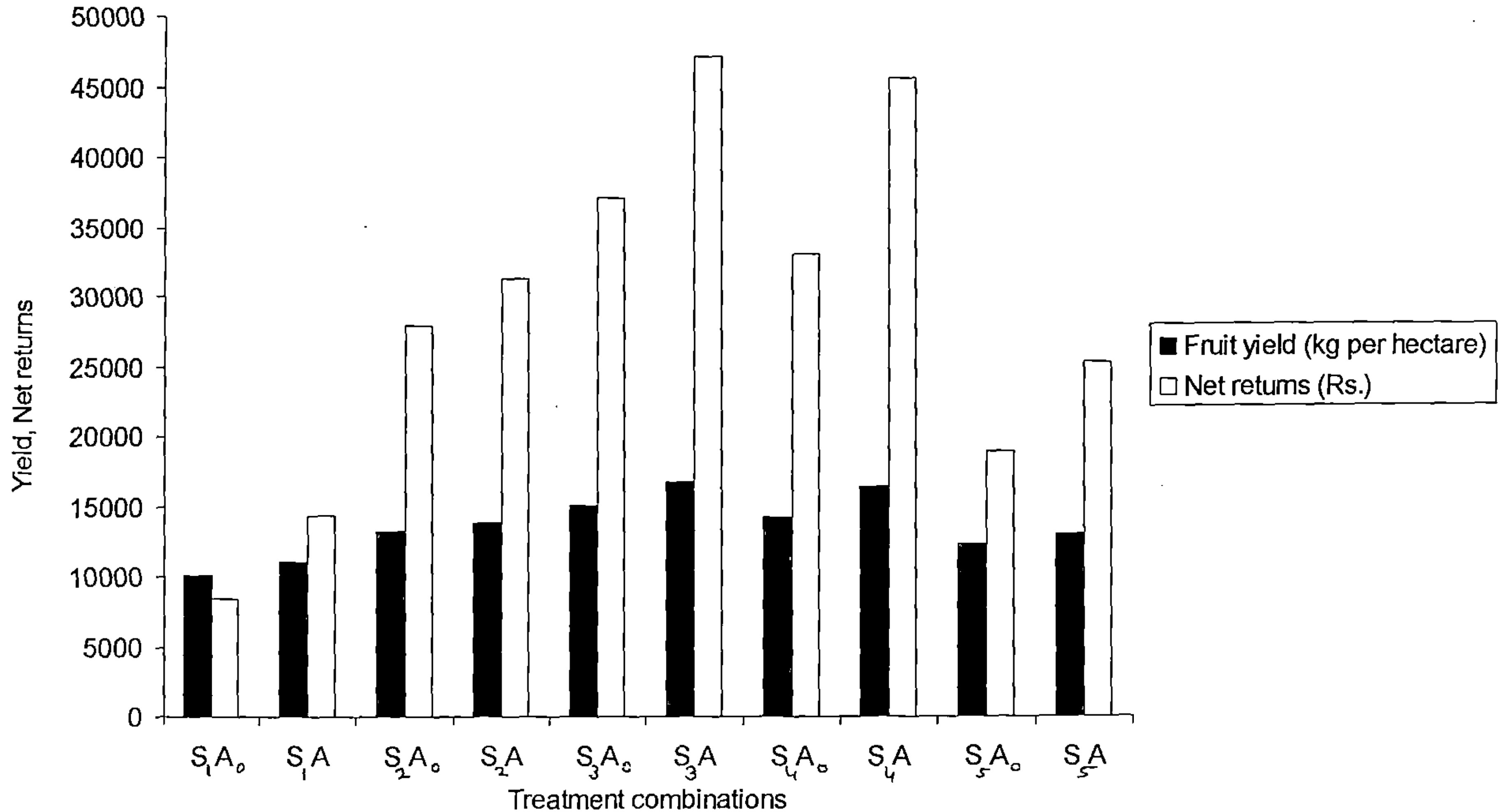

Fig. 14. Interaction effect of nitrogen sources and microbial inoculation on fruit yield (kg ha^{-1}) and net returns (Rs.)

5.2.6. Interaction effect of nitrogen sources and microbial inoculation on yield of bhindi

The interaction between organic nitrogen sources and microbial inoculation showed that yield of bhindi increased significantly by the combined application of organic manure and Azospirillum inoculation(Fig.14). Azospirillum along with greenleaf registered 14.74 percent increase in yield as compared to green leaf alone. Similarly S_1A, S_2A, S_3A and S_5A registered 9.78 percent, 4.30 percent, 11.25 percent and 6.27 percent increase in yield over no inoculation. This very well showed that Azospirillum inoculation is a must to reap maximum benefit from organic manures. Rajasekhar *et al.* (1955) got better yield in bhindi from plants treated with Azospirillum + FYM and inorganic fertilizers. 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. Use of FYM, green manures or other organic amendments enhanced the benefits from inoculation (Wani, 1990).

5.2.7. Interaction effect of nitrogen levels and microbial inoculation on yield of bhindi

In the interaction between nitrogen levels and Azospirillum inoculation, an yield increase of about 14 percent was observed by Azospirillum inoculation at $N_1$and N_2 levels (Fig .15). But at the highest level of nitrogen (N_3) the percentage increase in yield was only about 4.7. This showed that efficiency of Azospirillum inoculation was less at higher levels of nitrogen Wam and Konde (1986) reported that performance of Azospirillum was better at lower doses of nitrogen.

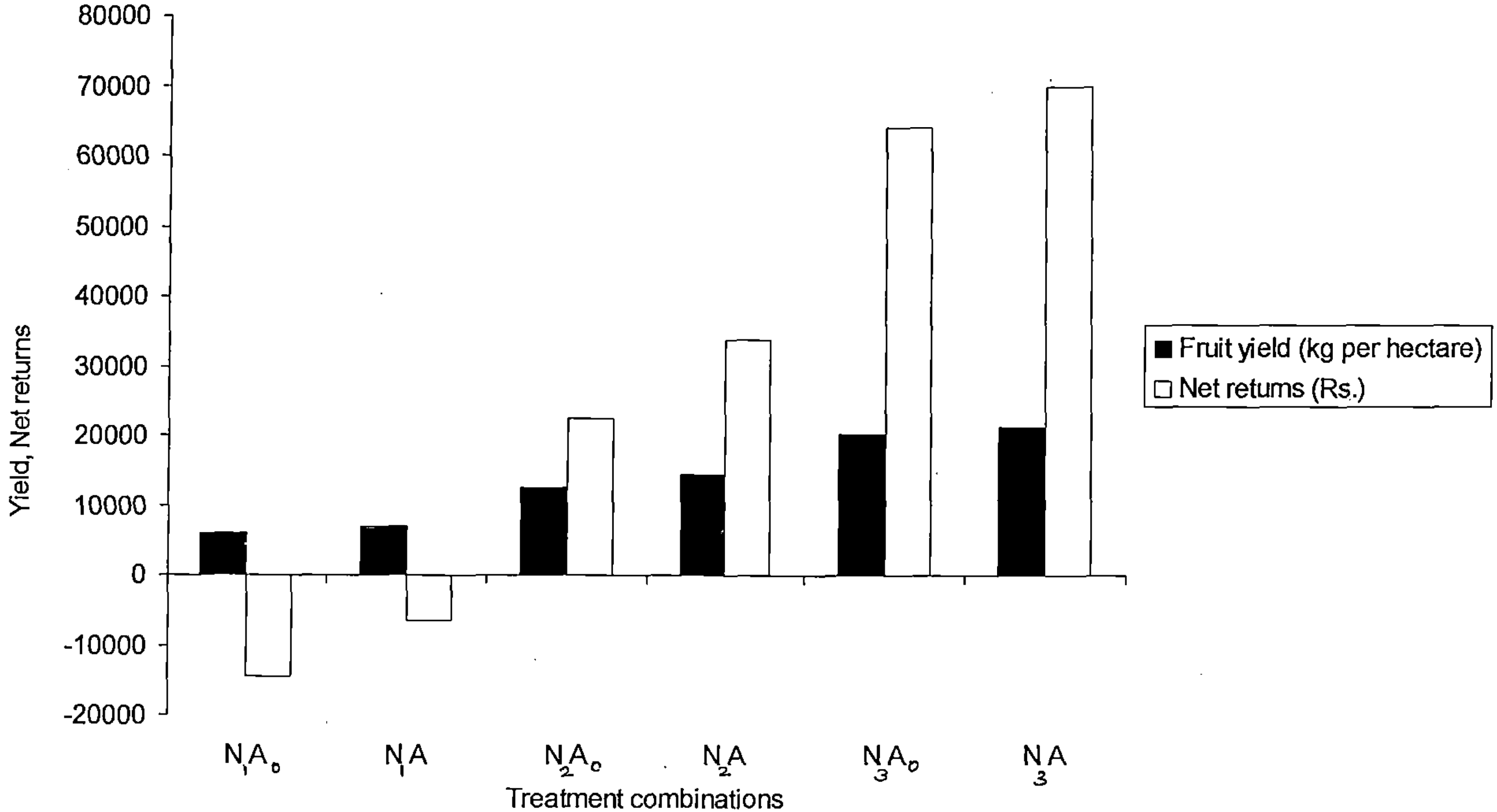

Fig.15. Interaction effect of nitrogen levels and microbial inoculation on fruit yield (kg ha^{-1}) and net returns (Rs.)

5.2.8. Economics of production

Among various nitrogen sources, combined application of FYM and neemcake (S_3) registered the maximum profit of Rs. 42120.5 ha^{-1} and was on par with that recorded by FYM + green leaf (Rs. 39215.5 ha^{-1}) and FYM + poultry manure (Rs. 29625.5 ha^{-1}). The better returns obtained from these sources is due to the higher yield obtained from these sources as compared to others.

The plants treated with POP recommended dose of nutrients (12t FYM + 50:8:25 kg ha^{-1} NPK through feritilizers) registered a profit of Rs. 21015 ha^{-1} and was on par with that of FYM + enriched compost (Rs. 211833.5 ha^{-1}). The minimum profit (Rs. 11357.5 ha^{-1}) was recorded by the plants treated with FYM alone (S_5).

The lower profit obtained due to FYM application as compared to other nitrogen sources might be due to the high cost of FYM and low gross income which inturn reduced the net returns.

In the case of enriched compost the profit obtained was almost comparable with that of POP even though the gross income was much higher for enriched compost as compared to that of POP. The low net returns from enriched compost might be due to the high cost of production for enriched compost as compared to that of POP. The cost of 1 ton enriched compost is Rs. 5000/- of which 50 per cent of the cost goes as labour wages. Instead of hired labour, if family labour is used then cost of production of enriched compost can be reduced substantially, which inturn helps in increasing the net returns.

Application of N_1 level of nitrogen resulted in a loss of Rs. 8969 ha^{-1}. This was because, the cost of production incurred was much higher as compared to the returns. N_2 and N_3 levels recorded a profit of Rs. 28032 ha^{-1} and Rs. 66977.5 ha^{-1} respectively.

Azospirillum inoculation registered a higher profit (Rs. 32352 ha^{-1}) than control (Rs. 25059 ha^{-1}) even though the statistical difference was insignificant.

In the case of interaction between nitrogen sources and nitrogen levels, various nitrogen sources at N_3 level registered higher returns as compared to their N_2 and N_1 levels. The returns obtained from S_5 and S_1 at N_3 level was almost comparable with that obtained from S_4 and S_3 at N_2 level. This showed that S_3N_2 and S_4N_2 were equivalent toS_5N_3 and S_1N_3, with respect to the net returns.

Interaction effect of nitrogen sources and Azospirillum inoculation showed that, the returns obtained from S_3A, S_4A, S_3Ao, S_4Ao and S_2A were comparable and were superior to other treatment combinations.

In the interaction between nitrogen levels and microbial inoculation, various nitrogen levels N_1, N_2 and N_3 showed higher returns with Azospirillum inoculation as compared to no inoculation. N_1Ao and N_1A registered a loss of Rs. 11462.9 and Rs. 6398.1 respectively.

In the case of net returns, N_2A registered a percentage increase of 83.53per.cent over N_2Ao and N_3A registered a percentage increase of 18.37per cent as compared to N_3Ao. This showed that the performance of Azospirillum was better at N_2 level as compared to N_3 level of nitrogen. Wam and Konde (1986) reported that performance of Azospirillum was better at lower doses of nitrogen.

Thus the result showed that, the application of FYM and neemcake at N_3 level of nitrogen along with Azospirillum inoculation produced the highest net returns as compared to other treatment combination.

SUMMARY

SUMMARY

The study entitled "Organic nutrition in okra (*Abelmoschus esculentus*)" has been carried out as a field experiment under the Department of Agronomy, College of Agriculture, Vellayani during 1997 – 98. The main objectives of the study were to assess the effect of dual application of phosphate sources and microbial inoculants on the quality of compost and to standardize an organic nutrient schedule for bhindi. Two successive experiments as detailed below were conducted to achieve the objectives envisaged.

1. Standardisation of agro-techniques for enriching compost.

This study was aimed to assess the effect of phosphate sources and microbial inoculants on the ripening period and nutrient composition of compost. The treatments constituted of ordinary compost (uninoculated and unamended compost) and enriched composts prepared with varying levels of (5%, 10% and 20%) rockphosphate or bonemeal and microbial inoculants (Azotobacter and Phosphobacter). The experiment was laid out in randomised block design with nine treatments and three replications.

The results of the experiment are summarised below.

1. C:N ratio of enriched composts was lower than ordinary compost (19.35). Lowest C:N ratio (13.71) was observed in compost treated with 20 per cent bonemeal and microbial inoculants.

2. Enriched compost matured earlier than ordinary compost (120 days). Ripening period was lowest (82 days) for the compost prepared with 20 per cent bonemeal and microbial inoculants and

was on par with the compost enriched with 20 per rcent rockphosphate and microbial inoculants.

3. Enriched compost recorded higher nutrient status than ordinary compost. Compost enriched with 20 per cent bonemeal and microbial inoculants showed the maximum N (2.78%), P (4.66%) and K (1.12%) content. The phosphorus content of compost enriched with 20per cent rockphosphate and microbial inoculants (4.63%) was comparable with bonemeal treated compost. Ordinary compost registered an N, P and K content of 0.52per cent, 0.48 percent and 0. 73per cent respectively.

From the results it can be inferred that, addition of phosphate sources and microbial inoculants accelerated the rate of decomposition and improved the manurial value of compost. Addition of 20per cent bonemeal along with Azotobacter and Phosphobacter @ 1 kg per ton of material was found to be the most superior treatment in this study.

2. Organic nutrient scheduling in okra

The objective of the study was to standardize an organic nutrient schedule for bhindi by comparing the effects of various nitrogen sources, nitrogen levels and Azospirillum inoculation on growth, yield and quality of okra, variety Arka anamika. The treatments consisted of five organic nitrogen sources (S_1 - FYM alone, S_2 - FYM + poultry manure, S_3 - FYM + neemcake, S_4 – FYM + green leaf, and S_5 – FYM + enriched compost); three levels of nitrogen (N_1 - 50 kg N ha^{-1}, N_2 - 100 kg N ha $^{-1}$ and N_3 - 150 kg N ha^{-1}), two levels of microbial inoculation (control and Azospirillum) and absolute control (POP recommendation of Kerala Agricultural University, 12t FYM + 50:8:25 kg NPK ha^{-1}). The experiment was laid out in 5x3x2+1 factorial randomised block design with 3 replications.

The results of the investigation are summarised below.

1. Effect of various nitrogen sources on growth, yield and quality of bhindi was significant.

All organic nitrogen sources (neemcake, green leaf , poultry manure and enriched compost) except FYM (treatment S_1) showed superior response than POP recommendation (FYM + chemical fertilizers). Growth characters like plant height, LAI, DMP, yield attributes like fruit number per plant, fruit weight, fruit length and fruit yield ha^{-1} were higher in organic manure treated plants. Plants treated with organic manures produced fruits with higher crude protein and ascorbic acid contents and lower crude fibre content than that of POP recommendation.

2. Application of FYM + neemcake recorded the highest germination percentage (93%) and was on par with that of FYM + greenleaf and FYM + poultry manure. Plant height at 30 DAS was maximum (16.12 cm) for FYM + poultry manure. Plant height at 60 DAS (57.71cm) and LAI at 30 DAS (0.807) and 60 DAS (1.53) were highest with the combined application of FYM and green leaf. DMP was non significantly influenced by nitrogen sources.

3. FYM + neemcake recorded maximum number of fruits per plant (12 fruits) where as weight (32g) and length (16 cm) of fruits were maximum for FYM + green leaf, which also showed early flowering within a period of 41 days.

4. FYM + neemcake and FYM + green leaf recorded comparable and maximum yield of 158 and 153 q ha^{-1} respectively.

5. Application of FYM + poultry manure and FYM + enriched compost produced fruits with the maximum crude protein content (17.92%) and ascorbic acid content (21.85 mg 100 g^{-1} fresh fruit) respectively. Crude fibre content was lowest (10.59%) when supplied with FYM + enriched compost and was on par with that of FYM + neemcake.

6. Keeping quality of fruits was highest (5.7 days) in FYM + neemcake, closely followed by FYM + enriched compost.

7. Nitrogen and potassium uptake by plants was maximum in FYM + neemcake and phosphorus uptake was highest in FYM + poultry manure.

8. The available nitrogen, phosphorus and potassium status of the soil after the experiment were highest in FYM + neemcake, FYM + enriched compost and FYM alone respectively. The available phosphorus content in FYM + poultry manure was comparable with FYM + enriched compost.

9. FYM + neemcake application recorded the maximum profit (Rs. 42120 ha^{-1}) and was comparable with that of FYM + green leaf and FYM + poultry manure. Benefit cost ratio was highest (1.80) in FYM + neemcake.

10. Effect of various nitrogen levels on growth, yield and quality of okra was significant. Each higher level was significantly superior to the next lower level. Growth characters viz. plant height, LAI, shoot dry weight , fruit dry weight, yield attributes like fruits per plant (14), fruit weight (30.8g), and fruit length (16.36 cm); per plant productivity and total fruit yield (208q ha^{-1}) were highest at N_3 (150 kg N ha^{-1}) level of nitrogen. Time of 50

percent flowering was non significantly influenced by nitrogen levels. Quality attributes like crude protein content (19.32%) and ascorbic acid content (23.64 mg $100g^{-1}$ fresh fruit) were maximum and crude fibre content (8.87%) was minimum at N_3 level of nitrogen.

11. Incremental dose of nitrogen improved the keeping quality of fruits and the maximum (6.75 days) was recorded at N_3 level.

12. Application of the highest level of nitrogen resulted in the maximum uptake of N, P, and K by plants (including fruits).

13. The available N,P,and K status of the soil after the experiment were maximum with the application of N_3 level of nitrogen

14. Maximum profit (Rs. 66977 ha^{-1}) and benefit cost ratio (2.16) were higher at N_3 level. Application of lowest level of nitrogen (50 kg N ha^{-1}) resulted in a loss of Rs. 8969 ha^{-1}.

15. Azospirillum inoculation produced significantly higher fruit yield (141.3 q ha^{-1}) than control.

16. Quality attributes of fruits like crude protein content (17.73%) and ascorbic acid content were significantly higher and crude fibre content was lower for Azospirillum inoculated plants than control.

17. Nutrient uptake was favourably influenced by Azospirillum inoculation. K uptake was significantly higher.

18. Available nitrogen status of soil improved with Azospirillum inoculation. There was no influence on P and K content.

19. Azospirillum inoculation showed a higher profit of Rs. 32352 ha^{-1} and benefit cost ratio (1.61) than control.

20. In the case of interaction between nitrogen sources, nitrogen levels and microbial inoculation, S_3N_3A (FYM + neemcake at N_3 level of nitrogen and Azospirillum inoculation) recorded the highest germination percentage and number of fruits. Plant height was maximum for S_2N_3A and was on par with S_4N_3A. S_4N_3A (FYM + green leaf at N_3 level + Azospirillum) recorded the maximum LAI, fruit length and fruit weight. Total fruit yield was highest for S_3N_3A (242.75 q ha^{-1}) and was on par with that of S_4N_3A (228.4 q ha^{-1}) and S_2N_3A (225.9 q ha^{-1}). $S_4N_2A_0$ showed early flowering. Among the quality aspects S_2N_3A recorded the highest crude protein content and S_5N_3A (FYM + enriched compost at N_3 level and Azospirillum) showed the maximum ascorbic acid content. Crude fibre content was least for S_3N_3A which also recorded the best keeping quality of fruits. The available N, P and K status of the soil after the experiment were maximum for S_3N_3A , S_5N_3A and S_1N_3A respectively.

21. Profit was maximum for S_3N_3A and was on par with S_4N_3A and S_2N_3A.

The present study revealed that the substitution of chemical fertilizers with organic manures such as neemcake, green leaf, poultry manure and enriched compost was beneficial for increasing the yield and improving the quality of bhindi.

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* *Original not seen*

APPENDICES

Appendix – I

Weather data during the composting period

Standard week	Period		Rainfall (mm)	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative humidity (%)
	From	To				
27	2.7.97	8.7.97	7.73	29.32	22.94	87.14
28	9.7.97	15.7.7	5.93	29.73	23.74	85.71
29	16.7.97	22.7.87	1.47	29.85	23.94	87.00
30	23.7.97	5.8.97	9.24	29.45	23.43	88.71
31	30.7.97	5.8.97	3.33	30.9	24.36	91.71
32	6.8.97	12.8.97	5.16	29.2	23.17	89.71
33	13.8.97	19.8.97	0	30.4	24.18	87.86
34	20.8.97	26.8.97	3.07	29.8	23.57	92.29
35	27.8.97	2.9.97	2.8	30.1	24.06	90.71
36	3.9.97	9.9.97	5.01	30.3	24.16	87.43
37	10.9.97	16.9.97	12.69	29.5	23.39	91.57
38	17.9.97	23.9.97	28.89	29.4	23.34	96.00
39	24.9.97	30.9.97	9.13	29.7	23.91	90.86
40	1.10.97	7.10.97	3.12	29.8	23.66	86.00
41	8.10.97	14.10.97	5.52	29.1	23.14	90.72
42	15.10.97	21.10.97	5.94	29.9	23.92	93.86
43	22.10.97	28.10.97	7.17	29.7	23.87	93.14

Appendix – II

Weather data during the composting period

Standard week	Period		Rainfall (mm)	Maximum Temperature (^0C)	Minimum Temperature (^0C)	Relative humidity (%)
	From	To				
1	1.1.98	7.1.98	0	31.68	22.6	95.26
2	8.1.98	14.1.98	0	31.84	22.36	93.3
3	15.1.98	21.1.98	0	31.66	23.63	96.57
4	22.1.98	28.1.98	0.29	31.76	23.79	96.29
5	29.1.98	4.2.98	0	32.39	22.73	95.14
6	5.2.98	11.2.98	0	32.26	23.61	94.00
7	12.2.98	18.2.98	2.63	31.83	32.71	93.57
8	19.2.98	25.2.98	0.06	31.86	24.79	91.87
9	26.2.98	4.3.98	0	32.80	23.53	92.43
10	5.3.98	11.3.98	0	33.00	23.73	88.00
11	12.3.98	18.3.98	0	33.60	24.11	87.43
12	19.3.98	25.3.98	0	33.23	24.46	90.43
13	26.3.98	1.4.98	0	33.70	25.11	88.00
14	2.4.98	8.4.98	0.43	33.19	25.44	89.71
15	9.4.98	15.4.98	0.69	34.3	25.84	90.86
16	16.4.98	22.4.98	4.71	34.17	26.60	90.57
17	23.4.98	29.4.98	1.21	34.21	26.23	88.29
18	30.4.98	6.5.98	2.91	34.07	25.66	82.29

ABSTRACT

ABSTRACT

A field experiment was conducted at the Department of Agronomy, College of Agriculture, Vellayani to find out the effect of dual application of phosphate sources and microbial inoculants on the quality of compost and to standardize an organic nutrient schedule for bhindi. Two successive experiments; (1) standardisation of agro-techniques for enriching compost and (2) organic nutrient scheduling in okra were conducted to achieve the objectives envisaged. In the first experiment ordinary compost (uninoculated and unamended compost) was compared with various enriched composts prepared using phosphate sources such as rockphosphate or bonemeal at various levels (5%, 10%, 20%) and microbial inoculants (Azotobacter and Phosphobacter). The experiment was laid out in randomised block design with nine treatments and three replications.

In the second experiment an organic nutrient schedule was standardised for bhindi, variety Arka anamika by comparing the effects of five organic nitrogen sources [FYM alone (S_1), FYM + poultry manure (S_2), FYM + neemcake (S_3), FYM + greenleaf (S_4), and FYM + enriched compost (S_5)], three nitrogen levels [50 kg ha^{-1} (N_1), 100 kg ha^{-1} (N_2) and 150 kg ha^{-1} (N_3)] and microbial inoculation (control and Azospirillum) on growth, yield and quality of bhindi. POP recommendation of Kerala Agricultural University (12t FYM + 50:8:25 kg NPK ha^{-1}) was the absolute control used in the study. The experiment was laid out in 5x3x2+1 factorial randomised block design with three replications.

The results of the investigation are summarised below.

Addition of phosphate sources and microbial inoculants reduced the decomposition period and improved the manurial value of enriched composts as compared to the ordinary compost. Lowest C:N ratio and ripening period and highest N, P and K content was recorded by the compost enriched with 20 percent bonemeal and microbial inoculants. Compost treated with 20 percent rockphosphate and bonemeal was comparable with bonemeal with respect to C:N ratio, ripening period and P content. Ordinary compost was the most inferior treatment in the study.

Among nitrogen sources, all organic nitrogen sources (neemcake, green leaf, poultry manure and enriched compost) except FYM (S_1) were superior to POP recommendation. FYM + neemcake (S_3) recorded the maximum germination percentage and number of fruits plant^{-1}, where as plant height, LAI, fruit weight and fruit length were highest for FYM + green leaf (S_4), which also took the minimum days for 50 percent flowering. All the growth and yield parameters were highest at N_3 level of nitrogen and with Azospirillum inoculation.

FYM + neemcake recorded the maximum yield (158 q ha^{-1}) and was on par with FYM + green leaf. Yield was maximum at N_3 level and with Azospirillum inoculation.

Crude protein content and ascorbic acid content were maximum for FYM + poultry manure and FYM + enriched compost respectively. FYM + enriched compost and FYM + neem cake recorded comparable and lowest crude fibre content and highest keeping quality of fruits. Various quality attributes were better under N_3 level of nitrogen and Azospirillum inoculation.

N and P uptake were highest for FYM + neem cake where as K uptake was maximum for FYM + poultry manure, at N_3 level of nitrogen and with Azospirillum inoculation. The available N, P and K status of the soil were highest in FYM + neemcake, FYM + enriched compost and FYM alone treated plots respectively, at N_3 level of nitrogen and Azospirillum inoculation.

FYM + neem cake recorded the maximum profit and was comparable with FYM + green leaf and FYM + poultry manure. B:C ratio was highest in FYM + neem cake. Profit was maximum at N_3 level of nitrogen and Azospirillum inoculation.

In the case of interactions S_3N_3A (FYM + neem cake at N_3 level and with Azospirillum) recorded the highest fruit yield and profit ha^{-1} and was comparable with S_4N_3A (FYM + green leaf at N_3 level with Azospirillum) and S_2N_3A (FYM + poultry manure at N_3 level and Azospirillum)

The present study revealed that the substitution of chemical fertilizers with organic manures such as neem cake, green leaf, poultry manure and enriched compost was beneficial for increasing the yield and improving the quality of bhindi.