INFLUENCE OF ORGANIC MANURES AND *AZOSPIRILLUM* ON GROWTH, YIELD AND QUALITY OF GINGER (*Zingiber officinale* Rosc.)

BY

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ABSTRACT OF THESIS

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DEPARTMENT OF PLANTATION CROPS AND SPICES
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DECLARATION

I hereby declare that the thesis entitled "**Influence of organic manures and *Azospirillum* on growth, yield and quality of ginger (*Zingiber officinale* Rosc.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other University or Society.

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Certified that the thesis entitled "**Influence of organic manures and *Azospirillum* on growth, yield and quality of ginger (*Zingiber officinale* Rosc.)**" is a record of research work done independently by **Mrs.Thulasi Chengat**, 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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CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mrs.Thulasi Chengat**, a candidate for the degree of **Master of Science in Horticulture**, agree that the thesis entitled "**Influence of organic manures and *Azospirillum* on growth, yield and quality of ginger (*Zingiber officinale* Rosc.)**" may be submitted by Mrs.Thulasi Chengat in partial fulfilment of the requirement, for the degree.

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Introduction

INTRODUCTION

Ginger is an important spice crop, known in India from ancient times, used both as spice and medicine. India accounts for about 50 per cent of world's ginger production with an area and production of 55,500 ha and 1,56,180 tonnes respectively (Spice Board, 1994). Due to its increased demand, the soil management practices and mineral nutrition aspects of the crop had received much attention among the scientists.

Ginger is a soil depleting crop and requires heavy supply of nutrients to obtain high yields. A lion share of this requirement is being met through the use of chemical fertilizers. The chemical fertilizers are based on non-renewable energy sources and are very expensive. Besides, they affect the soil health and gradually soil productivity will be depleted. So attention has now been directed to find out an appropriate technology which will help to maintain the soil health and thereby retain soil productivity. We are turning to the use of organic fertilizers and pesticides which are eco friendly. The organic manures and biofertilizers are in no way harmful to nature and organically grown produces are becoming more popular among the health and quality conscious farmers and they fetch a premium price in the market. Studies on nutrient needs of ginger had been so far restricted to the combined use of organic and inorganic fertilizers. The effect of organic manures alone on growth, yield and quality of ginger as well as on chemical properties of soil remains to be studied.

Azospirillum has been reported to be associated with the roots of many annual and perennial crops. It is stated that the organism can fix atmospheric nitrogen upto an extent of 5-30 kg ha^{-1} $year^{-1}$ (Brady, 1988). The inoculation of this micro-organism to the soil can reduce the nitrogen requirement of many crops. Moreover, it is suspected to be synthesising phytohormones which can regulate plant growth (Venkateswarlu and Rao, 1984).

Among the different ginger cultivars recommended in Kerala, Maran is gaining popularity because of its high yield and high recovery of dry ginger (20.4%). The yield of dry ginger per hectare is 3,972.90 kg (Ratnambal et al. 1987). So the present study was carried out using the cultivar Maran with the following objectives.

i) To find out the response of organic manures and *Azospirillum* on growth, yield and quality of ginger.

ii) To understand the pattern of nutrient uptake as influenced by the organic manures and *Azospirillum*.

iii) To find out the impact of organic manures and *Azospirillum* on chemical properties of soil, and on pests and diseases incidence.

Review of Literature

REVIEW OF LITERATURE

The effect of organic manures, neem cake and *Azospirillum* on growth and yield has been well established in many crops. However, information on the above aspects are scanty in ginger. The literature available in annual horticultural crops on the effect of organic manures, neem cake and *Azospirillum* on growth, yield and quality is reviewed and presented in this chapter.

2.1 Influence of farmyard manure

A review of the results on the influence of farmyard manure on growth, yield, quality of the produce and incidence of pests and diseases showed both positive and negative trends.

2.1.1 Vegetables

In chillies, Cerna (1980) reported that NPK application in the absence of farmyard manure retarded the formation of vegetative organs and subsequently reproductive organs. Shinde and Yadava (1982) reported that in capsicums, farmyard manure at 50-200 q ha^{-1} adversely affected the uptake of soil applied phorate.

Sivasangaranathan and Pain (1982) reported that the dry pod yield of chillies did not differ significantly with different levels of farmyard manure viz. 12.5 t ha^{-1}, 20 t ha^{-1} and no farmyard manure. However, the organic matter content was always greater in farmyard manure applied plots than in unmanured plots. No evidence could be obtained for any short term improvement in water and nutrient uptake. The size, weight, dry matter and ascorbic acid content of fruits of capsicum were improved by the application of farmyard manure. The average yield with farmyard manure was 40.55 t ha^{-1} while it was 29.6 t ha^{-1} without farmyard manure and the proportions of first grade fruits were 60.40 per cent and 55.25 per cent respectively (Valsikova and Ivanic, 1982). Nair and Peter (1990) studied the effects of organic and inorganic fertilizers and their combinations on yield and storage life of chilly var. KAU cluster. Farmyard manure was applied alone (30 t ha^{-1}) or in combination (20 or 15 t ha^{-1}) with fertilizer mixtures containing N (75, 125, 175 kg ha^{-1}), P_2O_5 (50 kg ha^{-1}) and K (25 kg ha^{-1}). The combination of organic and inorganic fertilizer increased the yield of chilly compared to separate application of either organic or inorganic fertilizers alone. However storage life was adversely affected by higher levels of farmyard manure and fertilizers. Lazic *et al.* (1992) obtained better yield and fruits with excellent quality in capsicums with the use of organic fertilizers alone.

In brinjal, increase in number of fruits per plant and total yield was reported by Asiegbu and Uzo (1984) with increase in the quantity of farmyard manure applied upto 10 t ha^{-1}.

In tomato, Linardakis and Tsikalis (1984) could get highest total and marketable yields due to the application of farmyard manure whereas N and K fertilizers recorded a lesser effect. Fayad and Sweelam (1989) reported that application of triple superphosphate together with cattle manure reduced the populations of *Meloidogyne javanica* and increased nutrient uptake and growth of tomato plants.

Knaflewski (1984) reported that fertilization with farmyard manure (20-60 t ha^{-1}) increased the yield of cucumber, but had no effect on the quality. According to Joseph (1985) the lowest rotting percentage of oriental pickling melon was registered when the crop was supplied with farmyard manure and wood ash. Organic form of manures showed a definite advantage over inorganic fertilizers in respect of the storability of oriental pickling melon.

Baumann (1980) recorded an average yield increase of 11.2 per cent in cabbage by the use of organic manures. However, Knaflewski (1984) did not find increase in yield due to organic manures in cabbage. Subhan (1988) compared the relative efficiency of farmyard manure (15, 20, 25 or 30 t ha^{-1}) on cabbage and found that farmyard manure brought about an increase in plant diameter at 60 days after planting while the number of leaves and the number of days to crop maturity had reduced. Application of 25 or 30 t ha^{-1} of farmyard manure gave the largest cabbages and highest yield.

In spinach and leek, Baumann (1980) observed increased yield as a result of organic manure application. However, Knaflewski (1984) observed no significant influence on the yield of celery and leek due to the application of farmyard manure. According to Pechova and Prugar (1986) farmyard manure applied to lettuce crop @ 60 t ha^{-1} positively affected nitrification process in the soil and NO_3 accumulation in the crop and these effects were influenced by the quality of farmyard manure and the growing conditions in different cropping years. Babalota (1988) observed a reduction in the populations of *Meloidogyne incognita, Pratylenchus* sp. and *Helicotylenchus* sp. as a result of incorporation of farmyard manure (10 or 20 kg ha^{-1}) in celosia.

Lazic *et al.* (1992) reported that carrots and beet roots when grown with organic fertilizers alone produced better yield, with excellent quality fruits. They contained high dry matter, ß-carotene (for carrots) and betanin (for beet roots).

2.1.2 Spices and aromatic plants

In ginger, Paulose (1973) recorded that 25-30 t ha^{-1} of well decomposed cattle manure or compost were applied at the time of planting in India. It has been found that for raising an economic crop of ginger on virgin soils in Wynad, application of nitrogenous and phosphatic manures is not necessary provided the crop is supplied with about 25 t of cattle manure and about 17 tonnes of green leaf mulch per ha (Council of Scientific and Industrial Research, 1984). According to Pruthi (1993) application of quick rotting green leaves at the rate of 25 t ha^{-1} resulted in 200 per cent increase in yield over unmulched area.

In turmeric, Saha (1988) recorded the highest yield (11826 kg) of fresh rhizomes from plots supplied with 50 t ha^{-1} of farmyard manure. The effect of different levels of farmyard manure on growth and yield of turmeric was reported by Balashanmugam *et al.* (1989). Farmyard manure was applied at the rate of 12.5, 15.0, 17.5, 20.0, 22.5 or 25.0 t ha^{-1}. The fresh rhizome yield increased with increasing farmyard manure dose from, 25,550 kg ha^{-1} at the lowest rate to 32,370 kg/ha at the highest. The yield with no farmyard manure was 23,625 kg ha^{-1}.

Pareek *et al.* (1984) obtained marked increase in the number of tillers, and oil yields in palmarosa as a result of farmyard manure application. It also improved soil texture. However, Rao *et al.* (1989) reported that application of farmyard manure to palmarosa had no significant effect on total herb and oil yield. Maheswari *et al.* (1991) reported that application of farmyard manure 15 t ha^{-1} gave 8 per cent higher biomass and 10 per cent higher oil yield in palmarosa, but geraniol content did not respond to farmyard manure.

2.2 Influence of poultry manure

The effect of application of poultry manure on growth and yield of crop plants has been well documented.

2.2.1 Vegetables

Homma *et al.* (1979) observed a reduction in the incidence of Fusarium wilt in tomato by the addition of poultry manure to the soil. Application of poultry manure (10 t ha^{-1}) appreciably increased the yield and fruit size and reduced blossom end rot in tomato (Prezotti *et al.*, 1987). Babalota (1989) observed that poultry manure application resulted in better growth, vigour and yield in tomato. It also increased the phosphorus content of soil. Control of root knot nematode, *Meloidogyne* sp. in tomato with poultry manure has been reported by Chindo and Khan (1986 & 1990). The experiment revealed that poultry manure has tremendous potential for the control of root knot nematode. Besides, at the rates of 4 t ha^{-1} and 8 t ha^{-1}, it brought about significant increase in growth and yield of tomato.

Abusaleha and Shanmugavelu (1988) reported that the number of fruits, length and girth of fruits and total yield in okra, were significantly influenced by the application of poultry manure in combination with ammonium sulphate. In okra, application of poultry manure resulted in an increase in growth and yield and reduction in nematode populations in soil as observed by Khan (1994).

Lima *et al.* (1984) obtained significant increase in yield of cucumber due to the application of chicken manure (10 t ha^{-1}). Incidence of Fusarium wilt was significantly reduced by 30-35 per cent, when the plants were supplied with chicken manure in cucumber (Seo, 1986). Segovia (1988) observed that when melon seedlings were supplied with cattle manure or poultry manure the highest yield (43 t ha^{-1}) was obtained with 80 t cattle manure per hectare followed by 10 t poultry manure per hectare. No symptom of toxicity was noticed.

Filho and Hamerschmidt (1985) reported the economics of carrot production by the use of poultry manure without pesticides. Cost of cultivation was 60 per cent lower than with normal culture. Higher levels of macro and micronutrients in compost and chicken manure significantly increased the growth of bean plants, enhanced nodulation and increased uptake of N, P, Ca, Mg, S, Mn and Cu (Browaldh, 1992).

2.2.2 Spices

Bureau of Agricultural Economics, Canberra (1971) recorded that in Queensland, poultry manure is applied at the rate of 10 t ha^{-1} or poultry manure + sawdust at the rate of 20 t ha^{-1} for getting higher yield in ginger. Stirling (1989) obtained the highest yield and significant reduction in root knot nematode when soil was amended with poultry manure and sawdust.

2.3 Influence of neem cake

Neem cake is widely used in agriculture both as organic manure and as pesticide.

Singh *et al.* (1980) observed that out of the different oil cakes applied to tomato for controlling root knot nematode, neem cake was found to be the most effective, which also enhanced the plant growth. Bhattacharya and Goswami (1989) reported that there was significant increase in plant growth and reduction in root galling as well as root and soil populations of *Meloidogyne incognita* when neem cake was applied to tomato.

Sadanandan and Iyer (1986) observed a reduction in rhizome rot and increase in yield of ginger when neem cake was applied at the rate of 2 t ha^{-1}. The application of neem cake added organic carbon and potash to the soil. Thakore *et al.* (1987) also observed significant reduction in rhizome rot of ginger due to application of neem cake.

2.4 Influence of *Azospirillum*

Azospirillum is an aerobic nitrogen fixing bacterium, which occurs as associative symbiont in the rhizosphere of many crop plants in tropics. Its use as bio-fertilizer was reported by many workers. It was found to influence the growth and yield of many crop plants like rice, wheat, maize, sweet potato, pulses, oilseeds, fruit crops, vegetables and some plantation crops (Venkateswarlu and Rao, 1983; Hill *et al.*, 1983; Govindan and Purushothaman, 1985).

The occurrence of *Azospirillum* in Indian soils was first reported by Kumari *et al.* (1976). Tarrand *et al.* (1978) reported that all wild types of *Azospirillum* strains fix atmospheric nitrogen efficiently either as free living bacteria or in association with plants. Venkateswarlu and Rao (1984) reported that the improvement in plant growth obtained by inoculation with *Azospirillum* strains was not related to their N fixing capacity but to phytohormone synthesis. Brady (1988) reported that relatively high values of nitrogen fixation had been observed in association with certain tropical grasses, but rate of 5-30 kg ha^{-1} $year^{-1}$ were thought to be more typical.

2.4.1 Vegetables

Hadas and Okon (1987) reported that there was significant increase in root length (35%) and in top and root dry matter (90 and 50% respectively) and total leaf area (90%) in 18 day-old tomato plants as a result of *Azospirillum* inoculation compared to non inoculated control. Bashan *et al.* (1989) stated that in tomato and brinjal, singificant earlier maturation and increase in yield were detected as a result of *Azospirillum* inoculation. In *Capsicum*, Paramaguru and Natarajan (1993) observed an increase in the height, number of branches and number of lateral roots by treating the seeds with *Azospirillum* and also due to soil application.

Parvathan *et al.* (1989) found a significant increase in the plant height, shoot girth, root length and root volume in okra var. Pusa Savani with soil application of *Azospirillum* at the rate of 2-5 kg ha^{-1}. Subbiah (1991) observed a substantial increase in yield and N use efficiency in okra cv. Co-2 which received 50 per cent recommended rate of N plus soil applied *Azospirillum* (2 kg/ha).

Thamburaj (1991) reported that application of *Azospirillum* increased plant height, number of leaves, shoot girth, dry and fresh weight of foliage, weight of bulbs, bulb yield and net profit per acre in onion. In addition, it improved the uptake of plant nutrients like N, P, K, Ca, Mg, Zn, Cu and Mn and helped to save

25 per cent of the fertilizers to be added. It also improved the production of growth substances like gibberellic acid, indole acetic acid and dihydrozeatin which had a positive influence on the physiological activity of the plants. Bulb quality was also superior.

In seed treatment studies with *Azospirillum*, Sundarvelu and Muthukrishnan (1993) observed that when radish cv. Japanese white was treated with *Azospirillum*, the seedling vigour was increased with production of longer leaves, longer and thicker roots and higher root weight than control.

2.4.2 Spices

Bopiah and Khader (1989) obtained increase in plant height, shoot and root dry weight in black pepper by dipping the rooted cuttings in culture solution of *Azospirillum*.

Patil and Konde (1988) observed an increase in dry ginger weight, N content and saving of 33 per cent fertilizer nitrogen due to *Azospirillum* inoculation. In ginger cv. Mahi, Konde *et al.* (1990) inoculated finger sets with *Azotobacter chroococcum* and/or *Azospirillum brasilense*. They recorded increased rhizome yield from plants given 25 or 50 kg N ha^{-1} and NPK uptake of inoculated plants was compared with uninoculated control. Ginger yields were the highest (20.34 t ha^{-1}) when plants were given 50 kg N ha^{-1} and inoculated with both the species of bacteria. Uninoculated plants with no nitrogen fertilizer, yielded 10.25 t ha^{-1} and uninoculated plants with 75 kg N ha^{-1}, yielded 17.44 t ha^{-1}.

2.4.3 Banana

Banana plants inoculated with *Azospirillum* showed increase in height and girth of pseudostem, leaf production and leaf area as reported by Jeeva *et al.* (1988). It also resulted in increased bunch weight.

Materials and Methods

MATERIALS AND METHODS

The present study was conducted at the College of Horticulture, Vellanikkara, Thrissur during 1994-95. Experiments were designed to gather information on the response of organic manures and *Azospirillum* on growth, yield and quality of ginger, incidence of pests and diseases and chemical properties of soil, the economics of organic farming and to suggest suitable recommendations under organic farming system in ginger.

3.1 Field experiment

3.1.1 Site, climate and soil

The area was located at 10° 32' N latitude, 76° 10' E longitude at an altitude of 22.25 m above mean sea level.

The details of the meteorological observations for the period of the experiment are presented in Appendix-I.

The soil of the experimental plot was deep, laterite with clay loam texture. The chemical characteristics of soil are presented in Appendix-II.

3.1.2 Design and layout

Design	- Randomised Block Design
No. of treatments	- 8
No. of replications	- 4
Gross plot size	- 4 m x 1 m
Net plot size	- 3.5 m x 0.5 m

Total experimental area	- 220 m^2 inclusive of channels
Width of channel	- 0.5 m
Spacing	- 25 cm x 25 cm
Seed rhizome size	- 15 g
No. of plants/plot	- 64
Variety	- Maran

3.1.3 Treatments

The manurial and fertilizer doses were fixed based on Package of Practices Recommendations (Kerala Agricultural University, 1993). The treatments were fixed on the basis of N content of 30 t of farmyard manure and quantity of organic manure required to supply 75 kg N/ha, in the form of farmyard manure, poultry manure or neem cake. Total nitrogen supplied by each treatment was 195 kg/ha.

There were 8 treatments as listed below:

T_1 Farmyard manure 30 t ha^{-1} + 75 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1} as per Package of Practices Recommendations - control

T_2 Farmyard manure 48 t ha^{-1}
30 t ha^{-1} as basal + 9 t ha^{-1} each at 60 and 120 DAP

T_3 Farmyard manure 30 t ha^{-1} + poultry manure 5 t ha^{-1} Farmyard manure 30 t ha^{-1} as basal + 2.5 t ha^{-1} poultry manure each at 60 and 120 DAP

T_4 Poultry manure 13 t ha^{-1}

8 t ha^{-1} as basal + 2.5 t ha^{-1} each at 60 and 120 DAP

T_5 Farmyard manure 30 t ha^{-1} + neem cake 1.5 t ha^{-1} Farmyard manure 30 t ha^{-1} as basal + neem cake 0.75 t ha^{-1} each at 60 and 120 DAP

T_6 Neem cake 3.8 t ha^{-1}

2.3 t ha^{-1} as basal and 0.75 t ha^{-1} each at 60 and 120 DAP

T_7 Farmyard manure 30 t ha^{-1} + *Azospirillum* 2.5 kg ha^{-1} (in 3 splits, as basal, 60 and 120 DAP) + 37.5 kg N ha^{-1} (50% saving of N) + 50 kg P_2O_5 ha^{-1} + 50 kg K_2O ha^{-1})

T_8 Farmyard manure 30 t ha^{-1} + *Azospirillum* 2.5 kg ha^{-1} (in 3 splits, as basal, 60 and 120 DAP) + 56 kg N ha^{-1} (25% saving of N) + 50 kg P_2O_5 ha^{-1} + 50 kg K_2O ha^{-1}

Acid tolerant strain of *Azospirillum* was procured from College of Agriculture, Vellayani.

3.1.4 Field culture

The land was thoroughly ploughed and beds of size 4 m x 1 m x 0.25 m were formed at a spacing of 50 cm between the beds.

The seed rhizomes of the cv. Maran, were cut into bits of 15 g weight having two healthy viable buds. They were planted at a spacing of 25 cm x 25 cm on 23rd May 1994.

All the cultural operations except manuring were followed as per the Package of Practices Recommendations (Kerala Agricultural University, 1993). The crop was harvested on 11th January, 1995.

3.1.5 Sampling technique

Random sampling technique was adopted to select the sample plants for recording various biometric and quality characters. Ten plants were selected at random within the net area of each plot as observation plants.

3.1.6 Observations

3.1.6.1 Pre-harvest observations

Pre-harvest observations were started 90 days after planting and were continued upto 180 days at monthly intervals.

3.1.6.1.1 Plant height

The height of the selected plants were measured from the base of the main pseudostem to the tip of the top most leaf, the average was worked out and expressed in centimeter.

3.1.6.1.2 No. of tillers/clump

The number of tillers was determined by counting the number of aerial shoots arising around a single plant and the average of the ten sample plants was worked out for each plot.

3.1.6.1.3 No. of leaves/tiller

The tillers were randomly selected from each of the sample plant and number of leaves of those tillers was recorded separately. The number of leaves/tiller was then determined by calculating their mean.

3.1.6.1.4 Leaf area

Leaf area of each sample plant was measured in a leaf area meter and expressed in square centimeter (cm^2).

3.1.6.1.5 Fresh weight of rhizome/clump

The sample plants were uprooted and the rhizomes were separated and weighed immediately and the weight was expressed in gram.

3.1.6.1.6 Dry weight of rhizome/clump

After taking the fresh weight, the rhizomes were oven dried to constant weight at 70°C and the weight was recorded in gram.

3.1.6.1.7 Dry weight of roots

Roots were separated from the uprooted sample plants, dried in a hot air oven and weight recorded when constant weight was attained.

3.1.6.1.8 Dry weight of pseudostem

Pseudostems of the uprooted sample plants were separated and oven dried to constant weight and weighed.

3.1.6.1.9 Dry weight of leaves

From the uprooted sample plants leaves were separated, dried in a hot air oven to constant weight and weight was recorded in gram.

3.2.6.1.10 Total dry matter

Total dry matter per plant was recorded by adding dry weight of leaves, pseudostems and roots. TDM/plant was multiplied by total number of plants/ha to get dry matter production per ha.

3.1.6.2 Post harvest observations

3.1.6.2.1 Green ginger yield

After harvest, the rhizomes were washed free of soil, the roots were removed and the fresh weight of rhizomes per plant was recorded from 10 randomly selected plants from each plot. Yield per hectare was calculated by multiplying the individual plant yield with total number of plants/ha.

3.1.6.2.2 Dry ginger production

The rhizomes of individual plants used for recording fresh weight were dried to get a constant weight and the dry ginger yield per plant was recorded, from which the dry ginger yield per hectare was worked out as in the case of green ginger yield.

3.1.6.2.3 Driage

Percentage driage was calculated from fresh weight and loss in weight on drying. It is the ratio of dry weight and fresh weight of rhizomes expressed as percentage.

3.1.6.3 Quality analysis

Fresh rhizome samples collected for quality analysis were chopped and dried. The dried samples were mechanically ground.

3.1.6.3.1 Oleoresin content

The oleoresin percentage was determined as per the Official Analytical Methods of the American Spice Trade Association (1960) using the Soxhlet method of extraction with acetone as the solvent.

3.1.6.3.2 Volatile oil content

Water distillation using Clevenger apparatus as per Official Analytical Methods of the American Spice Trade Association (1960) was employed for the extraction of essential oil and it was expressed as percentage.

3.2 Plant analysis

3.2.1 Content of N, P and K in different plant parts

Samples were taken for plant analysis starting from 90 DAP upto harvest at monthly intervals. The different plant parts like leaf, pseudostem, root and rhizome were analysed for N, P and K content.

The dried plant samples were analysed for total N by microkjeldahl digestion and distillation method (Jackson, 1973). For the estimation of total phosphorus and potassium, the plant material was first digested with triacid (HNO_3 : H_2SO_4 : $HClO_4$ in the ratio 10:1:4) mixture. Phosphorus content of the digested plant material was determined by Vanado molybdo phosphoric yellow colour method

(Jackson, 1973) and potassium content of the triacid extract was estimated using flame photometer (Jackson, 1973).

3.2.2 Uptake of N, P and K

Nitrogen, phosphorus and potassium uptake by the different plant parts at different stages were computed from the content of each of these elements and the dry matter production. It was expressed as kg ha^{-1}.

3.2.3 Nitrate reductase activity of leaves

Nitrate reductase activity of fresh leaves was estimated by the method suggested by Klepper *et al.* (1971).

3.3 Soil analysis

Soil samples were analysed for available nitrogen by alkaline permanganate method (Jackson, 1973). Available P was determined in Bray I extract using ascorbic acid blue colour method (Watanabe and Olson, 1965) and available K was estimated in neutral normal ammonium acetate extract using flame photometer (Jackson, 1973). Soil pH was directly read in a pH meter with 1:2.5 soil water suspension (Jackson, 1973).

3.4 Pest and disease incidence

The number of plants infected by soft rot disease, in all the plots were noted. The mean value in each treatment was worked out and expressed as percentage.

The percentage of infestation by rhizome maggot was also worked out in a similar manner.

3.5 Economics of cultivation

Cost of cultivation for each treatment was worked out based on the wage rate and cost of inputs during 1994-95. Total returns per treatment per hectare was worked out by multiplying the total yield with cost of green ginger @ Rs.5/kg. Using these data, percentage increase in yield and profit over the control, net profit and benefit cost ratio were worked out.

3.6 Statistical analysis

The experimental data were subjected to analysis of variance for randomised block design following the method of Panse and Sukhatme (1985).

Results

RESULTS

Studies were conducted at the College of Horticulture, Vellanikkara during 1994-95 to collect information on the influence of different sources of organic manures and *Azospirillum* on growth, yield and quality of ginger cv. Maran, incidence of pests and diseases and chemical properties of soil. The observations recorded were statistically analysed and the results obtained are described in the following pages.

4.1 Pre-harvest observations

4.1.1 Height of plant

The data on height of plants at monthly intervals from 90 DAP to 180 DAP are furnished in Table 1. The data on plant height at 90, 120 and 150 DAP indicated that the different treatments could not significantly influence plant height. However, at 90 DAP and 120 DAP, combined application of farmyard manure and poultry manure resulted in maximum plant height of 58.70 cm and 55.78 cm respectively. The plants were comparatively shorter in plots treated with neem cake alone.

At 150 DAP, application of *Azospirillum* + 75 per cent N produced taller plants of 51.30 cm. The plots supplied with neem cake alone produced the shortest plants of 46.27 cm.

Plant height was significantly influenced by the treatments at 180 DAP. The highest plant height of 62.60 cm was recorded by the plants supplied with *Azospirillum* + 75 per cent N. The plants supplied with poultry manure, farmyard

Table 1. Effect of different sources of organic manures and *Azospirillum* on plant height

Treatments	Height (cm)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	53.91	50.63	49.37	50.43
Farmyard manure	55.87	55.60	49.30	51.50
Farmyard manure + poultry manure	58.70	55.78	49.00	53.40
Poultry manure	56.77	55.67	49.97	54.83
Farmyard manure + neem cake	56.60	54.53	50.77	48.37
Neem cake	50.50	49.13	46.27	47.57
Azospirillum + 50% N	55.83	52.22	48.23	46.23
Azospirillum + 75% N	55.24	54.60	51.30	62.60
SEm±				1.59
CD (0.05)	NS	NS	NS	4.82

NS - Nonsignificant; DAP - Days after planting

manure + poultry manure, farmyard manure alone and control were on par. The treatment *Azospirillum* + 50 per cent N recorded the lowest plant height of 46.23 cm.

The results, in general, suggested that though not significant, incorporation of poultry manure and *Azospirillum* + 75 per cent N increased the plant height during all stages of growth. Application of neem cake reduced the plant height. The effect of other forms of organic manures were inconsistent during the different stages.

4.1.2 Number of tillers/plant

The data presented in Table 2 showed that number of tillers were not significantly influenced by the treatments, except at 120 DAP. At 120 DAP, the treatment *Azospirillum* + 75 per cent N recorded the highest number of tillers of the 12.67, which was on par with all other treatments except application of neem cake only (9.47). The data also indicated that at all stages, application of *Azospirillum* + 50 per cent N produced plants with more number of tillers consistently except at 120 DAP and 180 DAP. The application of neem cake alone resulted in lower number of tillers at 90 DAP and 120 DAP. At 150 DAP, the lowest number of tillers (10.33) was produced by the plants in plots treated with farmyard manure + neem cake and at 180 DAP the lowest value of 8.90 was recorded by plants which received poultry manure alone.

The results indicated that the tiller production was not significantly influenced by the different forms of organic manures and *Azospirillum*.

Table 2. Effect of different sources of organic manures and *Azospirillum* on number of tillers

Treatments	Number tillers/plant			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	9.63	11.63	12.93	11.73
Farmyard manure	9.53	11.43	12.37	10.42
Farmyard manure + poultry manure	9.37	12.40	12.57	10.00
Poultry manure	8.80	12.63	12.33	8.90
Farmyard manure + neem cake	9.63	11.13	10.33	11.07
Neem cake	8.60	9.47	11.53	9.22
Azospirillum + 50% N	10.03	12.17	13.63	10.80
Azospirillum + 75% N	8.77	12.67	12.57	12.07
SEm±		0.61		
CD (0.05)	NS	1.85	NS	NS

NS - Nonsignificant; DAP - Days after planting

4.1.3 Number of leaves/tiller

With respect to the leaf number/tiller, the results were not significant at all stages of plant growth (Table 3). However, the leaf number was the highest in plots treated with poultry manure, farmyard manure + poultry manure, farmyard manure + neem cake and *Azospirillum* + 75 per cent N and farmyard manure + neem cake at 90, 120, 150 and 180 DAP respectively. The results indicated that the leaf number was not significantly influenced by the different types of organic manures and *Azospirillum*.

4.1.4 Total leaf area per plant

The data on the influence of treatments on leaf are per plant are presented in Table 4. The treatments did not show any significant difference at 90 and 120 DAP. The application of farmyard manure alone and poultry manure alone produced higher leaf area per plant at 90 and 120 DAP with 3652.43 cm^2 and 5267.28 cm^2 respectively. On the other hand, the leaf area was the minimum in treatments involving farmyard manure and neem cake at both stages with 1802.44 cm^2 and 2187.55 cm^2 respectively. At 150 DAP the leaf area per plant was the maximum in plants which received poultry manure alone (2729.41 cm^2) which was on par with all the treatments except the control, farmyard manure + poultry manure and farmyard manure + neem cake. The lowest value of 1339.66 cm^2 was recorded by the treatment farmyard manure + neem cake.

At 180 DAP, the application of farmyard manure registered the highest leaf area/plant of 4315.63 cm^2 which was significantly superior to the control,

Table 3. Effect of different sources of organic manures and *Azospirillum* on number of leaves

Treatments	Number of leaves/tiller			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	11.47	15.83	14.57	13.84
Farmyard manure	11.53	14.92	14.13	13.89
Farmyard manure + poultry manure	11.50	16.38	14.33	12.30
Poultry manure	12.37	14.51	14.57	13.30
Farmyard manure + neem cake	11.97	15.52	15.03	15.37
Neem cake	10.67	15.95	14.80	13.90
Azospirillum + 50% N	11.13	15.13	14.32	12.13
Azospirillum + 75% N	11.20	14.44	15.03	11.10
SEm±				
CD (0.05)	NS	NS	NS	NS

NS - Nonsignificant; DAP - Days after planting

Table 4. Effect of different sources of organic manures and *Azospirillum* on leaf area

Treatments	Total leaf area per plant (cm²)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	2510.45	2577.69	1788.30	1900.83
Farmyard manure	3652.43	3835.49	2554.71	4315.63
Farmyard manure + poultry manure	2501.33	3668.83	1830.35	2183.89
Poultry manure	2052.53	5267.28	2729.41	3374.17
Farmyard manure + neem cake	1802.44	2137.55	1339.66	1735.38
Neem cake	2152.48	3057.62	2372.29	4104.72
Azospirillum + 50% N	2831.95	2887.73	2471.35	4128.42
Azospirillum + 75% N	2965.02	2311.74	2053.25	3524.71
SEm±			284.60	381.00
CD (0.05)	NS	NS	863.20	1155.70

NS - Nonsignificant; DAP - Days after planting

farmyard manure + poultry manure and farmyard manure + neem cake. The treatment was on par with all the other treatments.

The results suggested the superiority of farmyard manure and poultry manure in increasing the leaf area at 150 and 180 DAP, respectively.

4.1.5 Dry weight of leaves

The treatment showed significant difference with respect to the dry weight of leaves at all stages of growth except 150 DAP as shown in Table 5. The maximum leaf dry weight of 17.13 g was recorded by the plots receiving farmyard manure alone which was on par with the other treatments except, poultry manure alone and neem cake alone which registered lower values.

At 120 DAP, application of poultry manure was significantly superior and it recorded a dry weight of 22.07 g which was on par with farmyard manure, neem cake, *Azospirillum* + 75 per cent N and control. The lowest dry weight of 12.55 g was recorded by farmyard manure + poultry manure. At 150 DAP, though the results were not significant, poultry manure recorded the highest value of 28.5 g followed by farmyard manure with 25.75 g. The lowest value of 19.17 g was recorded by *Azospirillum* + 75 per cent N.

At 180 DAP, the plants receiving farmyard manure alone produced significantly higher leaf dry weight of 31.08 g, but was on par with all other treatments except control which produced the minimum leaf dry weight of 20.68 g.

4.1.6 Dry weight of pseudostem/plant

The data pertaining to the dry weight of pseudostem per plant, presented

Table 5. Effect of different sources of organic manures and *Azospirillum* on dry weight of leaves

Treatments	Dry weight of leaves/plant (g)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	17.08	18.06	22.33	20.68
Farmyard manure	17.13	20.39	25.75	31.08
Farmyard manure + poultry manure	14.51	12.55	22.83	25.02
Poultry manure neem cake	10.15	22.07	28.50	26.88
Neem cake	10.70	16.78	20.33	25.80
Azospirillum + 50% N	16.50	13.42	22.42	28.67
Azospirillum + 75% N	13.85	17.97	19.17	27.19
SEm±	1.66	1.98		2.45
CD (0.05)	5.67	6.01	NS	7.43

NS - Nonsignificant; DAP - Days after planting

in Table 6 revealed that application of organic manures and *Azospirillum* did not influence this character significantly at 90, 120 and 150 DAP. Plots supplied with *Azospirillum* + 75 per cent N produced plants with maximum dry weight of 23.30 g, which was on par with the plots receiving farmyard manure at 180 DAP. At 90 DAP, the treatment farmyard manure alone recorded the highest value of 11.87 g.

The application of poultry manure alone resulted in production of plants with maximum dry weight of pseudostem of 16.35 g and 18.17 g respectively at 120 and 150 DAP.

The results in general suggest that when chemical fertilizers were substituted with different forms of organic manures, slightly favourable effect was produced by farmyard manure at 90 DAP, poultry manure at 120 and 150 DAP and *Azospirillum* + 75 per cent N at 180 DAP.

4.1.7 Dry weight of roots

Significant influence of treatments on root dry weight was evident only at 120 DAP (Table 7). The highest value of dry weight of roots of 1.93 g was recorded by the treatment *Azospirillum* + 50 per cent N which was on par with control plots which recorded 1.65 g. The lowest value of 0.65 g was registered by the plants which received a combination of farmyard manure and poultry manure. This was on par with all the other treatments.

The treatments farmyard manure + poultry manure, poultry manure alone and *Azospirillum* + 50 per cent N showed higher values at 90 DAP, 150 DAP and 180 DAP respectively.

Table 6. Effect of different sources of organic manures and *Azospirillum* on dry weight of pseudostem

Treatments	Dry weight of pseudostem per plant (g)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	10.98	11.86	16.67	14.10
Farmyard manure	11.87	13.56	17.83	21.79
Farmyard manure + poultry manure	9.80	14.04	18.08	20.67
Poultry manure	7.80	16.35	18.17	17.08
Farmyard manure + neem cake	9.65	11.82	17.33	16.91
Neem cake	6.77	9.65	15.25	15.75
Azospirillum + 50% N	11.48	11.25	17.83	20.50
Azospirillum + 75% N	9.87	10.21	16.00	23.30
SEm±				1.62
CD (0.05)	NS	NS	NS	4.91

NS - Nonsignificant; DAP - Days after planting

4.1.8 Fresh weight of rhizomes

The results presented in Table 8 revealed that with respect to the fresh weight of rhizomes, the treatments differed significantly at 150 DAP and 180 DAP.

At 90 DAP, the treatment farmyard manure alone, produced the maximum fresh weight of 252.08 g, though not significant. The lowest value of 127.75 g was recorded by the treatment poultry manure alone.

At 120 DAP, plots which received poultry manure alone gave maximum value of 351.67 g. The minimum weight of 194.31 g was recorded by plants which received neem cake alone.

The application of poultry manure alone recorded the highest weight of fresh rhizomes of 316.17 g at 150 DAP, which was on par with combined application of farmyard manure + neem cake (259.73 g), farmyard manure + poultry manure (243.63 g) and *Azospirillum* + 50 per cent N (221.78 g). The lowest value of 146.38 g was registered by the control plots which was on par with the other treatments. At 180 DAP, the application of farmyard manure alone was found to be significantly superior (508.81 g) and it was on par with combination of farmyard manure and poultry manure (410.75 g). The lowest value was given by control plots with 195.75 g which was on par with the other treatments except *Azospirillum* + 75 per cent N.

The results in general suggested that substituting chemical fertilizers with organic manures in the form of farmyard manure and farmyard manure + neem cake produced higher mean values of fresh weight of rhizomes when compared to

Table 8. Effect of different sources of organic manures and *Azospirillum* on fresh weight of rhizomes

Treatments	Fresh weight of rhizomes per plant (g)			
	90 DAP	120 DAP	150 DAP	180DAP
Control	216.33	228.63	146.38	195.75
Farmyard manure	252.08	313.08	179.57	508.81
Farmyard manure + poultry manure	200.17	247.24	243.63	410.75
Poultry manure	127.75	351.67	316.17	285.28
Farmyard manure + neem cake	231.75	263.02	259.73	241.29
Neem cake	158.33	194.31	159.33	241.29
Azospirillum + 50% N	108.33	259.17	221.78	304.03
Azospirillum + 75% N	182.50	207.44	158.64	337.96
SEm±			31.43	38.04
CD (0.05)	NS	NS	95.33	115.38

NS - Nonsignificant; DAP - Days after planting

control at all stages of growth. Incorporation of farmyard manure alone registered higher mean values at 90 and 180 DAP. The data also revealed that application of poultry manure alone produced higher values for fresh weight at 120 and 150 DAP. Incorporation of neem cake reduced the fresh weight at 90 DAP and 120 DAP. The control plots recorded only lower fresh weight at 150 and 180 DAP.

4.1.9 Dry weight of rhizomes/plant

The results furnished in Table 9 showed that the treatments did not significantly influence the dry weight of rhizomes at 90 DAP and 120 DAP. At 90 DAP, the plots treated with farmyard manure alone gave the higher values of 18.39 g and at 120 DAP, application of poultry manure showed the highest mean value of 19.77 g.

At 150 DAP and 180 DAP the treatments differed significantly. The plots supplied with poultry manure alone produced plants with the highest dry weight of rhizomes of 59.39 g and it was on par with a combination of farmyard manure and neem cake (49.83 g). The lowest value of 27.23 g was recorded by the plants supplied with neem cake alone. At 180 DAP, the highest value of 101.02 g was recorded by the plants which received farmyard manure alone which was on par with the combined application of farmyard manure and poultry manure, with a dry weight of 83.24 g. The control plots recorded the lowest dry weight of 40.34 g.

The results revealed that among the different sources of organic manures studied, farmyard manure significantly influenced the dry weight of rhizomes/plant at 180 DAP. The use of poultry manure alone recorded the highest dry weight of rhizomes at 150 DAP.

Table 9. Effect of different sources of organic manures and *Azospirillum* on dry weight of rhizomes

Treatments	Dry weight of rhizomes per plant (g)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	14.90	15.36	39.52	40.34
Farmyard manure	18.39	18.70	29.32	101.02
Farmyard manure + poultry manure	15.19	15.60	41.28	83.24
Poultry manure	9.17	19.77	59.39	63.50
Farmyard manure + neem cake	14.31	14.91	49.83	41.57
Neem cake	11.40	12.05	27.23	48.33
Azospirillum + 50% N	13.70	14.33	35.28	59.36
Azospirillum + 75% N	15.63	13.95	30.49	72.08
SEm±			5.44	7.68
CD (0.05)	NS	NS	16.50	23.29

NS - Nonsignificant; DAP - Days after planting

4.1.10 Total dry matter

The data furnished in Table 10 showed that the effect of treatments on dry matter production of ginger was significant at all stages except at 120 DAP. Application of farmyard manure alone resulted in the highest dry matter production at 90, 120 and 180 DAP. At 90 DAP, the treatment recorded the highest dry matter of 4633.14 kg ha^{-1}. This was on par with all other treatments except poultry manure alone and neem cake alone which recorded lower values (2810.41 kg ha^{-1} and 2848.27 kg ha^{-1} respectively). The data on total dry matter production indicated that farmyard manure had positive influence at 90, 120 and 180 DAP, while poultry manure recorded the best results at 150 DAP. Though the control plants produced comparatively better dry matter during the initial stages of growth, the total dry matter at the final stage was significantly lower.

At 150 DAP, maximum dry matter was recorded by plants supplied with poultry manure alone with a mean of 10,013.48 kg ha^{-1}, which was on par with the plants which received farmyard manure + poultry manure and farmyard manure + neem cake. Dry matter production was the minimum in plants which received neem cake alone (5915.93 kg ha^{-1}). Dry matter production in the control plots was the minimum at 180 DAP which was on par with the plots supplied with either neem cake alone or in combination with farmyard manure. At this stage, the application of farmyard manure was found to be significantly superior to all other treatments which recorded a value of 14419.47 kg ha^{-1} except farmyard manure + poultry manure (12184.98 kg ha^{-1}) and *Azospirillum* + 75 per cent N (11732.56 kg ha^{-1}).

Table 10. Effect of different sources of organic manures and *Azospirillum* on total dry matter production

Treatments	Total dry matter (kg ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	4200.26	4369.69	7366.59	7151.00
Farmyard manure	4633.14	4994.33	6179.69	14419.47
Farmyard manure + poultry manure	3974.05	3988.64	7771.85	12184.98
Poultry manure	2810.41	4551.21	10013.48	10134.50
Farmyard manure + neem cake	3628.99	4002.29	8362.61	7172.97
Neem cake	2848.27	3771.42	5915.93	9560.75
Azospirillum + 50% N	4102.21	3809.90	7139.76	10263.27
Azospirillum + 75% N	3823.24	4005.70	6150.52	11732.56
SEm±	386.24		740.99	960.99
CD (0.05)	1171.48	NS	2247.44	2914.71

NS - Nonsignificant; DAP - Days after planting

4.2 Post-harvest observations

4.2.1 Yield of green ginger

The data given in Table 11 showed that the treatments did not differ significantly with respect to yield of green ginger. But the highest yield of 24,048.48 kg ha^{-1} was registered by farmyard manure alone followed by farmyard manure + poultry manure with a green ginger yield of 20,805.82 kg ha^{-1}. The lowest value of 16,864.97 kg ha^{-1} was registered by treatment involving neem cake alone.

4.2.2 Yield of dry ginger

The yield of dry ginger also was not significantly affected by the treatments. The results indicated the same trend as in the case of green ginger yield. The maximum yield was recorded in the treatment farmyard manure alone with a mean value of 4607.80 kg ha^{-1}. An yield increase of 29.23 per cent was recorded by this treatment when compared to the control. The application of neem cake alone resulted in the lowest yield of 3008.42 kg ha^{-1}.

4.2.3 Dry ginger recovery

Dry ginger recovery (%) was not significantly influenced by the treatments as shown in Table 11. Dry ginger recovery was the maximum (20.85%) when *Azospirillum* was applied along with 75 per cent N and the minimum driage of 17.83 per cent was recorded by farmyard manure + poultry manure and neem cake alone.

Table 11. Effect of different sources of organic manures and *Azospirillum* on yield and quality of rhizomes at harvest

Treatments	Green ginger (kg ha^{-1})	Dry ginger (kg ha^{-1})	Increase in yield over control		Driage (%)	Oil (%)	Oleoresin (%)
			(kg)	(%)			
Control	19890.42	3565.51	-	-	18.00	1.14	10.90
Farmyard manure	24048.48	4607.80	+1042.00	29.23	19.27	1.39	9.67
Farmyard manure + poultry manure	20805.82	3727.47	+161.96	4.54	17.83	1.29	10.03
Poultry manure	18773.33	3397.80	-167.71	-4.70	18.10	1.11	8.23
Farmyard manure + neem cake	19812.85	3587.40	+21.89	0.61	18.10	1.35	8.67
Neem cake	16864.97	3008.42	-557.09	-15.62	17.83	1.22	10.03
Azospirillum + 50% N	20448.97	3994.11	+428.60	12.02	19.54	1.41	8.37
Azospirillum + 75% N	20014.55	4169.62	+604.11	16.94	20.85	1.51	9.63
SEm ±						0.04	
CD(0.05)	NS	NS			NS	0.13	NS

NS - Nonsignificant; DAP - Days after planting

4.2.4 Essential oil

It was evident from Table 11 that the treatments differed significantly with regard to the volatile oil percentage in ginger. Inoculation of the biofertilizer + 75 per cent N recorded highest value of 1.51 per cent. It was on par with *Azospirillum* + 50 per cent N (1.41%) and farmyard manure alone (1.39%). The content of volatile oil was the minimum in plots treated with poultry manure (1.11%).

4.2.5 Oleoresin

The influence of different treatments on oleoresin content of ginger (Table 11) was not significant. The highest value of 10.90 per cent was recorded by the control, followed by farmyard manure + poultry manure and neem cake alone. Oleoresin content was the minimum in the rhizome of the plants grown in plots with poultry manure alone (8.23%).

The data on yield and quality parameters showed that the treatments did not affect the yield and quality except the essential oil content. Though the yield differences were not significant, both green and dry ginger yields were higher than the control in plots supplied with farmyard manure, farmyard manure + poultry manure, *Azospirillum* + 50 per cent N and *Azospirillum* + 75 per cent N. Though dry recovery was not statistically significant, *Azospirillum* + 75 per cent N recorded the highest value of 20.85 per cent. In respect of oil, this treatment was significantly superior to all other treatments except farmyard manure and *Azospirillum* + 50 per cent N.

4.3. Nitrogen content in different plant parts

4.3.1 Leaf

With respect to nitrogen content in the leaf the treatments exhibited significant difference at 90 DAP only (Table 12). The treatment farmyard manure + neem cake and *Azospirillum* + 75 per cent N showed the maximum N content of 2.36 per cent and it was on par with farmyard manure alone and poultry manure alone. Nitrogen content in the leaves was the lowest in the treatment neem cake alone (2.01%).

At 120 DAP, the treatment *Azospirillum* + 50 per cent N recorded the highest N per cent (2.62%) and it was the lowest in farmyard manure + poultry manure. At 150 and 180 DAP control plants showed the highest N per cent, the lowest value being recorded by the leaf samples collected from plots receiving poultry manure and farmyard manure respectively.

4.3.2 Pseudostem

As far as N content in pseudostem is concerned there was no significant difference among the treatments at 90, 120 and 180 DAP (Table 13).

At 150 DAP, *Azospirillum* + 50 per cent N recorded the highest value of 1.58 per cent though it was on par with *Azospirillum* + 75 per cent N and neem cake alone. N content was the lowest (1.12%) in the farmyard manure applied plots.

Though not significant, plots supplied with poultry manure alone recorded the highest values at 90 and 120 DAP (1.51% and 1.37% respectively). The lowest nitrogen content was exhibited by the treatment neem cake alone, with

Table 12. Effect of different sources of organic manures and *Azospirillum* on nitrogen content in leaf

Treatments	Nitrogen content in leaf (%)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	2.10	2.24	2.10	2.47
Farmyard manure	2.33	2.00	1.75	1.63
Farmyard manure + poultry manure	2.17	1.99	1.75	1.79
Poultry manure	2.24	2.41	1.68	1.80
Farmyard manure + neem cake	2.36	2.40	2.35	1.91
Neem cake	2.01	2.45	2.08	1.84
Azospirillum + 50% N	2.19	2.62	1.87	1.77
Azospirillum + 75% N	2.36	2.21	1.75	1.75
SEm±	0.044			
CD (0.05)	0.14	NS	NS	NS

NS - Nonsignificant; DAP - Days after planting

Table 13. Effect of different sources of organic manures and *Azospirillum* on nitrogen content in the pseudostem

Treatments	Nitrogen content in pseudostem (%)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	1.28	1.21	1.28	1.24
Farmyard manure	1.38	1.33	1.12	1.00
Farmyard manure + poultry manure	1.44	1.37	1.20	0.93
Poultry manure	1.51	1.37	1.14	0.83
Farmyard manure + neem cake	1.44	1.31	1.26	1.19
Neem cake	1.21	1.19	1.42	1.03
Azospirillum + 50% N	1.45	1.28	1.58	1.31
Azospirillum + 75% N	1.35	1.33	1.45	1.12
SEm±			0.09	
CD (0.05)	NS	NS	0.29	NS

NS - Nonsignificant; DAP - Days after planting

values, 1.21 per cent and 1.19 per cent respectively. The treatments poultry manure and *Azospirillum* + 50 per cent N recorded the lowest (0.83%) and highest (1.31%) values respectively at 180 DAP.

4.3.3 Roots

The treatments influenced the N content in roots at all stages except at 150 DAP (Table 14). The control plots recorded the maximum value of 1.03 per cent and it was on par with poultry manure and neem cake. At 120 DAP, the treatments poultry manure and *Azospirillum* + 75 per cent N gave the highest N content with a value of 1.77 per cent and it was on par with farmyard manure + neem cake (1.70%). Percentage of N at 150 DAP was the maximum in the treatment farmyard manure alone and it was the lowest in farmyard manure + poultry manure and *Azospirillum* + 75 per cent N.

At 180 DAP, application of *Azospirillum* + 75 per cent N resulted in significantly superior N content of 1.56 per cent. Nitrogen percentage was the lowest in the treatment neem cake alone (0.89%).

4.3.4 Rhizome

Nitrogen percentage in the rhizome was significantly influenced by the different treatments, at all stages (Table 15). Nitrogen content in the rhizomes was the highest (1.82%) in the treatment farmyard manure + neem cake at 90 DAP and the lowest value was registered by *Azospirillum* + 50 per cent N. At 120 DAP, the treatment *Azospirillum* + 75 per cent N recorded the maximum nitrogen content of 1.54 per cent in the rhizomes and it was on par with all the other treatments except poultry manure (0.84%) and farmyard manure + poultry manure (1.19%).

Table 14. Effect of different sources of organic manures and *Azospirillum* on nitrogen content in the root

Treatments	Nitrogen content in root (%)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	1.03	1.11	1.19	1.10
Farmyard manure	0.84	1.05	1.21	1.21
Farmyard manure + poultry manure	0.89	0.91	0.98	1.12
Poultry manure	0.98	1.77	1.09	1.05
Farmyard manure + neem cake	0.84	1.70	1.09	1.12
Neem cake	0.98	0.93	1.00	0.89
Azospirillum + 50% N	0.91	1.54	1.04	1.14
Azospirillum + 75% N	0.86	1.77	0.98	1.56
SEm ±	0.04	0.04	-	0.07
CD (0.05)	0.12	0.12	NS	0.20

NS - Nonsignificant; DAP - Days after planting

Table 15. Effect of different sources of organic manures and *Azospirillum* on nitrogen content in rhizome

Treatments	Nitrogen content in rhizome (%)				
	90 DAP	120 DAP	150 DAP	180 DAP	Harvest
Control	1.54	1.44	1.79	1.89	2.06
Farmyard manure	1.42	1.23	1.66	1.49	1.42
Farmyard manure + poultry manure	1.52	1.19	1.35	1.17	1.99
Poultry manure	1.54	0.84	1.61	1.19	1.26
Farmyard manure + neem cake	1.82	1.26	1.39	1.35	1.35
Neem cake	1.54	1.28	1.75	1.38	1.31
Azospirillum + 50% N	1.40	1.49	1.35	1.52	1.35
Azospirillum + 75% N	1.56	1.54	1.38	1.54	1.33
SEm±	0.06	0.12	0.11	0.10	0.19
CD (0.05)	0.18	0.37	0.35	0.32	0.60

NS - Nonsignificant; DAP - Days after planting

The control plants recorded the maximum nitrogen content in rhizomes and it was on par with all other treatments except farmyard manure + poultry manure, farmyard manure + neem cake and *Azospirillum* + N, which registered lower values at 150 DAP.

At 180 DAP and harvest also the control plants contained maximum nitrogen. Lower values were recorded by the treatments farmyard manure + poultry manure and poultry manure alone at 180 DAP.

4.4 Uptake of nitrogen by different plant parts

4.4.1 Uptake of nitrogen by leaves

Nitrogen uptake by leaves at monthly intervals from 90 DAP to 180 DAP is furnished in Table 16. The results revealed significant variation at 120 DAP. The uptake of nitrogen by leaves was the highest in the treatment poultry manure alone (48.69 kg ha^{-1}) which was on par with the control (38.01 kg ha^{-1}), neem cake (38.08 kg ha^{-1}), farmyard manure (37.60 kg ha^{-1}) and *Azospirillum* + 75 per cent N (36.62 kg ha^{-1}). The uptake was the lowest in plots which received farmyard manure + poultry manure with a value of 22.96 kg ha^{-1}. The application of farmyard manure resulted in higher nitrogen uptake by leaves at 90 DAP and 180 DAP, whereas the combined application of farmyard manure and neem cake recorded the highest value at 150 DAP. Application of farmyard manure + poultry manure resulted in the lowest uptake of nitrogen at 180 DAP.

4.4.2 Uptake of nitrogen by pseudostem

With respect to uptake of N by pseudostem (Table 17) significant

Table 16. Effect of different sources of organic manures and *Azospirillum* on uptake of nitrogen by leaves

Treatments	Uptake of nitrogen by leaves (kg ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	34.57	38.01	43.57	45.85
Farmyard manure	37.56	37.60	41.95	47.48
Farmyard manure + poultry manure	29.80	22.96	37.20	41.45
Poultry manure	20.96	48.69	44.53	44.95
Farmyard manure + neem cake	29.24	33.59	46.73	46.06
Neem cake	20.72	38.08	38.79	44.85
Azospirillum + 50% N	33.56	29.46	39.01	47.27
Azospirillum + 75% N	31.13	36.62	31.50	44.16
SEm±		4.54		
CD (0.05)	NS	13.77	NS	NS

NS - Nonsignificant; DAP - Days after planting

Table 17. Effect of different sources of organic manures and *Azospirillum* on uptake of nitrogen by pseudostem

Treatments	Uptake of nitrogen by pseudostem (kg ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	13.58	13.64	19.83	16.48
Farmyard manure	15.48	17.40	18.48	20.45
Farmyard manure + poultry manure	13.55	18.78	20.19	18.10
Poultry manure	10.82	20.14	18.80	12.56
Farmyard manure + neem cake	13.06	14.48	20.31	18.56
Neem cake	7.59	11.89	19.78	15.24
Azospirillum + 50% N	15.38	13.32	26.44	25.33
Azospirillum + 75% N	11.82	12.55	21.45	24.28
SEm±		2.20	1.49	
CC (0.05)	NS	6.67	4.52	NS

NS - Nonsignificant; DAP - Days after planting

variation among the treatments was noticed at 120 DAP and 150 DAP only. Maximum N uptake of 20.14 kg ha^{-1} was observed in plots which received poultry mannure alone at 120 DAP. The treatment was on par with farmyard manure + poultry manure (18.78 kg ha^{-1}), farmyard manure (17.40 kg ha^{-1}), farmyard manure + neem cake (14.48 kg ha^{-1}) and the control (13.64 kg ha^{-1}). The lowest uptake of 11.89 kg ha^{-1} was registered by the plants supplied with neem cake alone. Inoculation of *Azospirillum* + 50 per cent N significantly increased the uptake of nitrogen to 26.44 kg ha^{-1} at 150 DAP. All the other treatments were on par. At 180 DAP, the application of *Azospirillum* + 50 per cent N showed the highest uptake of 25.33 kg ha^{-1} which was closely followed by *Azospirillum* + 75 per cent N (24.28 kg ha^{-1}).

4.4.3 Uptake of nitrogen by roots

The data on N uptake by ginger roots given in Table 18 revealed that N uptake was not significantly influenced by the different treatments at all stages of growth except at 120 DAP. At 90 DAP, the maximum uptake value of 2.85 kg ha^{-1} was recorded by the treatment poultry manure alone. Nitrogen uptake was the minimum in plots supplied with *Azospirillum* + 75 per cent N (1.35 kg ha^{-1}). The treatments were significantly different at 120 DAP, and *Azospirillum* + 50 per cent N recorded the highest uptake (2.72 kg ha^{-1}). This was on par with the control (1.71 kg ha^{-1}) and farmyard manure + neem cake (1.69 kg ha^{-1}). The lowest uptake (0.57 kg ha^{-1}) was obtained with farmyard manure + poultry manure. At 150 DAP and 180 DAP the treatments, farmyard manure alone and *Azospirillum* + 50 per cent N recorded maximum uptake values of 1.6 kg ha^{-1} and 2.35 kg ha^{-1}, respectively. The uptake was the lowest in plots treated with *Azospirillum* + 75 per cent N at 150 DAP (0.37 kg ha^{-1}) and neem cake alone at 180 DAP (1.31 kg ha^{-1}).

Table 18. Effect of different sources of organic manures and *Azospirillum* on uptake of nitrogen by roots

Treatments	Uptake of nitrogen by roots (kg ha^{-1})							
	90 DAP		120 DAP		150 DAP		180 DAP	
	O	T	O	T	O	T	O	T
Control	2.65	1.43	1.71	1.29	0.75	0.85	1.73	1.29
Farmyard manure	1.86	1.35	0.96	0.98	1.60	1.23	1.87	1.36
Farmyard manure + poultry manure	2.66	1.56	0.57	0.74	1.13	1.04	1.86	1.34
Poultry manure	2.85	1.66	1.18	1.07	1.52	1.19	1.36	1.15
Farmyard manure + neem cake	1.78	1.28	1.69	1.28	1.19	1.09	1.78	1.33
Neem cake	1.59	1.25	0.91	0.95	0.67	0.81	1.31	1.13
Azospirillum+50% N	2.17	1.42	2.72	1.64	1.30	1.14	2.35	1.50
Azospirillum+75% N	1.35	1.15	1.48	1.21	0.37	0.57	2.07	1.40
SEm±				0.13				
CD (0.05)		NS		0.39		NS		NS

NS - Nonsignificant; DAP - Days after planting
O - Original value
T - Transformed value

4.4.4 Uptake of nitrogen by rhizomes

The data furnished in Table 19 indicated that the results were not significant at 90 DAP and 120 DAP. However, higher mean values were recorded by plants supplied with farmyard manure, with 24.31 kg ha^{-1} and 21.48 kg ha^{-1} at 90 DAP and 120 DAP respectively. At 150 DAP, the application of poultry manure alone recorded the highest uptake of N of 87.56 kg ha^{-1}, which was on par with the control (66.07 kg ha^{-1}) and farmyard manure + neem cake (62.35 kg ha^{-1}). Nitrogen uptake by rhizomes was the lowest (39.92 kg ha^{-1}) with *Azospirillum* + 75 per cent N. Incorporation of farmyard manure alone brought about significantly higher N uptake of 140.78 kg ha^{-1} by ginger rhizomes at 180 DAP, which was on par with plants receiving *Azospirillum* + 75 per cent N with an uptake of 106.44 kg ha^{-1}. Uptake was the lowest when the plots were supplied with a combination of farmyard manure + neem cake (52.32 kg ha^{-1}).

The results of N uptake by rhizomes, at harvest showed the highest value of 74.18 kg ha^{-1} by the control which was on par with farmyard manure + poultry manure (72.38 kg ha^{-1}) and farmyard manure alone (63.09 kg ha^{-1}).

4.4.5 Total uptake of nitrogen

The data given in Table 20 showed that total uptake of N by ginger plants was not significant at all stages of plant growth except at 180 DAP. At this stage, N uptake was significantly higher in plots supplied with farmyard manure alone (210.37 kg ha^{-1}) which was on par with *Azospirillum* + 75 per cent N (176.95 kg ha^{-1}). The lowest value of 118.72 kg ha^{-1} was recorded by farmyard manure + neem cake.

Table 19. Effect of different sources of organic manures and *Azospirillum* on uptake of nitrogen by rhizomes

Treatments	Uptake of nitrogen by rhizomes (kg ha^{-1})				
	90 DAP	120 DAP	150 DAP	180 DAP	Harvest
Control	21.63	20.24	66.07	72.60	74.18
Farmyard manure	24.31	21.48	45.79	140.78	63.09
Farmyard manure + poultry manure	21.72	17.27	53.70	89.19	72.38
Poultry manure	13.64	13.65	87.56	70.47	42.71
Farmyard manure + neem cake	24.10	17.49	62.35	52.32	48.30
Neem cake	16.35	13.91	42.72	60.88	39.78
Azospirillum + 50% N	17.85	20.05	46.13	82.21	53.75
Azospirillum + 75% N	22.43	20.51	39.92	106.44	55.70
SEm±			9.58	12.46	
CD (0.05)	NS	NS	29.05	37.79	NS

NS - Nonsignificant; DAP - Days after planting

Table 20. Effect of different sources of organic manures and *Azospirillum* on total uptake of nitrogen

Treatments	Total N uptake (kg ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	71.84	73.60	130.22	136.65
Farmyard manure	79.20	77.43	107.81	210.37
Farmyard manure + poultry manure	67.73	59.58	112.22	150.60
Poultry manure	48.26	83.65	152.41	129.34
Farmyard manure + neem cake	68.18	67.25	130.58	118.72
Neem cake	46.24	64.78	101.96	122.28
Azospirillum + 50% N	68.99	65.55	112.88	157.37
Azospirillum + 75% N	66.74	71.18	93.24	176.95
SEm±				15.77
CD (0.05)	NS	NS	NS	47.83

NS - Nonsignificant; DAP - Days after planting

4.5 Phosphorus content in different plant parts

4.5.1 Leaf

The treatments varied significantly with respect to P content in leaf (Table 21). The treatment poultry manure registered the maximum value of 0.71 per cent and it was on par with all other treatments except control, *Azospirillum* + 50 per cent N and neem cake alone. The treatment farmyard manure recorded the maximum P content of 0.65 per cent and 0.56 per cent respectively at 120 DAP and 180 DAP. At 150 DAP, P content was the maximum in the treatment farmyard manure + poultry manure and it was on par with all other treatments except neem cake and *Azospirillum* + 75 per cent N. At all stages plants in plots supplied with neem cake alone showed lower values.

4.5.2 Pseudostem

The results indicated that P percentage in the pseudostem varied considerably with the different treatments at 90, 150 and 180 DAP (Table 22).

At 90 DAP, plots supplied with poultry manure alone registered the highest P content in the pseudostem (0.97%) and it was on par with the treatments farmyard manure alone, farmyard manure + neem cake and *Azospirillum* + 75 per cent N. Phosphorus content was the lowest (0.68%) in the treatment neem cake alone.

At 120 DAP, P percentage in the plants in farmyard manure supplied plots was the highest (0.97%). The lowest value (0.69%) was recorded by farmyard manure + neem cake.

Table 21. Effect of different sources of organic manures and *Azospirillum* on phosphorus content in leaf

Treatments	Phosphorus content in leaf (%)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	0.64	0.53	0.50	0.45
Farmyard manure	0.69	0.65	0.49	0.56
Farmyard manure + poultry manure	0.70	0.59	0.51	0.41
Poultry manure	0.71	0.58	0.45	0.50
Farmyard manure + neem cake	0.65	0.61	0.45	0.43
Neem cake	0.50	0.53	0.43	0.45
Azospirillum + 50% N	0.55	0.57	0.50	0.49
Azospirillum + 75% N	0.66	0.64	0.42	0.51
SEm±	0.02	0.02	0.02	0.015
CD (0.05)	0.06	0.06	0.06	0.05

NS - Nonsignificant; DAP - Days after planting

Table 22. Effect of different sources of organic manures and *Azospirillum* on phosphorus content in pseudostem

Treatments	Phosphorus content in pseudostem (%)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	0.75	0.87	0.90	0.44
Farmyard manure	0.96	0.97	1.06	0.34
Farmyard manure + poultry manure	0.79	0.92	1.06	0.26
Poultry manure	0.97	0.80	0.70	0.35
Farmyard manure + neem cake	0.91	0.69	0.81	0.56
Neem cake	0.68	0.95	0.62	0.72
Azospirillum + 50% N	0.73	0.82	0.68	0.86
Azospirillum + 75% N	0.90	0.91	0.81	0.72
SEm±	0.058	-	0.064	0.028
CD (0.05)	0.15	NS	0.19	0.085

NS - Nonsignificant; DAP - Days after planting

At 150 DAP, plots incorporated with farmyard manure alone and farmyard manure + poultry manure recorded the highest content of P in the pseudostem. Plots supplied with neem cake alone showed the lowest (0.62%) percentage of P. At 180 DAP, application of *Azospirillum* + 50 per cent N resulted in significantly higher value (0.86%) for P percentage in the pseudostem. It was the lowest (0.26%) in the treatment farmyard manure + poultry manure.

4.5.3 Roots

The results on the content of P in roots of ginger indicated that significant difference existed among the treatments at 120, 150 and 180 DAP (Table 23).

At 90 DAP, higher values were exhibited by both farmyard manure + neem cake and neem cake alone. The lowest value was recorded by the treatment farmyard manure alone. However, at 120 DAP, this treatment registered the highest value for P content in roots (0.49%) and it was on par with poultry manure alone (0.48%) and the treatment neem cake alone recorded the lowest value (0.29%). Phosphorus content of plants receiving farmyard manure + neem cake and *Azospirillum* + 50 per cent N was the highest (0.53%) at 150 DAP and it was on par with farmyard manure alone, poultry manure alone and neem cake alone. Control plots and plots receiving farmyard manure + poultry manure recorded the lowest P content of 0.39 per cent in roots at this stage.

At 180 DAP, application of *Azospirillum* + 50 per cent N and farmyard manure + neem cake brought about a significant increase in root P content with a

Table 23. Effect of different sources of organic manures and *Azospirillum* on phosphorus content in root

Treatments	Phosphorus content in root (%)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	0.44	0.38	0.39	0.46
Farmyard manure	0.31	0.49	0.49	0.52
Farmyard manure + poultry manure	0.45	0.38	0.39	0.43
Poultry manure	0.38	0.48	0.48	0.23
Farmyard manure + neem cake	0.48	0.39	0.53	0.54
Neem cake	0.48	0.29	0.48	0.46
Azospirillum + 50% N	0.44	0.42	0.53	0.54
Azospirillum + 75% N	0.44	0.35	0.46	0.48
SEm±		0.008	0.0156	0.014
CD (0.05)	NS	0.024	0.047	0.042

NS - Nonsignificant; DAP - Days after planting

value of 0.54 per cent. Percentage of P was the lowest in plants supplied with poultry manure alone.

4.5.4 Rhizome

The influence of different treatments on P content in the rhizomes was found to be significant from 90 DAP to harvest except at 150 DAP (Table 24). The plots receiving farmyard manure + neem cake recorded the highest value of 0.54 per cent though it was on par with *Azospirillum* + 75 per cent N, control and farmyard manure alone at 90 DAP. Phosphorus content of the rhizomes was the lowest (0.37%) in the treatment poultry manure alone.

At 120 DAP, the treatment poultry manure showed significant improvement in the content of P in the rhizomes, with a value of 0.58 per cent. The control plants recorded the lowest value (0.23%). Though not significant, the highest (0.59%) and lowest (0.45%) values were recorded by the treatments farmyard manure + poultry manure and farmyard manure + neem cake respectively at 150 DAP. At 180 DAP, the treatment farmyard manure + neem cake recorded the highest percentage of P in the rhizomes (0.50%) which was on par with the other treatments except farmyard manure + poultry manure, control and poultry manure. Phosphorus content in the rhizomes at harvest was found to be the highest in plots receiving poultry manure alone and it was on par with those plots receiving a combination of farmyard manure and neem cake.

4.6 Uptake of phosphorus by different plant parts

4.6.1 Uptake of phosphorus by leaves

The results on the uptake of P by the leaves at 90, 120, 150 and 180 DAP are presented in Table 25.

Table 24. Effect of different sources of organic manures and *Azospirillum* on phosphorus content in rhizome

Treatments	Phosphorus content in rhizome (%)				
	90 DAP	120 DAP	150 DAP	180 DAP	Harvest
Control	0.52	0.23	0.49	0.42	0.57
Farmyard manure	0.49	0.42	0.50	0.49	0.57
Farmyard manure + poultry manure	0.48	0.43	0.59	0.35	0.59
Poultry manure	0.37	0.58	0.54	0.44	0.70
Farmyard manure + neem cake	0.54	0.50	0.45	0.50	0.65
Neem cake	0.44	0.37	0.49	0.49	0.50
Azospirillum + 50% N	0.40	0.49	0.56	0.48	0.45
Azospirillum + 75% N	0.52	0.42	0.48	0.47	0.48
SEm±	0.017	0.019	-	0.015	0.02
CD (0.05)	0.05	0.058	NS	0.045	0.06

NS - Nonsignificant; DAP - Days after planting

Table 25. Effect of different sources of organic manures and *Azospirillum* on uptake of phosphorus by leaves

Treatments	Uptake of phosphorus by leaves (kg ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	9.86	8.79	10.49	8.62
Farmyard manure	10.90	12.21	11.67	16.09
Farmyard manure + poultry manure	9.28	6.71	10.94	9.50
Poultry manure	8.03	12.02	11.90	12.53
Farmyard manure + neem cake	7.43	8.39	9.01	10.38
Neem cake	5.01	8.26	8.18	10.85
Azospirillum + 50% N	8.67	7.18	10.45	13.02
Azospirillum + 75% N	8.47	10.64	7.58	12.88
SEm±	0.96	1.07		1.01
CD (0.05)	2.91	3.25	NS	3.06

NS - Nonsignificant; DAP - Days after planting

The data at 90 DAP revealed that incorporation of farmyard manure registered significantly higher mean uptake of P of 10.90 kg ha^{-1}, which was on par with the control (9.86 kg ha^{-1}), farmyard manure + poultry manure (9.28 kg ha^{-1}), *Azospirillum* + 50 per cent N (8.67 kg ha^{-1}), *Azospirillum* + 75 per cent N (8.47 kg ha^{-1}) and poultry manure (8.03 kg ha^{-1}). The least effective treatment was neem cake which recorded a mean uptake of 5.01 kg ha^{-1}. The results at 120 DAP showed that farmyard manure recorded significantly higher uptake of 12.21 kg ha^{-1}. This treatment was on par with poultry manure (12.02 kg ha^{-1}), *Azospirillum* + 75 per cent N (10.64 kg ha^{-1}). The lowest uptake of 6.71 kg ha^{-1} at this stage was recorded by farmyard manure + poultry manure. The data for 150 DAP showed no significant difference among the treatments. However, the highest mean uptake value of 11.90 kg ha^{-1} was recorded by poultry manure. The least effective treatment was *Azospirillum* + 75 per cent N which recorded the lowest value of 7.58 kg ha^{-1}. At 180 DAP, farmyard manure was significantly superior to all other treatments which recorded the highest uptake of 16.09 kg ha^{-1}. The control plants registered the lowest uptake of P by the leaves of 8.62 kg ha^{-1} at this stage.

The results obtained on the P uptake by leaves, the general suggested the superiority of farmyard manure at all stages of growth except at 150 DAP, when poultry manure recorded the highest uptake.

4.6.2 Uptake of phosphorus by pseudostem

The results obtained during the studies on uptake of P by pseudostem at monthly intervals starting from 90 DAP to 180 DAP are furnished in Table 26. The data at 90 DAP and 120 DAP did not reveal significant difference among the

Table 26. Effect of different sources of organic manure and *Azospirillum* on uptake of phosphorus by pseudostem

Treatments	Uptake of phosphorus by pseudostem (ka ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	8.01	9.40	13.95	5.72
Farmyard manure	10.63	12.26	17.63	6.81
Farmyard manure + poultry manure	7.22	12.40	18.10	4.94
Poultry manure	6.98	11.90	12.11	5.60
Farmyard manure + neem cake	8.30	7.60	13.33	8.74
Neem cake	4.33	9.55	8.81	10.54
Azospirillum + 50% N	7.72	8.51	11.30	16.21
Azospirillum + 75% N	7.81	8.22	12.16	15.51
SEm±			1.49	0.70
CD (0.05)	NS	NS	4.52	2.12

NS - Nonsignificant; DAP - Days after planting

treatments. However, the highest mean value was recorded by farmyard manure at 90 DAP (10.63 kg ha^{-1}). At 120 DAP, the highest mean uptake of P was recorded by farmyard manure + poultry manure (12.40 kg ha^{-1}) which was closely followed by farmyard manure alone (12.26 kg ha^{-1}). The same trend was followed during 150 DAP also, when these treatments recorded higher mean values. Farmyard manure + poultry manure recorded significantly higher P uptake of 18.10 kg ha^{-1} which was on par with farmyard manure (17.63 kg ha^{-1}). Farmyard manure was on par with the control and farmyard manure + neem cake. The lowest uptake was recorded by the plants receiving neem cake alone.

At 180 DAP, the treatments were significantly different and *Azospirillum* + 50 per cent N recorded the highest uptake of 16.21 kg ha^{-1} which was on par with *Azospirillum* + 75 per cent N. These treatments excelled others. The lowest uptake of 4.94 kg ha^{-1} was recorded by farmyard manure + poultry manure, at this stage.

The results in general suggested that though farmyard manure helped to increase P uptake at 90 DAP, it was overtaken by farmyard manure + poultry manure during 120 DAP and 150 DAP. These treatments were later superseded by *Azospirillum* treatments, which significantly increased P uptake by the pseudostem at 180 DAP.

4.6.3 Uptake of phosphorus by roots

The treatments differed with respect to uptake of P by roots only at 120 DAP (Table 27). The data indicated that at 90 DAP, the application of farmyard manure + poultry manure recorded the highest mean uptake of 1.32 kg ha^{-1}. The lowest value was registered by the treatment neam cake alone (0.6 kg ha^{-1}).

Table 27. Effect of different sources of organic manures and *Azospirillum* on uptake of phosphorus by roots

Treatments	Uptake of phosphorus by roots (kg ha^{-1})							
	90 DAP		120 DAP		150 DAP		180 DAP	
	O	T	O	T	O	T	O	T
Control	0.89	0.94	0.58	0.75	0.74	0.85	0.25	0.49
Farmyard manure	0.69	0.83	0.45	0.67	0.82	0.90	0.64	0.78
Farmyard manure + poultry manure	1.32	1.11	0.23	0.48	0.79	0.89	0.44	0.65
Poultry manure	1.10	1.04	0.32	0.56	0.31	0.55	0.73	0.81
Farmyard manure + neem cake	0.95	0.85	0.40	0.62	0.86	0.93	0.58	0.76
Neem cake	0.60	0.77	0.28	0.53	0.67	0.81	0.33	0.56
Azospirillum+50% N	0.99	0.98	0.74	0.85	1.11	1.05	0.62	0.69
Azospirillum+75% N	0.70	0.83	0.30	0.54	0.64	0.78	0.18	0.40
SEm±				0.072				
CD (0.05)		NS		0.22		NS		NS

NS - Nonsignificant; DAP - Days after planting
O - Original value
T - Transformed value

Phosphorus uptake by roots at 120 DAP was the highest in the treatment, *Azospirillum* + 50 per cent N (0.74 kg ha^{-1}) though it was on par with the control (0.58 kg ha^{-1}) and farmyard manure (0.45 kg ha^{-1}). The lowest uptake (0.23 kg ha^{-1}) was registered by the plants receiving farmyard manure + poultry manure. The treatment *Azospirillum* + 50 per cent N recorded the maximum value (1.11 kg ha^{-1}) for P uptake by roots at 150 DAP, which was closely followed by farmyard manure + neem cake with an uptake of 0.86 kg ha^{-1}. Phosphorus uptake by roots at this stage was the minimum (0.31 kg ha^{-1}) in plots receiving poultry manure alone. The highest uptake of 0.73 kg ha^{-1} was recorded by the treatment poultry manure at 180 DAP, and it was followed by farmyard manure alone. The lowest uptake of 0.18 kg ha^{-1} was recorded by *Azospirillum* + 75 per cent N.

The results on the uptake of phosphorus by roots indicated that at 90 DAP, the treatment farmyard manure + poultry manure performed well. At 120 and 150 DAP the performance of the treatment *Azospirillum* + 50 per cent N was the best. The treatment poultry manure alone, was the best at 180 DAP.

4.6.4 Uptake of phosphorus by rhizome

The results furnished in Table 28 indicated significant difference among the treatments on P uptake by rhizomes at all stages except 120 DAP. The data during 90 DAP showed that the highest value of 8.44 kg ha^{-1} was recorded by farmyard manure, which was on par with the control (8.09 kg ha^{-1}), farmyard manure + poultry manure (6.86 kg ha^{-1}), *Azospirillum* + 75 per cent N (6.24 kg ha^{-1}) and farmyard manure + neem cake (6.14 kg ha^{-1}). The lowest uptake of 3.42 kg ha^{-1} was recorded by poultry manure alone. Though not significant, the highest

Table 28. Effect of different sources of organic manures and *Azospirillum* on uptake of phosphorus by rhizomes

Treatments	Uptake of phosphorus by rhizomes (kg ha^{-1})				
	90 DAP	120 DAP	150 DAP	180 DAP	Harvest
Control	8.09	3.19	18.13	15.45	26.16
Farmyard manure	8.44	5.70	13.75	46.29	20.99
Farmyard manure + poultry manure	6.86	5.95	22.86	27.18	22.10
Poultry manure	3.42	5.19	29.80	25.89	16.33
Farmyard manure + neem cake	6.14	6.80	20.85	19.38	15.83
Neem cake	4.15	3.92	12.65	21.81	11.63
Azospirillum + 50% N	4.25	6.51	18.51	26.66	13.06
Azospirillum + 75% N	6.24	6.42	10.10	31.19	14.01
SEm±	0.77		3.23	2.93	2.15
CD (0.05)	2.34	NS	9.80	8.59	6.52

NS - Nonsignificant; DAP - Days after planting

value of 6.8 kg ha^{-1} of P was recorded by farmyard manure + neem cake and the lowest uptake was registered by the control (3.19 kg ha^{-1}) at 120 DAP.

At 150 DAP, the uptake of P was the highest (29.80 kg ha^{-1}) in poultry manure alone, which was closely followed by farmyard manure + poultry manure (22.86 kg ha^{-1}) and farmyard manure + neem cake (20.85 kg ha^{-1}). These treatments were on par. The lowest value of 10.10 kg ha^{-1} was recorded by *Azospirillum* + 75 per cent N. The results obtained at 180 DAP clearly indicated the superiority of farmyard manure which recorded the highest value of 46.29 kg ha^{-1}. The control plots recorded the lowest uptake of 15.45 kg ha^{-1}. On the other hand, the control plots excelled all other treatments except farmyard manure and farmyard manure + poultry manure at harvest. The control recorded the highest uptake of 26.16 kg ha^{-1} of P at harvest which was on par with farmyard manure + poultry manure (22.10 kg ha^{-1}) and farmyard manure alone (20.99 kg ha^{-1}).

The results on the uptake of P by the rhizomes was not consistent. Farmyard manure recorded its superiority at 90 DAP and 180 DAP. At 120 DAP, farmyard manure + neem cake recorded higher values while at 150 DAP, poultry manure over took all the other treatments. The P uptake at harvest was significantly higher in the control.

4.6.5 Total uptake of phosphorus

The data on the total uptake of P, given in Table 29 showed that the treatment effects were significant during all the stages, except at 120 DAP. The results at 90 DAP showed that incorporation of farmyard manure increased significantly the total P uptake to 30.65 kg ha^{-1}, when compared to all other

Table 29. Effect of different sources of organic manures and *Azospirillum* on total uptake of phosphorus

Treatments	Total uptake of phosphorus (kg ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	26.85	21.95	42.82	28.42
Farmyard manure	30.65	30.62	43.68	65.17
Farmyard manure + poultry manure	24.67	25.29	52.34	39.48
Poultry manure	19.53	29.44	54.53	41.26
Farmyard manure + neem cake	22.81	23.19	43.76	36.64
Neem cake	14.08	22.02	29.98	40.84
Azospirillum + 50% N	16.68	22.94	40.88	53.06
Azospirillum + 75% N	23.23	25.61	30.01	56.06
SEm±	2.24		4.91	3.73
CD (0.05)	6.79	NS	14.89	11.31

NS - Nonsignificant; DAP - Days after planting

treatments except control (26.85 kg ha^{-1}), farmyard manure + poultry manure (24.67 kg ha^{-1}) and *Azospirillum* + 75 per cent N (23.33 kg ha^{-1}). The least effective treatment was found to be neem cake which recorded a mean uptake of 14.08 kg ha^{-1}. The total uptake of P at 120 DAP, though not statistically significant, was the highest in the treatment farmyard manure alone, with a value of 30.62 kg ha^{-1}. At 150 DAP, poultry manure recorded the highest value of 54.53 kg ha^{-1} which was closely followed by farmyard manure + poultry manure (52.34 kg ha^{-1}), farmyard manure + neem cake (43.76 kg ha^{-1}), farmyard manure alone (43.68 kg ha^{-1}), control (42.82 kg ha^{-1}) and *Azospirillum* + 50 per cent N (40.88 kg ha^{-1}). The lowest uptake of 29.98 kg ha^{-1} was recorded by neem cake treated plants. The data for 180 DAP clearly indicated the superiority of farmyard manure in increasing the P uptake to 65.17 kg ha^{-1} when compared to the other treatments except *Azospirillum* + 75 per cent N (56.06 kg P_2O_5 ha^{-1}) which was on par. The lowest mean uptake of P was recorded by the control with a value of 28.42 kg ha^{-1}.

The results on total P uptake showed the superiority of farmyard manure at all stages except 150 DAP, when its effect was on par with poultry manure.

4.7 Potassium content in different plant parts

4.7.1 Leaves

Potassium percentage in the leaves showed considerable variation among the treatments at 120, 150 and 180 DAP (Table 30). At 90 DAP, the treatment *Azospirillum* + 50 per cent N recorded the maximum foliar content of K. At 180 DAP also this treatment was the best and was on par with neem cake alone, poultry manure alone and control.

Table 30. Effect of different sources of organic manures and *Azospirillum* on potassium content in leaf

Treatments	Potassium content in leaf (%)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	2.93	1.74	1.25	2.79
Farmyard manure	2.43	2.00	1.66	1.96
Farmyard manure + poultry manure	2.73	2.13	1.35	1.50
Poultry manure	2.58	2.15	1.47	2.87
Farmyard manure + neem cake	2.58	1.85	1.91	2.03
Neem cake	2.89	1.69	1.86	3.07
Azospirillum + 50% N	2.96	1.53	1.58	3.12
Azospirillum + 75% N	2.88	2.27	1.87	2.03
SEm±		0.12	0.13	0.24
CD (0.05)	NS	0.36	0.39	0.73

NS - Nonsignificant; DAP - Days after planting

At 120 DAP, the treatment *Azospirillum* + 75 per cent N recorded the highest value of 2.27 per cent and it was on par with poultry manure alone, farmyard manure + poultry manure and farmyard manure alone.

At 150 DAP, the treatment farmyard manure + neem cake registered the maximum percentage of potassium (1.91%) in the leaves. This was on par with *Azospirillum* + 75 per cent of N, neem cake alone, farmyard manure alone and *Azospirillum* + 50 per cent N.

4.7.2 Pseudostem

The data revealed that at 90, 150 and 180 DAP the treatments differed significantly (Table 31). With the exception of farmyard manure + neem cake all other treatments were on par at 90 DAP, the maximum value for K percentage being given by the control plants (3.04%).

At 120 DAP, plots receiving neem cake alone and *Azospirillum* + 50 per cent N recorded the highest (3.16%) and lowest (2.54%) values respectively.

The highest percentage of K (2.65%) in the pseudostem was registered by plots receiving *Azospirillum* + 75 per cent N at 150 DAP though on par with *Azospirillum* + 50 per cent N, control, neem cake alone and farmyard manure + neem cake. The lowest K content of 1.03 per cent was registered by pseudostem of plants receiving poultry manure alone.

At 180 DAP the treatment neem cake alone recorded the maximum value (3.07%). This was on par with *Azospirillum* + 75 per cent N, 50 per cent N and

Table 31. Effect of different sources of organic manures and *Azospirillum* on potassium content in pseudostem

Treatments	Potassium content in pseudostem (%)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	3.04	2.85	2.21	2.17
Farmyard manure	2.98	2.80	1.19	1.55
Farmyard manure + poultry manure	2.73	2.60	1.23	1.87
Poultry manure	2.77	2.98	1.03	2.37
Farmyard manure + neem cake	2.03	2.69	2.05	2.55
Neem cake	2.87	3.16	2.18	3.07
Azospirillum + 50% N	2.95	2.54	2.48	2.70
Azospirillum + 75% N	2.96	2.65	2.65	2.72
SEm±	0.25		0.25	0.19
CD (0.05)	0.76	NS	0.76	0.57

NS - Nonsignificant; DAP - Days after planting

farmyard manure + neem cake. Plots receiving farmyard manure alone recorded the lowest value (1.55%).

4.7.3 Root

The plots receiving *Azospirillum* + 75 per cent N produced plants with significantly higher K content (2.93%) in roots than others (Table 32). Root K percentage was the lowest (1.87%) in farmyard manure + poultry manure.

At 120 DAP, plants supplied with *Azospirillum* + 50 per cent and poultry manure contained the maximum percentage of K in roots (2.58%) though it was on par with all the other treatments except farmyard manure alone which produced the lowest value (2.2%).

The treatments farmyard manure + neem cake and farmyard manure alone, produced plants with the highest (2.85%) and the lowest (2.03%) contents of K respectively in the roots at 150 DAP, though not significant.

At 180 DAP, the plots treated with *Azospirillum* + 50 per cent N recorded the maximum value of 3.02 per cent and was on par with farmyard manure alone and *Azospirillum* + 75 per cent N.

4.7.4 Rhizome

The treatments differed significantly with respect to K content in rhizomes at 90, 120 and 180 DAP (Table 33).

Percentage of potassium in the rhizomes at 90 DAP was the maximum (2.8%) in the treatment farmyard manure + neem cake and it was on par with all

Table 32. Effect of different sources of organic manures and *Azospirillum* on potassium content in root

Treatments	Potassium content in root (%)			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	1.97	2.25	2.18	2.42
Farmyard manure	2.46	2.20	2.03	2.87
Farmyard manure + poultry manure	1.87	2.43	2.32	2.28
Poultry manure	2.00	2.58	2.37	1.77
Farmyard manure + neem cake	2.50	2.22	2.85	2.43
Neem cake	2.00	2.27	2.78	2.33
Azospirillum + 50% N	2.62	2.58	2.83	3.02
Azospirillum + 75% N	2.93	2.42	2.40	2.73
SEm±	0.095	0.12		0.19
CD (0.05)	0.288	0.36	NS	0.576

NS - Nonsignificant; DAP - Days after planting

Table 33. Effect of different sources of organic manures and *Azospirillum* on potassium content in rhizome

Treatments	Potassium content in rhizome (%)				
	90 DAP	120 DAP	150 DAP	180 DAP	Harvest
Control	2.28	1.73	1.52	1.37	2.85
Farmyard manure	2.43	1.87	1.95	1.70	2.77
Farmyard manure + poultry manure	2.75	2.20	1.97	2.00	2.73
Poultry manure	2.77	2.73	2.07	1.87	2.72
Farmyard manure + neem cake	2.80	2.63	1.93	2.07	2.80
Neem cake	2.58	2.02	1.73	1.93	2.57
Azospirillum + 50% N	2.18	2.31	2.23	1.85	2.68
Azospirillum + 75% N	2.52	2.12	2.38	1.68	2.52
SEm±	0.18	0.25		0.067	NS
CD (0.05)	0.55	0.758	NS	0.203	

NS - Nonsignificant; DAP - Days after planting

others except *Azospirillum* + 50 per cent N which recorded the lowest value of 2.18 per cent.

At 120 DAP, K content in rhizomes was the maximum (2.73%) in plots receiving poultry manure alone and was on par with the other treatments except the control and farmyard manure alone. The control plants contained the lowest K percentage (1.73%).

At 180 DAP, rhizomes of the plants receiving a combination of farmyard manure and neem cake registered the highest value of K (2.07%) and the treatments farmyard manure + poultry manure, neem cake alone and poultry manure alone were on par. The control plots recorded the lowest value (1.37%).

At harvest, the potassium content in rhizomes did not differ significantly among the treatments.

4.8 Potassium uptake by different plant parts

4.8.1 Uptake of potassium by leaves

The data furnished in Table 34 indicated that at 90 DAP, the control plants recorded the highest potassium uptake of 47.31 kg ha^{-1} which was significantly superior to other treatments except *Azospirillum* + 50 per cent N (44.39 kg ha^{-1}), farmyard manure (38.53 kg ha^{-1}) and farmyard manure + poultry manure (36.22 kg ha^{-1}). The K uptake was the lowest in plants receiving poultry manure alone (24.55 kg ha^{-1}). The data at 120 DAP showed that incorporation of poultry manure alone, significantly increased the K uptake to 44.40 kg ha^{-1}, when compared to the other treatments except farmyard manure (37.81 kg ha^{-1}) and *Azospirillum* + 75 per cent N (37.62 kg ha^{-1}), which were on par. At this stage, the

Table 34. Effect of different sources of organic manures and *Azospirillum* on uptake of potassium by the leaves

Treatments	Uptake of potassium by leaves (kg ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	47.31	28.50	26.13	51.39
Farmyard manure	38.53	37.81	39.59	56.66
Farmyard manure + poultry manure	36.22	25.04	28.96	34.83
Poultry manure	24.55	44.40	38.49	71.63
Farmyard manure + neem cake	28.80	25.96	38.28	48.45
Neem cake	28.82	26.44	35.65	73.90
Azospirillum + 50% N	44.39	19.04	33.17	82.26
Azospirillum + 75% N	35.68	37.62	33.59	51.11
SEm±	3.81	3.34		5.92
CD (0.05)	11.56	10.13	NS	17.96

NS - Nonsignificant; DAP - Days after planting

K uptake was the lowest in plants which received *Azospirillum* + 50 per cent N with a value of 19.04 kg ha^{-1}. The data at 150 DAP did not reveal any significant difference among the treatments. However, the highest uptake of 39.59 kg ha^{-1} was recorded by farmyard manure, followed by poultry manure with a value of 38.49 kg ha^{-1}. The results at 180 DAP showed the superiority of *Azospirillum* + 50 per cent. In increasing the K uptake to 82.26 kg ha^{-1}, when compared to the other treatments except neem cake which recorded an uptake of 73.90 kg ha^{-1} and poultry manure with a value of 71.63 kg ha^{-1}. The K uptake by leaves was the lowest (34.83 kg ha^{-1}) in plants which received farmyard manure + poultry manure.

The data revealed that the treatments did not produce consistent results at different stages of growth. However, farmyard manure and poultry manure recorded comparatively more consistent results than the other treatments.

4.8.2 Uptake of potassium by pseudostem

The data on uptake of K by pseudostem at 90, 120, 150 and 180 DAP are furnished in Table 35. The data at 90 and 120 DAP did not show significant difference among treatments. However, the highest mean uptake of 32.83 kg ha^{-1} of K was registered by plants receiving farmyard manure alone at 90 DAP. The results at 120 DAP revealed that the highest mean value of 46.07 kg ha^{-1} was recorded by the plants supplied with poultry manure alone. At 150 DAP, application of *Azospirillum* + 50 per cent N increased the K uptake significantly to 40.85 kg ha^{-1}, which was on par with *Azospirillum* + 75 per cent N (39.71 kg ha^{-1}), control (34.28 kg ha^{-1}) and farmyard manure + neem cake (33.06 kg ha^{-1}). At 180 DAP, the application of *Azospirillum* + 75 per cent N significantly increased the K uptake to 58.98 kg ha^{-1} when compared to all other treatments except *Azospirillum* +50 per

Table 35. Effect of different sources of organic manures and *Azospirillum* on uptake of potassium by the pseudostem

Treatments	Uptake of potassium by pseudostem (kg ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	29.80	31.36	34.28	28.31
Farmyard manure	32.83	35.43	19.81	31.40
Farmyard manure + poultry manure	25.27	32.65	20.69	35.74
Poultry manure	20.14	46.07	17.52	38.41
Farmyard manure + neem cake	18.20	35.70	33.06	39.54
Neem cake	18.18	31.45	30.91	44.89
Azospirillum + 50% N	32.47	25.92	40.85	51.16
Azospirillum + 75% N	28.08	28.81	39.71	58.98
SEm±			3.25	4.07
CD (0.05)	NS	NS	9.86	12.34

NS - Nonsignificant; DAP - Days after planting

cent N. These two treatments were on par. The lowest K uptake was recorded by the control with a value of 28.31 kg ha^{-1}.

The data in general showed the superiority of farmyard manure at 90 DAP and poultry manure at 120 DAP. At later stages, incorporation of *Azospirillum* + N recorded higher uptake of potassium.

4.8.3 Uptake potassium by roots

The results obtained on uptake of K by roots are presented in Table 36. Maximum uptake was recorded by the treatment *Azospirillum* + 50 per cent N at all stages with values 6.09, 4.57, 3.41 and 6.21 kg ha^{-1} respectively. However, the treatment effect was significant at 120 DAP only. The lowest uptake of 3.23 kg ha^{-1} at 90 DAP was recorded by neem cake alone. The treatment farmyard manure + poultry manure recorded lowest value of 1.52 at 150 DAP. Inoculation of *Azospirillum* + 75 per cent N recorded the lowest value of 0.88 kg ha^{-1} at 150 DAP. At 180 DAP, the treatment poultry manure alone recorded the lowest uptake of 2.45 kg ha^{-1}.

4.8.4 Uptake of potassium by rhizomes

The results of uptake of K by the rhizomes from 90 DAP to harvest at monthly intervals are furnished in Table 37. The data showed no significant difference among the treatments at 90 and 120 DAP. However, higher mean uptake values of 41.99 kg ha^{-1} and 36.92 kg ha^{-1} were recorded by plants supplied with farmyard manure alone at 90 DAP and farmyard manure + neem cake at 120 DAP, respectively. The results at 150 DAP indicated that plants supplied with poultry

Table 36. Effect of different sources of organic manures and *Azospirillum* on uptake of potassium by the roots

Treatments	Uptake of potassium by roots (kg ha^{-1})							
	90 DAP		120 DAP		150 DAP		180 DAP	
	O	T	O	T	O	T	O	T
Control	3.96	1.99	3.45	1.83	1.38	1.14	3.69	1.91
Farmyard manure	5.58	2.33	2.04	1.42	2.77	1.61	4.43	2.09
Farmyard manure + poultry manure	5.45	2.26	1.52	1.22	2.66	1.60	4.15	2.04
Poultry manure	5.73	2.37	1.73	1.29	3.25	1.74	2.45	1.51
Farmyard manure + neem cake	5.24	2.21	2.24	1.47	3.12	1.76	3.86	1.97
Neem cake	3.23	1.79	2.20	1.48	2.56	1.60	3.41	1.83
Azospirillum+50% N	6.09	2.39	4.57	2.12	3.41	1.62	6.21	2.44
Azospirillum+75% N	4.61	2.13	2.01	1.41	0.88	0.89	3.59	1.85
SEm±				0.17				
CD (0.05)		NS		0.52		NS		NS

NS - Nonsignificant; DAP - Days after planting
O - Original value
T - Transformed value

Table 37. Effect of different sources of organic manures and *Azospirillum* on uptake of potassium by the rhizomes

Treatments	Uptake of potassium by rhizomes (kg ha^{-1})				
	90 DAP	120 DAP	150 DAP	180 DAP	Harvest
Control	29.64	22.66	55.83	52.06	130.17
Farmyard manure	41.99	32.81	53.02	160.81	103.29
Farmyard manure + poultry manure	38.22	32.03	75.43	155.45	103.09
Poultry manure	23.63	24.96	113.64	112.03	63.21
Farmyard manure + neem cake	37.89	36.92	88.99	79.99	27.90
Neem cake	27.28	22.50	42.53	102.24	59.33
Azospirillum + 50% N	28.99	31.18	73.24	101.95	78.09
Azospirillum + 75% N	36.41	27.47	65.84	111.04	72.50
SEm±			10.79	17.95	10.85
CD (0.05)	NS	NS	32.73	54.44	32.90

NS - Nonsignificant; DAP - Days after planting

manure were significantly better and the treatment recorded a K uptake of 113.64 kg ha^{-1}. This treatment was significantly superior to all other treatments except the plants receiving farmyard manure + neem cake with a value of 88.99 kg ha^{-1}. The uptake was the lowest (42.53 kg ha^{-1}) in plants which received neem cake alone. The data at 180 DAP, showed that the plants supplied with farmyard manure alone recorded the highest uptake of 160.81 kg ha^{-1}, followed by farmyard manure + poultry manure (155.45 kg ha^{-1}), poultry manure (112.03 kg ha^{-1}) and *Azospirillum* + 75 per cent N (111.04 kg ha^{-1}). During this stage, the lowest K uptake (52.06 kg ha^{-1}) was recorded by the control plants. On the other hand, the data at harvest showed that the control plants recorded the highest uptake of 130.17 kg ha^{-1} which was significantly superior to all other treatments except farmyard manure and farmyard manure + poultry manure. At this stage, the lowest value of 27.90 kg ha^{-1} was recorded by farmyard manure + neem cake.

The data furnished in the table indicated that the treatment effects were not consistent. Farmyard manure application showed better response at 90 DAP, 180 DAP and at harvest, while at 120 DAP, farmyard manure + neem cake was the best and at 150 DAP, poultry manure was the best.

4.8.5 Total uptake of potassium

The data on the total potassium uptake at 90, 120, 150 and 180 DAP are presented in Table 38. The results obtained at 90 DAP showed significant difference among the treatments. Application of farmyard manure resulted in the highest K uptake of 118.93 kg ha^{-1} which was significantly superior to all other treatments except *Azospirillum* + 50 per cent N (111.94 kg ha^{-1}), control (110.71 kg ha^{-1}), farmyard manure + poultry manure (105.16 kg ha^{-1}) and *Azospirillum* + 75 per

Table 38. Effect of different sources of organic manures and *Azospirillum* on total uptake of potassium

Treatments	Total uptake of potassium (kg ha^{-1})			
	90 DAP	120 DAP	150 DAP	180 DAP
Control	110.71	85.97	117.61	135.45
Farmyard manure	118.93	108.09	115.20	253.29
Farmyard manure + poultry manure	105.16	91.24	127.75	230.17
Poultry manure	74.05	117.15	172.89	224.52
Farmyard manure + neem cake	90.12	100.82	163.55	171.85
Neem cake	77.51	82.59	111.65	224.44
Azospirillum + 50% N	111.94	80.72	149.92	241.56
Azospirillum + 75% N	104.78	95.90	140.02	224.72
SEm±	9.65			23.44
CD (0.05)	29.27	NS	NS	71.09

NS - Nonsignificant; DAP - Days after planting

cent N (104.78 kg ha^{-1}). The treatments did not show any significant difference during 120 DAP and 150 DAP regarding total uptake of K. However, the treatment poultry manure alone registered the maximum uptake of 117.15 kg ha^{-1} and 172.89 kg ha^{-1} during 120 DAP and 150 DAP respectively. The treatment *Azospirillum* + 50 per cent N registered the lowest uptake of 80.72 kg ha^{-1} at 120 DAP. Application of neem cake alone recorded the minimum uptake of 111.65 kg ha^{-1} at 150 DAP. At 180 DAP, there existed considerable variation among the treatments. The treatment, farmyard manure recorded maximum uptake value of 253.29 kg ha^{-1} and it was on par with all the other treatments except, farmyard manure + neem cake and control, which recorded lower values of 171.85 kg ha^{-1} and 135.45 kg ha^{-1} respectively.

4.9 Nitrate reductase activity

The data on influence of different treatments on nitrate reductase activity of leaves are presented in Table 39. Significant variation was not observed among the treatments at 120 DAP and 150 DAP. At 120 DAP, the control plots showed the maximum activity of nitrate reductase with a value of 8.46 m mol h^{-1} g^{-1} of fresh leaves and it was closely followed by *Azospirillum* + 75 per cent N with a value of 8.37 m mol h^{-1} g^{-1}. Nitrate reductase activity was the minimum (3.01 m mol h^{-1} g^{-1}) in plots treated with farmyard manure alone. At 120 DAP, the maximum activity of 6.01 m mol h^{-1} g^{-1} was exhibited by plants which received *Azospirillum* + 75 per cent N. It was the minimum in the treatment poultry manure alone (3.51 m mol h^{-1} g^{-1}).

At 180 DAP, there was significant influence of the treatments on nitrate reductase activity of leaves. The control plots recorded maximum value of

Table 39. Effect of different sources of organic manures and *Azospirillum* on nitrate reductase activity of leaves

Treatments	Nitrate reductase activity (mmol h^{-1} g^{-1})		
	120 DAP	150 DAP	180 DAP
Control	8.46	5.72	5.92
Farmyard manure	3.01	4.53	1.83
Farmyard manure + poultry manure	4.17	4.11	3.05
Poultry manure	4.93	3.51	2.53
Farmyard manure + neem cake	5.23	3.84	3.51
Neem cake	5.69	3.84	4.40
Azospirillum + 50% N	6.33	5.72	4.82
Azospirillum + 75% N	8.37	6.01	5.09
SEm±			0.29
CD (0.05)	NS	NS	0.88

NS - Nonsignificant; DAP - Days after planting

5.92 m mol h^{-1} g^{-1} and it was on par with the treatment *Azospirillum* + 75 per cent N (5.09 m mol ha^{-1} g^{-1}). Nitrate reductase activity was the minimum (1.83 m mol ha^{-1} g^{-1}) in the treatment farmyard manure alone.

4.10 Soil studies

The results on soil reaction and nutrient content viz. organic carbon, available N, available P and available K after the harvest of the crop are furnished in Table 40.

4.10.1 Organic carbon

The results showed that there was an increase in organic carbon in all the treatments when compared to its initial content of 0.73 per cent (Appendix-II). Plots treated with farmyard manure alone recorded the highest value of organic carbon in soil (1.0%), though it was on par with the control plots (0.96%), plots treated with *Azospirillum* + 50 per cent N (0.93%), *Azospirillum* + 75 per cent N (0.91%) and neem cake (0.90%). Organic carbon content was the lowest in plots treated with poultry manure alone (0.76%).

4.10.2 Available nitrogen

All the treatments caused considerable increase in soil nitrogen content from the initial value of 336 kg ha^{-1} (Table 40 and Appendix-II). Moreover, significant variation existed among the different treatments, with regard to available N status of soil. It was the highest (398.53 kg ha^{-1}) in plots treated with *Azospirillum* + 75 per cent N though it was on par with *Azospirillum* + 50 per cent N (397.60 kg ha^{-1}) and control plots (394.80 kg ha^{-1}). The treatment farmyard manure + poultry manure recorded the lowest nitrogen content of 338.80 kg ha^{-1}.

Table 40. Effect of different sources of organic manures and *Azospirillum* on soil nutrient status

Treatments	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	Soil pH
Control	0.96	394.80	44.42	117.00	6.40
Farmyard manure	1.00	356.53	42.94	116.60	6.43
Farmyard manure + poultry manure	0.82	338.80	37.41	106.67	6.57
Poultry manure	0.76	346.27	40.38	105.00	6.52
Farmyard manure + neem cake	10.76	346.27	40.38	114.67	6.43
Neem cake	0.90	365.87	38.56	87.33	6.43
Azospirillum + 50% N	0.93	397.60	41.17	112.67	6.37
Azospirillum + 75% N	0.91	398.53	40.28	122.00	6.18
SEm±		3.86		2.51	
CD (0.05)	NS	11.70	NS	7.63	NS

NS - Nonsignificant; DAP - Days after planting

4.10.3 Available phosphorus

The data presented in Table 40 clearly indicated that the treatments were ineffective in influencing the available P content of soil. After the harvest of the crop, the available P was slightly higher than the initial value of 37.71 kg ha^{-1} in all the treatments except farmyard manure + poultry manure. The control plots recorded the maximum P content of 44.42 kg ha^{-1} and it was the lowest (37.41 kg ha^{-1}) in plots supplied with farmyard manure + poultry manure.

4.10.4 Available potassium

As in the case of N and P available potassium status of soil also increased after the crop in most of the treatments. K content of soil before the experiment was 105.0 kg ha^{-1} (Appendix-II) and the treatments altered the status of K in soil significantly (Table 40). *Azospirillum* + 75 per cent N increased the K status of soil significantly to 122 kg ha^{-1} and was on par with the control plots (117 kg ha^{-1}), plots treated with farmyard manure (116.6 kg ha^{-1}) and poultry manure (114.67 kg ha^{-1}). The lowest value of 87.33 kg ha^{-1} was recorded by the treatment neem cake alone.

4.10.5 pH

pH of the soil after the harvest of the crop was found to be unaffected by the different treatments. However, the minimum pH of 6.18 noticed in plots treated with *Azospirillum* + 75 per cent N and pH was maximum in plots supplied with farmyard manure + poultry manure (6.57).

4.11 Pest and disease incidence

4.11.1 Rhizome maggot

The percentage of infestation of the crop with rhizome maggot is furnished in Table 41. Plants supplied with neem cake showed the highest percentage of infestation of 5.21 per cent and it was the minimum in plots treated with poultry manure (1.56%).

4.11.2 Soft rot

Incidence of soft rot was found to be the maximum (2.6%) in plots supplied with farmyard manure + poultry manure (Table 41). Plants treated with neem cake were the least affected by the disease with 0.52 per cent incidence.

4.12 Economics

The results on the economics of cultivation of the crop as influenced by the different sources of manures are furnished in Table 42. The data showed that plots applied with farmyard manure alone, gave the highest returns (Rs.1,20,245/-), profit (Rs.68,465/-) and benefit cost ratio (2.32). This treatment gave an additional profit of 32.04 per cent over the control. This was followed by *Azospirillum* + 50 per cent N where the profit amounted to Rs.54,910/- ha^{-1} with a benefit cost ratio of 2.16. This treatment recorded 5.90 per cent increase in profit when compared to the control. The least economic treatment was neem cake alone, which exhibited the least benefit cost ratio of 1.50. A benefit cost ratio of 2.11 was obtained with *Azospirillum* + 75 per cent N, which recorded an increase of 1.36 per cent in the net profit than the control.

Table 41. Effect of different sources of organic manures and *Azospirillum* on pests and disease incidence

Treatments	Rhizome maggot (%)	Soft rot (%)
Control	2.60	2.08
Farmyard manure	2.08	2.08
Farmyard manure + poultry manure	3.13	2.60
Poultry manure	1.56	2.08
Farmyard manure + neem cake	2.08	1.56
Neem cake	5.21	0.52
Azospirillum + 50% N	2.60	1.04
Azospirillum + 75% N	3.12	1.04

Table 42. Economics of cultivation

Treatments	Total cost (Rs.)	Total return (Rs.)	Profit (Rs.)	Increase in profit over control (Rs.)	Increase in profit over control (%)	B/C ratio
Control	47,600.00	99,450.00	51,850.00	-	-	2.09
Farmyard manure	51,780.00	1,20,245.00	68,465.00	16,615.00	32.04	2.32
Farmyard manure + poultry manure	51,180.00	1,04,030.00	52,850.00	1,000.00	1.92	2.03
Poultry manure	49,860.00	93,865.00	44,005.00	-7,845.00	-15.13	1.88
Farmyard manure + neem cake	53,880.00	99,065.00	45,185.00	-6,665.00	-12.85	1.84
Neem cake	56,380.00	84,325.00	27,945.00	-23,905.00	-46.10	1.50
Azospirillum + 50% N	47,335.00	1,02,245.00	54,910.00	3,060.00	5.90	2.16
Azospirillum + 75% N	47,515.00	1,00,070.00	52,555.00	705.00	1.36	2.11

Discussion

DISCUSSION

The use of organic manures in soil improves the physical properties of soil and also balances the nutrient availability to plants and boosts up production and quality of crop. *Azospirillum*, a free living aerophilic microbacterium having the potential to fix atmospheric nitrogen has been reported to produce considerable economy in nitrogen and yield of many crops. In ginger, which is a crop requiring heavy supply of nutrients for growth and productivity, studies on the influence of organic manures and *Azospirillum* are limited. In the present investigation the effects of different organic manures and *Azospirillum* on growth, yield and quality of ginger, uptake of nutrients, soil nutrient status and economics of cultivation were studied. The results obtained are discussed in this chapter.

5.1 Vegetative characters

The results on vegetative characters viz. height of the plant, number of leaves/tiller, number of tillers/plant and total leaf area per plant revealed that the different forms of organic manures and *Azospirillum* failed to produce consistent results with respect to these characters. However, it was found that application of poultry manure and *Azospirillum* 2.5 kg ha^{-1} + 75 per cent N increased the plant height during all the stages of growth. During the active vegetative phase of the crop i.e., upto 120 DAP, all forms of organic manures exhibited an increase in height when compared to the control except neem cake. At later stages, rhizome development takes place at much faster rate than the vegetative growth (Johnson, 1978) and hence the data were not consistent.

The organic manures might have improved the physical conditions of the soil to which they are added, and the improvement in mineral uptake brought about by this might have contributed towards height increase. The results also revealed that application of neem cake alone 3.8 t ha^{-1} was inferior to others. The quantity of organic matter that gets added to soil by neem cake is too small to cause improvement in physical properties of soil (Garg *et al.*, 1971). Comparatively lower uptake of nutrients in this treatment might also have resulted in lower vegetative growth. The response of ginger plant to the treatment *Azospirillum* 2.5 kg ha^{-1} + 75 per cent N was also good. *Azospirillum* might have synthesised phytohormones, which in turn promoted vegetative growth as reported by Venkateswarlu and Rao (1984). However, the application of *Azospirillum* 2.5 kg ha^{-1} + 50 per cent N showed significant reduction in plant height at 180 DAP and it recorded the minimum value, though it recorded better mean values during the active vegetative phase of the crop.

Results on number of tillers per plant and number of leaves per tiller indicated no significant difference among the treatments. This observation confirms the results reported by Nair (1964) and Johnson (1978). According to them, number of tillers per clump and number of leaves per tiller were not influenced by application of fertilizers.

The data on total leaf area showed that application of farmyard manure and poultry manure significantly contributed towards increase in leaf area at 150 and 180 DAP. At earlier stages also though not significant, farmyard manure recorded higher values. This increase in leaf area might be due to the improvement in soil texture brought about by them (Pareek *et al.*, 1984) and the enhanced mineral and water uptake.

5.2 Dry matter production

The results on leaf dry weight showed that significant response was produced at 90, 120 and 180 DAP. The incorporation of farmyard manure alone produced a definite advantage in leaf dry matter production at 90 and 180 DAP. Poultry manure recorded the highest values at 120 and 150 DAP. Increase in the total area of leaves as a result of incorporation of these organic manures might have led to increase in leaf dry matter.

In respect of dry weight of pseudostem, the data did not reveal significant difference upto 150 DAP. Similar trend was noticed in the case of height of plant also.

Root dry weight was significant only at 120 DAP. At this stage *Azospirillum* + 50 per cent N recorded the highest value, which was on par with the control. Yahalom *et al.* (1984) also reported that *Azospirillum* brought about increased root dry weight in foxtail millet. The organism might have released growth promoting substances, which would help in increased root biomass (Laura *et al.*, 1994).

The dry weight of rhizomes/plant did not differ significantly at 90 and 120 DAP. At 150 DAP, the plots treated with poultry manure at the rate of 13 t ha^{-1} showed the highest dry weight which was on par with farmyard manure + neem cake. At 180 DAP, farmyard manure recorded the highest value which was on par with farmyard manure + poultry manure. Influence of poultry manure in increasing the yield of potato, sugarbeet etc. was reported by Giardini *et al.* (1992). Poultry manure is considered to have fertilizing properties intermediate between mineral fertilizers and farmyard manure (Giardini, 1985).

The same trend as dry weight of rhizomes was exhibited in total dry matter production also. The treatments poultry manure and farmyard manure recorded the highest value of dry matter production at 150 DAP and 180 DAP respectively. Application of farmyard manure significantly improved dry matter accumulation in groundnut (Intodia *et al.*, 1995).

5.3 Yield and quality

Yield of green ginger and dry ginger was found to be unaffected by the different treatments. However, plots supplied with farmyard manure alone at 48 t ha^{-1} recorded the highest yield of green ginger as well as dry ginger. The superiority of farmyard manure with respect to leaf area, dry matter production and nutrient uptake is reflected on rhizome yield also. This result is in accordance with the findings of Knaflewski (1984) in cucumber, Brar *et al.* (1995) in rice and wheat, Saha (1988) and Balashanmugam *et al.* (1989) in turmeric, Maheswari *et al.* (1991) in palmarosa, Patel *et al.* (1991) in chicory and Jain and Tiwari (1995) in soybean. Application of *Azospirillum* 2.5 kg ha^{-1} + 75 per cent N recorded increase in yield and also helped to save 25 per cent inorganic N. *Azospirillum* + 50 per cent N also gave comparatively higher yield and saved 50 per cent inorganic N. Similar observations were made by Patil and Konde (1988) in ginger, Subbiah (1991) in okra and Thamburaj (1991) in onion.

The dry recovery was found to be not significantly affected by the treatments. The drying percentage is a varietal character which is not significantly influenced by the environmental factors.

The percentage of essential oil in ginger was significantly improved by the inoculation of *Azospirillum* + 75 per cent N. Incorporation of farmyard manure was also equally effective regarding the oil content. Though the oil content is primarily governed by the cultivar, it is indicated that conditions during growth can also contribute some amount of variability (Purseglove *et al.*, (1981).

The content of oleoresin in ginger was not influenced by the different treatments significantly. This might be due to the fact that the synthesis of components of oleoresin are not significantly governed by the level of nutrients available in plant tissue. Similar results were reported by Johnson (1978) in ginger.

5.4 Nutrient content in different plant parts and uptake of nutrients

5.4.1 Nitrogen

Uptake of nitrogen by leaves was significantly influenced by the treatments only at 120 DAP and the treatment poultry manure alone recorded the maximum value. This was on par with neem cake, control, farmyard manure and *Azospirillum* + 75 per cent N. This increased uptake of N in these treatments is due to increased accumulation of dry matter in the leaves and higher percentage of N. *Azospirillum* being a root coloniser has a close contact with plant roots. It can soften the middle lamellae through action of pectinolytic enzymes thus enhancing the mineral absorption surface of cortex cells (Konde and Patil, 1993). The lowest uptake in the treatment farmyard manure + poultry manure can be attributed to the lowest dry matter and lowest content of N in the leaves. In the treatment, *Azospirillum* + 50 per cent N eventhough the N content in leaves was the highest because of lower dry matter production the uptake also remained lower.

Uptake of N by pseudostem was significant at 120 DAP and 150 DAP. As in the case of leaves, at 120 DAP it was the highest in plots supplied with poultry manure and at 150 DAP *Azospirillum* + 50 per cent N gave the highest value. The reason suggested for this is the highest N content along with highest dry matter production. Besides, rapid release of N and P from poultry manure has been reported by Robinson *et al.* (1995).

Maximum root uptake at 120 DAP was exhibited by the plants inoculated with *Azospirillum* + 50 per cent N. This might be due to the enhanced root development brought about by *Azospirillum* and higher percentage of N in roots. This positive effect on roots results in increased mineral uptake by the roots, as reported by Sarig *et al.* (1984) in sorghum and Laura *et al.* (1994) in pearl millet.

Uptake of N by rhizomes at 150 DAP, 180 DAP and at harvest and total uptake at 180 DAP were found to be significant. At 150 DAP and at harvest, poultry manure and control showed better performance. At 180 DAP, farmyard manure was found to be superior to others. The highest uptake was noticed in the treatment which recorded higher dry matter accumulation. The effect of farmyard manure in increasing the nutrient uptake was reported by Patel *et al.* (1991) in chicory and Brar *et al.* (1995) in rice.

Among the plant parts analysed for nitrogen contents, leaf showed higher values when compared to the pseudostem, roots and rhizome. However, in respect of uptake, higher values were recorded by the leaves upto 120 DAP. At later stages, rhizomes recorded higher uptake values. This is due to high dry matter accumulation by the rhizomes at later stages.

5.4.2 Phosphorus

The treatments significantly influenced the uptake of P by leaves at 90, 120 and 180 DAP. Incorporation of farmyard manure brought about increased uptake at these stages. Significant influence of farmyard manure is also evident in respect of the uptake of P by rhizomes and total P uptake. At 90 DAP and 180 DAP, farmyard manure excelled the others as regards the uptake by rhizomes and total uptake. This treatment recorded higher values for leaf content and dry weight of leaves. As dry matter increases uptake also increases. Total uptake at 120 DAP was also the highest in this treatment. Patel *et al.* (1991) in chicory and Brar *et al.* (1995) in rice obtained increased nutrient uptake due to farmyard manure application.

Plots which received farmyard manure + poultry manure and *Azospirillum* + 50 per cent N recorded significantly higher uptake values of P by pseudostem at 150 DAP and 180 DAP respectively. In these two cases, P content at the respective stages was higher. Moreover, dry matter production was also higher. Phosphorus uptake by roots also was significantly superior in plots receiving *Azospirillum* + 50 per cent N. The reason for favourable effect of *Azospirillum* has been discussed earlier. Increased accumulation of dry matter might also have led to the above result.

The treatment poultry manure was found to be superior to others as far as uptake by rhizomes and total uptake were concerned at 150 DAP. The factors leading to this result might be increased dry weight, and P content in rhizomes at this stage and fast rate of availability of nutrients from poultry manure.

In respect of P content in different plant parts, there was not much variation. However, P uptake was considerably increased in the rhizomes at later stages due to higher dry matter production.

5.4.3 Potassium

Results of the studies on uptake of potassium showed that, the different treatments influenced K uptake by leaves at 90, 120 and 180 DAP. At 90 DAP, control plots and plots supplied with *Azospirillum* + 50 per cent N, farmyard manure alone and farmyard manure + poultry manure recorded higher uptake of K by leaves. At 120 DAP, poultry manure alone, farmyard manure alone and *Azospirillum* + 75 per cent N showed better performance. Higher percentage of K along with higher dry matter accumulation in the leaves contributed to higher uptake also. At 180 DAP, *Azospirillum* + 50 per cent N, poultry manure and neem cake brought about higher uptake of K by leaves. Here, eventhough the leaf dry weight was the maximum for farmyard manure applied plots, K content in leaves was relatively lower and resulted in lower uptake.

Potassium uptake by pseudostem was the highest in the treatment *Azospirillum* + 50 per cent N at 150 DAP and it was on par with that of *Azospirillum* + 75 per cent N, control and farmyard manure + neem cake. At 180 DAP also, *Azospirillum* + 50 per cent N and *Azospirillum* + 75 per cent N recorded the highest values.

As in the case of N and P, root uptake of K also was the highest in the treatment *Azospirillum* + 50 per cent N at 120 DAP, due to the increased root dry weight and better mineral absorption as enhanced by *Azospirillum*.

The treatments significantly influenced the uptake of potassium by rhizomes from 150 DAP to harvest. Application of poultry manure brought about significant increase in potassium uptake by rhizomes at 150 DAP. At 180 DAP, plots supplied with farmyard manure recorded the maximum uptake of K by rhizomes. At harvest, it was the maximum in control plots and was on par with plots supplied with farmyard manure and farmyard manure + poultry manure. Higher nutrient content and higher dry matter accumulation are the factors leading to higher uptake values.

The results revealed that the treatments affected the total uptake of potassium significantly at 90 DAP and 180 DAP. At 90 DAP, plots supplied with farmyard manure recorded the maximum value and was on par with all others except control and farmyard manure + neem cake.

The favourable effect on K uptake due to inoculation of *Azospirillum* evidenced in the present study can be attributed to the enhanced mineral and water uptake. This confirms the findings of Konde and Patil (1993) and Laura *et al.* (1994). Increased potassium uptake as a result of farmyard manure incorporation was reported by Jain and Tiwari (1995). Rapid mineralisation of nutrients from poultry manure might have led to increased uptake of K.

The potassium content in different plant parts did not vary considerably. However, higher uptake valaues were recorded at the last two stages by the rhizomes, which can be attributed to the higher rate of dry matter accumulation.

5.4.4 Nitrate Reductase Activity

Nitrate reductase activity in plots which received inorganic form of N (control plots, *Azospirillum* + 50 per cent N and 75 per cent N) was higher than that in other plots, though it was significant only at 180 DAP. It is reported that with increase in nitrate application the NRA will increase (Sekhon *et al.*, 1988; Thomas, 1990).

5.5 Soil nutrient status

5.5.1 Organic carbon

In plots which received farmyard manure the organic carbon content was the highest. Increase in organic carbon level due to organic manuring was reported by Rao and Krishnan (1963), Biswas and Ali (1967), Prasad *et al.* (1971) and Nair (1988).

5.5.2 Available nitrogen

In plots which received inorganic nitrogen as such (the treatments *Azospirillum* + 50 per cent N; *Azospirillum* + 75 per cent and control), available N content was significantly higher than those supplied with organic manures alone. This might be due to the slow rate of availability of nutrients from organic manures.

5.5.3 Available phosphorus

Available phosphorus status of soil was not significantly affected by the different treatments. This may be due to the fixation of available P. It is reported that in highly weathered soils, P is immobile and these soils have high P fixing capacity (Sushama and Jose, 1994).

5.5.4 Available potassium

The treatments differed with respect to K status of soil. *Azospirillum* +

75 per cent N recorded the highest available K content which was on par with the control, farmyard manure and poultry manure. It is stated that organic manures quite often improve the available K status of soil. This is possibly due to the progressive incorporation of K through farmyard manure itself and greater capacity of organic colloids to hold the nutrient at the exchange surface (Kanwar and Prihar, 1962).

5.5.5 Soil pH

The soil reaction was not significantly influenced by the various treatments. This agrees with Spratt and Mc Curdy (1966) and Singh and Sharma (1968) who observed soil pH to be not influenced by short term fertilizer treatments.

5.6 Incidence of pests and diseases

Occurrence of rhizome maggot was found to be the minimum in the treatment poultry manure and it was the maximum in neem cake applied plots. In control plots the infestation was medium.

Incidence of soft rot was found to be the minimum in plots treated with neem cake. Similar observations were made by Sadanandan and Iyer (1986) and Thakore *et al.* (1987).

5.7 Economics

Incorporation of farmyard manure alone was the most profitable treatment. Eventhough the total cost involved was higher, the increased yield compensated the cost of inputs. The treatments *Azospirillum* + 50 per cent N and 75 per cent N also produced higher benefit cost ratios. Higher net profit per acre in onion due to application of *Azospirillum* was reported by Thamburaj (1991). In ginger also higher monetary benefit was recorded with low levels of nitrogen + inoculation of *Azospirillum* (Patil and Konde, 1988). Due to *Azospirillum* inoculation a saving of 33 per cent inorganic N in ginger and 50 per cent fertilizer N in okra were reported by Patil and Konde (1988) and Subbiah (1991) respectively.

Summary

SUMMARY

A field experiment was conducted at the College of Horticulture, Vellanikkara to study the influence of organic manures and *Azospirillum* on growth, yield and quality of ginger, chemical properties of soil, uptake of plant nutrients, incidence of pests and diseases and also on economics of cultivation in ginger. The experiment was laid out in randomized block design with the cultivar Maran. The important results of the study are summarised below.

With respect to height of the plant, better performance was exhibited by the treatments poultry manure and *Azospirillum* + 75 per cent N, during all the stages of crop growth. It was evident that the response of all organic manures was better than control except that of neem cake.

Significant variation did not exist with regard to the number of tillers per plant and number of leaves per tiller.

As regards the total leaf area per plant farmyard manure and poultry manure were found to be significantly superior.

The highest leaf dry weight was recorded by the treatments farmyard manure and poultry manure. No significant difference among the treatments was observed with respect to dry weight of pseudostem during the initial stages. However, the treatments farmyard manure, poultry manure and *Azospirillum* + 75 per cent N showed better performance. Plots supplied with *Azospirillum* + 50 per cent N produced the maximum root dry weight.

The treatments farmyard manure and poultry manure performed well, with respect to fresh weight of rhizomes. The same trend was exhibited in the case of dry weight of rhizomes also. The results were significant at 150 DAP and 180 DAP.

Dry matter accumulation was found to be significantly different among treatments at all stages of growth except at 120 DAP. Farmyard manure exhibited its superiority at all stages except at 150 DAP where poultry manure showed better performance.

Though nonsignificant, yield of green ginger (24,048.48 kg ha^{-1}) and dry ginger (4,607.80 kg ha^{-1}) was found to be the highest in farmyard manure applied plots. This treatment resulted in 29.23 per cent increase in dry ginger yield when compared to the control. *Azospirillum* inoculated plots also gave relatively higher yield. The maximum drying percentage was observed in the treatment *Azospirillum* + 75 per cent N. *Azospirillum* + 75 per cent N and farmyard manure alone also showed higher percentage of dry ginger recovery. The percentage of essential oil in ginger was found to be significantly improved by the different treatments. The treatments *Azospirillum* + 75 per cent N and farmyard manure alone resulted in higher oil content in the rhizomes. The content of oleoresin was not influenced by the different treatments.

The treatments poultry manure alone, *Azospirillum* + 50 per cent N and farmyard manure alone were superior to others with respect to uptake of N and P.

Nitrate reductase activity of leaves was found to be higher in the treatments *Azospirillum* + 50 per cent N, *Azospirillum* + 75 per cent N and control.

Organic carbon content in the soil after the harvest of the crop was the maximum in plots supplied with farmyard manure alone. The treatments *Azospirillum* + 50 per cent N, *Azospirillum* + 75 per cent N and control showed higher available N content in soil. There was no significant difference among the treatments with respect to available P and soil pH. Comparatively higher K content was exhibited by the treatments *Azospirillum* + 75 per cent N, control, farmyard manure and poultry manure.

Incidence of soft rot disease was found to be the minimum in plots treated with neem cake alone and incorporation of poultry manure resulted in the reduction of the infestation by rhizome maggot.

The treatment farmyard manure alone resulted in the highest returns (Rs.1,20,245/-), profit (Rs.68.465/-) and benefit cost ratio (2.32). This treatment gave an additional profit of 32.04 per cent over the control. Neem cake alone was the least profitable treatment, with a benefit cost ratio of 1.50 as against 2.09 in the control.

References

REFERENCES

Abusaleha, H. and Shanmugavelu, K.G. 1988. Studies on the effect of organic vs. inorganic source of nitrogen on growth yield and quality of okra (*Abelmoschus esculentus*). *Indian J. Hort.* **45**(3-4):312-318

* Asiegbu, J.E. and Uzo, J.O. 1984. Yield and yield component responses of vegetable crops to farmyard manure rates in the presence of inorganic fertilizer. *J. Agric. Univ. Puerto Rico.* **68**(3):243-252

* Babalota, J.O. 1988. Influence of organic manures and urea on the nematode pests of *Celosia argentia. Res. Bul.*, National Horticultural Research Institute, Ibadan. (3):10

Babalota, J.O. 1989. Effects of some organic manure on nematodes in tomato cultivation. *Pakistan J. Nematology* **7**(1):39-46

Balashanmugam, P.V., Vanangamudi, K. and Chamy, A. 1989. Studies on the influence of farmyard manure on the rhizome yield of turmeric. *Indian Cocoa, Arecanut Spices J.* **12**(4):126

Bashan, Y., Ream, Y., Lavanony, H. and Sade, A. 1989. Non specific responses in plant growth, yield and root colonization of noncereal crop plants to inoculation with *Azospirillum brasilense. Can. J. Bot.* **67**(5):1317-1324

* Baumann, E. 1980. Effect of different organic manures on the yield of field vegetable and on soil organic matter content. *Archiv fur Gartenbau* **28**(4):209-225

Bhattacharya, D. and Goswami, B.K. 1989. Effect of different dosages of neem and groundnut oil cakes on plant growth characters and population of rootknot nematode, *Meloidogyne incognita* in tomato. *Indian J. Nematology.* **18**(1):125-127

Biswas, T.D. and Ali, M.H. 1967. Influence of organic carbon and clay content of the soils on the permanent wilting percentage. *Indian J. agric. Sci.* **37**:322-331

Bopiah, B.M. and Khader, K.B.A. 1989. Effect of biofertilizers on growth of black pepper (*Piper nigrum). Indian J. agric. Sci.* **59**(10):682-683

Brady, N.C. 1988. *The Nature and Properties of Soil.* S.Chand and Company (Pvt.) Ltd., p.309

Brar, B.S., Dhillon, N.S. and Chand, M. 1995. Effect of farmyard manure application on grain yield and uptake and availability of nutrients in rice (*Oryza sativa*) - wheat (*Triticum aestivum*) rotation. *Indian J. agric. Sci.* **65**(5):350-353

Browaldh, M. 1992. Influence of organic and inorganic fertilizers on common bean (*Phaseolus vulgaris* L.) grown in a P-fixing mollic and osol. *Biological Agriculture and Horticulture.* **9**:87-104

* Bureau of Agricultural Economics, Canberra, 1971. *The Australian ginger growing industry*, Canberra, Australian Govt. Publishing House.

* Cerna, K. 1980. Effect of Farmyard manure and graduated ratio of mineral nutrients on yield formation in *Capsicum Sbornik UVTIZ, Zalradinictive* **7**:297-307

Chindo, P.S. and Khan, F.A. 1986. Effect of soil organic amendment with poultry manure on the damage caused by root-knot nematode *Meloidogyne incognita* on tomato. *Int. Nematology Network Newsl.* 3(4):30-33

* Chindo, P.S. and Khan, F.A. 1990. Control of root-knot nematodes *Meloidogyne* spp. on tomato, *Lycopersicon esculentum* Mill., with poultry manure. *Tropical Pest Management.* **36**(4):332-335

Council of Scientific and Industrial Research, 1984. Wealth of India, Raw materials. **11**:89-105

Fayad, M.N. and Sweelam, M.E. 1989. Effect of phosphorus fertilization, organic matter and root-knot nematode (*Meloidogyne javanica*) infection on growth and nutrient content of tomato (*Lycopersicon esculentum). Indian J. agric. Sci.* **59**(7):455-458

* Filho, N.G.L. and Hamerschmidt, I. 1985. Evaluation of carrot production using alternative horticulture. *Horticulture Brasileire* 3(2):46

Garg, A.C., Idnani, M.A. and Abraham, T.P. 1971. *Organic Manures* Indian Council of Agricultural Research, New Delhi. p.4

*Giardini, L. 1985. L'impiego agronomico della pollina. *Atti Convegno Pollina : i problemi per to smaltimentoe le nuove tecnologie, Forli 19 settembre*. pp.23-38

Giardini, L., Pimpini, F., Borin, M. and Gianquinto, G. 1992. Effects of poultry manure and mineral fertilizers on the yield of crops. *J. Agric. Sci.*, Cambridge **118**:207-213

Govindan, M. and Purushothaman, D. 1985. Occurrence of *Azospirillum* species, the nitrogen fixing bacteria in certain plantation crops. *Indian J. Microbiol.* **25**:141-143

Hadas, R. and Okon, Y. 1987. Effect of *Azospirillum* on root morphology and respiration in tomato seedlings. *Biology and fertility of soils*. 5(3):241-247

Hill W.A., Hill, P.B., Crossman, S.H. and Stevens, C. 1983. Characterization of N_2 fixing bacteria associated with sweet potato roots. *Can. J. Microbiol.* 29:860-862

*Homma, Y., Kubo, Ishi, M. and Ohata, K. 1979. The mechanism of the suppression of tomato *Fusarium* wilt by soil amendment with chicken manure. *Bul. Shikoku Agricultural Experimental Station*. (34):103-121

Intodia, S.K., Mahnot, S.C. and Sahu, M.P. 1995. Effect of organic manures and phosphorus on growth and yield of groundnut (*Arachis hypogaea* L.). *Crop Res.* 9(1):22-26

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall Inc. Englewood Cliffs. N.J. U.S.A. Prentice Hall of India (Pvt.) Ltd., New Delhi. p.498

Jain, R.C. and Tiwari, R.J. 1995. Influence of farmyard manure and sugar press mud on yield and nutrient content of soybean (*Glycine max* (L.) Merrill) in medium black soil of Madhya Pradesh. *Crop Res.* 9(2):215-217

Jeeva, S., Kulasekaran, M., Shanmugavelu, K.G. and Oblisami, G. 1988. Effect of *Azospirillum* on growth and development of banana cv. Poovan (AAB). *South Indian Hort.* **36**(1-2):1-4

Johnson, P.T. 1978. Foliar diagnosis, yield and quality of ginger (*Zingiber officinale* Rosc.) in relation to nitrogen, phosphorus and potassium. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur.

Joseph, L. 1985. Quality and storage life of oriental pickling melon (*Cucumis melo* var. *Conomon* (L.), makino) as influenced by major nutrients. M.Sc.(Hort.) thesis, Kerala Agricultural University, Thrissur.

Kanwar, J.S. and Prihar, S.S. 1962. Effect of continuous application of farmyard manure and fertilizers on crop yield and properties of soil. 1. Chemical properties. *J. Indian Soc. Soil Sci.* **10**:109

Kerala Agricultural University, 1993. *Package of Practice Recommendations 'Crops 93'*. Directorate of Extension, Mannuthy-680 651, Thrissur, Kerala, India.

*Khan, F.A. 1994. Effect of soil organic amendments on the development of *Pratylenchus brachyurus* and growth and yield of okra. *Afro-Asian J. Nematology* **4**(1):84-89

Klepper, L., Flesher, D. and Hageman, R.H. 1971. Generation of reduced Nicotinamide Adenine Dinucleotide for nitrate reduction in green leaves. *Pl. Physiol.* **48**:580-589

*Knaflewski, M. 1984. Effect of fertilizing with liquid manure and FYM on cucumber, late cabbage, celeriac and leek yields and on the quality of pickled cucumber and saucerkrant. *Naukour Akadimi Rolniozy* 27:177-202

*Konde, B.K., Patil, R.B. and Ruikar, S.K. 1990. Mineral uptake of ginger as influenced by N levels and inoculation with diazotrophic cultures. *Proc. Int. Congress Plant Path.*, New Delhi, 15-20 February 1988. 2:1084-1089

* Konde, B.K. and Patil, B.S. 1993. Yield and N, P uptake by chilli as influenced by *Glomus* and or *Azospirillum* inoculations with phosphate levels. *Bio inoculants for sustainable agricultural development* (eds.) Narasimhan, C.L., Kannan, K., Selvaraj, J. and Solaiappan, A.R. A.V.V.M. Sri Pushpan College, Poondi, Tamil Nadu, p.1-22

* Kumari, M.L., Kavimandan, S.K. and Rao, N.S.C. 1976. Occurrence of N fixing *Spirillum* in roots of rice, sorghum, maize and other plants. *Indian J. exp. Biol.* **14**:638-639

Laura, R.D., Raj, M., Sangwan, P.S. and Bagga, R.K. 1994. Effect of inorganic, organic and biofertilizer on pearl millet yields in dryland areas. *Crop Res.* **8**(3):499-503

* Lazic, B., Durovka, M., Horvat, T.S., Kis, M., Lazic, S., Markovic, V., Ilin, Z. and Petkovic, M. 1992. The effect of an organic production system on vegetable yield and quality. *Savremena Poljoprivreda* **40**(1-2):7-10

* Linardakis, D.K. and Tsikalas, P.E. 1984. Fertilization of protected tomato with N, K solutions - Effect on yield. *Proceedings of 3rd Conference on Protected Vegetables and Flowers.* **11**:8-12

* Lima, J.DE.A., Lopes, J.F., Castor, O.S., Horino, Y. and Souza, A.F. 1984. Agroeconomical evaluation of the use of organic matter for commercial cucumber production. *Pesquisa Agropecuaria Brasileira* **19**(4):407-410

Meheswari, S.K., Joshi, R.C., Gangrade, S.K., Chouhan, G.S. and Trivedi, K.C. 1991. Effect of farmyard manure and Zinc on rainfed palmarosa oil grass. *Indian Perfumer.* **35**(4):226-229

Nair, P.K.C. 1964. Investigations on turmeric in relation to NPK fertilization and rhizosphere bacterial population. M.Sc.(Ag) Thesis, University of Kerala.

Nair, M. 1988. Effect of organic, inorganic fertilizer and their combination on physiochemical and biological properties of soil cropped under clustered chilli (*Capsicum annuum* L.). M.Sc.(Hort.) Thesis, Kerala Agricultural University, Thrissur.

Nair, M. and Peter, K.V. 1990. Organic, inorganic fertilizers and their combinations on yield and storage life of hot chilli. *Veg. Sci.* **17**:7-10

Official Analytical Methods of the American Spice Trade Association, 1960. New York:41-42

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical methods for Agricultural workers* 4th Edn. ICAR, New Delhi. p.348

Paramaguru, P. and Natarajan, S. 1993. Effect of *Azospirillum* on growth and yield of chilli (*Capsicum annuum* L.) grown under semidry conditions. *South Indian Hort.* **41**(2):80-83

Pareek, S.R., Maheswari, M.L. and Gupta, R. 1984. Effect of farmyard manure and micro nutrients on yield and quality of palmarosa oil grass (*Cymbopogon martini* var. *motia*). *Indian Perfumer.* **28**(2):108-111

Parvathan, A., Vijayan, K.P. and Nazar, A. 1989. Effect of *Azospirillum* on growth and nutrient uptake of bhindi var. Pusa Savani. *South Indian Hort.* **37**(4):227-229

Patel, B.S., Barevadia, T.N., Patel, J.C. and Sadaria, S.G. 1991. Effect of FYM, N, P and K application on yield and nutrient uptake by chicory. *Indian J. Agron.* **36**(2):278-280

Patil, R.B. and Konde, B.K. 1988. Fertilizer use efficiency and use of biofertilizers for enhanced ginger yield under field conditions. *Cardamom* **21**(5):58-62

* Paulose, T.T. 1973. Ginger cultivation in India. *Proceedings of the conference on spices* 10-14 April 1972, London, Tropical Products Institute.

* Pechova, B. and Prugar, J. 1986. Nitrate content of head lettuce in relation to fertilization and climatic factors. *Sbornik UVTIZ, Zahradnictvi,* **13**(1):53-48

* Prasad, C.R., Shamiuddin, H. and Singh, B.N. 1971. Effect of continuous application of manures, fertilizers and lime on some chemical properties of acid red loam soil of Bihar. *Proc. Int. Symp. Soil Fertil. Evaln.* **1**:865-872

* Prezotti, L.C., Balbino, J.M.DE.S., Stock, L.A. and Ferreira, L.A. 1987. Effects of organic matter, phosphorus and calcium on the control of blossom end rot and on productivity in tomatoes. *Pesquisa em Empresa Capixaba de Pesquisa Agropecuaria EMCAPA,* Brazil, (45):9

Pruthi, J.S. 1993. *Major Spices of India - Crop Management, Post-Harvest Technology*. Indian Council of Agricultural Research. p.514

Purseglove, J.W., Brown, E.G., Green, C.L. and Robbins, S.R.J. 1981. *Spices*. Longman Group Limited, p.813

Rao, E.V.S.P., Singh, M., Rao, A.R.S.G. and Naraya, M.R. 1989. Response of palmarosa (*Cymbopogon martini* (Roxb.) Wats. var. motia) to farmyard manure and nitrogen. *Indian J. Agron.* **34**(3):376-378

Rao, W.V.B. and Krishnan, A. 1963. The effect of manuring and rotation on the soil fertility status and composition of barley crop in the permanent manurial series (A) at Pusa, Bihar. *Indian J. Agron.* **8**:345-357

Ratnambal, M.J., Gopalam, A. and Nair, M.K. 1987. Quality evaluation of ginger in relation to maturity. *J. Plantation Crops* **15**(2):108-117

* Robinson, J.S. and Sharpley, A.N. 1995. Release of nitrogen and phosphorus from poultry litter. *J. Environmental Quality*. **24**(1):62-67

Sadanandan, A.K. and Iyer, R. 1986. Effect of organic amendments on rhizome rot of ginger. *Indian Cocoa Arecanut Spices J.* **9**(4):94-95

Saha, A.K. 1988. Note on response of turmeric to manure and source of N and P under terrace conditions of mid-altitude Mizoram. *Indian J. Hort.* **45**(1-2):139-40

Sarig, S., Kapulnik, Y., Nur, I. and Okon, Y. 1984. Response of non-irrigated *Sorghum bicolor* to *Azospirillum* inoculation. *Expl. Agric.* **20**:59-66

* Segovia, L.R. 1988. Evaluation of the effects of manuring on the development and yield of melons on tunnels. *Informes de Investigecion-CENID-RASPA*. **35**:241-259

Sekhon, B.S., Kumar, S., Dhillon, K.S. and Singh, R. 1988. Effects of different nitrogen levels on nitrate assimilation and nitrogen fixation in field grown moong (*Vigna radiata.) J. Res. Punjab Agric. Univ.* **25**:595-600

Seo, I.S. 1986. Effect of organic matter on the occurrence of Fusarium wilt in cucumber. *Korean J. Plant Path.* 2(1):43-47

Shinde, V.K.R. and Yadava, C.P.S. 1982. Effect of farmyard manure on the uptake of phorate by some vegetables in loamy-sand soils. *Indian J. Agric. Sci.* 52(5):315-319

Singh, R.P., Khan, A.M. and Saxena, S.K. 1980. Effect of watering and mode of application of oil cakes and nematodes on their efficacy in controlling root knot nematode in tomato. *Acta Botanica Indica* **8**:193-195

* Singh, A. and Sharma, R.P. 1968. Long term experiments with fertilizers and manures on sugarcane in India. *Emp. J. exp. agric.* **4**:65-75

* Sivasangaranathan, M. and Pain, A. 1982. The effect of farmyard manure, nitrogen fertilizer and irrigation frequency on growth and yield of chillies on calcic red latosols. *Tropical Agriculturist.* **138**:59-68

Spratt, E.D. and McCurdy, E.V. 1966. The effect of various long term soil fertility treatments on the phosphorus status of a clay chernozem. *Can. J. Soil Sci.* **46**:29-36

Spices Board, 1994. *Spices Statistics.* Trade Information Service, Spices Board. p.5

* Stirling, G.R. 1989. Organic amendments for control of root-knot nematode (*Meloidogyne incognita*) on ginger. *Australian Pl. Path.* **18**(2):39-44

Subbiah, K. 1991. Studies on the effect of nitrogen and *Azospirillum* on Okra. *South Indian Hort.* **39**(1):37-44

* Subhan, H. 1988. Effect of organic materials on growth and production of cabbage (*Brassica oleracea* L.). *Bulletin Penelitian Hortikultura* **16**(4):37-41

Sundarvelu, S. and Muthukrishnan, T. 1993. Effect of seed treatment with *Azospirillum* and gibberellic acid on the growth and yield of raddish. *South Indian Hort.* **41**(4):212-213

Sushama, P.K. and Jose, A.I. 1994. Nutrition in ginger. *Advances in Horticulture - Plantation Crops and Spices Part I.* (Eds.) Chadha, K.L. and Rethinam, P. Malhotra Publishing House, New Delhi, India. **9**:491-498

Tarrand, J.J., Krieg, N.R. and Dobereiner, J. 1978. A taxonomic study of the *Spirillum lipoferum* with description of a new genus, *Azospirillum* gen. nov. and species. *Azospirillum brasilense* sp. nov. *Can. J. Microbiol.* **24**:967-980

* Thakore, B.B.L., Mathur, S., Singh, R.B. and Chakravarti, B.P. 1987. Soil amendment with oil cakes in ginger field for rhizome rot control. *Korean J. Plant Protection.* **26**(4):267-268

Thamburaj, S. 1991. Biofertilizers for onion crop. *Indian Fmg.* **36**(2):23

Thomas, M. 1990. Nitrate reductase activity in black pepper (*Piper nigrum* L.). M.Sc.(Ag.) Thesis, Kerala Agricultural University, Thrissur.

* Valsikova, M. and Ivanic, J. 1982. Effect of farmyard manure on some quality characteristics of capsicum. *Rostlinna Vyroba.* **28**(2):205-210

Venkateswarlu, B. and Rao, A.V. 1983. Response of pearl millet to inoculation with different strains of *Azospirillum brasiliense. Pl. Soil.* **74**:379-386

* Venkateswarlu, B. and Rao, A.V. 1984. Role of *Azospirillum* in the N economy of pearl millet under desertic conditions. *Golden Jubilee Sem. Soil Resources Productivity Mgmt.* **3**:58

Watanabe, F.S. and Olson, S.R. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. *Proc. Soil Sci. Soc. Am.* **29**:679-680

Yahalom, I., Kapulnik, Y. and Okon, Y. 1984. Response of *Setaria italica* to inoculation with *Azospirillum brasilense* as compared to *Azotobacter chroococcum. Pl. Soil.* **82**:77-85

* Originals not seen

APPENDIX-I

Meteorological data (monthly average) for the crop period
(May, 1993 to January, 1994)

Month		Maximum temperature Mean (°C)	Minimum temperature Mean (°C)	Relative humidity (%)	Total rainfall (mm)	Evaporation (mm)	Mean sunshine hours
1994	May	33.6	24.7	75	124.2	137.0	8.0
	June	28.9	22.9	90	955.1	84.2	2.0
	July	28.6	22.4	91	1002.1	86.1	1.4
	August	30.0	22.8	85	509.2	91.4	3.0
	September	31.8	23.2	78	240.5	113.9	7.3
	October	32.3	22.7	80	358.2	97.1	6.7
	November	31.8	23.3	68	125.3	137.9	8.1
	December	32.2	22.2	58	0.0	169.6	10.6
1995	January	32.0	22.4	59	0.0	178.5	9.6

APPENDIX-II

Chemical characteristics of soil in the experimental field
(Pre experimental data)

Available nitrogen	: 336.0 kg ha^{-1}
Available phosphorus	: 37.71 kg ha^{-1}
Available potassium	: 105.0 kg ha^{-1}
Organic carbon	: 0.73%
Soil pH	: 5.1

INFLUENCE OF ORGANIC MANURES AND *AZOSPIRILLUM* ON GROWTH, YIELD AND QUALITY OF GINGER (*Zingiber officinale* Rosc.)

BY

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ABSTRACT OF THESIS

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ABSTRACT

An investigation was undertaken at the College of Horticulture, Vellanikkara during May, 1994-January, 1995 with the objectives of studying the influence of organic manures and *Azospirillum* on growth, yield and quality of ginger, finding out their impact on chemical properties of soil and uptake of plant nutrients, studying influence on pests and diseases and working out economics of cultivation.

The experiment was laid out in randomised block design. The different organic manures included were farmyard manure, poultry manure and neem cake. The experiment was carried out using the cultivar Maran. The salient findings are abstracted below.

Plant height was found to be favourably influenced by the treatments except neem cake. Number of tillers per plant and number of leaves per tiller were not influenced by the different treatments.

Dry matter accumulation in the leaves and rhizomes was comparatively higher in the treatments poultry manure alone and farmyard manure alone. Root dry weight was the maximum in the treatments, *Azospirillum* + 75 per cent N. The treatment farmyard manure was significantly superior to others as far as total dry matter production was concerned.

Yield of green ginger and dry ginger and dry ginger recovery were found to be higher in the treatments farmyard manure and *Azospirillum*, though not significant. Oleoresin content was unaffected by the different treatments. Percentage

of essential oil was significantly higher in the treatments *Azospirillum* + 75 per cent N and farmyard manure.

Uptake of N and P was higher in the treatments poultry manure alone, *Azospirillum* + 50 per cent N and farmyard manure alone.

Incorporation of farmyard manure in the soil resulted in the enhancement in organic carbon content of soil. Plots receiving inorganic form of N contained more available N in soil after the experiment.

Neem cake was found to be effective in reducing the incidence of soft rot disease.

The most profitable among the different treatments was farmyard manure alone.