INTEGRATED PLANT NUTRITION SYSTEM (IPNS) FOR MAXIMISING YIELD IN BANANA, *MUSA* (AAB GROUP) 'NENDRAN'

By

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DECLARATION

I hereby declare that this thesis entitled "**INTEGRATED PLANT NUTRITION SYSTEM (IPNS) FOR MAXIMISING YIELD IN BANANA,** ***MUSA*** **(AAB GROUP) `NENDRAN'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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EXTERNAL EXAMINER

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Abbreviations used in this thesis

%	.....	per cent
@	.....	at the rate of
^{0}C	.....	degree Celsius
Ca	.....	calcium
cm	.....	centimetre
DAS	.....	days after sowing
DAP	.....	days after planting
DM	.....	dry matter yield
Fig.	.....	figure
FYM	.....	farm yard manure
g	.....	gram
ha^{-1}	.....	per hectare
K	.....	potassium
kg	.....	kilogram

mg	.....	milligram
MSL	.....	mean sea level
Mg	.....	magnesium
N	.....	nitrogen
NH_4 N	.....	ammoniacal nitrogen
NO_3 N	.....	nitrate nitrogen
P	.....	phosphorus
ppm	.....	parts per million
POP	.....	package of practices
RBD	.....	randomised block design
t	.....	tons
TSS	.....	total soluble solids
2,4-D	.....	2,4 dichloro phenoxy acetic acid

INTRODUCTION

INTRODUCTION

Banana is one of the major fruit crops of India occupying an area of 2,79,000 ha and its cultivation is as old as Indian civilisation. The productivity of the crop is 5.5 t ha^{-1}. Among the states growing banana, the largest area is in Kerala (72,200 ha). To the Keralite, the term `fruit' is rather a synonym of banana and is liked by one and all and it is available round the year at a reasonable price. Nendran is the most popular commercial cultivar in the state owing to its adaptability to varying environments, excellent fruit quality attributes, yield stability and sustained income.

In Kerala, banana is mostly grown by the marginal and poor farmers either in the homesteads or in well drained rice fields. During the last decade, the productivity of the crop has been more or less static (4.6 t ha^{-1}) due to uninterrupted cultivation in the same locations and excessive use of chemical inputs without adequate organic manure addition. The almost complete reliance on the use of chemical fertilizers in crop production is known to create problems such as deficiencies of plant nutrients, disturbances in soil reaction and specific conductance, decrease in soil life, fall in crop productivity and increase in environmental pollution (Phillips, 1972; Day *et al.*, 1978; Lahav and Turner, 1983; Anilakumar, 1993 and

Palaniappan *et al.*, 1995). It is in this context, the concept of Integrated Plant Nutrition (IPN) assumes importance as a means to achieve and sustain high productivity in banana.

The basic concept underlying Integrated Plant Nutrition System (IPNS) is to provide ideal nutrition for a crop through a proper combination of various nutrient resources and their optimum utilisation along with maintenance of soil productivity and ecology. The objective is to achieve high yield through balanced plant nutrition without impairing soil health (Mishra and Maheswari, 1988 and FAO, 1989). The components of IPNS consist of soil resources, bionutrients and mineral fertilizers. The organic and biological sources of nutrients utilised in the IPNS are those generated on the farm through *in situ* organic recycling as well as the biomass and bioinoculants brought from outside.

The ability of organic manures to improve and sustain the productive capacity of the soil is related to their influence on soil aggregation, exchange reactions and soil life. The forms of organic manures include compost, farmyard manure, green manure and crop and animal residues. The compost prepared by using earthworms is called vermicompost. It is now regarded as a very important component of the IPN package. It is easy to prepare, has excellent properties and is absolutely harmless to soil and plant (Ismail, 1995). In banana plantations, plenty of crop residues are available for vermicomposting.

Green manuring has long been recognised as a low cost technology for minimising investment on chemical N. In this practice, the plant biomass - either produced *in situ* or brought from outside - is directly incorporated in the soil.

Addition of green manures of succulent nature facilitates enhanced availability of N (Verma, 1995). The foremost quality of a green manure crop should be its ability to yield a large quantity of green matter in a short span of time. Such a crop will naturally have the ability to suppress weeds. Cowpea (*Vigna unguiculata* L.) is endowed with these agronomic traits and as such, can fit into the banana based cropping systems.

There are several soil microorganisms which have the ability to mobilise nutritionally important elements from nonuseable to useable forms through biological processes. These are being harnessed for improving nutrient supplies and crop yields. The biofertilizers are products containing the living cells of such organisms. One of the organisms now widely used is *Azospirillum (A. brasilence).* It is an associative microaerophilic N_2 fixer capable of improving soil fertility in association with crops. Inoculation of *Azospirillum* has shown positive interactions with applied N in several field trials with a mean response equivalent of 15 kg N ha^{-1} (Rao *et al.*, 1983).

The results of many of the long term manurial experiments conducted in India indicate that combined application of organic manures and fertilizers is the most appropriate agronomic practice for achieving high yield levels without impairing soil productivity. Organic manures and biofertilizers are in short supply at the present stage. Therefore, the use of fertilizers has to be continued till the availability of organic and biological sources of nutrients are freely available (Mishra and Kapoor, 1992 and Thampan, 1995). However, there is ample scope for reducing the excessive dependence on chemical fertilizers by developing local manurial resources and biofertilizers.

The plant growth regulators like 2,4-D are widely used on fruit crops for improving yield and quality. The cultivars differ in their response to growth regulators. In an IPNS for banana, the use of 2,4-D cannot be excluded as it offers immense possibilities for increasing yield without much investment (Anbazhakan and Shanmughavelu, 1980; Aravindakshan, 1981).

As the IPNS involves the use of various combinations of nutrient resources, their optimum combination for deriving the maximum benefit has to be determined. Banana being the most important commercial fruit crop of Kerala, development of an IPNS will benefit the growers for increasing and sustaining productivity and income. But no such attempt has so far been made on the crop. Therefore, the present investigation was undertaken with the following specific objectives:

To develop an effective IPNS using organic and inorganic sources of nutrients and the growth regulator, 2,4-D for higher fruit yield and quality.

To assess the effect of combinations of nutrient inputs on the physico chemical properties of the soil.

To work out the economics of crop production as influenced by various sources of nutrients and the growth regulator, 2,4-D.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Banana is well known for its water and nutrient exhaustive nature. Its root system spreads in the top 60 cm soil layer and forms a large mat of rhizosphere. Of the commonly applied plant nutrient elements, nitrogen (N) is the most important for banana production. The indispensability of N application for banana is well understood by the growers. Very often, there is excessive use of chemical N with low input of organic matter. This not only creates soil fertility hazards, but enhances the cost of production also. The ever increasing price of fertilizer N aggravates the problems. In recent years, therefore, the concept of IPNS has been developed so as to achieve high crop yield, preventing at the same time, resource base degradation on a sustained basis. In the Integrated Plant Nutrition System (IPNS), organic and biological sources of nutrients which are renewable in nature are utilised in conjunction with mineral fertilizers in order to benefit from the positive interactions emanating from their integrated use. The components of IPNS consists of organic manures, bionutrient resources and mineral fertilizers. Low cost growth regulators like 2,4-D could also be included in the management system considering their immense potential for increasing fruit yield in banana. The literature relevant to the present investigation is reviewed under the following broad sections.

(1) Role of N on growth and development of banana.

(2) Effect of N on fruit yield and quality attributes.

(3) Effect of *Azospirillum* on banana and other non-graminaceous plants.

(4) Effect of organic manures/vermicompost on banana and other crops.

(5) Effect of legumes/green manures on banana and other fruit crops.

(6) Effect of 2,4-D on the yield of banana and other fruit crops.

(7) Effect of 2,4-D on the quality attributes of fruit crops.

2.1. Role of N on growth and development

A large number of studies have been conducted on nutrition and fertilization of banana in different parts of the world under varying soil and agroclimatic conditions and with different clones.

Nitrogen has long been recognised as a plant nutrient associated with rapid growth. Tanaka (1937), based on sand culture experiments with the variety 'Hikushu', reported that N was the most important nutrient for plant growth and its omission led to poor growth. Croucher and Mitchell (1940) concluded, from their manurial trial with the banana cv. 'Gros Michel', that response to applied N was significantly positive at various locations in Jamaica. They also observed that foliar application of 1500 ppm N caused precocity of flowering besides increasing the fruit yield. Nair (1953) obtained good response to N application in banana cv. 'Poovan' in the heavy clayey soils of Adithurai, Tamil Nadu.

Steinhausen (1957) reported that N promoted vegetative growth in banana. Murray (1960), and Butler (1960) found that N deficiency led to marked reductions in leaf number, leaf size and suckering. Katyal and Chadha (1961) and Venkatesan *et al.* (1965) also made similar observations.

While comparing the number of leaves produced by N treated and untreated banana plants, Shanmugam and Velayutham (1972) observed that at flowering, the former treatment had produced 17 leaves as against 7 by the latter.

The beneficial effect of N on early growth and development became evident, according to Anjorin and Obigbesan (1984), only when moisture was not limiting. They also found that application of N upto 300 g plant^{-1} significantly increased plant height, pseudostem girth, pseudostem weight and leaf weight. However, at higher rates at and above 400 g plant^{-1}, applied N had a depressive effect on all these parameters. The positive influence of applied N on height and girth of pseudostem of banana has also been reported by Ashokkumar (1977), Chattopadhyay *et al.* (1980) and Valsamma (1980).

In a nutritional trial on banana cv. Robusta, Kohli *et al.* (1984) found that plant height and pseudostem girth increased significantly with incremental doses of N (0 to 750 g plant^{-1}). However, the effect of different levels of N on number of leaves plant^{-1} was not significant. On the other hand, Singh and Kashyap (1992) obtained higher pseudostem circumference and larger number of leaves plant^{-1} with 400 g N plant^{-1}. Arunachalam *et al.* (1976) also found positive correlation for pseudostem height, girth and leaf area with soil N as well as applied N.

Oubahou and Dafiri (1987) recommended 225-425 g N plant^{-1} for banana cv. Giant Cavendish for increasing plant height, pseudostem girth, and other yield components. These observations were later confirmed by Nair (1988), Thangaselvabai (1989) and Prabhuram (1992).

Mustaffa (1988) found that N levels (50,100, 150, 200 and 250 g N plant^{-1}) exerted a significant positive influence on pseudostem height, girth and number of leaves and that 250 g N plant^{-1} had the maximum values for all these parameters.

Sheela (1995) studied the response of tissue cultured nendran banana in reclaimed kayal lands of Vellayani and reported that applied N had no influence on leaf production month^{-1}, leaf retention month^{-1} and total number of leaves. Nevertheless, N influenced the height of pseudostem at the 5th month stage and girth at the early stages of growth.

2.1.1. Effect of N on crop duration

The influence of N on crop duration was first reported by Croucher and Mitchell (1940) in Jamaica. They observed earliness in flowering by two months due to N application. Later, similar observations were made by Steinhausen (1957), Butler (1960) and Venkatesan *et al.* (1965). Ramaswamy and Muthukrishnan (1974) recorded a reduction of 29 days in crop duration at the N level of 170 g plant^{-1}. Kohli *et al.* (1984), Thangaselvabai (1989), Nair (1988), Prabhuram (1992) and Singh and Kashyap (1992) also reported reduction in shooting time ranging from 5 to 16 days due to applied N.

Contrary to these findings, Gopimoney *et al.* (1979) found that N prolonged the maturity period in banana cv. Zanzibar (nendran). Valsamma (1980) observed similar results in banana cv. Palayankodan. Sheela (1995) observed that applied N (200, 300, 400 g plant^{-1}) had no significant influence on the duration of banana cv. Nendran.

2.1.2. Effect of N on fruit yield and quality attributes

Butler (1960) reported that N alone was effective in increasing banana fruit yield by 10-12 per cent and that a positive correlation existed between the individual bunch weight and the amount of N applied 6 to 7 months before the emergence of inflorescence.

Carpenter and Prevel (1965) opined that a total deficiency of N would seriously impair growth beyond flowering stage and that if flower bud differentiation coincided with a period of N deficiency, considerable reduction in yield and quality would occur.

Ramaswamy and Muthukrishnan (1974), in their studies on the yield response of banana cv. Robusta, observed that N was effective in maximising production. The critical N level in the leaf blade for maximum fruit yield was 1.4 per cent. The highest values for bunch weight, hand weight, fruit length and fruit circumference were obtained with 170 g N plant^{-1} and all these parameters showed a positive correlation with soil N. Beyond that level, all the parameters showed a decreasing trend. Similar observations were made by Jagirdar *et al.* (1963).

Randhawa *et al.* (1973) reported that banana cv. Robusta produced the maximum fruit yield (44.2 t ha-^{1}) when N was applied at the rate of 180 g plant^{-1}. Kohli *et al* (1976) got corraboratory results in banana cv. Robusta.

Ramanathan *et al.* (1973) found that in banana cv. Poovan, neither the forms (ammonium chloride and ammonium sulphate) nor the levels (55, 73.3, 91.6 and 110 g N plant-^{1}) of N had any effect on yield.

Singh *et al.* (1974) obtained an yield of 5.75 kg plant^{-1} when 168 g N, 84 g P and 336 g K were applied. They also found that application of N increased the number of hands and fingers.

Arunachalam *et al.* (1976) reported that positive correlations existed between soil N and foliar N and the yield attributing characters like bunch weight, number of hands, number of fruits, fruit length, fruit circumference, fruit density and pulp peel ratio. According to him, N (170 g plant^{-1}) increased the bunch yields by 24.0, 18.7, 27.0 and 17.7 per cent in cultivars, dwarf cavendish, giant cavendish, robusta and lacatan, respectively. A significant increase in number of hands and fingers was also noted at the same level (170 g plant^{-1}). Similar observations were made by Sunder Singh (1972), Ashokkumar and Shanmughavelu (1978), Chattopadhyay *et al.* (1980) and Holder and Gumbs (1983).

Pillai *et al.* (1977) observed that N levels (114 and 228 g plant^{-1}) had a significant influence on fruit number and bunch weight in banana cv. Nendran. The mean increase in fruit weight at 114 g of N, was 13 g^{-1} of applied N and beyond that level, the increase in bunch weight was marginal. The studies conducted at the Banana Research Station, Kannara, Kerala also indicated the positive effect of N on bunch weight in cv. Palayankodan (Aravindakshan *et al.*, 1996).

In her investigations on the yield response of banana cv. palayankodan to N (0, 100, 200, 300 and 400 g plant^{-1}), Valsamma (1980) found that bunch yield significantly increased up to the level of 200 g N plant^{-1}. Beyond that level, fruit yield declined. The dry matter production, on the other hand, showed a linear increase with increasing levels of applied N. Kohli *et al.* (1984) reported that application of N at the rate of 150 g plant^{-1} resulted in a 50 per cent increase in the total dry matter production in banana cv. Robusta. A further increase in N did not result in any significant enhancement in dry matter production. They also observed significant correlation between yield and foliar N level in the 16th leaf stage. Sankar and Rao (1993) obtained an increasing trend in bunch weight upto 100 g N plant^{-1}.

Sheela (1995) in her studies on the response of tissue cultured banana cv. Nendran to different levels of N (200, 300 and 400 g plant^{-1}) obtained the highest bunch yield (12.54 kg plant^{-1}) and the maximum number of fingers bunch^{-1} (50.02) with N applied at the rate of 300 g plant^{-1}.

Arunachalam (1972) reported an improvement in chemical composition of banana fruits due to application of N. Valsamma (1980) reported that N markedly improved the quality of fruits in respect of TSS, total sugars, reducing sugars and non-reducing sugars in banana cv. Palayankodan. The highest ascorbic acid content (7.81 mg 100 g^{-1}) and sugar acid ratio (35.51) and the lowest acidity (0.46%) were observed with N applied at the rate of 200 g plant^{-1}. Sankar and Rao (1993) observed that N markedly influenced the quality of fruits in banana cv. Robusta. They also found that the starch content increased upto 100 N plant^{-1} and declined thereafter.

According to Sheela (1995), the higher levels of applied N (300 g and 400 g plant^{-1}) decreased the reducing sugar content in banana fruits. But, the acidity of fruits increased with an increase in level of N from 200 g to 400 g plant^{-1}. She also noted a reverse trend in sugar acid ratio. Further, applied N had no influence on the pulp-peel ratio of fruits. Contrary to these results, Ram and Prasad (1988) reported that in banana cv. cambiergang applied N levels (100, 200 and 300 g plant^{-1}) had no effect on starch content and acidity of fruits.

2.2.1. N requirement of banana

Prevel (1966), based on sand culture experiments, reported that the quantity of N removed from the soil ranged from 1.05 kg to 2.05 kg per tonne of fruits. According to him, the optimum dose of N for maximum fruit yield depended on edaphic conditions and the cropping systems adopted.

Champion *et al.* (1958) got yield increases ranging between 18 and 25 tons ha^{-1} in banana cv. Robusta, with the application of N varying from 100 to 200 kg ha^{-1}. Bhan and Majumdar (1965) recommended a dose of 220 g of N plant^{-1} for banana cv. Martaman (AAB) (Syn. Rasthali).

Teaotia and Dubey (1971) obtained a significant increase in yield over the control with 90 g N plant^{-1}.

Veeraraghavan (1972) recorded significant increases in the number and weight of fruits in `Nendran' banana with 228 g N, 228 g P_20_5 and 456 g K_20 plant^{-1}.

Rao (1974) recommended 225 g of N clump^{-1} to be applied in two split doses within four months of planting in the forms of groundnut cake and ammonium sulphate in the deltaic areas of West Godawari district.

Pillai *et al.* (1977) in their nutritional studies on banana cv. Nendran with different levels of NPK (0, 114 and 228 g N and P_20_5, and 0, 228 and 456 g K_20 plant^{-1}) found that the optimum doses of N and K for realising maximum yield were 191 and 301 g plant^{-1}, respectively. The response to P was not significant.

Nambiar *et al.* (1979) reported that 225 g of N in combination with 225 g P_20_5 and 450 g K_20 plant^{-1} applied in two split doses at 30 and 150 days after planting resulted in the maximum bunch weight (9.73 kg plant^{-1}) in banana cv. Nendran. Aravindakshan (1996) found that in banana cv. Nendran the optimum doses of N, P and K for maximum bunch yield were respectively, 150, 150,300 g plant^{-1} under the conditions existing at Pilicode, Kerala.

Nair (1988) obtained the maximum yield (12.5 kg plant^{-1}) in banana cv. Nendran with the application of 400 g N and 600 g K_20 plant^{-1} in five split doses

Sanker and Rao (1993) got significantly good bunch weight with 100 g N and 15 g P_20_5 plant^{-1}. Valsamma (1980) reported that the bunch yield significantly increased upto the level of 200 g N plant-^{1} and that further increase to higher levels depressed the yield.

The experiments conducted at the Banana Research Station, Kannara to find out the optimum requirement of NPK for banana cv. Palayankodan, revealed that N doses of 150 and 300 g plant^{-1} were on par but significantly superior to the control with respect to bunch weight and number of hands bunch^{-1}. In another study with banana cv. Robusta, it was found that 100 g N plant^{-1} were sufficient for higher yield (Aravindakshan, 1996).

Kohli *et al.* (1984), from I.I.H.R., Bangalore reported that application of 150 g of N plant^{-1} was sufficient for banana cv. Robusta to give high yield (13.45 kg plant^{-1}). According to Reddy (1992), a dose of 200 g N plant^{-1} was necessary for higher average bunch weight as well as fruit yield in banana cv. Robusta. Langenegger (1984) in his nutrient study with two cultivars (Cavendish and Williams) of banana found that the most economical dose was 240 g N plant^{-1}.

Randhawa and Iyer (1978) recorded at I.I.H.R., Bangalore, high sugar content and low acidity in banana fruits produced by plants receiving N at the rate of 150 g plant^{-1}. The test variety was Basrai (Syn. dwarf cavendish). Singh *et al.* (1979), Chundawat *et al.* (1983) and Mustaffa (1983) reported similar results.

The fertilizer studies conducted on banana cv. robusta by Pillai and Khader (1980) in Tamil Nadu, revealed that the plants receiving 250 kg N, 100 kg P_20_5 and 1000 kg K_20 ha^{-1} in three split doses produced significantly heavier bunches.

Nanjan *et al.* (1980) reported that in Periyar river command area, the optimum doses of nutrients for maximum fruit yield in banana cv. Poovan were, 100 g N, 40 g P_20_5 and 350 g K_20 plant^{-1}. The ratoon crop required 200 g N, 40 g P_20_5 and 350 g K_20 plant^{-1}.

Obiefuna and Onyole (1987) found that an annual application of 200 g N plant^{-1} produced the heaviest bunch in Cavendish cultivar. Dave *et al.* (1990) recommended application of 180 g each of N, P and K for basrai banana in South Gujarat.

Selvaraj and Azhakiamanavalan, (1992) observed that the optimum level of N depended on varieties, with banana cv. Poovan requiring 160 g plant^{-1} and rasthali and nendran, 210 g each plant^{-1}.

The experimental results reviewed briefly in sections 2.1 and 2.2 reveal that banana is highly responsive to applied N with the optimum level depending on the genotype and the edaphic conditions. The beneficial effect of N results in an increase in yield attributing growth parameters like leaf number and leaf area and the bunch characters like number of hands bunch^{-1}, fingers hand^{-1}, finger size and fruit weight.

2.3. Effect of *Azospirillum* on banana and other nongraminaceous plants

The biofertilizers consisting of N_2 fixing organisms help to tap the N_2 present in abundance in the atmosphere, thus augmenting its supply to soil and crops. *Azospirillum* is an associative microaerophilic N_2 fixer. It colonises the rootmass and fixes N_2 in an environment of low oxygen tension. These bacteria induce the plant roots to secrete a mucilage which creates low oxygen environment and thereby helps to fix atmospheric N_2. High N_2 fixing capacity, low energy requirement, rapid proliferation in the roots of cereals and tolerance to high soil temperature (30-40^{0}C) make these organisms the most suitable for tropical conditions (Marwaha, 1995; Rao *et al.*, 1983). Tien *et al.* (1981) observed that *Azospirillum* softened middle lamella through the action of pectinolytic enzyme thus enhancing mineral absorption. Tien *et al.* (1979) reported that *Azospirillum* secretes growth promoting substances besides fixing N_2. Govindan and Chandy (1985) reported the superiority of *Azospirillum* inoculation over IBA treatment in inducing rooting in black pepper cuttings. According to Verma (1993), the yield increases due to *Azospirillum*, in many crops are due mainly to the release of growth promoting agents and protection from diseases than is from their N contribution by fixation.

Azospirillum inoculation is known to increase yield of crops by 5 to 20 per cent with a saving of N upto 40 per cent of the recommended dose (Dart and Wani, 1982). Several workers have noted significant increase in grain yield due to inoculation of *Azospirillum* with different doses of fertilizer N (Subbarao *et al.*, 1979; Rao *et al.*, 1983).

2.3.1. Effect of *Azospirillum* on banana

Govindan and Purushothaman (1985) proved the association of *Azospirillum* with banana and several plantation crops.

In a field trial conducted by Jeeva (1987) at Coimbatore with banana cv. Poovan to find out the effect of *Azospirillum* inoculation in combination with graded levels of fertilizer N, it was found that *Azospirillum* enhanced the height, midgirth of pseudostem, leaf number and leaf area. Besides, it enhanced the contents of N, P, Ca and Mg in leaves and reducing, non-reducing and total sugars in fruits. The results also indicated yield increase upto 13.1 per cent with the inoculation of *Azospirillum*. Combined application of *Azospirillum* with 75 per cent of the recommended dose of fertilizer N recorded the highest cost benefit ratio of 2.84.

Thangaselvabai (1989) studied the effect of split application of N and *Azospirillum* in banana cv. Rasthali. The results revealed that application of *Azospirillum* along with 100 and 75 g fertilizer N plant^{-1}, significantly increased the morphological characters like plant height, girth, number of leaves, leaf area, number of suckers plant^{-1} and yield. Besides, the total crop duration was reduced by 5-16 days. It was also observed that the bunch characters and dry matter production were significantly influenced by the split dressings of the higher dose of N (200 g plant^{-1}) and *Azospirillum*. The treatment influenced the quality of fruits in respect of total soluble solids (Brix), reducing and total sugars, ascorbic acid and starch contents. However, the highest bunch weight (19 kg plant^{-1}) was recorded by the treatment receiving *Azospirillum* and the normal recommended dose of fertilizer N (100 g plant^{-1}).

Wange and Patil (1994) reported that combined application of 100 per cent N + *Azotobacter* + *Azospirillum* improved the plant height, number of leaves, plant girth and yield in banana cv. `Basrai' .

2.3.2. Effect of *Azospirillum* on other crops

The field experiments conducted in Tamil Nadu to study the interaction effect of *Azospirillum* and fertilizer N on the yield of bhindi cv. C0-2, indicated that soil application of *Azospirillum* improved the yield and N use efficiency at 50 per cent of the recommended dose of N (Subbiah, 1991).

Thamburaj (1991) found that *Azospirillum* effected a saving of 25 per cent of the fertilizer recommendation in onion. Similar observations have been reported by Singh and Sharma (1993) in sweet orange and Subbiah (1994) in chilli.

Balasubramanian and Manickasundaram (1994) in their studies on high intensity cropping system viz., sorghum - sorghum ratoon - maize - sunflower with intercrops, observed that irrespective of the cropping systems, the treatment receiving biogas slurry with 75 per cent of the recommended N dose + *Azospirillum* inoculation to each crop needed less energy. Thus, considerable amount of energy could be saved by combined application of biodigested slurry and *Azospirillum*.

Anisarani (1995) reported that *Azospirillum*, phosphobacteria and VAM along with fertilizer N increased the fruit number by 39 per cent in papaya. It also increased total sugars, vitamin C and carotenoid contents in the fruit.

It is quite clear from the review that *Azospirillum* inoculation is an effective means of reducing the dependence on fertilizer N for field crops. The savings in fertilizer N computed in the case of banana is 25 per cent of the recommended dose. Besides, this practice in combination with fertilizer N, leads to impressive yield increases in the range of 13 to 25 per cent.

2.4. Effect of organic manures/vermicompost on banana and other fruit crops

2.4.1. Organic manures

Considerable volume of scientific data are available to show that the produce obtained from organic farming is nutritionally superior with respect to taste, lustre and keeping quality. The longer storage life of spinach grown with organic manure was found to be associated with lower levels of free aminoacid and nitrates and higher protein N to nitrate ratio (Mishra and Kapoor, 1992).

Studying the manurial requirement of `Poovan' banana in Tamil Nadu, Nair (1953) reported that application of N at the rate of 114 g plant^{-1} in the form of FYM at planting followed by 227 g of N in two equal split doses at 90 and 150 DAP resulted in the maximum bunch weight. Srivastava (1961) got larger fingers, heavier bunches, early flowering and ripening in `Basrai' banana by the application of a mixture of 681 g ammonium sulphate (340 g), 13.500 kg FYM and 1.6 kg of caster cake plant^{-1}.

Lahav (1973) found that in banana, application of FYM upto 80 t ha^{-1} year^{-1} enhanced the growth, hastened flowering and shortened the flowering to harvest period and increased the bunch yield by 33 per cent.

Lassoudiere and Godefroy (1971) obtained the best yield response with the application of banana bunch stalk at the rate of 80 t ha^{-1}.

Kotoky and Bhattacharyya (1991) found that organic mulches significantly increased the bunch weight and they could be profitably utilised for commercial banana production.

A study conducted at the Kerala Agricultural University, Vellanikkara, Kerala revealed that the optimum ratio of organic manure to inorganic N for banana was 25:75 and the best source of organic manure was neem cake containing 5.2 per cent N (950 g plant^{-1}) followed by FYM containing 0.4 per cent N (12.5 kg plant^{-1}) (KAU, 1993). Similar results were reported by Prabhuram (1992) and Indira (1997) wherein the organic sources tried were FYM and green manure, respectively.

Contrary to these results, Gomes *et al.* (1995) observed no significant difference in yield between the control and different sources and quantity of organic manure. Similarly, Lahav (1977), reported that the banana cultivars `Nanica and Williams Hybrid ' (AAA Group) cultivated in soils with 1.5 per cent of organic matter showed no significant yield response to the application of 30, 60 and 210 m^3 ha^{-1} of FYM.

2.4.2. Vermicompost

The earthworms are now being meaningfully employed in the preparation of compost. Vermicomposting means the use of earthworms for composting organic residues. It is estimated that 1000 tons of moist organic matter could be converted by earthworms into 300 tons of compost in a period of 2 months (Tapiador, 1981). The amount of soil these organisms pass through their bodies, is estimated to be as high as 15 t ha^{-1} year^{-1}. The earthworm casts are higher in bacteria, organic matter, total and nitrate N, available P and K (Brady, 1994; Gaur, 1982). The nutrients present in vermicompost are readily available to plants. The increase in earthworm population resulting from the application of vermicompost leads to easy transfer of nutrients to plants. As such, the availability of nutrients in earthworm rich soils is considerably high (Robinson *et al.*, 1992). According to

Gaur and Sadasivam (1993), vermicomposting is a fast and safe waste disposal method. Besides, it increases the availability of plant nutrients, controls pathogenic organisms and eliminates unfavourable odours. The humus material formed after the decomposition of organic matter influences the physical, chemical and biological characteristics of the soil and improves crop growth.

2.4.2.. Effect on crops

Rhee (1969) observed a tenfold increase in clover yields after inoculation with earthworms. Sharpley and Syres (1977) found increased P availability to plants with the use of vermicasts.

Kale and Bano (1983) indicated the possibility of replacing chemical fertilisers with vermicompost in their preliminary field trials with IR-20 rice. According to Senapathi *et al.* (1985), the application of worm-worked compost resulted in a 95 per cent increase in rice yield. The improvement in straw yield was 128 per cent.

Sacirage and Dzelilovic (1986) also found that by the application of 4, 6 and 8 kg m^{-2} of vermicompost, the cabbage dry matter yield increased from 1 to 66 per cent.

Kale *et al.* (1987) studied the influence of wormcast on the growth and mycorrhizal colonization of two ornamental plants (salvia and aster) and reported that the wormcast, when used as a manure in the place of FYM, significantly influenced both vegetative and flowering characters and increased mycorrhizal root colonization.

Curry and Boyle (1987) reported enhanced plant growth in the presence of earthworms. The beneficial influence was attributed to increased supply of readily available plant nutrients, and better soil physical conditions.

Shuxin *et al.* (1991) got 30-50 per cent increases in height, tillering, cane diameter and N uptake in sugarcane with the application of vermicompost. They also reported a 25 per cent increase in height and 50 per cent increase in weight of soyabean plants with the use of vermicompost.

Reddell and Spain (1991) suggested that part of growth stimulation credited to earthworms was attributable to more rapid and intensive infection by mycorrhizal propagules which almost was ubiquitous in earthworm casts under field situations.

Kale *et al.* (1992) found significantly higher levels of uptake of N and P in rice treated with vermicompost.

Gunjal and Nikam (1992) recommended earthworm inoculation in combination with heavy mulching with agricultural wastes for higher grape production without application of chemical fertilizers. Barve (1993) found an increase in fruit yield besides improvement in quality, both in taste and lustre, with the application of vermicompost to grapes. He also indicated a reduction in cost of cultivation.

Phule (1993) obtained more sugarcane yield from vermicompost-treated plots. The juice had 3-4 extra brix and lesser salts as compared to that of canes treated with chemical fertilizers. In watermelon, vigorous growth and increased number of flowers and fruits were observed when treated with vermicompost (Ismail *et al.*, 1991).

By applying vermicompost, Khamkar (1993) obtained healthier coccinia plants with higher yield. The fruits had better keeping quality. The study also indicated a reduced cost of cultivation through low labour cost and low doses of fertilizer and pesticides.

Vadiraj *et al.* (1993) reported that use of vermicompost as a component of potting mixture in cardamom nursery helped in seedling growth and dry matter production in a short span of time.

Dharmalingam *et al.* (1995) found that by pelleting soyabean seeds with vermicompost, seed yield could be increased by 16 per cent over the conventional practice.

Pushpa and Prabhakumari (1997) got an yield of 25 t ha^{-1} from tomato with the application of 25 tonnes of vermicompost ha^{-1} in combination with inorganic fertilizers containing 75 kg N, 25 kg P and 25 kg K ha^{-1}. The yield attributes like weight and girth of fruits and plant characters like height, number of leaves, number of flowers and fruits increased significantly with the application of vermicompost.

Govindan *et al.* (1995) found that application of vermicompost at the rate of 12 t ha^{-1} resulted in the maximum vegetative growth (height of plant, number of leaves and number of branches $plant^{-1}$) and the highest fresh fruit yield (176.03 g $plant^{-1}$). They also observed that the fruit yield increased with the increased substitution of FYM with vermicompost.

Rajalekshmi *et al.* (1997) in their studies on various organic manures in combination with chemical fertilizers (NPK @ 75:40:25 kg ha^{-1}) on chillies found that the yield was the highest (8.36 t ha^{-1}) in the treatment receiving vermicompost + NPK fertilizers and the lowest in vermiculture (alone) treatment.

Ushakumari (1996) reported that 12 t ha^{-1} of vermicompost applied along with full and $^{3}/_{4}$th recommended dose of inorganic fertilizers for bhindi (NPK

50-8-25) yielded respectively, 43 and 26 per cent more fruits than that of 12 t FYM and inorganic fertilizers .

Jiji *et al.* (1996) showed that vermicompost when applied along with the full dose of inorganic fertilizers increased the yield by 21.1 and 19.0 per cent in bittergourd and cowpea, respectively.

The foregoing review reiterates the need for enriching agricultural lands with crop residues and other sources of organic matter so as to improve the soil physical conditions and productivity. Vermicompost is a better alternative to other forms of organic manure as the nutrients present in it is readily available to plants. The yield response of crops to fertilizers become more evident when they are applied in combination with vermicompost.

2.5. Effect of legumes/green manures on banana and other fruit crops

Green manuring has been a common agricultural practice from time immemorial. The practice brings about a number of favourable effects in the soil leading to better crop producing capacity. Green manure crops provide N in the range of 40-80 kg ha^{-1} to the succeeding crop. They meet their own N requirement and also leave some N to the companion and succeeding crops (Mishra and Kapoor, 1992). However, the amount of N fixed by legumes through root nodule bacteria exhibits considerable variation. The fixation of N is influenced by soil factors, particularly, nutrient status (Rai and Brahmaprakash, 1993). The fertilizer N equivalent of cowpea was 60 kg ha^{-1} when maize was grown as succeeding crop and it was 38 kg ha^{-1} when wheat was grown. For other legumes, the fertilizer N equivalent ranges from 20 to 123 kg ha^{-1} (Wani *et al.*, 1991).

In legume based cropping systems, the increased availability of soil N contributes significantly to soil fertility. However, other factors such as enhanced availability of nutrients other than N, improved soil structure, reduced disease incidence and faster mycorrhizal colonization are also responsible for increased yields (Cook and Ellis, 1987; Wani *et al.*, 1991).

One of the advantages of using green manures as source of N is that a larger proportion of the N accumulated is generally available for return to the soil because much less N is removed from the system in agricultural produce as compared to the quantity of N harvested in the seed of legume crops. There may be exceptions. A number of rotational trials have demonstrated that legumes can increase the capacity of soils to supply plant available N regardless of whether detectable changes in total soil N are noticed or not (Peoples *et al.*, 1995).

Peoples and Crasswell (1992) reported an increase in the yield of succeeding nonlegumes (after legumes), by 0.5 to 3 t ha^{-1} representing a 30 to 350 per cent increase. Kumar *et al.* (1983) observed that the grain yield of maize following pigeonpea was 57 per cent more than that of maize grown after fallow.

Ahlawat *et al.* (1981) indicated that maize yield was higher when it was followed by legumes, than wheat or fallow. Ramakrishnan and Rangarajan (1993) obtained an yield increase of 180 per cent in rice by the incorporation of cowpea at 60 days after sowing over no manure application and the treatment contributed 74 kg N ha^{-1} to soil.

Verma (1993) reported that there was an increase of 16.3 per cent in wheat yield when it was taken after pigeonpea. When rice was grown after chickpea and lentil, the yield increases were 7.9 and 13.2 per cent, respectively.

2.5.1. Effect of green manures on banana

Ravikumar (1980) found that growing lab-lab in the interspaces of banana had a complementary effect and it in no way affected the dry matter production.

According to Chacko and Reddy (1981), growing cowpea as an intercrop in banana resulted in the development of a dense canopy covering the entire ground area and suppressed weed growth completely for a period of 70 days. Besides, the biomass produced, which later formed a mulch on the soil, was advantageous in reducing soil moisture evaporation. The amount of N added to the soil by cowpea biomass itself justified the cost of initial cowpea seed material used for sowing. All these were reflected by way of high banana yield.

Valsamma *et al.* (1987) reported that intercrops like cowpea, ginger, turmeric and tuber crops did not affect the growth and yield of banana. Savithri (1990) found that intercropping cowpea in banana basins could reduce the weed population, weed dry matter and nutrient removal by weeds up to its harvest (60 days). Nybe *et al.* (1991) from their studies on weed control in banana concluded that the most effective and economic method of weed control in banana was to raise two crops of cowpea in succession - the first at the time of planting of banana and the second, immediately after the incorporation of the cowpea crop.

Prabhuram (1992) observed that a green manure crop like sesbania along with 25 per cent of the recommended dose of N (200 g N plant^{-1}) as FYM and the rest as urea, recorded high fruit yield in banana.

Ray and Yadav (1996) obtained the best yield in banana (77.2 t ha^{-1}) by applying 25 per cent of the recommended dose of N as FYM (5.5 kg plant^{-1}), *in situ* green manuring with cowpea and 75 per cent of the N as inorganic fertilizers (NPK 150:37.5:150 g plant^{-1}). An economic analysis of the data further confirmed that it was the most remunerative with a B:C ratio of 2.5.

2.5.2. Effect of green manure on other crops

Chen and Wang (1987) investigated the effect of green manuring on soil chemical properties and the growth performance of three important grain crops. The application of 22.5 to 30 tonnes ha^{-1} of green manure for five years increased the soil organic matter content by 7.3 to 33.6 per cent. The quality of soil organic matter and active organic matter content were also increased. It also helped to increase the yield of wheat, rice and maize by 956 kg, 805 kg and 2474 kg ha^{-1}, respectively.

Singh *et al.* (1989) reported that growth and yield of rainy season onion increased significantly with the addition of N, P and green manures. In contrast, Mustaffa (1990) found that green manuring *in situ* with either peas, lupins, soyabean or rape beans did not have any effect on the quality and yield of maize.

Wani (1992) estimated the residual effect of leguminous crops on succeeding cereal crops ranging in nutrient value from 20 to 120 kg ha^{-1}. Giri and Pal (1994) estimated the nitrogen requirement of succeeding wheat at 66 and 123 kg N ha^{-1} respectively, when the preceding pigeon pea was intercropped with and without fodder cowpea. Siddeswaran and Palaniappan (1994) found out that the fertilizer equivalent of cowpea haulms was at 18-20 kg.

Studies conducted by Prasad *et al.* (1995) revealed that integrated use of green manure and organic manure with chemical fertilizers built up the available nutrient status of the soil and was much more effective than the use of chemical fertilizers alone in augmenting crop productivity and nutrient availability in calcareous soils in a rice wheat cropping system.

The experimental results outlined in this section suggest that it is a good cultural practice to raise a leguminous green manure crop like cowpea in the banana gardens. The intercrop controls weeds and enriches the soil with nitrogen. Further, the soil organic matter status is improved when the intercrop is incorporated.

2.6. Effect of 2,4-D on banana and other fruit crops

The plant growth is controlled by certain chemicals produced by the plant itself. These chemicals are called hormones. Some synthetic growth regulating chemicals produce such effects through changing the internal levels of the naturally - occurring hormones, thereby causing a modification of growth and development in the desired direction and to the desired extent (Nickell, 1986). Auxins are the most important plant growth substances and 2,4 Dichlorophenoxy acetic acid (2,4-D) is a synthetic auxin (Noggle and Fritz, 1989). The application of 2,4-D has been reported to increase growth, yield and quality of produce in many of the cultivated crops.

2.6.1. Effect of 2,4-D on banana

Anbazhagan (1978) got increased bunch weight, fruit weight, fruit length and pulp weight of banana with the application of 2,4-D at the rate of 25 ppm. The treatment also hastened maturity and thus shortened the total cropping period. Further, there was a spectacular increase in the net profit over the control.

The response of three banana cultivars - Poovan, Monthan and Nendran - to 2,4-D was studied by Anbazhagan and Shanmughavelu (1980). They found that 2,4-D at the rate of 25 ppm appreciably increased the bunch weight and advanced the maturity of bunches. Aravindhakshan (1981) experimented the effect of pre-harvest application of 2,4-D at 3 levels viz., 2 ppm, 4 ppm, and 10 ppm on nendran banana and found that all the treatments increased the finger length and weight. The maximum increase in weight (191.8 g fingers^{-1}) was brought about by the dose 10 ppm.

Rajendran (1983) reported that 2,4-D application in the range of 10-20 ppm significantly reduced the total crop duration (15-22 days) and increased the bunch weight, number of hands bunch^{-1} and number of fingers bunch^{-1}. When the rate of 2,4-D application was increased from 5 to 20 ppm, the corresponding increases in bunch weight was 16 to 88 per cent.

Chellappan (1983) in his studies on the yield response of banana cultivars to graded levels of 2,4-D, observed that Matti (8.49 kg bunch^{-1}), Neypoovan (10.17 kg bunch^{-1}) and Robusta (19.06 kg bunch^{-1}) registered the highest bunch weights at 30 ppm.

Application of 2,4-D (20 ppm) immediately after the opening of the last hand completely removed the seediness in Kottaivazhai and the treated bunches were found better than the normal poovan in respect of bunch and fruit characters (Vijaykumar and Shanmughavelu, 1983).

Satyanarayana (1985) observed that 2,4-D applied at the rate of 25 ppm resulted in a significant improvement in fruit size, fruit weight and bunch weight while at 50 ppm it had a depressive effect.

2.6.2. Effect of 2,4-D on the yield of other crops

Singh *et al.* (1959) reported that application of 2,4-D at the rates ranging from 10 to 40 ppm enhanced the size of fruit in Fajri variety of mango. Chadha and Singh (1963) observed an increase in fruit length, when 2,4-D was sprayed on Langra mango. Staggered application of 2,4-D from bud differentiation stage till the fruits were 2 to 3 cm in diameter, resulted in larger fruit size and higher weight (Veera and Das, 1971). Increased fruit size was also observed by

Maurya *et al.* (1979), when mango fruits of pea size were sprayed with 2,4-D at fortnightly intervals till harvest. Similar effect was noticed in Banarasi variety of ber by Singh and Singh (1976).

Hield (1967) reported that spraying 2,4-D on small green citrus fruits increased the fruit size but in oranges it enhanced the rind thickness and roughness. In sweet orange, Sharma and Randhawa (1967) found that 2,4-D applied at the rate of 20 ppm effected the greatest increase in fruit size. Singh and Gupta (1972) observed the maximum fruit weight in Mosambi orange by spraying 2,4-D at the rate of 20 ppm at flowering stage. Sinha *et al.* (1977) recorded significant increases in the size (length and diameter) and weight of fruits and juice percentage with foliar application of 2,4-D at the rates ranging from 10 to 20 ppm on Nagpur santra oranges. Hochberg *et al.* (1977) reported that the increase in grape fruit size due to 2,4-D application was only marginal.

In sweet lime, Kumar *et al.* (1975) found increased fruitset and delayed fruit maturity due to 2,4-D sprayed at the rates ranging from 5 to 20 ppm at full bloom stage.

Babu *et al.* (1984) reported that 2,4-D effected a significant increase in fruit yield in Kagzi lime. They also observed that the fruit drop was minimum with 20 ppm 2,4-D treatment. The fruits, however, took 12 to 15 days more for maturation. In lemon, application of 2,4-D at the rate of 25 ppm produced the maximum diameter, weight and volume of fruits (Kumar *et al.*, 1991).

Srivastava *et al.* (1973) observed that 2,4-D sprayed at pit-hardening stage hastened fruit maturity by 5 to 8 days in peach cv. Alexander.

While Bajwa and Mishra (1969) observed increased fruit size in New Castle apricots with 2,4-D application, Srivastava *et al.* (1971) found no marked changes in fruit weight, volume and stone size of fruits.

Studies by Pollack and Fisher (1971) on apple, plum, sourcherry and raspberry revealed that application of sodium salt of 2,4-D advanced the fruit ripening. In sourcherry, Nyoki (1973) found that 2,4-D increased the fruitset at the expense of fruit size. In raspberry, Ivanova (1995) found that 2,4-D applied at the rate of 40 ppm during flowering increased the yield.

Venkatesan and Mohideen (1994) reported that foliar application of 2,4-D at the rate of 20 ppm increased the length, girth, weight and volume of fruit in pomegranate. Further, fruit juice and aril were was also increased.

Singh and Lal (1994) found that application of 40 ppm NAA followed by 1 ppm 2,4-D in winter season and 20 ppm NAA followed by 1 and 5 ppm 2,4-D in summer season was the most suitable practice for higher production of chilli, cv. Pant C-1.

Kumar *et al.* (1995) found that foliar application of 2,4-D at the rate of 5 and 10 ppm significantly increased the number of nuts and nut yield tree^{-1} in cashew as compared to control. The effect of the growth regulator was more pronounced under increased levels of NPK and this was attributed to their positive interaction effects.

2.7. Effect of 2,4-D on the quality attribute of fruit crops

2.7.1. Effect of 2,4-D on quality of fruits in banana

Anbazhagan (1978) reported that 2,4-D increased the levels of TSS ascorbic acid, total sugar and sugar acid ratio in fruits. It also promoted the pulp peel ratio and decreased nonreducing sugars.

Aravindhakshan (1981) found that application of 2,4-D increased TSS and reducing sugars. Rajendran (1981) obtained increased TSS and total sugar with the application of 2,4-D at the rate of 20 ppm on banana cv. Palayankodan.

Chellappan (1983) observed that 2,4-D increased the fruit TSS, ascorbic acid content and sugar acid ratio and reduced the acidity in all the cultivars of banana experimented. It also decreased the pulp peel ratio and increased the dry weight of fruits. Besides, 2,4-D raised the endogenous levels of auxins, gibberellins, cytokinins and inhibitor like substance during the course of fruit development.

2.7.2 Effect of 2,4-D on the quality of fruits in other crops

In Fajri variety of mango, 2,4-D applied at the rates ranging from 10 to 40 ppm improved the fruit quality (Singh *et al.*, 1959). Chadha and Singh (1963) reported increased ascorbic acid content in mango with 2,4-D application at 40 and 60 ppm. Veera and Das (1971) found that acidity, TSS and ascorbic acid contents were increased significantly when the fruits of mango cv. `Banganapalli' were treated with 40 ppm 2,4-D. Maurya *et al.* (1979) also got similar results in mango with respect to TSS and ascorbic acid contents.

In citrus, delayed colour development due to 2,4-D application was noticed by Hield *et al.* (1967). In Kinnow Mandarins, Chundawat and Randhawa (1975) found high levels of TSS and ascorbic acid and low acidity when 2,4-D at the rate of 10 ppm was applied along with 20 ppm aureofungin. In `Banarasi' variety of Ber, 2,4-D treatment increased the TSS content (Singh and Singh, 1976). Increased percentage of sugars and reduced ascorbic acid contents were recorded by Sinha *et al.* (1977), when 2,4-D was sprayed on Nagpur santra oranges.

Kumar *et al.*, (1975) reported that 2,4-D at 5 to 20 ppm increased the TSS and ascorbic acid content of sweet lime. Veera and Das (1971) recorded the lowest ascorbic acid content and acidity in fruits of litchi cv. Muzaffarpur with 2,4-D application.

Pollack and Fisher (1971) reported that sodium salt of 2,4-D advanced the ripening, improved the fruit colour and increased the sugar and vitamin `C' contents of apples, plums, sourcherries and raspberries. Srivastava *et al.* (1973) reported enhanced fruit colour development when 2,4-D was applied at the pit hardening stage in peach cv. Alexander.

Pillai (1978) pointed out that 2,4-D application at the rates of 5, 10 and 20 ppm increased the reducing and nonreducing sugars in tomato but it had little effect on ascorbic acid content.

Kaur *et al.* (1990) got increased TSS, ascorbic content and pulp percentage and decreased peel percentage by the application of 2,4-D at 30 ppm in sweet orange.

Kumar *et al.* (1991) observed that in lemon cv. spring flush, 2,4-D at 50 ppm level produced the maximum TSS and acidity.

Siddiqui *et al.* (1995) found that application of 2,4-D did not affect the fruit qualities like TSS, acidity, ascorbic acid, starch and reducing and nonreducing sugars in ber.

It, thus, appears from the review that sodium salt of 2,4-D can be effectively used for enhancing the bunch weight in banana. The growth regulator does not impair the quality attributes of fruits. The optimum concentration of 2,4-D falls in the range of 5 to 30 ppm.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation, Integrated Plant Nutrition System (IPNS) for banana cv. Nendran, was conducted during two consecutive cropping seasons of 1994-'95 and 1995-'96 at the Regional Agricultural Research Station, Kumarakom. The materials used and methods adopted for the study are detailed below:

3.1. Location

The experimental site was located at Kumarakom ($9^0 3'$ N latitude 76^0 $3'$E longitude) at an elevation of 0.6 m below MSL. This area has been reclaimed from the Vembanad lake and converted into a bund and channel system a few decades ago for planting coconut. The bunds were of uniform size (100 m x 9 m) having an elevation of 1.2 m from the channel bottom.

The soil of the site was riverine alluvium of the order Entisol and sub order Psamments. The texture of the soil was silty clay. The physico-chemical characteristics of the soil are presented in Tables 1(a) and 1(b).

Table 1(a) Mechanical composition of the soil of the experimental site

Soil depth (cm)	Composition (%)			Method of analysis
	Sand	Silt	Clay	
0 - 30	65 - 70	4.4 - 5.0	22 - 28	Bouycos Hydrometer (Piper, 1966)

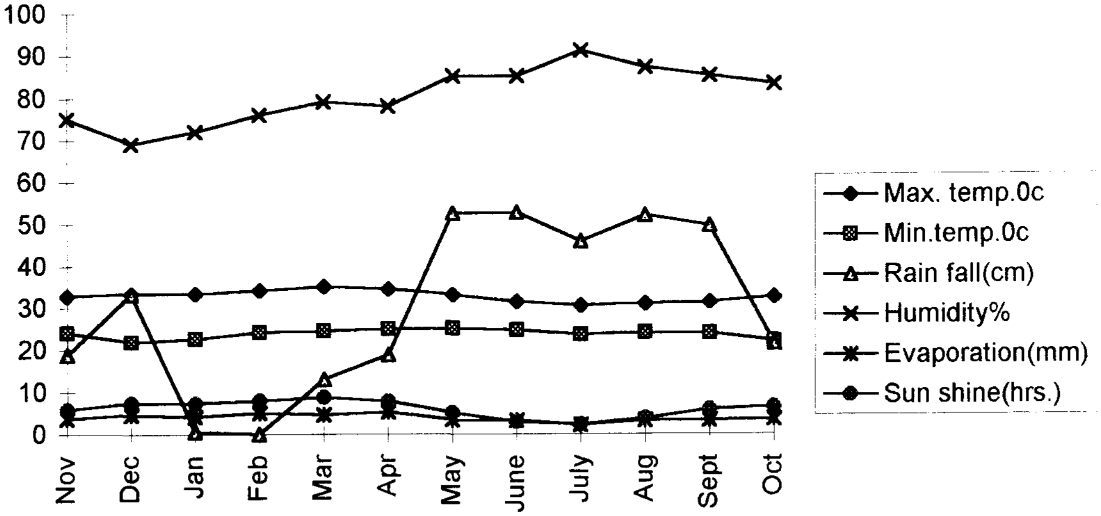
Table 1(b) Chemical composition of the soil of the experimental site

Item	Content at soil depth (0 - 30 cm)	Method
Organic carbon (%)	1.30	Walkley and Black (1934)
Total nitrogen (%)	0.15	A.O.A.C. (1977)
Available P (kg ha^{-1})	12.00	Jackson (1973)
Available K (kg ha^{-1})	120	Jackson (1973)
pH (1:2.5 soil water)	5.50	A.O.A.C. (1977)
Electrical conductivity (dsm^{-1})	0.62	A.O.A.C. (1977)

3.2. Climate

Kumarakom enjoys a humid tropical climate with rainy autumn, mild winter and hot summer. A few showers are received during the winter season. The average annual rainfall is 3000 mm. The high intensity of rains during the South-West monsoon (June-September) leads to heavy floods, a characteristic feature of Kuttanad. The mean maximum temperature is 32.0°C. The mean minimum temperature is 21.0°C. The relative humidity is as high as 90 per cent. Salinity builds up in the waterbodies surrounding Kumarakom during the summer months.

The data on various weather parameters (monthly rainfall, mean maximum and minimum temperature, relative humidity and sunshine hours) during



Weather parameters during cropping period ('94--'95)

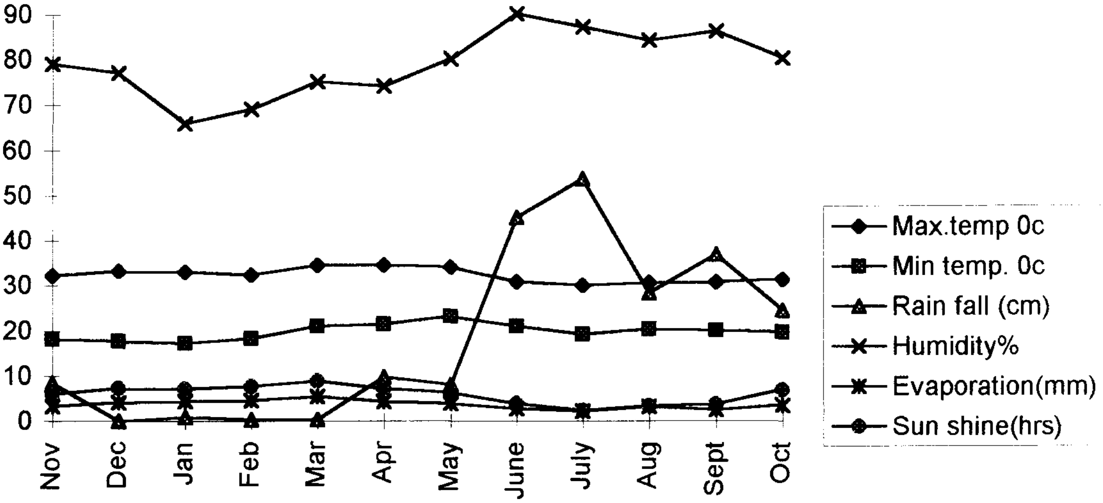


Fig. 1 Weather parameters during cropping period ('95-96)

the experimental period from November 1994 to October 1996 are presented in Appendix I and Fig. 1. The mean maximum and minimum temperatures during the cropping periods were, 32.4^{0}C 21.50^{0}C, respectively. The total rainfall received during the first and second years of the experimental period was 3364.8 mm and 3181.2 mm, respectively, with the maximum in the month of June in the first year and July in the second year. The water table fluctuated between 30 cm and 180 cm during the cropping periods.

3.3. Cropping history

An unfertilized fodder crop (guinea grass) was grown in the experimental site for three years prior to the commencement of the present investigation. Each bund had a population of ten 60-year-old coconut palms (West Coast Tall), planted on the two borders at 7.5 m apart in east-west direction. The test variety of banana was planted as an intercrop in between these two rows of coconut palms.

3.4. Experimental design and layout

The experiment was laid out in a confounded factorial design with two replications (Fig. 2). The treatments consisted of combinations of 4 levels each of biofertilizer/organic manure, fertilizer N and growth regulator 2,4-D. There were, thus, 64 treatments in a replication (Table 2).

Biofertilizer/organic manure (B)

B_0 - No biofertilizer/organic manure

B_1 - *Azospirillum* at the rate of 100 g plant^{-1}

B_2 - Cowpea in the interspaces of banana and incorporating it in the basins two times in a cropping season

B_3 - Vermicompost at the rate of 5 kg $plant^{-1}$

Fertilizer nitrogen (N)

N_0 - No N

N_1 - 95 g N $plant^{-1}$ (50% of the recommended dose of N as per Package of Practices, KAU, 1995)

N_2 - 143 g N $plant^{-1}$ (75% of the recommended dose of N as per Package of Practices, KAU, 1995)

N_3 - 190 g N $plant^{-1}$ (100% of the recommended dose of N as per Package of Practices, KAU, 1995)

Growth regulator 2, 4-D (G)

G_0 - No 2,4-D application (water spraying only)

G_1 - 2,4-D Sodium salt at the rate of 15 ppm as spray on bunches at the end of the female phase

G_2 - 2,4-D Sodium salt at the rate of 30 ppm as spray on bunches at the end of the female phase

G_3 - 2,4-D Sodium salt at the rate of 45 ppm as spray on bunches at the end of the female phase

Phosphorus (115 g $plant^{-1}$) and potassium (300 g $plant^{-1}$) were applied uniformly to all the treatments as per Package of Practices Recommendations (KAU, 1995).

Table 2 Treatment details

Sl. No.	Treatment	Notation	Sl. No.	Treatment	Notation
1	$B_0N_0G_0$	T_1	20	$B_1N_0G_3$	T_{20}
2	$B_0N_0G_1$	T_2	21	$B_1N_1G_0$	T_{21}
3	$B_0N_0G_2$	T_3	22	$B_1N_1G_1$	T_{22}
4	$B_0N_0G_3$	T_4	23	$B_1N_1G_2$	T_{23}
5	$B_0N_1G_0$	T_5	24	$B_1N_1G_3$	T_{24}
6	$B_0N_1G_1$	T_6	25	$B_1N_2G_0$	T_{25}
7	$B_0N_1G_2$	T_7	26	$B_1N_2G_1$	T_{26}
8	$B_0N_1G_3$	T_8	27	$B_1N_2G_2$	T_{27}
9	$B_0N_2G_0$	T_9	28	$B_1N_2G_3$	T_{28}
10	$B_0N_2G_1$	T_{10}	29	$B_1N_3G_0$	T_{29}
11	$B_0N_2G_2$	T_{11}	30	$B_1N_3G_1$	T_{30}
12	$B_0N_2G_3$	T_{12}	31	$B_1N_3G_2$	T_{31}
13	$B_0N_3G_0$	T_{13}	32	$B_1N_3G_3$	T_{32}
14	$B_0N_3G_1$	T_{14}	33	$B_2N_0G_0$	T_{33}
15	$B_0N_3G_2$	T_{15}	34	$B_2N_0G_1$	T_{34}
16	$B_0N_3G_3$	T_{16}	35	$B_2N_0G_2$	T_{35}
17	$B_1N_0G_0$	T_{17}	36	$B_2N_0G_3$	T_{36}
18	$B_1N_0G_1$	T_{18}	37	$B_2N_1G_0$	T_{37}
19	$B_1N_0G_2$	T_{19}	38	$B_2N_1G_1$	T_{38}

(Table 2 contd.)

39	$B_2N_1G_2$	T_{39}	52	$B_3N_0G_3$	T_{52}
40	$B_2N_1G_3$	T_{40}	53	$B_3N_1G_0$	T_{53}
41	$B_2N_2G_0$	T_{41}	54	$B_3N_1G_1$	T_{54}
42	$B_2N_2G_1$	T_{42}	55	$B_3N_1G_2$	T_{55}
43	$B_2N_2G_2$	T_{43}	56	$B_3N_1G_3$	T_{56}
44	$B_2N_2G_3$	T_{44}	57	$B_3N_2G_0$	T_{57}
45	$B_2N_3G_0$	T_{45}	58	$B_3N_2G_1$	T_{58}
46	$B_2N_3G_1$	T_{46}	59	$B_3N_2G_2$	T_{59}
47	$B_2N_3G_2$	T_{47}	60	$B_3N_2G_3$	T_{60}
48	$B_2N_3G_3$	T_{48}	61	$B_3N_3G_0$	T_{61}
49	$B_3N_0G_0$	T_{49}	62	$B_3N_3G_1$	T_{62}
50	$B_3N_0G_1$	T_{50}	63	$B_3N_3G_2$	T_{63}
51	$B_3N_0G_2$	T_{51}	64	$B_3N_3G_3$	T_{64}

Treatments - 64 Replication - 2

																Blocks	
T_{8}	T_{20}	T_{1}	T_{60}	T_{23}	T_{53}	T_{48}	T_{29}	T_{50}	T_{63}	T_{11}	T_{38}	T_{35}	T_{26}	T_{14}	T_{41}	1	
T_{54}	T_{64}	T_{27}	T_{30}	T_{2}	T_{42}	T_{36}	T_{12}	T_{15}	T_{39}	T_{24}	T_{17}	T_{51}	T_{45}	T_{57}	T_{5}	2	
T_{55}	T_{21}	T_{31}	T_{3}	T_{40}	T_{28}	T_{46}	T_{52}	T_{18}	T_{58}	T_{16}	T_{9}	T_{33}	T_{43}	T_{61}	T_{6}	3	**Rep. I**
T_{19}	T_{7}	T_{10}	T_{56}	T_{49}	T_{34}	T_{47}	T_{62}	T_{37}	T_{22}	T_{59}	T_{25}	T_{32}	T_{4}	T_{44}	T_{13}	4	
T_{23}	T_{50}	T_{1}	T_{48}	T_{14}	T_{26}	T_{60}	T_{29}	T_{11}	T_{8}	T_{53}	T_{63}	T_{20}	T_{35}	T_{41}	T_{38}	1	
T_{36}	T_{64}	T_{5}	T_{30}	T_{24}	T_{54}	T_{17}	T_{57}	T_{39}	T_{2}	T_{15}	T_{51}	T_{42}	T_{12}	T_{45}	T_{27}	2	
T_{52}	T_{6}	T_{3}	T_{33}	T_{18}	T_{31}	T_{21}	T_{55}	T_{16}	T_{61}	T_{43}	T_{46}	T_{58}	T_{40}	T_{9}	T_{28}	3	**Rep. II**
T_{10}	T_{59}	T_{37}	T_{19}	T_{4}	T_{62}	T_{32}	T_{47}	T_{49}	T_{25}	T_{34}	T_{13}	T_{7}	T_{44}	T_{22}	T_{56}	4	

Fig.2 LAYOUT OF EXPERIMENT

Number of blocks - 8

Number of treatments block^{-1} - 16

Test variety of banana - Nendran

Plot size - 6 m x 4 m

Spacing - 2 m x 2 m

Number of plants plot^{-1} - 6

The experimental lay out is presented in Fig.2.

3.5. Field preparation and planting

The experimental area was dug twice and all weeds and stubbles were removed. Pits of size of 50 cm^2 x 30 cm (depth) were dug at a spacing of 2 m x 2 m. Farm yard manure (10 kg pit^{-1}) was applied at the planting time. Phorate 10 G (25 g pit^{-1}) was applied before planting as a prophylactic measure against the incidence of rhizome weevil, pseudostem weevil and bunchy top disease. Healthy uniform suckers were planted in the pits. The crop was irrigated during the summer months.

3.5.1. Application of *Azospirillum*

A commercial preparation of *Azospirillum brasilense* obtained from National Biofertilizer Development Corporation was applied at the rate of 100 g plant^{-1} by mixing it with powdered cowdung in three split doses. The schedule of application of biofertilizer is given in Appendix II.

3.5.2. Raising cowpea

Fodder cowpea cv. Karnataka local was raised in the interspaces of banana adopting a seed rate of 40 kg ha^{-1} immediately after planting suckers.

The seeds were inoculated with an appropriate rhizobium culture before sowing. The fodder crop was cut, weighed and incorporated in the basins of banana at the time of flowering. Two crops of cowpea were, thus, incorporated in the basins of banana during each cropping period.

3.5.3. Application of 2, 4-D

A commercial preparation of the sodium salt of 2, 4-D (Fernoxone) was used for the experiment. The material was dissolved first in 2 ml alcohol and the required volume made up using double distilled water. The solution so prepared was sprayed on the bunches soon after the female phase.

3.6. Incubation study

An incubation study was conducted in earthen pots of $0.27m^3$ using the soil of the experimental site in order to understand the pattern of mineralisation of biofertilizers, compost and green manure. Cowpea was sown after treating the seeds with rhizobium and incorporated in to the soil at the time of flowering. *Azospirillum* and vermicompost were incorporated in the soil in separate pots. Soil samples were drawn and analysed for available N (both ammoniacal and nitrate N) and organic carbon at weekly intervals.

3.7. General condition of the crop

The crop stand was satisfactory throughout the period of growth in both the cropping periods. In the second year, the rain fall was below normal and the quality of irrigation water used was poor. This affected growth and yield to some extent. Handweeding was done as and when required. Earthing up was done after every fertilizer application and the plants were propped well before the onset of monsoon. The plants receiving no fertilizer N remained stunted and their growth rate was very poor.

3.8. Biometric observations

3.8.1. Growth characters

Four plants from each plot excluding the boarder plants were selected and pre-tagged. These plants served as observational plants.

3.8.1.1. Height of pseudostem

The height of pseudostem was measured from the base of the plant to the axil of the youngest leaf at monthly intervals upto shooting.

3.8.1.2. Girth of pseudostem

The girth of pseudostem at 10 cm above the ground level was measured at monthly intervals upto shooting.

3.8.1.3. Number of functional leaves

The number of leaves on the pseudostem was counted and recorded at monthly intervals.

3.8.1.4. Total leaf area

The leaf area was computed using the formula:

Leaf area of index leaf = Length of lamina x width of lamina x 0.8

Total leaf area = leaf number x leaf area of index leaf

3.8.1.5. Phylacron

It was calculated by counting the average number of days between successive leaf emergence.

3.8.2. Duration of the crop

3.8.2.1. Date of shooting

The date of shooting of plants in each treatment was observed, based on which the number of days taken from planting to shooting was worked out.

3.8.2.2. Date of harvest

The bunches were harvested as soon as they matured. The total crop duration in each treatment was arrived at based on the number of days taken from planting to harvest.

3.8.3. Post harvest observations

3.8.3.1. Bunch characters

The bunches were harvested when fully mature as indicated by the disappearance of angles from fingers (Simmonds, 1959). The following observations were recorded on bunch characters.

3.8.3.2. Weight of bunch

Each matured bunch was weighed separately. The weight (kg) included the portion of the peduncle up to the first scar (exposed outside the plant).

3.8.3.3. Number of hands bunch^{-1}

The number of hands in each bunch was counted immediately after harvest.

3.8.3.4. Number of fingers bunch^{-1}

The number of fingers in each bunch was counted soon after harvest.

3.8.3.5. Weight of fingers

The middle fruit on the top row of the second hand (from the base of the bunch) was selected as the representative finger (Gottreich *et al.*, 1964) for estimating the mean finger length, girth and weight.

3.8.3.6. Fruit size

The girth was measured at the middle portion of the finger and length from the portion of attachment to the top using a fine thread and a scale and expressed as cm.

3.8.3.7. Pulp-Peel ratio

The weight of peel and pulp of ripe fruits was recorded separately and the ratio worked out.

3.8.4. Qualitative analysis

The fruits collected from well ripe bunches were used for quality analysis. The middle fruit on the top row of the second hand was selected as the representative finger. The samples taken from each fruit from three portions *viz.*, top, middle and bottom were analysed for the following constituents.

3.8.4.1. Total soluble solids (TSS)

The total soluble solids (TSS) were estimated using a pocket refractometer and expressed as brix..

3.8.4.2. Total sugar

The total sugar of the samples was determined as per the method described by AOAC (1977) and expressed as percentage.

3.8.4.3. Reducing sugars

This was estimated as per the method described by AOAC (1977).

3.8.4.4. Nonreducing sugars

The content of nonreducing sugars was computed from the values of total sugars and reducing sugars (Ranganna, 1977).

3.8.4.5. Acidity

The acidity of fruit pulp (percentage of citric acid) was estimated as per the method described by AOAC (1977).

3.8.4.6. Sugar Acid ratio

This was arrived at by dividing the value of total sugars with that of titrable acidity.

3.8.4.7. Ascorbic acid

The ascorbic acid content in fruit pulp was estimated as per the method described by Paul-Gyorgy and Pearson (1967). It was expressed as mg 100^{-1} mg mature fresh fruit.

3.8.5. Nutrient content of leaf

The nutrient contents of the 3rd leaf were estimated as per the methods cited against each:

Nutrient	**Method**
Nitrogen	Macro-kjeldahl digestion/ distillation (AOAC, 1977)
Phosphorus	Vanadomolybdophosphoric yellow colour (AOAC, 1977)
Potassium	Flame photometry (Jackson, 1973)

3.8.6. Nutrient content of fruit

The middle fruit on the top row of the second hand of matured bunches was selected as the representative sample. The nutrient content was estimated by the following methods:

Nutrient	**Method**
Nitrogen	Macro-kjeldahl distillation (Bremner and Keeney, 1965)
Phosphorus	Vanadomolybdophosphoric yellow colour (AOAC, 1977)
Potassium	Flame photometry (Jackson, 1973)

3.8.7. 2, 4-D residue

2, 4-D residue from fruit was detected as per GLC method (Sankaran *et al.*, 1993).

3.9. Other observations

3.9.1. Benefit Cost ratio

The benefit cost ratio of various treatments were worked out, considering all aspects of cost of cultivation and the income derived. The norms and rates prevalent at the Regional Agricultural Research Station, Kumarakom were followed.

3.9.2. Soil nutrient status

The soil samples drawn from the experimental plots before planting and after the harvest of the crop were analysed for available nitrogen, phosphorus and potassium, following the procedures prescribed by Jackson (1973).

3.9.3. Soil physical properties

The physical properties of soil samples viz., apparent specific gravity, absolute specific gravity, pore space (%) and maximum water holding capacity (%) were determined by the procedures prescribed by Page (1982).

3.10. Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance as per the layout of the experiment (Panse and Sukhatme, 1967). The physical optima for applied N and 2,4-D were worked out separately for each organic input for both the years of experimentation fitting the quadratic response surface function,

$$Y = bo+b_1N+b_2G+b_{11}N^2+b_{22}G^2+b_{12}NG$$ (Das and Giri, 1979)

RESULTS

RESULTS

The present study was undertaken for two years in 1994-'95 and 1995-'96 at the Regional Agricultural Research Station, Kumarakom, of Kerala Agricultural University with the objective of formulating an Integrated Plant Nutrition System for banana cv. Nendran, the most popular fruit crop of Kerala. The results are presented in this chapter.

4.1. Growth characters

The data generated on growth characters of the crop as influenced by different levels of organic inputs and fertilizer N are presented in this section. The growth regulator, 2,4-D was applied at bunching stage only and as such, this treatment does not find a place in the summary Tables of this section.

4.1.1. Plant height

The data summarised in Table 3 shows that the influence of organic inputs on pseudostem height was significant only during the first year. Vermicompost (B_3) was the most effective, producing relatively taller plants at initial stages of growth. However, this treatment was significantly superior only to cowpea (B_2) at one month after emergence and cowpea (B_2) and control (B_0) at two months after emergence. At the other stages of growth, all the treatments were on par in their effect on pseudostem height.

Table 3 Effect of organic inputs and applied N on pseudostem height

Main effect	Pseudostem height (cm)							
	I Year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shoot-ing stage
	Months after emergence				Months after emergence			
B$_0$	75.16	142.58	232.41	242.00	103.41	152.52	209.92	214.31
B$_1$	76.50	149.73	234.94	240.75	99.23	146.41	206.77	211.00
B$_2$	71.09	141.16	227.69	236.91	107.02	155.55	217.42	221.72
B$_3$	78.75	153.33	233.80	237.98	103.67	154.78	207.47	213.41
F $_{3,60}$	**5.99****	**7.24****	**0.64**	**0.40**	**0.84**	**0.66**	**0.64**	**0.58**
CD (0.05)	**3.723**	**6.093**	-	-	-	-	-	-
N$_0$	69.70	125.16	172.36	186.78	86.19	111.42	145.53	150.97
N$_1$	78.31	149.78	247.75	251.63	110.81	163.61	232.89	236.59
N$_2$	77.55	156.69	253.03	258.53	110.05	169.80	234.16	239.59
N$_3$	75.94	155.17	255.69	260.70	106.28	164.42	229.00	233.28
F $_{3,60}$	**8.85****	**46.34****	**100.66****	**89.59****	**11.13****	**29.07****	**50.68****	**50.09****
CD (0.05)	**3.723**	**6.093**	**11.296**	**10.551**	**9.846**	**14.373**	**17.204**	17.123

** Significant at 0.01 level

Table 4 Interaction of organic inputs and applied N on pseudostem height

Treatment combination	Pseudostem height (cm)							
	I year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shooting stage
	Months after emergence				Months after emergence			
b_0n_0	67.81	106.69	144.63	161.38	78.06	99.94	134.88	140.75
b_0n_1	75.50	145.31	255.13	264.75	111.50	160.81	232.63	235.63
b_0n_2	79.06	161.25	266.38	271.00	114.81	182.50	251.69	256.00
b_0n_3	78.25	157.06	263.50	270.88	109.25	166.81	220.50	224.88
b_1n_0	73.25	135.94	183.00	191.63	80.44	105.19	147.38	152.63
b_1n_1	78.69	150.50	244.50	251.75	110.31	158.25	241.69	244.75
b_1n_2	77.25	161.38	256.38	259.50	106.38	165.50	211.38	215.75
b_1n_3	76.81	151.13	255.88	260.13	99.81	156.69	226.63	230.88
b_2n_0	64.00	116.00	170.63	187.12	105.50	131.38	175.63	181.38
b_2n_1	74.25	147.88	247.13	252.25	108.81	164.25	232.13	236.13
b_2n_2	71.44	147.00	235.13	244.88	116.75	167.69	241.38	245.88
b_2n_3	74.69	153.75	257.88	263.38	101.00	158.88	220.56	223.50
b_3n_0	73.75	142.00	191.19	207.00	84.75	109.19	124.25	129.13
b_3n_1	84.81	155.44	244.25	237.75	112.63	171.13	225.13	229.88
b_3n_2	82.44	157.13	254.25	258.75	103.25	163.50	232.19	240.75
b_3n_3	74.00	158.75	245.50	248.44	115.06	175.31	248.31	253.88
$F_{9,60}$	**1.33**	**3.89****	**3.27****	**3.96****	**1.19**	**0.97**	**2.05***	**2.15***
C.D. (0.05)	-	**12.194**	**22.571**	**21.106**	-	-	**34.412**	**34.244**

* Significant at 0.05 level
** Significant at 0.01 level

Plate 1 A field view of experimental plots

The effect of fertilizer N on pseudostem height was significant over the control at all the stages of growth during both the years of experimentation. The levels N_3, N_2 and N_1 were, however, on par except at the second stage when the level N_2 (143 g plant^{-1}) produced significantly taller plants over the level N_1 (95 g plant^{-1}).

The interaction effects of organic inputs and fertilizer N on pseudostem height were significant at all the stages of growth except one month after emergence during the first year and also during the first two stages of growth in the second year of experimentation. Application of N produced relatively taller plants in the absence of organic inputs. The organic inputs were almost on par in their effect when they were applied in combination with different levels of N (Table 4).

4.1.2. Pseudostem girth

The effect of organic inputs on pseudostem girth was significant at all the stages of growth except one month after emergence during the first year (Table 5). Cowpea (B_2) was the least effective treatment producing significantly lower pseudostem girth at the second and third stages of growth. It was, however, on par with *Azospirillum* (B_1) and the control (B_0) at shooting. At this stage, vermicompost produced significantly more pseudostem girth over the control (B_0) and cowpea (B_2). During the second year of experimentation, none of the organic inputs produced significant effect on pseudostem girth at any of the stages of growth.

Table 5 Effect of organic inputs and applied N on pseudostem girth

Main effect	Pseudostem girth (cm)							
	I Year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shooting stage
	Months after emergence				Months after emergence			
B_0	19.58	37.69	49.23	50.88	30.83	39.91	46.95	49.20
B_1	19.50	38.50	49.27	51.02	30.58	38.83	45.98	48.51
B_2	19.52	35.58	46.27	49.27	31.00	40.83	48.16	50.41
B_3	19.81	39.14	51.02	52.91	30.75	41.28	46.03	48.73
$F_{3, 60}$	**0.11**	**5.15****	**7.08****	**4.49****	**0.05**	**0.99**	**1.25**	**0.96**
CD (0.05)	-	**1.934**	**2.106**	**1.991**	-	-	-	-
N_0	18.53	32.64	41.50	44.11	26.86	31.77	38.73	41.16
N_1	19.68	39.58	51.20	53.05	32.56	43.48	50.45	52.88
N_2	19.56	39.31	51.47	53.28	31.73	42.52	49.73	52.08
N_3	20.64	39.38	51.61	53.63	32.00	43.08	48.20	50.72
$F_{3, 60}$	**3.95***	**24.64****	**44.92****	**42.97**	**10.7****	**26.88**	**35.61****	**39.56****
CD (0.05)	**1.232**	**1.934**	**2.106**	**1.991**	**2.284**	**3.094**	**2.583**	**2.452**

* Significant at 0.05 level
** Significant at 0.01 level

Table 6 Interaction of organic inputs and applied N on pseudostem girth

Treatment combination	Pseudostem girth (cm)							
	I year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shooting stage
	Months after emergence				Months after emergence			
b_0n_0	17.63	30.50	39.56	41.63	24.63	28.38	37.06	38.81
b_0n_1	20.40	41.19	51.94	52.88	33.31	43.63	51.75	54.44
b_0n_2	19.31	40.13	52.19	53.88	34.63	45.00	51.50	54.10
b_0n_3	21.00	38.94	53.25	55.13	30.75	42.63	47.50	49.45
b_1n_0	19.25	35.69	42.75	44.94	27.88	30.75	39.25	41.85
b_1n_1	18.69	39.06	53.31	54.75	32.19	42.63	50.69	53.13
b_1n_2	20.13	39.81	51.06	52.38	29.56	40.81	45.94	48.38
b_1n_3	19.94	39.44	49.94	52.00	32.69	41.13	48.06	50.69
b_2n_0	17.19	29.94	38.69	42.13	28.56	36.88	42.30	44.85
b_2n_1	20.25	36.75	48.25	51.13	31.38	42.31	50.81	52.59
b_2n_2	18.88	36.06	48.06	51.06	33.13	42.38	51.94	53.88
b_2n_3	21.75	39.56	50.06	52.75	30.94	41.75	47.56	50.31
b_3n_0	20.06	34.44	45.00	47.75	26.38	31.06	36.31	39.13
b_3n_1	19.38	41.31	51.31	53.44	33.38	45.38	48.56	51.38
b_3n_2	19.94	41.25	54.56	55.81	29.63	41.88	49.56	51.98
b_3n_3	19.88	39.56	53.19	54.63	33.63	46.81	49.69	52.44
$F_{9, 60}$	**1.56**	**1.48**	**1.26**	**1.31**	**1.57**	**1.39**	**1.34**	**1.70**

Plate 2 A field view of banana plants with cowpea in the interspaces

Applied N exerted significant effect on pseudostem girth during both the years of experimentation. The three N levels (N_1, N_2 and N_3) were superior to the control (N_0) producing significantly larger girth at all the stages of growth. Within these treatments, however, the differences were of little statistical significance.

None of the interaction effects was significant during the two years (Table 6) of experimentation.

4.1.3. Number of functional leaves

The organic inputs had no significant effect on the number of functional leaves produced at the first, second and third month after emergence during the first year (Table 7, Fig 3), but at shooting stage, *Azospirillum* (B_1) produced the maximum number of leaves (8.83 plant-^{1}) but it was on par with the control (B_0). Cowpea (B_2) and vermicompost (B_3) recorded less number of leaves. During the second year, the organic inputs were on par in their effect on leaf production at the first two stages of growth. At the subsequent stages, *Azospirillum* (B_1) produced the maximum number of leaves - 9.86 plant^{-1} - at three months after emergence and 10.39 plant^{-1} at shooting - and it was significantly superior to the other treatments.

As in the case of pseudostem height, the three levels of applied N - N_1, N_2, N_3 - were significantly superior to the untreated control (N_0) in their effect on leaf production during both the years of experimentation. However, these three levels were on par at the first two stages in 1994-'95 and at all the stages except shooting in 1995-'96. The level of N receiving cent per cent of the recommended

Table 7 Effect of organic inputs and applied N on number of functional leaves

Main effect	No.of leaves plant^{-1}							
	I Year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shooting stage
	Months after emergence				Months after emergence			
B_0	9.38	10.50	7.39	8.56	9.08	10.13	9.33	9.64
B_1	9.36	10.34	7.45	8.83	9.22	10.34	9.86	10.39
B_2	9.72	10.66	7.52	8.20	9.78	10.59	9.78	9.69
B_3	9.48	10.22	7.31	8.05	9.44	10.20	8.97	9.89
$F_{3, 60}$	**0.71**	**1.28**	**0.34**	**10.15****	**1.93**	**0.99**	**5.68****	**10.38****
CD (0.05)	-	-	-	**0.312**	-	-	**0.492**	0.304
N_0	7.95	9.08	6.70	7.86	7.59	8.13	7.14	7.78
N_1	9.88	10.73	7.36	8.39	9.98	11.09	10.02	10.44
N_2	10.13	11.08	7.61	8.34	10.03	11.02	10.30	10.52
N_3	9.98	10.84	8.00	9.05	9.91	11.03	10.48	10.88
$F_{3, 60}$	**27.28****	**30.16****	**13.39****	**19.43****	**29.16****	**50.03****	**81.39****	**179.52****
CD (0.05)	**0.561**	**0.483**	**0.421**	**0.312**	**0.626**	**0.584**	**0.492**	**0.304**

** Significant at 0.01 level

Table 8 Interaction of organic inputs and applied N on number of functional leaves

Treatment combination	No. of leaves							
	I year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shooting stage
	Months after emergence				Months after emergence			
b_0n_0	7.69	9.06	6.94	7.88	7.38	7.69	7.19	7.69
b_0n_1	8.88	10.88	7.13	8.44	8.75	10.81	9.81	10.00
b_0n_2	10.44	11.38	7.50	8.69	9.81	11.31	10.13	10.31
b_0n_3	10.50	10.69	8.00	9.25	10.38	10.69	10.19	10.56
b_1n_0	8.13	9.19	6.63	8.21	7.94	8.63	7.56	8.13
b_1n_1	10.50	10.88	7.69	8. 75	10.19	11.13	10.63	11.06
b_1n_2	9.50	10.81	7.50	8.81	9.69	10.88	10.44	11.00
b_1n_3	9.31	10.50	8.00	9.50	9.06	10.75	10.81	11.38
b_2n_0	8.75	9.25	6.38	6.88	8.06	8.63	7.38	7.81
b_2n_1	10.06	11.00	7.38	8.25	10.56	11.25	10.06	10.50
b_2n_2	10.50	11.31	7.81	8.50	10.50	11.00	10.63	10.75
b_2n_3	9.56	11.06	8.50	9.19	10.00	11.50	11.06	10.89
b_3n_0	7.25	8.75	6.88	7.88	7.00	7.56	6.44	7.50
b_3n_1	10.06	10.19	7.25	8.13	10.44	11.19	9.56	10.19
b_3n_2	10.06	10.81	7.63	7.94	10.13	10.88	10.00	11.00
b_3n_3	10.56	11.13	7.50	8.25	10.19	11.19	9.88	10.88
F $_{9, 60}$	**3.04****	**0.67**	**1.06**	**4.14****	**1.79**	**0.77**	**0.38**	**2.26****
C.D. (0.05)	**1.112**	-	-	**0.632**	-	-	-	**0.601**

** Significant at 0.01 level

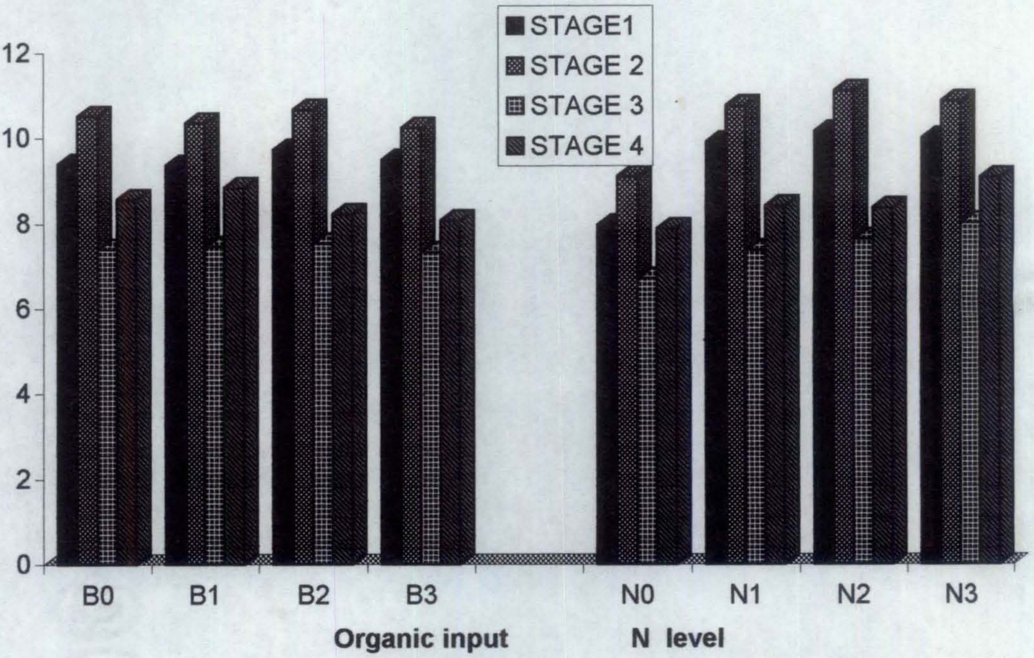


Fig. 3a Effect of organic inputs and applied N on functional leaves(`94-`95)

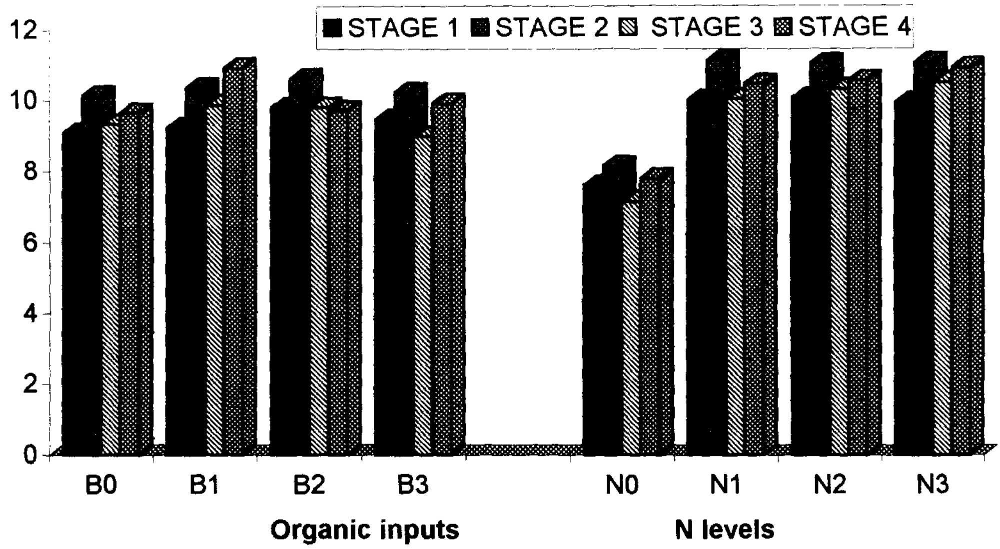


Fig.3b Effect of organic inputs and applied N on functional leaves (`95-`96)

dose (N_3) was significantly superior to all the other N levels at three months after emergence in the first year and at shooting during both the years. At shooting stage, this level produced 9.05 leaves plant^{-1} in 1994-'95 and 10.88 leaf plant^{-1} in 1995-'96.

The interaction effect of organic inputs and fertilizer N on number of leaves was significant at shooting stage during both the years of experimentation with the treatment combination B_1N_3 (*Azospirillum* with 100 per cent fertilizer N) producing the highest number of leaves (9.5 and 11.38 plant^{-1}, respectively). However, it was on par with B_0N_3 and B_2N_3 in the first year and with B_1N_1, B_3N_2, B_1N_2, B_2N_3 and B_3N_3 in the second year. The organic inputs - *Azospirillum* and vermicompost - in combination with applied N was found to be effective in the production of more functional leaves (Table 8).

4.1.4. Leaf area

The effect of organic inputs on leaf area (Table 9) was statistically significant only at one month after emergence in the first year. At this stage, Azospirillum (B_1) produced significantly larger leaf area (0.26 m^2) over the other treatments. The mean leaf area at shooting ranged between 1.06 and 1.11 m^2 in the first year and between 0.72 and 0.77 m^2 in the following year.

Applied N at the three levels (N_1, N_2, N_3) exerted its influence significantly on leaf area at all the stages of growth. The level N_2 topped the other levels in most of the stages of growth during both the years of experimentation. As

Table 9 Effect of organic inputs and applied N on leaf area

Main effect	Leaf area (m^2)							
	I Year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shooting stage
	Months after emergence				Months after emergence			
B_0	0.14	0.52	0.96	1.06	0.26	0.53	0.67	0.74
B_1	0.26	0.47	0.94	1.08	0.27	0.51	0.68	0.73
B_2	0.12	0.44	0.93	1.08	0.31	0.57	0.74	0.77
B_3	0.14	0.47	0.95	1.11	0.28	0.54	0.69	0.72
$F_{3, 60}$	**23.65****	**1.89**	**0.24**	**0.68**	**2.01**	**0.79**	**1.94**	**1.63**
CD (0.05)	**0.028**	-	-	-	-	-	-	-
N_0	0.13	0.36	0.70	0.83	0.20	0.30	0.43	0.46
N_1	0.17	0.51	0.98	1.11	0.31	0.61	0.79	0.85
N_2	0.18	0.52	1.04	1.21	0.31	0.64	0.79	0.86
N_3	0.17	0.52	1.06	1.19	0.30	0.60	0.78	0.80
$F_{3, 60}$	**3.11****	**10.65****	**46.53****	**50.91****	**19.40****	**27.44****	**60.64****	**121.47****
CD (0.05)	**0.028**	**0.068**	**0.068**	**0.073**	**0.028**	**0.079**	**0.072**	**0.051**

** Significant at 0.01 level

Table 10 Interaction of organic inputs and applied N on leaf area

Treatment combination	Leaf area(m^2)							
	I year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shooting stage
	Months after emergence				Months after emergence			
b_0n_0	0.11	0.32	0.74	0.84	0.16	0.25	0.36	0.42
b_0n_1	0.13	0.62	0.94	1.04	0.27	0.59	0.77	0.84
b_0n_2	0.15	0.59	1.04	1.15	0.31	0.70	0.84	0.87
b_0n_3	0.15	0.57	1.12	1.21	0.32	0.56	0.72	0.75
b_1n_0	0.18	0.42	0.68	0.81	0.19	0.32	0.40	0.43
b_1n_1	0.26	0.46	1.02	1.16	0.32	0.58	0.80	0.91
b_1n_2	0.30	0.53	1.05	1.24	0.30	0.61	0.72	0.86
b_1n_3	0.28	0.47	1.02	1.13	0.27	0.53	0.79	0.83
b_2n_0	0.11	0.33	0.70	0.79	0.26	0.37	0.57	0.59
b_2n_1	0.13	0.44	0.97	1.12	0.31	0.68	0.82	0.84
b_2n_2	0.11	0.47	1.02	1.23	0.36	0.62	0.83	0.86
b_2n_3	0.13	0.53	1.03	1.20	0.29	0.62	0.75	0.79
b_3n_0	0.11	0.36	0.69	0.87	0.18	0.29	0.39	0.51
b_3n_1	0.16	0.52	0.98	1.13	0.35	0.58	0.77	0.80
b_3n_2	0.14	0.49	1.05	1.22	0.28	0.62	0.78	0.83
b_3n_3	0.14	0.52	1.08	1.23	0.34	0.69	0.84	0.84
$F_{9,60}$	**0.74**	**1.14**	**0.51**	**0.75**	**2.15***	**0.78**	**1.84**	**5.03****
C.D. (0.05)	-	-	-	-	**0.069**	-	-	**0.098**

* Significant at 0.05 level
** Significant at 0.01 level

Plate 3 A field view of banana plants receiving *Azospirillum*

was expected, the unmanured control (N_0) had the lowest leaf area, the difference between it and N_2 being 0.38 m^2 and 0.40 m^2 at shooting in the first year and second year, respectively.

The interaction between organic inputs and inorganic N on leaf area had no significant effect during the first year (Table 10). However, in the second year, it was significant during one month after emergence and at shooting stage. The maximum leaf area of 0.91 m^2 was recorded by the combination B_1N_1 at the shooting stage but it was on par with B_0N_2 (0.87 m^2), B_2N_2 (0.86 m^2), B_2N_1 (0.84 m^2), B_3N_3 (0.84 m^2), B_2N_1 (0.84 m^2) and B_3N_2 (0.83 m^2).

4.1.5. Total leaf area

The organic inputs exerted significant effect on total leaf area, only at the third and final stages of growth in the second year of experimentation (Table 11; Fig. 4). At both these stages, cowpea (B_2) produced the largest total leaf area (7.40 and 7.92 m^2, respectively) and it was significantly superior to the other three organic inputs which were on par.

Compared to the unmanured control, the three levels of applied N had significant effect on total leaf area at all the stages of growth. But, among themselves - N_3, N_2, N_1 - there was no significant difference at the early two stages of growth during both the years. At the later two stages of the first year, the three levels differed significantly with N_3 producing the highest values of 8.55 and 9.17 m^2, respectively. The trend was the same in these two stages in the second year also. However, the levels N_3 and N_2 were on par and significantly superior to N_1.

Plate 4 A field view of banana plants receiving vermicompost

Table 11 Effect of organic inputs and applied N on total leaf area

Main effect	Total leaf area (m^2)							
	I Year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shooting stage
	Months after emergence				Months after emergence			
B_0	1.27	5.32	6.99	7.77	2.61	5.67	6.35	7.15
B_1	1.20	5.13	6.98	7.57	2.63	5.38	6.67	7.16
B_2	1.16	4.80	6.90	7.51	3.19	6.37	7.40	7.92
B_3	1.28	5.17	6.91	7.43	2.87	5.92	6.53	6.96
$F_{3,60}$	**0.95**	**1.23**	**0.04**	**0.47**	**2.57**	**1.54**	**4.30****	**4.76****
CD (0.05)	-	-	-	-	-	-	**0.632**	**0.565**
N_0	0.88	3.15	4.34	5.02	1.57	2.43	2.76	3.31
N_1	1.31	5.64	7.07	7.68	3.20	6.67	7.34	7.76
N_2	1.40	5.85	7.83	8.40	3.35	7.42	8.38	8.94
N_3	1.32	5.78	8.55	9.17	3.18	6.82	8.47	9.19
$F_{3,60}$	**15.91****	**43.27****	**71.63****	**72.64****	**25.48****	**46.02****	**147.63***	**196.32****
CD (0.05)	**0.169**	**0.565**	**0.621**	**0.593**	**0.479**	**0.96**	**0.632**	**0.565**

* Significant at 0.05 level
** Significant at 0.01 level

Table 12 Interaction of organic inputs and applied N on total leaf area

Treatment combination	Total leaf area (m^2)							
	I year (1994-'95)				II Year (1995-'96)			
	1	2	3	Shooting stage	1	2	3	Shooting stage
	Months after emergence				Months after emergence			
b_0n_0	0.79	2.65	4.55	5.59	1.25	2.15	2.59	3.22
b_0n_1	1.20	6.39	6.68	7.33	2.56	6.12	7.23	7.49
b_0n_2	1. 59	6.47	7.81	8.61	3.23	8.20	8.58	9.48
b_0n_3	1.52	5.79	8.94	9.56	3.40	6.22	7.03	8.40
b_1n_0	1.04	4.00	4.34	4.71	1.56	2.23	2.76	3.09
b_1n_1	1.22	5.44	7.65	8.42	3.21	5.99	7.16	7.78
b_1n_2	1.40	5.98	7.77	8.26	3.15	7.06	7.72	8.27
b_1n_3	1.15	5.08	8.14	8.90	2.62	6.23	9.05	9.50
b_2n_0	0.83	2.79	4.10	4.76	2.16	3.30	3.15	3.77
b_2n_1	1.38	5.00	6.85	7.45	3.34	8.10	8.26	8.77
b_2n_2	1.17	5.32	7.93	8.49	4.04	7.12	8.96	9.33
b_2n_3	1.24	6.10	8.73	9.33	3.20	7.06	9.24	9.81
b_3n_0	0.85	3.16	4.36	5.03	1.31	2.04	2.56	3.15
b_3n_1	1.45	5.74	7.11	7.53	3.69	6.55	6.72	6.98
b_3n_2	1.44	5.64	7.79	8.25	2.97	7.31	8.26	8.68
b_3n_3	1.36	6.14	8.39	8.91	3.51	7.77	8.59	9.05
$F_{9,60}$	**1.65**	**2.11***	**0.59**	**0.86**	**1.48**	**0.97**	**1.58**	**1.41**
C.D. (0.05)	-	**1.128**	-	-	-	-	-	-

* Significant at 0.05 level

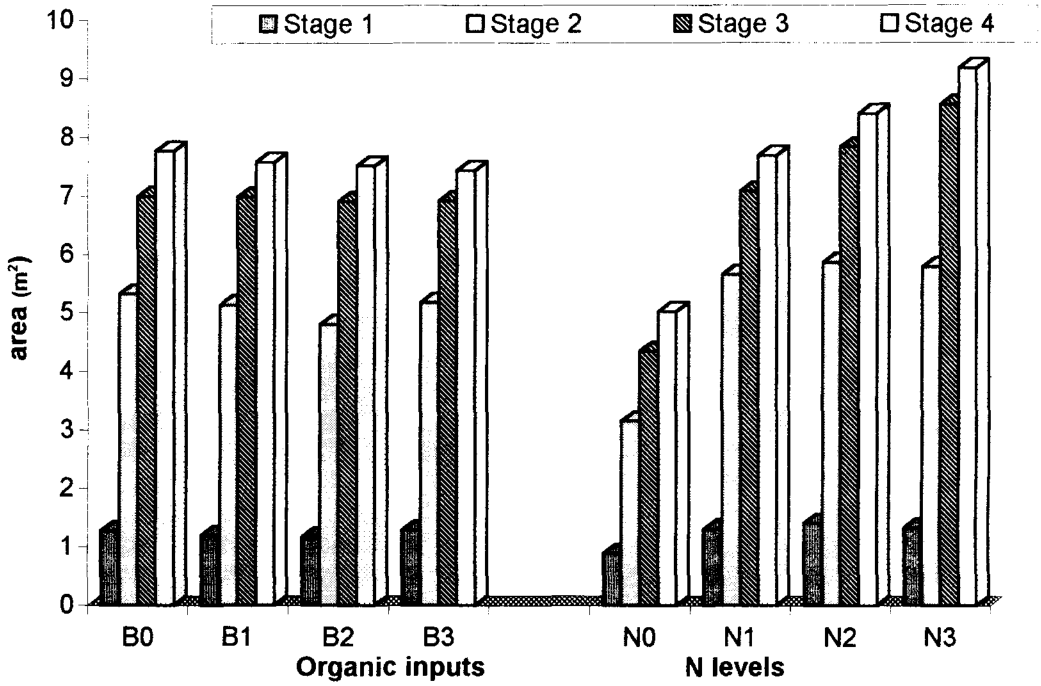


Fig. 4a Effect of organic inputs and applied N on total leaf area (`94--`95)

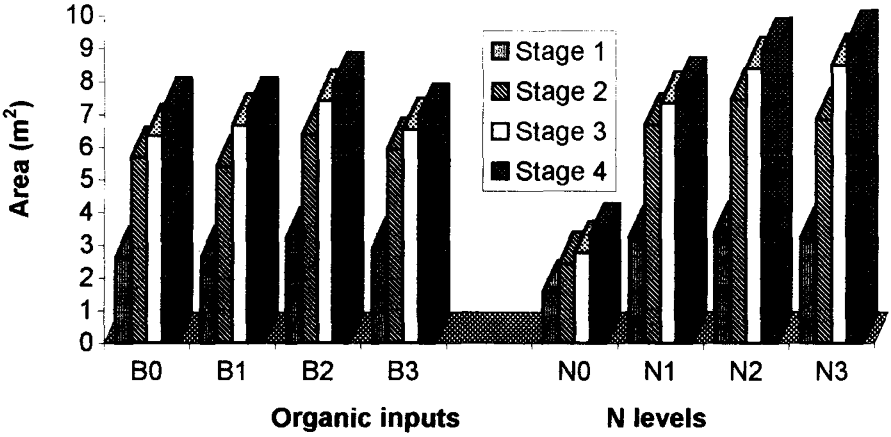


Fig.4b Effect of organic inputs and applied N on total leaf area ('95-'96)

The interaction between organic inputs and applied N had no marked effect on total leaf area at any of the growth stages except at the second stage in the first year (Table 12).

4.1.6. Phylacron

Phylacron is the number of days taken between successive leaf emergence. The influence of organic inputs on phylacron was quite evident during both the years of experimentation (Table 13; Fig.5). It took, on an average, 14.34 and 14.38 days during 1994-'95 and 1995-'96, respectively, for a leaf to emerge in the plants receiving no organic inputs (B_0). Cowpea (B_2) also behaved similarly but the difference between it and the untreated control (B_0) was significant. The other two treatments B_1 (*Azospirillum*) and B_3 (vermicompost), which were on par, significantly shortened the phylacron. The former registered the least time interval of 12.59 days in the first year and 12.63 days in the second year for successive leaf emergence as compared to the latter which recorded 12.69 and 12.78 days, respectively.

With regard to applied N, the highest level, N_3 significantly reduced the phylacron (12.34 and 12.38 days) and it was on par with N_1 but superior to N_2 and the control (N_0). The treatment receiving no N (control) had the longest time intervals of 15.03 and 15.25 days in the first and second years of experimentation, respectively.

In the absence of both the organic and inorganic inputs (B_0N_0), the plants took significantly more number of days in between successive emergence of leaves (Table 14). Applied N significantly shortened the phylacron particularly in

Table 13 Effect of organic inputs and applied N on phylacron

Main effect	Phylacron (days)	
	I Year (1994-'95)	II Year (1995-'96)
B_0	14.34	14.38
B_1	12.59	12.63
B_2	13.66	13.72
B_3	12.69	12.78
$F_{3, 60}$	19.87**	24.29**
C.D. (0.05)	**0.536**	**0.476**
N_0	15.03	15.25
N_1	12.66	12.63
N_2	13.25	13.25
N_3	12.34	12.38
$F_{3, 60}$	41.16**	60.86**
C.D. (0.05)	**0.536**	**0.476**

** Significant at 0.01 level

Table 14 Interaction of organic inputs and applied N on phylacron

Treatment combination	Phylacron	
	I Year (1994-'95)	II Year (1995-'96)
b_0n_0	15.25	15.38
b_0n_1	14.50	14.25
b_0n_2	14.75	14.88
b_0n_3	12.88	13.00
b_1n_0	14.63	15.00
b_1n_1	11.38	11.00
b_1n_2	12.00	11.50
b_1n_3	11.38	11.00
b_2n_0	15.25	15.38
b_2n_1	13.63	14.00
b_2n_2	12.63	12.50
b_2n_3	13.13	13.00
b_3n_0	15.00	15.25
b_3n_1	11.13	11.25
b_3n_2	12.03	12.13
b_3n_3	12.00	12.50
$F_{9,60}$	**4.18****	**8.21****
CD (0.05)	**1.045**	**0.942**

** Significant at 0.01 level

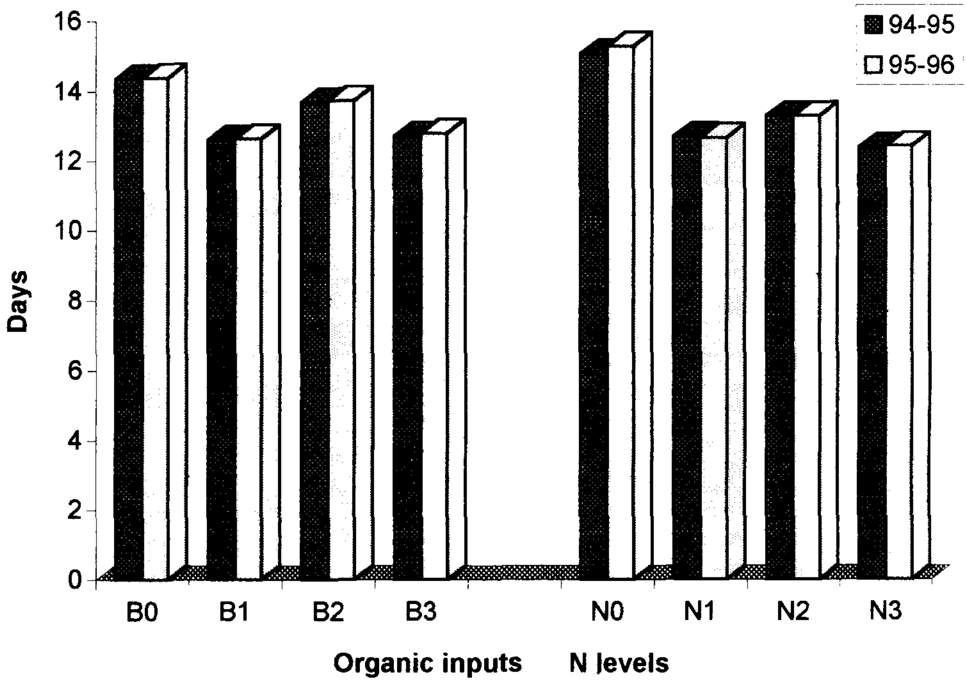


Fig. 5 Effect of organic inputs and applied N on phylacron

the presence of *Azospirillum* (B_1) and vermicompost (B_3). The shortest duration was recorded by the treatment combination B_3N_1 (11.13 days) but there was no significant difference between it and B_1N_1, B_1N_3, B_1N_2, B_3N_2 and B_3N_3 during the first year. The interaction between *Azospirillum* and applied N (B_1 x N) and vermicompost and applied N (B_3 x N) seemed to be more effective in reducing the phylacron. A similar trend was observed in the second year also with *Azospirillum* and applied N, when B_1N_1 and B_1N_3 registered the least duration of 11 days. These treatment combinations were, however, on par with B_1N_2 and B_3N_1.

4.2. Crop duration

4.2.1. Number of days to shooting and total crop duration

It could be observed from the data summarised in Table 15 that the organic inputs had no appreciable influence on the number of days to shooting and the total crop duration during the first year of experimentation (Fig.6). But, during the second year, vermicompost (B_3) took significantly more number of days to shooting (241.16 days) as compared to the control (B_0) and cowpea (B_2). It was, however, on par with *Azospirillum* (B_1) which recorded 233 days. Statistically, B_1, B_0 and B_2 were on par in their effect on days to shooting. The organic inputs did not exhibit any influence on fruit maturity period from shooting to harvest in any of the years of experimentation.

Applied N significantly shortened the number of days to shooting and the total crop duration during both the years. The unmanured control (N_0) took 300.34 and 292.75 days, respectively, in 1994-'95 and 1995-'96 to shooting as against N_3 which took only 188.5 and 208.22 days in the respective years. This treatment

Table15 Effect of organic inputs, applied N and growth regulator on crop duration

Main effect	I Year (1994-'95)			II Year (1995-'96)		
	Days for shooting	Days from shooting to harvest	Total duration (days)	Days for shooting	Days from shooting to harvest	Total duration (days)
B_0	225.66	80.41	306.72	227.53	88.78	316.31
B_1	215.44	80.09	295.84	233.00	87.22	310.22
B_2	217.84	78.44	297.72	224.03	87.09	311.13
B_3	221.38	79.25	298.59	241.16	88.09	329.56
$F_{3,60}$	**2.76**	**0.82**	**2.48**	**3.88***	**0.58**	**3.65***
C.D. (0.05)	-	-	-	**10.710**	-	**13.20**
N_0	300.34	80.63	379.25	292.75	86.88	370.38
N_1	199.06	80.31	279.38	212.53	90.13	302.66
N_2	192.41	79.00	271.44	212.22	87.19	298.97
N_3	188.50	78.25	268.81	208.22	87.00	295.22
$F_{3,60}$	**402.25****	**1.29**	**304.19****	**116.79****	**2.23**	**59.02****
C.D. (0.05)	**7.571**	-	**8.630**	**10.710**	-	**13.20**
G_0	227.5	81.34	309.47	240.16	91.44	328.63
G_1	224.00	80.38	304.38	235.13	87.94	316.22
G_2	220.81	78.81	295.59	229.38	86.50	312.13
G_3	221	77.66	289.44	230.5	85.31	310.25
$F_{3,60}$	**2.5**	**2.78***	**8.58****	**2.31**	**6.47****	**3.14***
CD (0.05)	-	**2.769**	**8.630**	-	**2.952**	**13.20**

* Significant at 0.05 level
** Significant at 0.01 level

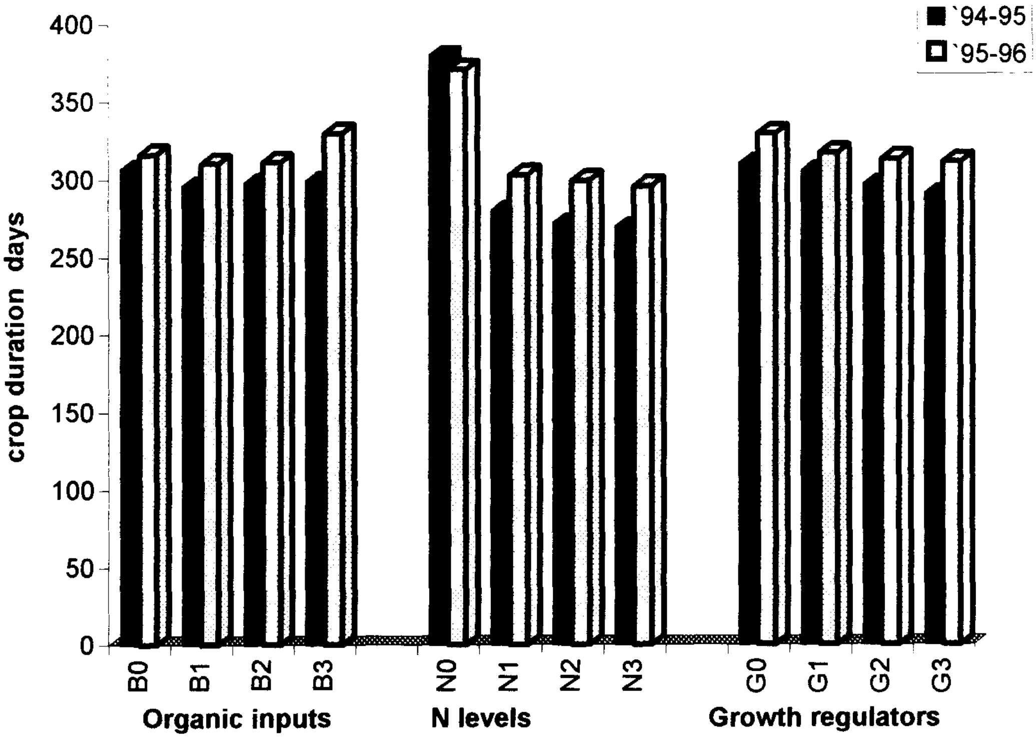


Fig. 6 Effect of organic inputs, fertilizer N and 2,4-D on crop duration

received 100 per cent of the recommended dose of N. The difference between N_0 and N_3 was highly significant. The differences between N_1 and N_2 and between N_2 and N_3 were, however, not significant.

The total duration of the crop also followed the same trend with the N_3 level registering 268.81 and 295.22 days, respectively, in the first year and in the second year as against 379.25 and 370.38 days recorded by the control (N_0). The unfertilized control (N_0) prolonged the crop duration significantly as compared to any of the levels of applied N, which were on par. The treatment effects on fruit maturity from shooting to harvest were not significant. Applied N had no marked influence on the period of fruit maturity commencing from shooting to harvest.

The growth regulator tended to shorten the duration from shooting to fruit maturity and the total duration. The plants sprayed with 30 or 45 ppm of 2,4-D. (G_2 or G_3) matured fast as compared to those receiving no 2,4-D (G_0) during both the years of experimentation. However, the difference between G_0 and G_1 (15 ppm), touched the level of significance only in second year as regards the number of days from shooting to fruit maturity. In the matter of total duration, these two treatments were on par.

The interaction effect of organic inputs and applied N on crop duration was not significant in any of the years of experimentation (Table 16). The N x G interaction exhibited its significant effect during the first year when N_0G_0 which was on par with N_0G_1 registered the longest crop duration of 400.13 days. The lowest duration was recorded by N_2G_2 (265.25 days) but it was on par with all the treatment combinations except N_1G_1, N_1G_0, N_0G_3, N_0G_2, N_0G_1 and N_0G_0 (Table 17).

Table 16 Interaction of organic inputs and applied N on crop duration

Treatment combination	I Year (1994-'95)			II Year (1995-'96)		
	Days for shooting	Days from shooting to harvest	Total duration (days)	Days for shooting	Days from shooting to harvest	Total duration (days)
b_0n_0	316.25	82.38	399.88	286.50	87.25	373.75
b_0n_1	204.38	80.50	284.88	208.50	87.88	296.38
b_0n_2	192.25	79.38	271.75	206.38	90.75	297.13
b_0n_3	189.75	79.38	270.38	208.75	89.25	298.00
b_1n_0	287.50	78.88	366.38	295.25	87.50	345.25
b_1n_1	199.75	80.25	280.00	210.25	89.75	300.00
b_1n_2	189.38	80.63	270.00	217.75	84.88	300.13
b_1n_3	185.13	80.63	267.00	208.75	86.75	295.50
b_2n_0	292.25	78.13	370.38	284.88	83.88	369.25
b_2n_1	196.50	79.63	276.13	206.13	92.13	298.25
b_2n_2	192.88	77.25	270.13	201.25	86.50	287.25
b_2n_3	189.75	78.75	274.25	203.88	85.88	289.75
b_3n_0	305.38	83.13	380.38	304.38	88.88	393.25
b_3n_1	195.63	80.88	276.50	225.25	90.75	316.00
b_3n_2	195.13	78.75	273.88	223.50	86.63	311.38
b_3n_3	189.38	74.25	263.63	211.50	86.13	297.63
$F_{9, 60}$	**1.36**	**1.13**	**1.54**	**0.27**	**1.06**	**1.02**

* Significant at 0.05 level

Table 17 Interaction of N and growth regulator on crop duration

Treatment combination	Bunch maturity (days)		Total duration (days)	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
n_0g_0	83.25	90.63	400.13	390.63
n_0g_1	83.25	87.38	390.00	373.13
n_0g_2	79.75	85.13	375.00	359.25
n_0g_3	76.25	84.38	351.88	358.50
n_1g_0	80.00	92.50	288.75	309.00
n_1g_1	79.50	90.63	285.88	301.13
n_1g_2	81.13	89.88	274.13	300.50
n_1g_3	80.63	87.50	268.75	300.00
n_2g_0	81.25	90.88	274.88	311.38
n_2g_1	79.38	87.13	275.00	297.00
n_2g_2	77.25	86.13	265.25	294.13
n_2g_3	78.13	84.63	270.63	293.38
n_3g_0	80.88	91.75	274.13	303.50
n_3g_1	79.38	86.63	266.63	293.63
n_3g_2	77.13	84.88	268.00	294.63
n_3g_3	75.63	84.75	266.50	289.13
$F_{9,60}$	**0.80**	**0.14**	**2.19***	**0.30**
CD (0.05)	-	-	**17.26**	-

* Significant at 0.05 level

4.3. Yield attributing characters

The data generated on the effect of organic inputs, fertilizer N and 2,4-D on yield attributing characters are presented in Table 18 and Fig. 7 and 8.

4.3.1. Number of hands bunch^{-1}

Neither the organic inputs nor the growth regulator exerted any significant effect on number of hands bunch^{-1} in both years of experimentation (Table 18). On the other hand, applied N at the levels N_3, N_2 and N_1 significantly improved the mean number of hands over the control (N_0). The three levels were, however, on par in their effect during both the years of experimentation.

The interaction effect of organic inputs and inorganic N on number of hands bunch^{-1} (Table 19) was significant during the second year only when B_3N_3 (4.56 bunch^{-1}) topped the list of treatment combinations although it was on par with B_2N_2 (4.5), B_0N_1 (4.5), B_3N_1 (4.41), B_1N_2, B_1N_1 and B_0N_2 (4.38 each).

4.3.2. Number of fingers bunch^{-1}

As in the case of number of hands bunch^{-1}, the influence of organic inputs and 2,4-D on number of fingers bunch^{-1} was of little statistical significance compared to the control during both the years of experimentation (Table 18). Applied N levels N_3, N_2 and N_1 were on par in their effect on number of fingers bunch^{-1} but they were significantly superior to the control (N_0) during both the years.

The number of fingers bunch^{-1} were not influenced by B x N interactions during any of the years of experimentation (Table 19).

Table 18 Effect of organic inputs, applied N and growth regulator on yield attributes

Main effect	No.of hands (bunch^{-1})		No. of fingers (bunch^{-1})		Fruit weight (g)	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
B_0	4.69	4.03	36.94	30.31	149.46	135.34
B_1	4.71	3.94	37.73	29.57	162.50	138.63
B_2	4.61	4.14	36.82	32.36	161.74	152.44
B_3	4.66	4.02	35.78	31.37	168.43	149.03
$F_{3,60}$	**0.67**	**1.78**	**1.24**	**2.40**	**1.81**	**2.50**
C.D. (0.05)	-	-	-	-	-	-
N_0	4.01	3.17	29.32	19.45	115.34	103.59
N_1	4.85	4.37	39.61	34.05	164.63	153.53
N_2	4.90	4.34	39.63	34.77	183.55	160.13
N_3	4.91	4.25	38.72	35.34	188.61	157.44
$F_{3,60}$	**61.38****	**85.53****	**48.67****	**94.67****	**138.10****	**43.86****
C.D. (0.05)	**0.169**	**0.169**	**2.034**	**2.231**	**8.230**	**11.526**
G_0	4.59	3.94	37.22	30.17	152.16	126.66
G_1	4.65	4.06	37.13	30.92	159.59	143.88
G_2	4.68	4.02	36.84	30.60	169.31	146.28
G_3	4.74	4.11	36.09	31.92	168.08	157.88
$F_{3,60}$	**1.27**	**1.37**	**0.50**	**0.89**	**5.72****	**9.98****
CD (0.05)	-	-	-	-	**8.023**	**11.526**

** Significant at 0.01 level

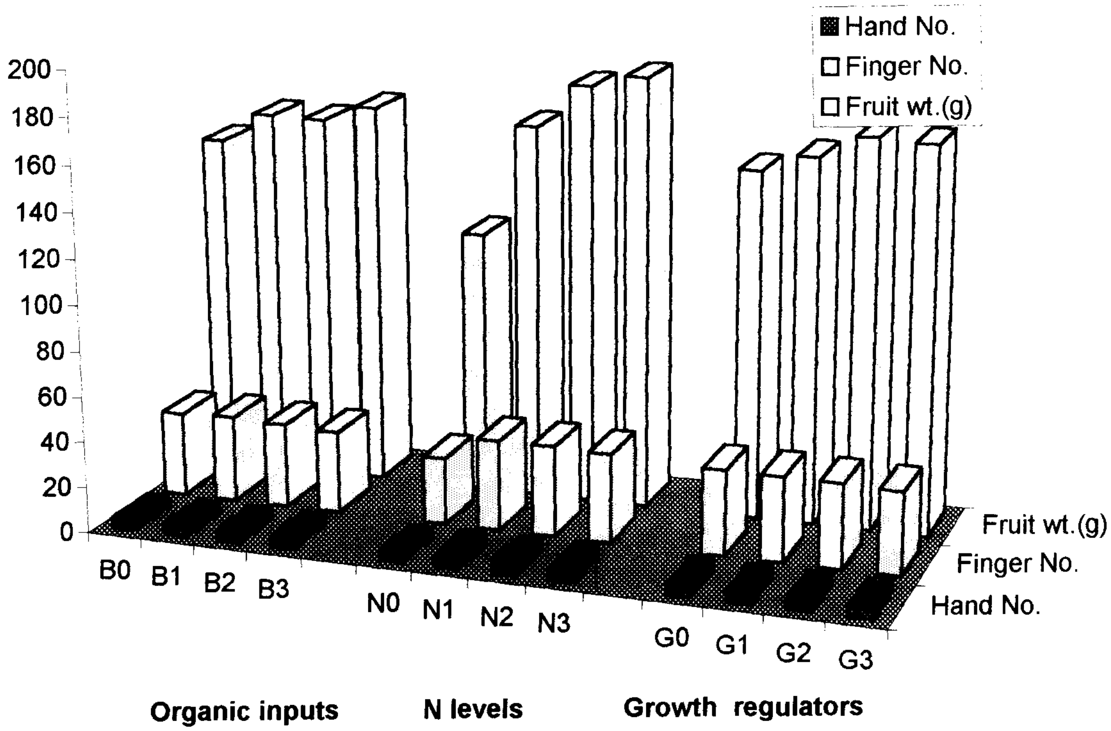


Fig. 7 Effect of organic inputs, fertilizer N and 2,4-D on yield attributes (`94-`95)

4.3.4. Fruit weight

None of the organic inputs had significant effect on fruit weight during both the years of experimentation (Table 18).

Among the levels of N, the highest fruit weight (188.61 g $fruit^{-1}$) was produced by the level N_3, but it was statistically on par with N_2 during the first year. Both these levels were significantly superior to N_1 and N_0. The difference between N_1 and N_0 was also significant. During the second year, all the three levels of applied N - N_3, N_2, N_1 - were on par and superior to the control (N_0).

In the first year, 2,4-D applied at the rate of 30 ppm (G_2) produced the highest mean fruit weight (169.31 g). However, it was on par with the level G_3 (45 ppm). Both these levels were significantly superior to G_1 (15 ppm) and G_0 (control) which were on par. During the second year, G_3 was significantly superior to the other levels, registering a mean fruit weight of 157.88 g. The levels G_2 and G_1 were on par, but significantly superior to the control (G_0). The mean gain in weight due to the application of growth regulator at the rate of 45 ppm was 31.22 g over the control (G_0) during the second year.

The interaction effect of fruit weight touched the level of significance in the second year with B_3N_3 recording the highest fruit weight of 191.99 g $fruit^{-1}$ (Table 19). It was, however, on par with B_2N_2, B_3N_2, B_2N_3 and B_1N_3. These combinations were found to be significantly superior to applied N alone even at its highest dose (N_3).

None of the yield attributes were significantly influenced by the interaction effect of N and growth regulator (Table 20).

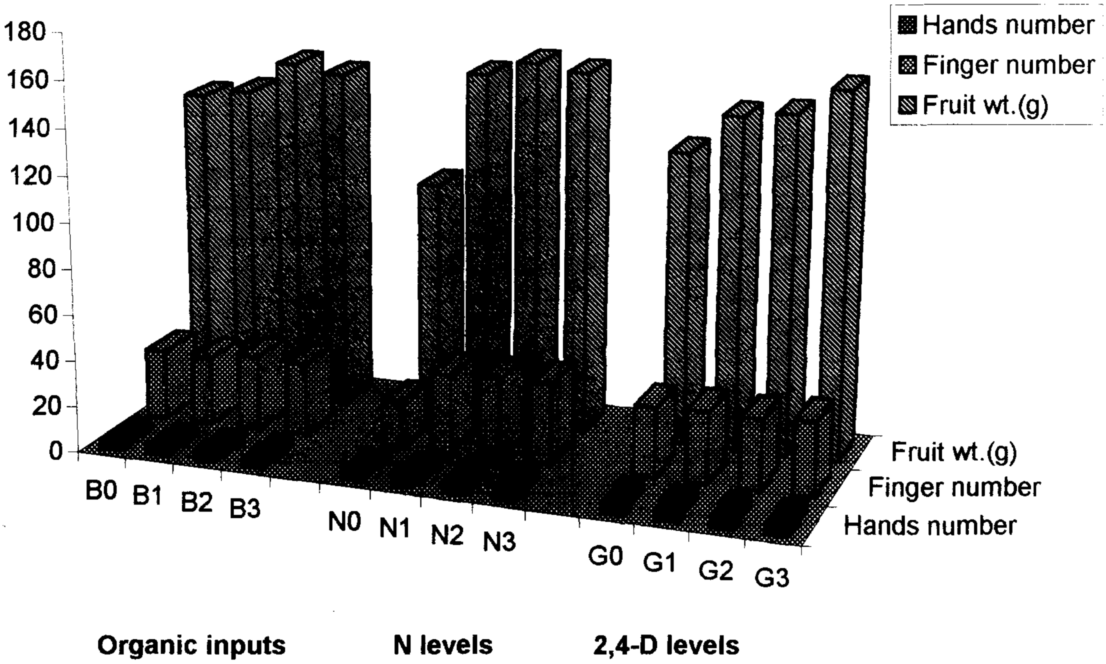


Fig .8 Effect of organic inputs, fertilizer N and 2,4-D on yield attributes 1995-`96

Table 19 Interaction of organic inputs and applied N on yield attributes

Treatment combination	No.of hands bunch^{-1}		No.of fingers bunch^{-1}		Fruit weight (g)	
	I year 1994-'95	II year 1995-'96	I year 1994-'95	II year 1995-'96	I year 1994-'95	II year 1995-'96
b_0n_0	3.96	3.13	29.58	19.44	110.18	95.13
b_0n_1	4.96	4.50	37.25	33.30	150.46	136.63
b_0n_2	4.94	4.38	40.19	35.00	166.99	162.88
b_0n_3	4.91	4.13	40.75	33.51	170.20	146.75
b_1n_0	4.18	2.88	31.00	16.44	127.84	97.00
b_1n_1	4.79	4.38	40.25	33.49	168.43	142.88
b_1n_2	5.03	4.38	41.81	33.61	167.80	150.25
b_1n_3	4.85	4.13	37.88	34.75	185.95	164.38
b_2n_0	3.88	3.69	29.59	23.69	102.53	116.38
b_2n_1	4.86	4.19	40.44	34.39	166.45	166.13
b_2n_2	4.75	4.50	39.25	35.65	191.70	161.13
b_2n_3	4.94	4.19	38.00	35.72	186.30	166.13
b_3n_0	4.03	3.00	27.13	18.25	120.84	105.88
b_3n_1	4.77	4.41	40.50	35.03	173.20	141.50
b_3n_2	4.89	4.13	37.25	34.81	187.71	156.25
b_3n_3	4.95	4.56	38.25	37.38	191.99	152.50
$F_{9, 60}$	**0.81**	**4.01****	**1.29**	**1.02**	**2.97****	**1.41**
C D (0.05)	-	**0.352**	-	--	**16.094**	-

** Significant at 0.01 level

Table 20 Interaction of N and growth regulator on yield attributes

Treatment combination	No.of hands (bunch^{-1})		No. of fingers (bunch^{-1})		Fruit weight (g)	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
n_0g_0	3.89	2.75	27.75	17.38	95.16	87.75
n_0g_1	3.89	3.31	30.44	20.31	117.41	111.38
n_0g_2	3.96	3.31	29.34	19.06	125.53	114.50
n_0g_3	4.30	3.31	29.75	21.06	123.28	100.75
n_1g_0	4.76	4.38	39.91	33.66	152.64	137.50
n_1g_1	4.81	4.31	40.13	32.72	154.44	148.88
n_1g_2	4.91	4.34	39.63	34.89	174.26	150.63
n_1g_3	4.90	4.44	38.75	34.93	177.20	177.13
n_2g_0	4.94	4.44	42.44	35.61	185.17	144.13
n_2g_1	4.88	4.38	40.38	34.97	179.58	155.25
n_2g_2	4.91	4.13	39.19	32.18	186.61	153.50
n_2g_3	4.88	4.44	36.50	36.31	182.84	187.63
n_3g_0	4.79	4.19	38.75	34.03	177.65	137.25
n_3g_1	5.01	4.25	37.56	35.68	186.95	160.00
n_3g_2	4.95	4.31	39.19	36.28	190.85	166.50
n_3g_3	4.90	4.25	39.38	35.38	189.00	166.00
$F_{9,60}$	**1.01**	**1.83**	**1.20**	**0.77**	**1.92**	**1.43**

Table 21 Interaction of organic inputs and growth regulator on yield attributes

Treatment combination	No.of hands (bunch^{-1})		No. of fingers (bunch^{-1})		Fruit weight (g)	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
b_0g_0	4.60	4.00	36.31	28.72	143.31	122.50
b_0g_1	4.68	4.13	37.25	30.32	145.49	141.50
b_0g_2	4.70	4.00	39.50	31.59	150.41	138.00
b_0g_3	4.80	4.00	34.69	30.63	158.63	144.75
b_1g_0	4.68	3.81	38.94	29.40	145.14	118.88
b_1g_1	4.66	3.88	37.25	28.19	166.80	148.88
b_1g_2	4.69	4.00	35.00	28.56	167.01	150.00
b_1g_3	4.81	4.06	39.75	32.15	171.05	176.38
b_2g_0	4.48	4.00	36.69	31.13	148.04	144.50
b_2g_1	4.60	4.19	37.44	31.89	161.74	156.38
b_2g_2	4.59	4.13	35.59	31.88	169.51	157.38
b_2g_3	4.76	4.19	37.56	34.56	175.56	161.50
b_3g_0	4.63	3.88	36.94	31.44	164.14	120.75
b_3g_1	4.64	4.06	36.56	33.29	164.35	136.75
b_3g_2	4.76	3.97	37.25	30.40	178.10	149.75
b_3g_3	4.60	4.19	32.38	30.34	167.15	148.88
$F_{9,60}$	**0.39**	**0.37**	**2.17***	**0.89**	**2.35***	**1.43**
CD 0.05)	-	-	**4.068**	-	**16.086**	-

Plate 5 Fingers showing the effect of graded levels of fertilizer N

The interaction effect of organic inputs and growth regulator (B x G) was significant on number of fingers bunch^{-1} and fruit weight during the first year of experimentation (Table 21). The highest number of fingers bunch^{-1} was recorded by B_1G_3 which was on par with all the treatment combinations except B_0G_3, B_1G_2, B_3G_3 and B_2G_2. The highest fruit weight was recorded by B_3G_2 which was on par with all the treatment combinations except B_0G_0, B_0G_1, B_0G_2 B_1G_0, B_2G_0, and B_2G_1.

4.3.5. Fruit length

The data in respect of fruit length summarised in Table 22 and Fig. 9 revealed that vermicompost (B_3) was significantly superior to the other organic inputs which were on par during the first year. It registered a mean fruit length of 20.65 cm. During the second year, however, the trend of the result was in favour of cowpea (B_2) which ranked first in fruit length (20.12 cm) although, the treatment differences were not significant.

The influence of applied N on fruit length was significant during both the years of experimentation with the higher levels (N_3 and N_2), which were on par amongst themselves, producing, respectively, 21.5 cm and 21.47 cm in the first year and 20.97 and 20.23 cm in the second year. These two levels were significantly superior to N_1 and N_0 in the first year and only to N_0 in the second year. The difference between N_2 and N_1 was not significant during the second year.

The different concentrations of 2,4-D increased the fruit length. All the three levels - G_3, G_2, G_1 - were significantly superior to G_0 (control). But amongst themselves, there was little statistical difference in the first year. In the second year, G_3 and G_1 were on par. Similarly, G_1 and G_2 were also on par.

Table 22 Effect of organic inputs, applied N and growth regulator on fruit size

Main effect	Fruit length (cm^{-1})		Fruit girth (cm^{-1})	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
B_0	19.47	19.21	12.16	12.18
B_1	19.90	19.56	12.57	12.61
B_2	19.86	20.12	12.3	12.61
B_3	20.65	19.34	12.33	12.45
$F_{3,60}$	**4.54****	**2.17**	**2.65**	**1.15**
C.D. (0.05)	**0.649**	-	-	-
N_0	16.31	16.87	11.54	11.93
N_1	20.59	20.16	12.47	12.61
N_2	21.50	20.23	12.57	12.79
N_3	21.47	20.97	12.84	12.66
$F_{3,60}$	**114.93****	**44.48****	**33.48****	**29.08****
C.D. (0.05)	**0.649**	**0.766**	**0.282**	**0.223**
G_0	19.01	18.98	11.98	11.86
G_1	20.28	19.96	12.56	12.92
G_2	20.56	19.15	12.41	12.66
G_3	20.03	20.14	12.47	12.76
$F_{3,60}$	**8.58****	**4.43****	**7.04****	**36.12****
CD (0.05)	**0.649**	**0.766**	**0.282**	**0.223**

** Significant at 0.01 level

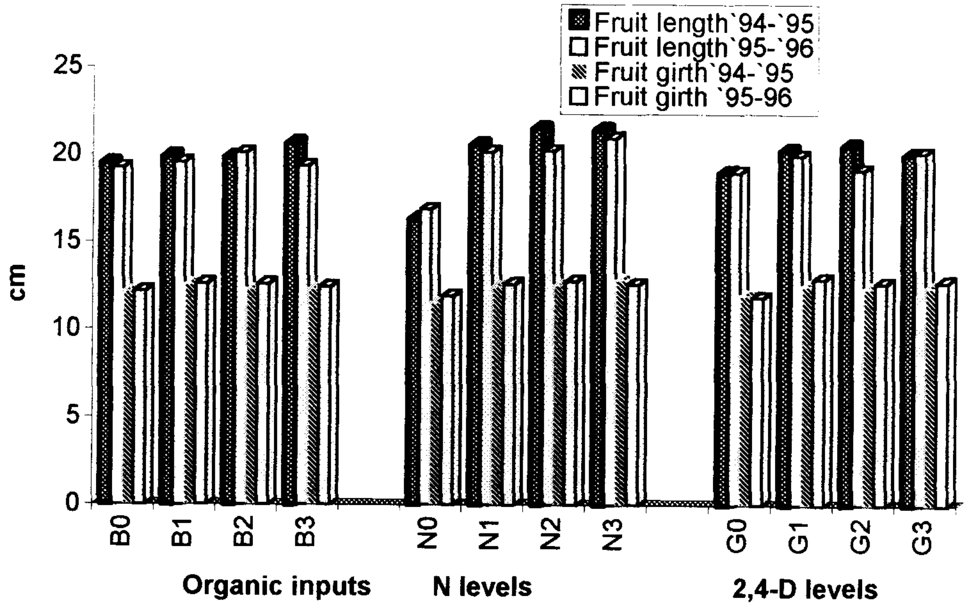


Fig. 9. Effect of organic inputs,fertilizer N and 2,4-D on fruit size

Table 23 Interaction of organic inputs and applied N on fruit size

Treatment combination	Fruit length (cm^{-1})		Fruit girth (cm^{-1})	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
b_0n_0	15.40	16.11	11.29	11.19
b_0n_1	20.00	19.50	12.17	12.49
b_0n_2	21.21	20.80	12.6	12.51
b_0n_3	21.28	20.42	12.60	12.52
b_1n_0	16.05	17.20	12.29	12.26
b_1n_1	21.33	20.74	12.80	12.61
b_1n_2	21.00	19.10	12.84	12.70
b_1n_3	21.22	21.20	12.76	12.85
b_2n_0	15.91	17.36	10.98	12.21
b_2n_1	20.03	20.88	12.31	12.66
b_2n_2	21.50	20.36	12.90	12.67
b_2n_3	21.99	21.89	13.19	12.98
b_3n_0	17.89	16.81	11.60	12.06
b_3n_1	21.00	19.54	12.60	12.18
b_3n_2	22.31	20.65	12.83	12.98
b_3n_3	21.40	20.35	12.90	12.59
$F_{9,60}$	**1.76**	**1.49**	**3.70****	**5.28****
CD (0.05)	-	-.	**0.556**	**0.452**

** Significant at 0.01 level

None of the interaction effects (B x N) and (N x G) touched the level of significance during any of the years of experimentation (Table 23 and 24).

4.3.6. Fruit girth

It could be seen from the data presented in Table 22 and Fig. 9 that the organic inputs had no significant influence on fruit girth in any of the years of experimentation.

The levels of applied N exerted their influence on fruit girth, significantly over the control (N_0). There were, however, no conspicuous differences between the levels N_3 and N_2 and also between N_2 and N_1 during both the years.

The growth regulator applied at the concentrations of 15 (G_1), 30 (G_2) and 45 (G_3) ppm were statistically on par, but significantly superior to the control (G_0) in its effect on fruit girth during both the years. The improvement in girth brought about by the lowest level G_1 (15 ppm) over the control (G_0) amounted to 0.58 cm in 1994-'95 and 1.06 cm in 1995-'96.

The interaction effect of organic inputs and inorganic N on fruit girth was significant during both the years of experimentation (Table 23). During the first year, B_2N_3 recorded the highest fruit girth (13.19 cm). However, it was on par with B_1N_1, B_1N_2, B_1N_3, B_2N_2, B_3N_2 and B_3N_3. During the second year, the best treatment combinations were B_2N_3 and B_3N_2, producing the same fruit girth of 12.98 cm, but they were on par with B_3N_3, B_2N_2, B_1N_2, B_2N_1, B_1N_3. B_1N_2 and B_1N_1.

The interaction effect of applied N and 2,4-D was significant during the second year (Table 24). The highest fruit girth (13.71 cm) was recorded by N_3G_1 and it was significantly superior to the other combinations. When fertilizer N was

Plate 6 Fingers showing the effect of 2.4-D with vermicompost and 100% fertilizer N

Table 24 Interaction of N and growth regulator on fruit size

Treatment combination	Fruit length (cm^{-1})		Fruit girth (cm^{-1})	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
n_0g_0	15.72	16.13	11.30	11.37
n_0g_1	16.01	17.79	11.74	11.93
n_0g_2	16.61	16.08	11.60	12.05
n_0g_3	16.91	17.50	11.51	12.38
n_1g_0	19.78	19.50	12.20	12.18
n_1g_1	21.06	20.30	12.61	13.03
n_1g_2	20.67	19.59	12.28	12.84
n_1g_3	20.85	21.26	12.80	12.90
n_2g_0	20.40	20.11	12.00	12.04
n_2g_1	21.90	20.45	12.88	13.01
n_2g_2	22.23	19.88	12.85	13.03
n_2g_3	21.41	20.48	12.54	13.10
n_3g_0	20.06	20.19	12.40	11.84
n_3g_1	22.13	21.29	13.01	13.71
n_3g_2	22.74	21.06	12.92	13.24
n_3g_3	20.95	21.33	13.01	12.65
$F_{9,60}$	**1.25**	**0.57**	**0.85**	**4.82****
CD (0.05)	-	-	-	**0.452**

** Significant at 0.01 level

applied in combination with organic inputs, fruit girth was higher than when it was applied alone even at its highest level (N_3).

4.4. Yield

4.4.1. Bunch weight

The data pertaining to the influence of organic inputs, inorganic N and 2,4-D are summarised in this section. The growth regulator was applied only at the bunching stage of the crop.

As is evident from the data presented in Table 25 and Fig. 10, vermicompost (B_3) produced the highest bunch weight of 6.8 kg plant^{-1} during the first year of experimentation, but it was on par with the next best treatment, cowpea (B_2). The latter, however, was on par with *Azospirillum* (B_1). The quantum of yield improvement brought about by the treatment (B_3) over the control (B_0) was 1.02 kg plant^{-1} equivalent to 17.64 per cent. The treatment receiving no organic inputs (B_0) produced the lowest bunch weight of 5.98 kg plant^{-1} but it was statistically on par with *Azospirillum* (B_1) which yielded 6.30 kg plant^{-1}. The mean bunch weight, on an average, was comparatively low during the second year due to sub optimal weather conditions. The best treatment producing the highest yield of 5.2 kg plant^{-1} was cowpea (B_2) and it was significantly superior to the rest of the treatments including the control (B_0). The yield increases recorded by cowpea (B_2) over the next best treatment B_3 (vermicompost) and the unmanured control (B_0) were, respectively, 14.82 per cent and 19.5 per cent.

The best fertilizer treatment producing the highest bunch weight (7.84 kg and 5.84 kg plant^{-1}) was N_2 (75% of the recommended dose of N) in both the

Table 25 Effect of organic inputs, applied N and growth regulator on bunch weight

Main effect	Bunch weight (kg plant^{-1})		
	I Year (1994-'5)	II Year (1995-'96)	Pooled Mean
B_0	5.98	4.34	5.17
B_1	6.30	4.49	5.34
B_2	6.50	5.20	5.85
B_3	6.80	4.79	5.78
$F_{3,60}$	**4.76****	**10.35****	**10.689****
C.D. (0.05)	**0.423**	**0.286**	**0.332**
N_0	2.99	2.12	2.55
N_1	7.12	5.32	6.22
N_2	7.84	5.84	6.84
N_3	7.63	5.54	6.59
$F_{3,60}$	**242.88****	**278.26****	**495.19**
C.D. (0.05)	**0.423**	**0.286**	**0.332**
G_0	6.02	4.33	5.18
G_1	6.45	4.68	5.56
G_2	6.50	4.783	5.64
G_3	6.66	5.03	5.85
$F_{3,60}$	**3.63***	**8.97****	**10.04****
CD (0.05)	**0.423**	**0.286**	**0.332**

* Significant at 0.05 level
** Significant at 0.01 level

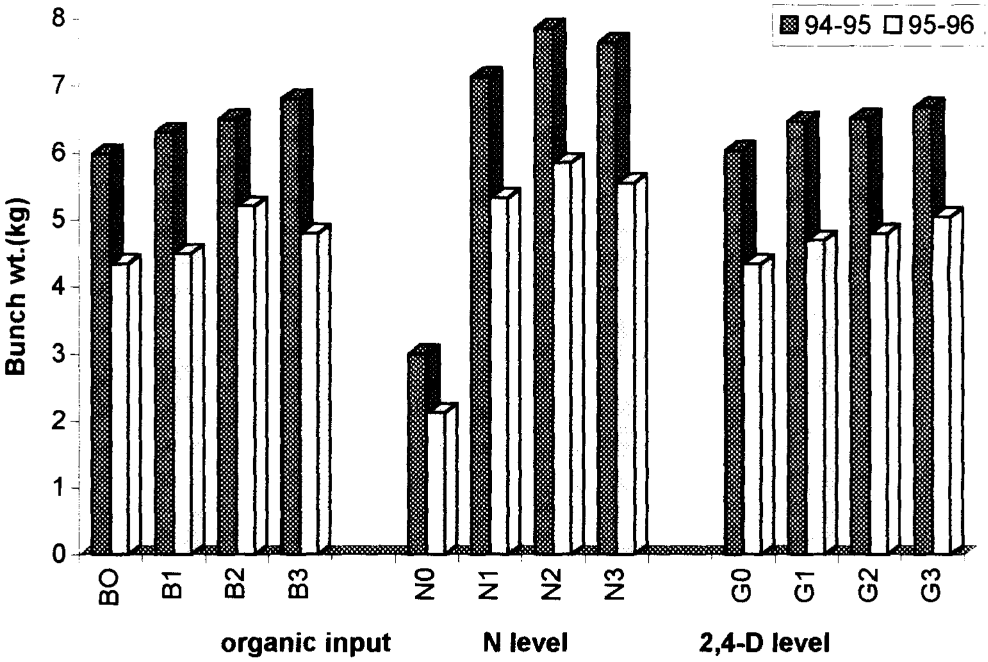


FIG.10 Effect of organic inputs, fertilizer N and 2,4-D on bunch weight

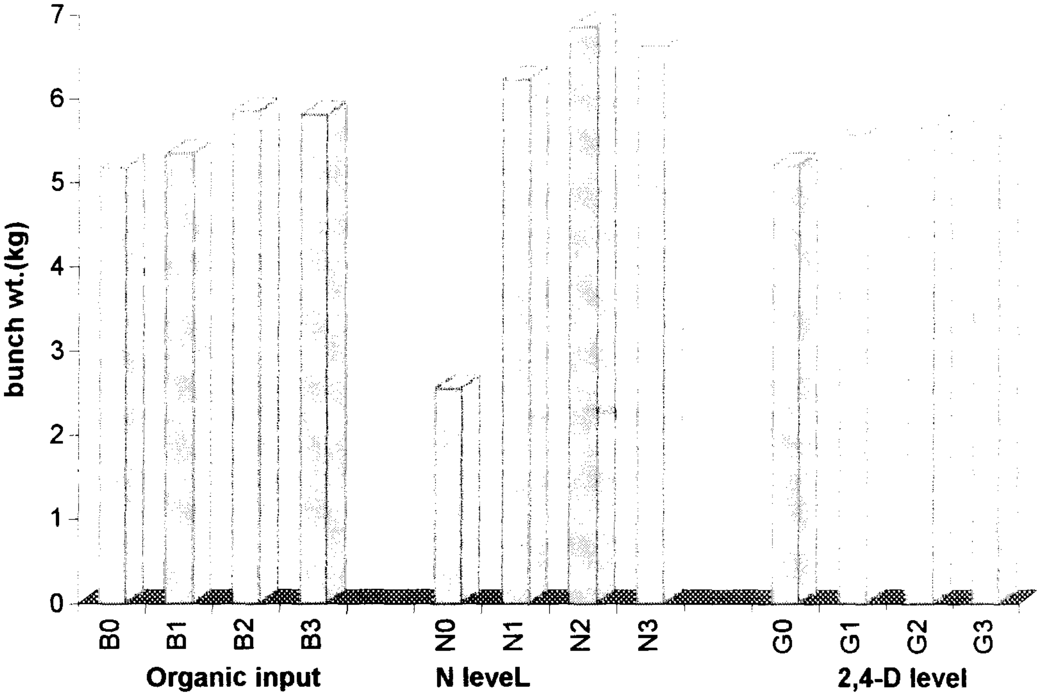


Fig.11 Effect of organic inputs, applied N and 2,4-D on bunch weight (Pooled)

years of experimentation. During the first year, it was on par with N_3 (cent % of the dose) and significantly superior to both N_1 and N_0. However, in the second year, N_2 was significantly superior to N_3, N_1 and N_0. The level N_1 was significantly superior to the control receiving no fertilizer N (N_0). The N_2 level registered mean yield increases of 162.2 per cent and 175.47 per cent during 1994-'95 and 1995-'96, respectively, over the control (N_0).

During the first year, 2,4-D, the growth regulator, applied at the rate of 45 ppm, (G_3) recorded the highest bunch weight of 6.66 kg plant^{-1} and it was on par with 30 ppm (G_2) and 15 ppm (G_1). All these three levels were significantly superior to the control (G_0). During the second year, the different levels of applied 2,4-D (G_1, G_2 and G_3) exhibited the same trend.

A pooled analysis of the results gathered during the two years (Fig. 11) showed that cowpea (B_2) produced the highest bunch weight (5.85 kg plant^{-1}) but it was on par with vermicompost (B_3) (5.80 kg plant^{-1}). These treatments, were superior to *Azospirillum* (B_1) and the control (B_0). Among the N levels, N_2 produced the maximum bunch weight of 6.84 kg plant^{-1} and it was on par with N_3 and significantly superior to N_1 and N_0. With regard to 2,4-D, G_3 (45 ppm) recorded a significantly higher bunch weight of 5.85 kg plant^{-1} as compared to G_1 (5.55 kg plant^{-1}) and G_2 (5.64 kg plant^{-1}). However, G_1 and G_2 were on par and superior to G_0.

The data pertaining to interaction effects of organic inputs and fertilizer N are presented in Table 26 and Fig. 12.

Plate 7 Bunches from plants receiving 50% and 100% of the recommended dose of fertilizer N

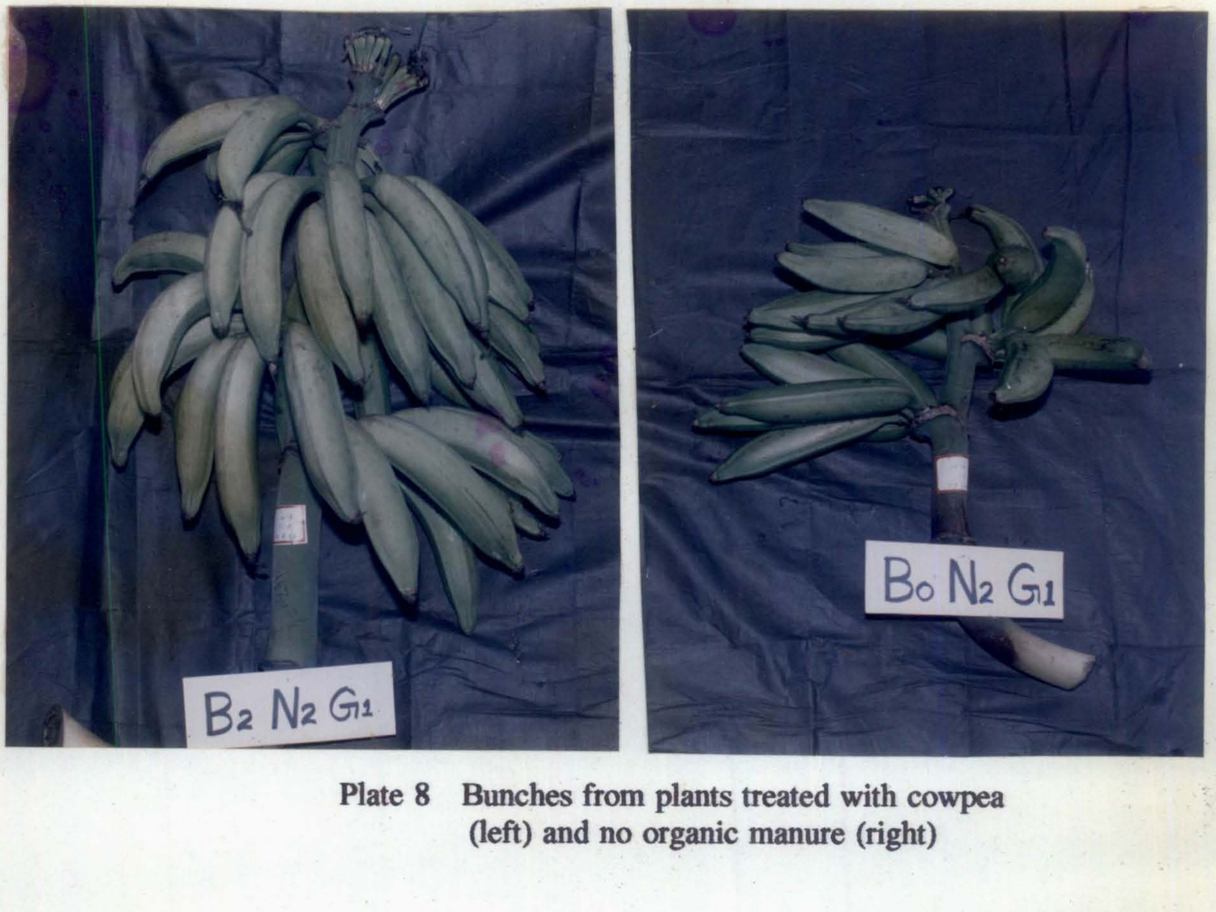


Plate 8 Bunches from plants treated with cowpea (left) and no organic manure (right)

Table 26 Interaction of organic inputs and applied N on bunch weight

Treatment combination	Bunch weight (kg plant^{-1})		
	I Year (1994-'95)	II Year (1995-'96)	Pooled Mean
b_0n_0	2.04	1.85	1.95
b_0n_1	6.89	4.99	5.94
b_0n_2	7.43	5.39	6.32
b_0n_3	7.53	5.14	6.32
b_1n_0	2.57	1.55	2.06
b_1n_1	6.83	5.15	5.99
b_1n_2	8.41	5.78	7.1
b_1n_3	7.41	5.48	6.44
b_2n_0	3.36	3.10	3.25
b_2n_1	7.17	5.54	6.32
b_2n_2	7.39	6.14	6.77
b_2n_3	8.09	5.95	7.02
b_3n_0	3.98	1.94	2.94
b_3n_1	7.59	5.60	6.60
b_3n_2	8.13	6.02	7.08
b_3n_3	7.50	5.61	6.52
$F_{9,60}$	**2.93****	**2.05***	**2.95****
CD (0.05)	**0.832**	**0.565**	**0.665**

* Significant at 0.05 level
** Significant at 0.01 level

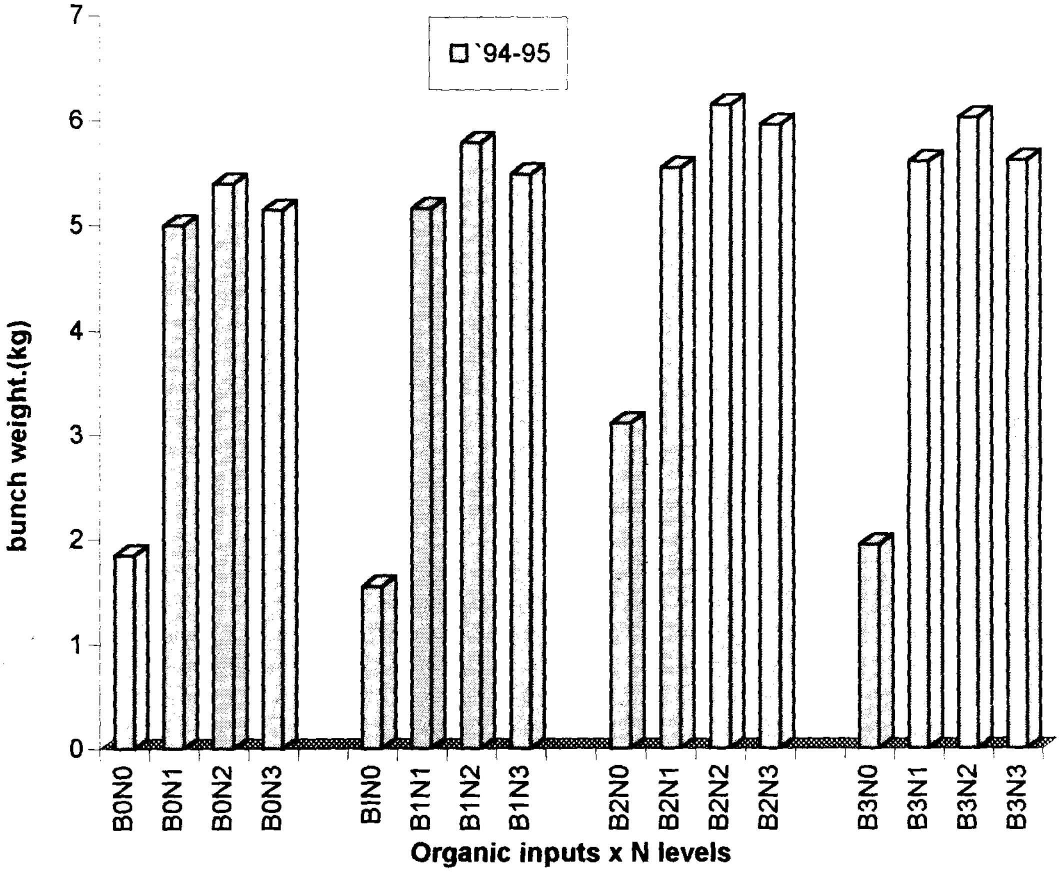


Fig. 12a Interaction effect of organic inputs and applied N on bunch weight (`94-95)

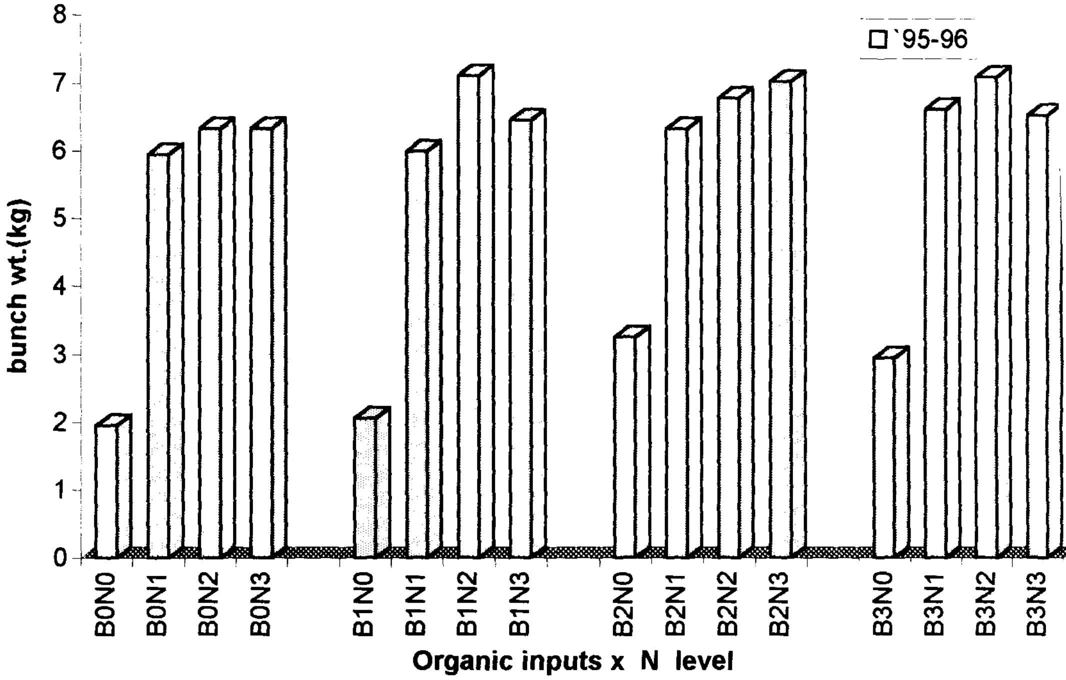


Fig 12.b Interaction effect of organic inputs and applied N on bunch weight `95-96)

Table 27 Interaction of N and growth regulator on bunch weight

Treatment combination	Bunch weight (kg plant^{-1})		
	I Year (1994-'95)	II Year (1995-'96)	Pooled Mean
n_0g_0	2.49	1.54	2.02
n_0g_1	2.78	2.33	2.56
n_0g_2	3.06	2.20	2.63
n_0g_3	3.37	2.43	2.90
n_1g_0	6.52	5.10	5.81
n_1g_1	6.85	4.83	5.84
n_1g_2	7.21	5.37	6.29
n_1g_3	8.16	6.00	7.04
n_2g_0	8.08	5.68	6.88
n_2g_1	7.93	5.90	6.92
n_2g_2	8.09	5.61	6.85
n_2g_3	7.27	6.15	6.71
n_3g_0	7.08	5.00	6.01
n_3g_1	7.78	5.68	6.73
n_3g_2	7.84	5.96	6.90
n_3g_3	7.83	5.53	6.68
$F_{9,60}$	**2.74****	**3.34****	**3.528****
CD (0.05)	**0.832**	**0.565**	**0.665**

** Significant at 0.01 level

The highest bunch weight of 8.41 kg $plant^{-1}$ was registered by the treatment combination B_1N_2 during the first year of experimentation. However, it was on par with B_3N_2 (8.13 kg), B_2N_3 (8.09 kg) and B_3N_1 (7.59 kg $plant^{-1}$) and significantly superior to all the other combinations. These combinations were significantly superior to applied N even at its highest level in the absence of any organic input. During the second year, the best treatment combination was B_2N_2 (6.14 kg $plant^{-1}$). Nevertheless, it was on par with B_3N_2 (6.02 kg), B_2N_3 (5.95 kg), B_1N_2 (5.78 kg), B_3N_1 (5.6 kg) and B_3N_3 (5.61 kg $plant^{-1}$). By and large, the combination of fertilizer N with vermicompost (B_3), cowpea (B_2) and *Azospirillum* (B_1) were more effective on bunch yield as compared to fertilizer N applied alone. The pooled data indicated the superiority of the treatment combinations B_1N_2 (7.1 kg $plant^{-1}$), B_3N_2 (7.08 kg), B_2N_3 (7.02 kg), B_2N_2 (6.77 kg) and B_3N_1 (6.6 kg $plant^{-1}$). These combinations were significantly superior to the others.

The interaction effects of applied N and growth regulator on bunch weight summarised in Table 27 and Fig. 13 showed statistical significance during both the years of experimentation.

In the first year, the highest bunch weight $plant^{-1}$ was recorded by N_1G_3 (8.16 kg), but it was on par with N_2G_2 (8.09), N_2G_0 (8.08 kg), N_2G_1 (7.93 kg), N_3G_2 (7.84 kg), N_3G_3 (7.83 kg) and N_3G_1 (7.78 kg). In second year, the best treatment combination was N_2G_3 (6.15 kg $plant^{-1}$). It was, however, on par with N_1G_3 (6.00 kg), N_3G_2 (5.96 kg), N_2G_1 (5.90 kg), N_3G_1 and N_2G_0 (each 5.68 kg) and N_2G_2 (5.61 kg). In the absence of applied N, the influence of the growth regulator on bunch weight was of little significance.

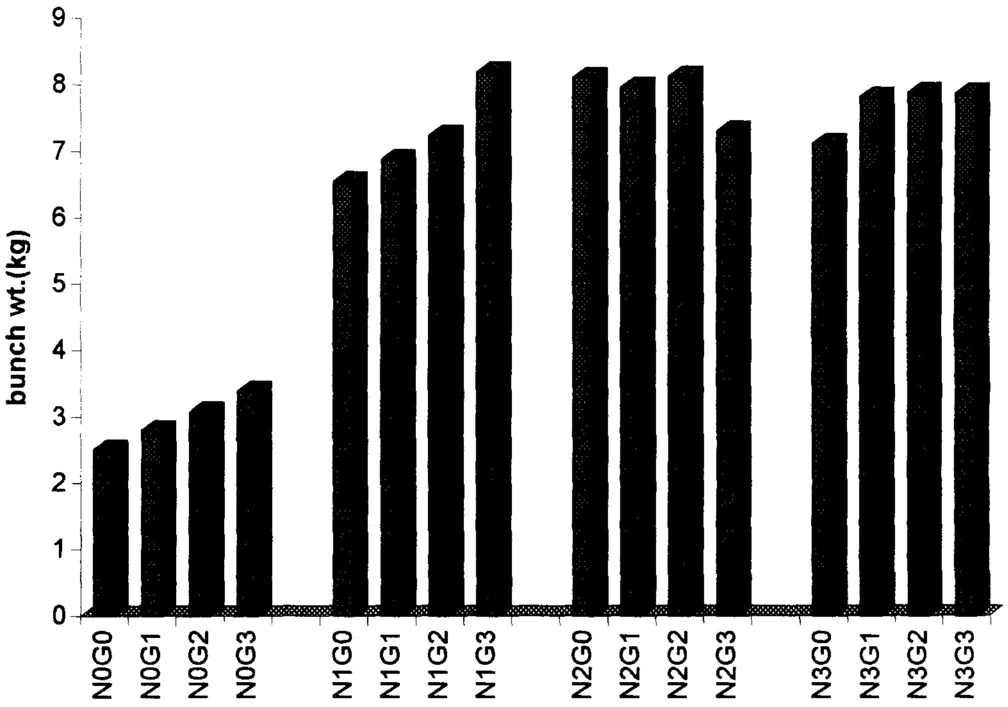


Fig. 13a Interaction effect of applied N and growth regulator on bunch weight('94-'95)

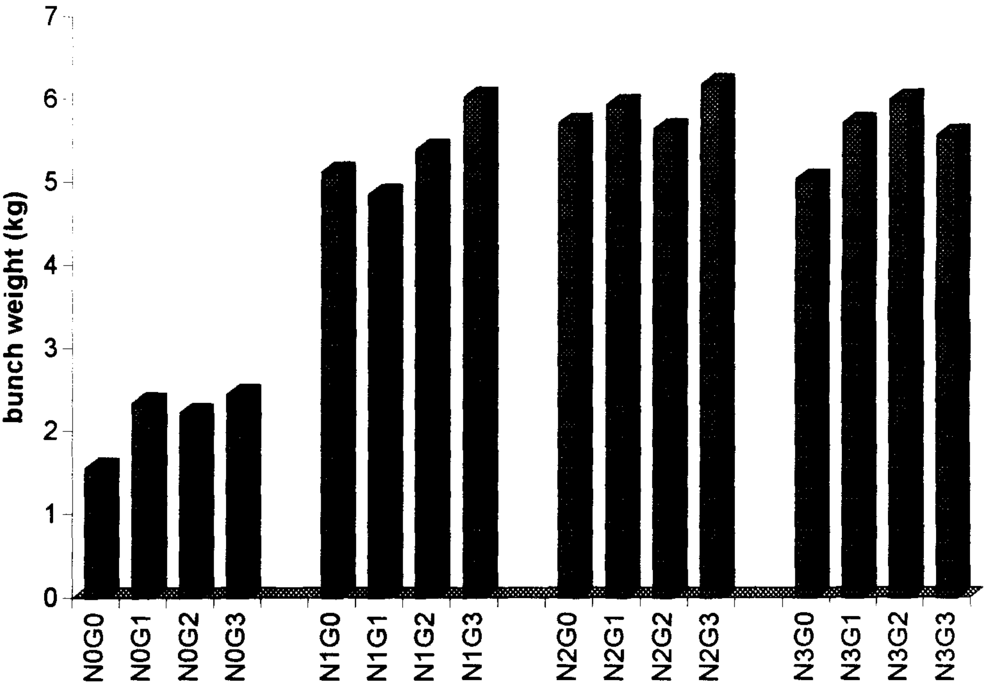


Fig. 13b Interaction effect of applied N and growth regulator on bunch weight (`95-`96)

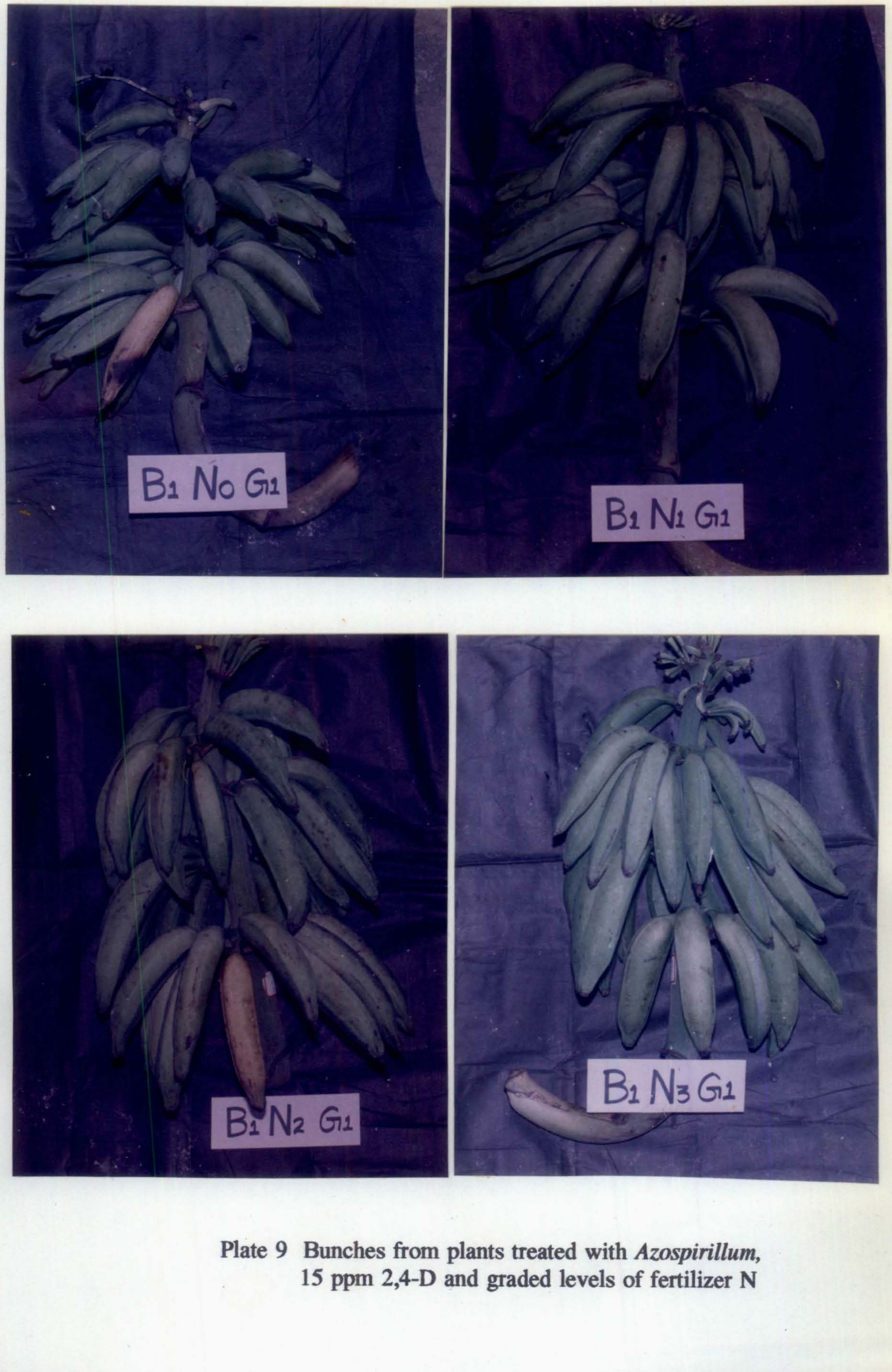


Plate 9 Bunches from plants treated with *Azospirillum*, 15 ppm 2,4-D and graded levels of fertilizer N

Table 28 Interaction of organic inputs and growth regulator on bunch weight

Treatment combination	Bunch weight (kg plant^{-1})		
	I Year (1994-'95)	II Year (1995-'96)	Pooled Mean
b_0g_0	5.28	3.93	4.61
b_0g_1	5.83	4.30	5.07
b_0g_2	6.19	4.53	5.36
b_0g_3	6.60	4.62	5.61
b_1g_0	6.25	4.00	5.12
b_ng_1	6.11	4.14	5.12
b_1g_2	6.28	4.59	5.44
b_1g_3	6.58	5.23	5.90
b_2g_0	5.87	4.67	5.27
b_2g_1	6.57	5.48	6.03
b_2g_2	6.89	5.12	6.01
b_2g_3	6.69	5.52	6.06
b_3g_0	6.76	4.73	5.71
b_3g_1	6.85	4.82	5.84
b_3g_2	6.82	4.90	6.55
b_3g_3	6.76	4.73	5.73
$F_{9, 60}$	**1.48**	**2.74****	**2.23***
CD (0.05)	--	**0.565**	**0.665**

* Significant at 0.05 level

** Significant at 0.01 level

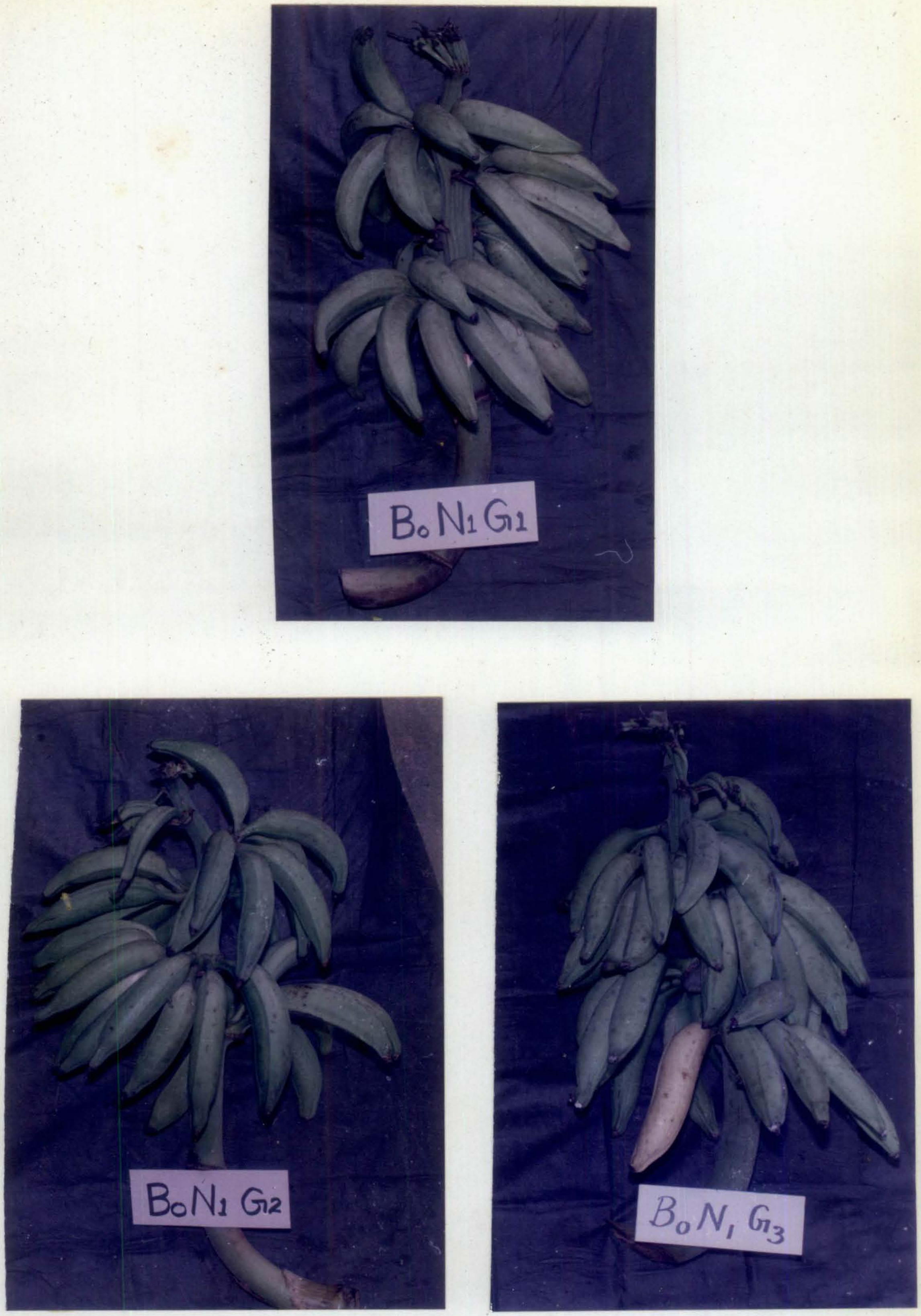


Plate 10 Bunches from plants receiving different levels of 2,4-D.

The pooled data showed that the interaction effects were significant in respect of treatment combinations N_1G_3 (7.04 kg plant^{-1}), N_2G_1 (6.92 kg), N_2G_0 (6.88 kg), N_2G_2 (6.85 kg), N_3G_1 (6.73 kg), N_3G_2 (6.9 kg), N_2G_3 (6.71 kg) and N_3G_3 (6.68 kg) over the other combinations.

The interaction effects of B x G were significant during the second year only when B_2G_3 topped the list of treatment combinations with a bunch weight of 5.52 kg plant^{-1} (Table 28). However, it was on par with B_2G_1 (5.48 kg), B_1G_3 (5.23 kg) and B_2G_2 (5.12 kg plant^{-1}). A pooled analysis of the data showed that the interaction effect was significant for treatment combinations B_3G_2, B_2G_3, B_2G_2, B_2G_1 and B_1G_3.

4.4.2. Dry matter yield

The data pertaining to the effect of organic inputs, inorganic N and growth regulator on DM yield are summarised in Table 29 and Fig. 14.

During the first year, the highest yield of 2.61 kg plant^{-1} was produced by vermicompost (B_3) which was on par with cowpea (B_2) but significantly superior to the control (B_0) and *Azospirillum* (B_1). The magnitude of yield increase registered by this treatment over the control (B_0) was 13.59 per cent. However, there was no significant difference between B_1 and B_0. Similarly, B_2 and B_1 were on par. During the second year, cowpea (B_2) recorded the highest DM yield (1.90 kg plant^{-1}) but it was on par with vermicompost (B_3). Both these treatments were statistically superior to B_1 and B_0 which were on par. The quantum of yield difference between cowpea (B_2) and the control (B_0) was 0.29 kg plant^{-1} (18.0%). The superiority of cowpea and vermicompost over the other treatments was clearly evident in the results.

Table 29 Effect of organic inputs, applied N and growth regulator on DM yield (kg plant^{-1})

Main effect	I Year (1994-'95)	II Year (1995-'96)
B_0	2.29	1.61
B_1	2.40	1.69
B_2	2.46	1.90
B_3	2.61	1.81
$F_{3, 60}$	**5.25****	**10.11****
C D (0.05)	**0.169**	**0.113**
N_0	1.14	0.81
N_1	2.82	2.05
N_2	2.94	2.13
N_3	2.85	2.05
$F_{3, 60}$	**230.39****	**252.73****
C D (0.05)	**0.169**	**0.113**
G_0	2.27	1.65
G_1	2.46	1.80
G_2	2.48	1.84
G_3	2.58	1.86
$F_{3, 60}$	**5.03****	**5.95****
C D (0.05)	**0.169**	**0.113**

** Significant at 0.01 level

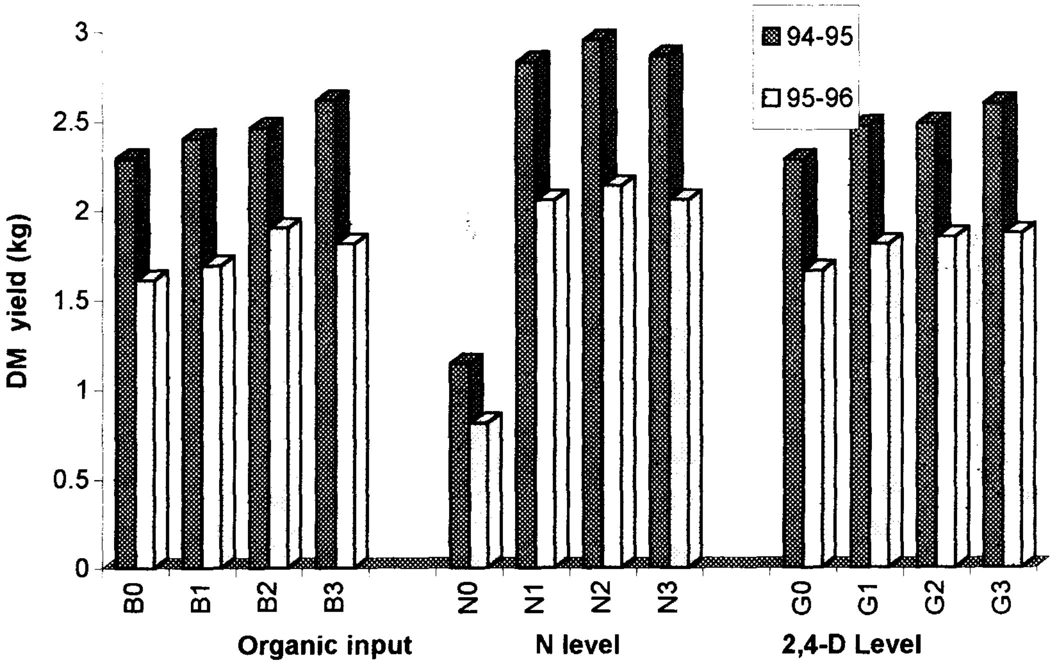


Fig.14 Effect of organic inputs, fertilizer N and 2,4-D on DM yield

With regard to applied N, the highest DM yield was produced by the level N_2 (75% of the recommended dose) during both the years. However, it was on par with N_3 and N_1 but significantly superior to the control (N_0). The yield improvement brought about by this level of N over the control amounted to 157.9 per cent in the first year and 162.96 per cent in the following year.

Application of 2,4-D at the rate of 45 ppm (G_3) recorded the highest DM yield (2.58 and 1.86 kg plant^{-1}, respectively) during both the years of experimentation. However, it was on par with G_1 and G_2 but significantly superior to G_0. There were no significant differences between G_1 and G_2 in both the years.

The interaction effect of organic inputs and applied N (B x N) on dry matter yield was significant during both the years of experimentation (Table 30). The best treatment combination producing the maximum DM yield (3.14 kg plant^{-1}) was B_1N_2 in the first year. It was, however, on par with the higher levels of N (N_2 and N_3) applied in combination with cowpea (B_2) and with N_1, N_2 and N_3 levels superimposed on vermicompost (B_3). In second year, the highest DM yield (2.19 kg plant^{-1}) was recorded by B_3N_2 and it was significantly superior to B_0N_1, B_0N_3, B_1N_0, B_2N_0, B_3N_0 and B_0N_0. The treatment combinations producing high DM yields indicated a saving of 25 per cent in the recommended dose of fertilizer N when it was applied in combination with either *Azospirillum*, vermicompost or cowpea.

The interaction between N and 2,4-D led to significant trends in DM yield (Table 31). During the first year, the highest dry matter yield was recorded by N_1G_3 (3.43 kg plant^{-1}) which was on par with N_3G_1 and significantly superior to the other combinations. In second year also, the best result (2.39 kg plant^{-1}) was

Table 30 Interaction of organic inputs and applied N on DM yield

Treatment combination	Dry matter yield (kg plant^{-1})	
	I year (1994-'95)	II Year (1995-'96)
b_0n_0	0.78	0.71
b_0n_1	2.74	1.95
b_0n_2	2.77	1.97
b_0n_3	2.68	1.82
b_1n_0	0.99	0.60
b_1n_1	2.68	1.99
b_1n_2	3.14	2.07
b_1n_3	2.78	2.09
b_2n_0	1.28	1.20
b_2n_1	2.69	2.07
b_2n_2	2.86	2.16
b_2n_3	3.10	2.15
b_3n_0	1.50	0.73
b_3n_1	2.97	2.18
b_3n_2	3.10	2.19
b_3n_3	2.86	2.13
$F_{9,60}$	**3.30****	**2.74****
C D (0.05)	**0.321**	**0.226**

** Significant at 0.01 level

Table 31 Interaction of N and growth regulator on DM yield

Treatment combination	Dry matter yield (kg plant^{-1})	
	I Year (1994-'95)	II Year (1995-'96)
n_0g_0	0.93	0.58
n_0g_1	1.09	0.88
n_0g_2	1.16	0.88
n_0g_3	1.37	0.90
n_1g_0	2.48	1.95
n_1g_1	2.59	1.90
n_1g_2	2.78	1.94
n_1g_3	3.43	2.39
n_2g_0	3.01	2.21
n_2g_1	3.03	2.22
n_2g_2	3.06	2.01
n_2g_3	2.66	2.11
n_3g_0	2.64	1.86
n_3g_1	3.12	2.21
n_3g_2	2.81	2.10
n_3g_3	2.85	2.03
$F_{9, 60}$	5.68**	4.91**
CD (0.05)	**0.321**	**0.226**

** Significant at 0.01 level

Table 32 Interaction of organic inputs and growth regulator on DM yield

Treatment combination	Dry matter yield (kg plant^{-1})	
	I Year (1994-'95)	II Year (1995-'96)
b_0g_0	1.91	1.42
b_0g_1	2.22	1.56
b_0g_2	2.17	1.65
b_0g_3	2.57	1.72
b_1g_0	2.34	1.58
b_1g_1	2.24	1.57
b_1g_2	2.34	1.58
b_1g_3	2.69	2.02
b_2g_0	2.27	1.79
b_2g_1	2.64	2.16
b_2g_2	2.77	1.86
b_2g_3	2.15	1.77
b_3g_0	2.55	1.80
b_3g_1	2.74	1.92
b_3g_2	2.54	1.69
b_3g_3	2.60	1.83
$F_{9, 60}$	**6.05****	**4.28****
CD (0.05)	**0.321**	**0.226**

** Significant at 0.01 level

registered by the combination N_1G_3 followed by N_2G_0, N_2G_1 and N_3G_2 which were on par.

The interaction effect of organic inputs and growth regulator (B x G) on DM yield was significant during both years of experimentation (Table 32). During the first year, B_2G_2 recorded the highest DM yield (2.97 kg plant^{-1}) which was on par with B_3G_1, B_1G_3, B_3G_3, B_2G_1, B_3G_2, B_3G_0 and B_0G_3. In the second year, the highest DM was produced by B_2G_1 which was on par with B_1G_3 and superior to the other combinations.

4.5. Fruit quality

The data pertaining to the effect of organic inputs, inorganic N and 2,4-D on fruit quality are presented in Table 33.

4.5.1. Pulp peel ratio

The different organic inputs failed to produce any significant effect on pulp peel ratio.

With regard to applied N, the level N_3 registered the highest ratio of 2.44. It was, however, on par with N_2 and significantly superior to N_1 and N_0. The difference between the levels N_2 and N_1 was also not significant. Nevertheless, these levels were significantly superior to the control, N_0.

The growth regulator applied at the rate of 30 ppm produced the highest pulp peel ratio of 2.36, but it was on par with the other levels barring G_0. The difference between G_3 (45 ppm) and the control (G_0) was not significant.

Table 33 Effect of organic inputs, applied N and growth regulator on fruit quality

Main effect	Pulp-peel ratio	TSS (brix)	Acidity (%)	Total sugar (%)	Reducing Sugar (%)	Non-reducing sugar (%)	Sugar acid ratio	Ascorbic acid content (mg 100 g^{-1})
B_0	2.35	20.09	0.56	20.70	14.06	7.13	38.08	15.77
B_1	2.24	18.38	0.61	20.47	13.48	6.99	35.09	15.86
B_2	2.19	19.78	0.59	20.85	15.55	5.38	36.68	15.76
B_3	2.23	18.97	0.57	19.86	14.43	5.43	36.28	15.76
$F_{3,60}$	**1.43**	**2.87***	**2.98***	**1.45**	**7.23****	**19.81****	**1.75**	**0.43**
CD (0.05)	-	**1.293**	**0.028**	-	**0.921**	**0.678**	-	-
N_0	2.05	18.22	0.64	17.60	12.71	5.40	28.65	15.31
N_1	2.23	19.88	0.58	20.52	13.46	7.07	35.81	16.04
N_2	2.29	19.00	0.54	24.30	16.56	7.77	46.26	15.87
N_3	2.44	20.13	0.57	19.47	14.79	4.69	35.40	15.94
$F_{3,60}$	**8.02****	**3.56***	**14.25****	**61.06****	**27.24****	**35.59****	**61.26****	**18.29****
CD (0.05)	**0.163**	**1.293**	**0.028**	**1.017**	**0.921**	**0.678**	**2.627**	**0.22**
G_0	2.08	15.38	0.62	19.80	13.56	6.75	34.18	15.74
G_1	2.35	19.78	0.59	18.84	14.07	4.84	32.50	15.68
G_2	2.36	21.16	0.56	20.99	13.72	7.25	38.29	15.90
G_3	2.21	20.91	0.56	22.25	16.18	6.09	41.15	15.83
$F_{3,60}$	**5.79****	**33.98****	**7.53****	**16.72****	**14.19****	**18.93****	**17.87****	**1.60**
CD (0.05)	**0.163**	**1.293**	**0.028**	**1.017**	**0.921**	**0.678**	**2.627**	-

* Significant at 0.05 level
** Significant at 0.01 level

Among the B x N combinations, B_0N_3 produced the highest pulp peel ratio of 2.67 per cent and it was significantly superior to all the other treatment combinations except B_1N_3, B_2N_2 and B_3N_2. These were on par (Table 34).

The N x G interaction was also significant with N_3G_1 registering the highest ratio of 2.75. This treatment combination was, however, on par with N_3G_2, N_2G_1 and N_1G_3 (Table 35).

4.5.2. Total soluble solids (TSS)

The highest value of TSS (20.09 brix) was recorded by the control (B_0) receiving no organic inputs although it was on par with the treatments B_2 (cowpea) and B_3 (vermicompost). There was also no significant difference between B_3 and B_1.

Applied N at the levels, N_3 and N_1 were on par with N_2 but they were significantly superior to the control (N_0) in their effect on TSS. The difference between N_2 and N_0 was also not significant.

The growth regulator dose to produce the maximum TSS (21.16) was 30 ppm (G_2) but it was on par with 45 ppm (G_3) and was significantly superior to G_1 (15 ppm) and the control (G_0). The difference between G_3 and G_1 also did not touch the level of significance although these levels were superior to the control (G_0).

The interaction effect of organic inputs and inorganic N was significant with B_0N_1 recording the highest TSS of 22.38. It was on par with B_2N_1 and, B_3N_2 and superior to all the other combinations (Table 34).

The N x G interaction was also significant with N_3G_2 registering the highest TSS of 23.13 brix. However, it was on par with N_1G_3, N_3G_1, N_2G_2, N_1G_2 and N_0G_3.

Table 34 Interaction of organic inputs and applied N on fruit quality

Treatment combination	Pulp - peel ratio	TSS (brix)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Sugar acid ratio	Ascorbic acid content (mg 100 g^{-1})
b_0n_0	1.88	18.25	0.57	17.83	13.94	5.91	33.70	15.09
b_0n_1	2.26	22.38	0.58	22.52	13.50	8.94	39.18	16.29
b_0n_2	2.28	18.63	0.53	28.29	18.94	9.35	53.51	16.04
b_0n_3	2.67	18.13	0.57	14.16	9.85	4.30	25.91	15.66
b_1n_0	2.00	18.63	0.68	18.90	13.26	5.63	28.25	15.70
b_1n_1	2.22	18.50	0.58	20.59	12.04	8.56	35.83	15.73
b_1n_2	2.33	18.13	0.59	21.47	13.13	8.34	39.05	15.75
b_1n_3	2.41	18.25	0.59	20.94	15.51	5.44	37.24	16.25
b_2n_0	1.96	17.88	0.64	20.08	14.58	5.55	32.27	15.17
b_2n_1	2.07	20.88	0.59	19.87	13.90	6.07	34.26	16.10
b_2n_2	2.45	18.88	0.55	22.36	17.05	5.44	41.06	15.74
b_2n_3	2.29	19.50	0.57	21.11	16.66	4.46	39.13	16.03
b_3n_0	2.09	18.13	0.68	13.58	9.08	4.50	20.38	15.26
b_3n_1	2.19	17.75	0.57	19.12	14.40	4.72	33.98	16.03
b_3n_2	2.36	20.38	0.49	25.09	17.14	7.96	51.42	15.94
b_3n_3	2.28	19.63	0.55	21.67	17.13	4.56	39.32	15.80
$F_{9,60}$	**3.37****	**2.11***	**1.85**	**20.05****	**17.09****	**5.54****	**12.47****	**2.94***
C.D. (0.05)	**0.322**	**2.613**	-	**2.048**	**1.836**	**1.836**	**5.254**	**0.43**

* Significant at 0.05 level
** Significant at 0.01 level

Table 35 Interaction of N and growth regulator on fruit quality

Treatment combination	Pulp - peel ratio	TSS (brix)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Sugar acid ratio	Ascorbic acid content (mg 100 g^{-1})
n_0g_0	1.97	13.38	0.70	13.98	11.05	4.94	22.10	14.97
n_0g_1	2.00	18.63	0.65	16.36	12.10	4.26	25.11	15.29
n_0g_2	2.15	19.13	0.63	18.50	12.30	6.20	30.12	15.57
n_0g_3	2.08	21.75	0.59	21.55	15.40	6.20	37.26	15.40
n_1g_0	1.98	15.50	0.58	20.66	13.31	7.35	36.42	16.00
n_1g_1	2.20	20.25	0.58	19.90	15.21	4.80	34.54	15.85
n_1g_2	2.35	21.25	0.58	22.05	13.43	8.54	38.26	16.07
n_1g_3	2.43	22.50	0.58	19.48	11.89	7.60	34.04	16.22
n_2g_0	2.04	15.63	0.56	28.33	18.87	10.15	52.51	16.06
n_2g_1	2.46	18.88	0.57	21.23	16.03	5.33	38.05	15.62
n_2g_2	2.37	21.13	0.51	19.56	11.88	7.68	38.51	15.94
n_2g_3	2.27	20.38	0.51	28.09	20.17	7.92	55.97	15.85
n_3g_0	2.35	17.00	0.66	16.23	11.69	4.55	25.69	15.93
n_3g_1	2.75	21.38	0.56	17.87	12.93	4.95	32.30	15.96
n_3g_2	2.58	23.13	0.52	23.87	17.28	6.60	46.27	16.02
n_3g_3	2.06	19.00	0.54	19.90	17.26	2.64	37.35	15.84
F $_{9,60}$	**2.60***	**2.32***	**1.92**	**22.05****	**16.33****	**8.14****	**14.31****	**1.26**
C.D. (0.05)	**0.322**	**2.613**	-	**2.048**	**1.836**	**1.356**	**5.254**	-

* Significant at 0.05 level
** Significant at 0.01 level

4.5.3. Acidity

Among the organic inputs, *Azospirillum* (B_1) produced the highest acidity value of 0.61 per cent, but it was statistically on par with cowpea (B_2). The latter treatment was, however, on par with vermicompost (B_3) and the control (B_0).

Applied N had a depressive effect on acidity. The N_0 level produced the maximum acidity (0.64%) and it was significantly superior to the rest of the N levels. There was statistically little difference between the levels N_1 and N_3 and between N_3 and N_2.

As in the case of applied N, the growth regulator reduced the acidity. The maximum acidity was produced by the control, G_0 but it was on par with G_1 (15 ppm) and significantly superior to the other levels. The levels, G_2 (30 ppm) and G_3 - (45 ppm) were, however, on par in their effect on acidity.

None of the interaction effect was significant.

4.5.4. Total sugar

None of the organic inputs had significant effect on total sugar. Nevertheless, the highest value (20.85%) was recorded by cowpea (B_2), closely followed by the control (B_0).

The levels of applied N differed significantly among themselves in their effect on total sugar in fruits. The best treatment producing the maximum total sugar content (24.3%) was N_2 which received only 75 per cent of the recommended dose of N for banana. The next best treatment was N_1. The applied N at its highest level (190 g plant^{-1}, the recommended dose), showed a depressive effect on total sugar. It was, however, significantly superior to the control, N_0.

The beneficial influence of 2,4-D on total sugar content was quite conspicuous in the results. The growth regulator applied at 45 ppm (G_3) recorded the highest value of 22.25 per cent and it was significantly superior to the rest of the treatments including the control (G_0) while the level G_2 (30 ppm) was statistically superior to G_0 and G_1. The lower level, G_1, was on par with G_0.

Among the B x N combinations, B_0N_2 produced the highest sugar content (28.29%) and it was significantly superior to all the other treatment combinations. Among N x G interactions, N_2G_0 recorded the highest sugar content of 28.33 per cent and it was on par with N_2G_3 and superior to the other combinations.

4.5.5. Reducing sugar

The organic inputs differed significantly among themselves in their effect on reducing sugar with cowpea (B_2) topping the list (15.55%). The next best input was vermicompost (B_3) with a reducing sugar value of 14.43 per cent. *Azospirillum* (B_1) was the least effective.

The reducing sugar in fruit pulp was observed to be markedly influenced by applied N. The best N level to produce the maximum content of reducing sugar was N_2 (16.56%) and it was significantly superior to N_3, N_1 and N_0 although the difference between these latter two treatments did not touch the level of statistical significance.

The effect of the growth regulator was seen confined to the higher level of 45 ppm (G_3) and it was significantly superior to the rest of the levels which were on par.

Among B x N interactions B_0N_2 produced the highest reducing sugar content of 18.94 per cent and it was on par with B_3N_2 (17.14%) and B_3N_3 (17.13%). The interaction effect of N and growth regulator was significant with N_2G_3 producing the highest reducing sugar content. It was, however, on par with N_2G_0.

4.5.6. Nonreducing sugar

The nonreducing sugar in the fruit pulp attained the highest value of 7.13 per cent in the treatment receiving no organic inputs (B_0). The difference between it and *Azospirillum* (B_1) was of little statistical significance. Both these treatments were, however, significantly superior to vermicompost (B_3) and cowpea (B_2) which were on par.

The levels of N differed significantly among themselves in their effect on nonreducing sugar. The highest content was recorded by the level N_2 (7.77%) receiving 75 per cent of the recommended dose of N for banana. The N_3 level of N (100% of the dose) registered the least content of nonreducing sugar (4.69%).

Among the levels of 2,4-D, the least content (4.84%) of nonreducing sugar was recorded by G_1 (15 ppm). All the other levels were significantly superior to it. The differences between G_2 and G_0 and between G_0 and G_3 were not significant. The highest content of nonreducing sugar (7.25%) was produced by the level G_2.

Among B x N combinations, B_0N_2 recorded the maximum nonreducing sugar content. It was on par with B_0N_1, B_1N_1 and B_1N_2. The N x G interaction was also significant with N_2G_0 producing the highest nonreducing sugar content and it was significantly superior to the other combinations.

4.5.7. Sugar acid ratio

The organic inputs did not exhibit any significant effect on sugar acid ratio (Table 33).

With regard to applied N, its level N_2 produced the highest sugar acid ratio (46.26) and it was significantly superior to the other levels including the control (N_0). These levels differed significantly among themselves in this aspect.

Among the 2,4-D levels, G_3 ranked first with a ratio of 41.15. The level G_2 ranked second (38.29). The difference between these treatments was significant. G_0 and G_1 were on par recording significantly lower values compared to G_3 and G_2.

Among B x N combinations, B_0N_2 produced the highest sugar acid ratio of 53.51 followed by B_3N_2 with a ratio of 51.42 (Table 34). They were superior to all the other combinations.

The interaction effect of N and growth regulator was significant. N_2G_3 recorded the highest sugar acid ratio and it was on par with N_2G_0 (Table 35).

4.5.8. Ascorbic acid

The organic inputs failed to produce any significant effect on ascorbic acid content in fruits. The three levels of applied N were on par and significantly superior to the control (N_0) in their effect. As in the case of organic inputs, the different concentrations of 2,4-D had no conspicuous influence on ascorbic acid content.

None of the interactions was significant.

4.5.9. Nutrient content of fruits

The data relating to the effect of organic inputs, inorganic N and 2,4-D on nutrient content of fruits at harvest are presented in Table 36.

It could be seen from the Table that the organic inputs did not influence the N, K and Mg content in fruits. The highest Ca content (0.14%) in fruits was registered by cowpea (B_2) and it was significantly superior to the control (B_0) and vermicompost (B_3). The applied N level, N_3, registered the highest N content (0.61%) but it was on par with N_1 and N_2. All these levels were significantly superior to N_0.

The highest P content (0.13%) was recorded by vermicompost (B_3). The applied N had no effect on the P content in fruits. On the other hand, it exerted its marked influence on K, Ca and Mg contents with the level, N_2 registering the highest values in respect of all these nutrients. Among the levels N_1, N_2 and N_3, however, there was no significant difference in K and N contents. The levels N_2 and N_3 were on par in respect of Ca content.

The effect of the growth regulator, touched the level of significance on P content with its levels G_2 and G_3 recording the same value of 0.13 per cent. These were superior to the control G_0 and were on par with G_1.

Among B x N interactions, the highest N content was registered by B_2N_3 (0.67%). This was on par with B_0N_3, B_2N_1 and B_3N_2. The highest K content was recorded by B_2N_3 (1.82%) followed by B_3N_2 (1.79%). They were on par. B_2N_2 recorded the highest Ca content (0.33%) whereas Mg content was the highest in B_3N_2 (0.26%) (Table 37).

Table 36 Effect of organic inputs, applied N and growth regulator on nutrient content of fruits

Main effect	Nutrient content (%)				
	N	P	K	Ca	Mg
B_0	0.57	0.12	1.54	0.07	0.16
B_1	0.55	0.12	1.65	0.09	0.18
B_2	0.58	0.12	1.61	0.14	0.18
B_3	0.56	0.13	1.64	0.07	0.20
$F_{3, 60}$	**0.66**	**3.37***	**2.76**	**3.21***	**2.36**
C.D. (0.05)	-	**0.011**	-	**0.056**	-
N_0	0.50	0.12	1.52	0.06	0.15
N_1	0.57	0.12	1.62	0.06	0.18
N_2	0.58	0.12	1.66	0.15	0.21
N_3	0.61	0.13	1.65	0.11	0.18
$F_{3, 60}$	**8.77****	**1.61**	**4.2****	**5.85****	**6.23****
C.D. (0.05)	**0.056**	-	**0.085**	**0.056**	**0.028**
G_0	0.54	0.11	1.55	0.07	0.16
G_1	0.57	0.12	1.61	0.10	0.18
G_2	0.57	0.13	1.64	0.09	0.19
G_3	0.57	0.13	1.65	0.11	0.19
$F_{3, 60}$	**1.05**	**5.00****	**2.46**	**1.07**	**2.50**
CD (0.05)	-	**0.011**	-	-	-

* Significant at 0.05 level
** Significant at 0.01 level

Table 37 Interaction of organic inputs and applied N on nutrient content of fruits

Treatment combination	Nutrient content (%)				
	N	P	K	Ca	Mg
b_0n_0	0.49	0.10	1.41	0.04	0.10
b_0n_1	0.54	0.12	1.61	0.05	0.17
b_0n_2	0.58	0.11	1.50	0.10	0.16
b_0n_3	0.66	0.13	1.65	0.10	0.20
b_1n_0	0.53	0.14	1.73	0.09	0.20
b_1n_1	0.56	0.11	1.59	0.06	0.15
b_1n_2	0.58	0.13	1.78	0.08	0.20
b_1n_3	0.52	0.11	1.53	0.13	0.17
b_2n_0	0.51	0.10	1.47	0.08	0.16
b_2n_1	0.59	0.11	1.57	0.07	0.18
b_2n_2	0.58	0.12	1.57	0.33	0.20
b_2n_3	0.67	0.14	1.82	0.12	0.18
b_3n_0	0.49	0.12	1.48	0.05	0.14
b_3n_1	0.58	0.14	1.70	0.05	0.19
b_3n_2	0.61	0.14	1.79	0.10	0.26
b_3n_3	0.58	0.13	1.60	0.08	0.19
$F_{9, 60}$	**2.97****	**3.99****	**4.54**	**2.60***	**3.05****
C.D. (0.05)	**0.085**	**0.028**	**0.169**	**0.113**	**0.056**

* Significant at 0.05 level
** Significant at 0.01 level

Table 38 Interaction of N and growth regulator on nutrient content of fruits

Treatment combination	Nutrient content (%)				
	N	P	K	Ca	Mg
n_0g_0	0.48	0.11	1.46	0.04	0.14
n_0g_1	0.49	0.11	1.49	0.06	0.16
n_0g_2	0.49	0.13	1.56	0.06	0.15
n_0g_3	0.54	0.12	1.59	0.07	0.15
n_1g_0	0.55	0.12	1.55	0.05	0.15
n_1g_1	0.64	0.12	1.64	0.05	0.18
n_1g_2	0.58	0.12	1.63	0.05	0.20
n_1g_3	0.61	0.13	1.64	0.08	0.19
n_2g_0	0.55	0.10	1.54	0.09	0.19
n_2g_1	0.56	0.12	1.64	0.20	0.21
n_2g_2	0.58	0.14	1.73	0.17	0.24
n_2g_3	0.53	0.14	1.72	0.15	0.22
n_3g_0	0.57	0.12	1.64	0.09	0.18
n_3g_1	0.60	0.13	1.68	0.10	0.17
n_3g_2	0.65	0.13	1.62	0.09	0.19
n_3g_3	0.61	0.13	1.66	0.15	0.19
F	**0.83**	**1.00**	**0.52**	**0.43**	**0.84**

The interaction effect of applied N and growth regulator was not significant on nutrient content in fruits (Table 38).

4.5.10. Ripening period and shelf life of fruits

The influence of organic inputs, inorganic N and growth regulator on ripening period and shelf life of fruits are summarised in Table 39.

4.5.10.1. Ripening period

The data presented in Table 39 clearly indicated that vermicompost (B_3) prolonged the ripening period of fruits as compared to the unmanured control (B_0), cowpea (B_2) and *Azospirillum* (B_1) during both the years of experimentation. The latter three treatments were on par. Vermicompost (B_3) was significantly superior to the other inputs in 1994-'95 but it was on par with B_0 in 1995-'96.

The untreated control (N_0) registered relatively longer ripening periods, 6.66 and 6.16 days, respectively, in 1994-'95 and 1995-'96. This treatment was significantly superior only to N_1 and N_3 in the first year. The differences between N_2 and N_1 and between N_1 and N_3 were of little statistical significance.

The influence of 2,4-D on ripening period touched the level of significance only in the second year of experimentation when the level G_0 (0 ppm) recorded 6.63 days as against 6.06 days by G_1. The difference was significant. The treatment G_1 was also superior to G_3 and G_2 which were on par in their effect on ripening period of fruits.

The effect of interaction between organic inputs and N was significant only during the first year of experimentation. While B_3N_0 recorded the longest duration of 8.75 days, B_2N_1 registered the shortest period of 4.75 days. The

Table 39 Effect of organic inputs, applied N and growth regulator on ripening period and shelf life of fruits

Main effect	Time for ripening (days)		Shelf life (days)	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
B_0	5.97	5.81	4.13	3.72
B_1	5.53	5.72	4.06	3.69
B_2	5.84	5.50	4.03	4.03
B_3	7.22	6.34	3.94	3.72
$F_{3,60}$	**12.55****	**3.26***	**0.36**	**1.75**
C.D. (0.05)	**0.593**	**0.565**	-	-
N_0	6.66	6.16	4.31	3.72
N_1	5.84	5.94	4.16	3.66
N_2	6.41	5.59	3.78	4.09
N_3	5.66	5.69	3.91	3.69
$F_{3,60}$	**5.01****	**1.64**	**3.40***	**2.78***
C.D. (0.05)	**0.593**	-	**0.367**	**0.352**
G_0	6.44	6.63	4.25	4.38
G_1	6.38	6.06	4.09	3.88
G_2	5.84	5.31	4.03	3.47
G_3	5.91	5.38	3.78	3.44
$F_{3,60}$	**2.18**	**9.83****	**2.24**	**12.77****
CD (0.05)	-	**0.565**	-	**0.352**

* Significant at 0.05 level
** Significant at 0.01 level

Table 40 Interaction of organic inputs and applied N on ripening period and shelf life of fruits

Treatment combination	Ripening period (days)		Shelf life (days)	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
b_0n_0	6.25	5.88	4.75	3.63
b_0n_1	5.88	5.50	4.00	3.25
b_0n_2	6.13	6.25	3.75	4.13
b_0n_3	5.63	5.63	4.00	3.88
b_1n_0	5.50	5.75	4.00	4.00
b_1n_1	6.00	6.38	4.00	3.50
b_1n_2	5.50	5.25	4.13	3.75
b_1n_3	5.13	5.50	4.13	3.50
b_2n_0	6.13	6.00	4.25	3.63
b_2n_1	4.75	6.00	4.13	4.13
b_2n_2	6.88	4.75	3.75	4.50
b_2n_3	5.63	5.25	4.00	3.88
b_3n_0	8.75	7.00	4.25	3.63
b_3n_1	6.75	5.88	4.50	3.75
b_3n_2	7.13	6.13	3.50	4.00
b_3n_3	6.25	6.38	3.50	3.50
$F_{9,60}$	**2.46***	**1.47**	**1.35**	**1.18**
C D (0.05)	**1.182**	-	-	-

* Significant at 0.05 level

treatment B_3N_0 was significantly superior to the other combinations of organic inputs and fertilizer N (Table 40).

The effect of N x G interactions was not significant (Table 41).

4.5.10.2. Shelf life

The organic inputs failed to produce any significant effect on shelf life during both the years of experimentation (Table 39).

As regards the influence of applied N on shelf life, the treatment differences, as a matter of fact, showed an erratic trend. The applied N tended to shorten the shelf life in the first year but the N_2 level (75% of the recommended dose) prolonged it in the following year. The differences between N_2 and the other levels were significant statistically during this year. In the first year, on the other hand, N_0 and N_1 were on par and significantly superior to N_3 and N_2. The latter two levels also did not exhibit significant difference.

The influence of 2,4-D on shelf life was significant only during the second year of experimentation. The untreated control (G_0) registered the longest shelf life of 4.38 days and it was significantly superior to the other levels. The lower level of 2,4-D (15 ppm, G_1) ranked second with a shelf life of 3.88 days. This treatment was significantly superior to G_2 and G_3 which were on par. The higher levels (30 and 45 ppm), thus, tended to shorten the shelf life of fruits.

The shelf life of fruits was not influenced by B x N and N x G interactions (Table 40 and 41).

Table 41 Interaction of N and growth regulator on ripening period and shelf life

Treatment combination	Ripening period (days)		Shelf life (days)	
	I Year (1994-'95)	II Year (1995-'96)	I Year (1994-'95)	II Year (1995-'96)
n_0g_0	7.25	7.00	4.38	4.63
n_0g_1	7.38	6.38	4.38	4.13
n_0g_2	6.00	5.75	4.50	3.00
n_0g_3	6.00	5.50	4.00	3.13
n_1g_0	6.63	6.50	4.25	4.13
n_1g_1	6.00	6.00	4.38	3.50
n_1g_2	5.75	5.50	4.38	3.50
n_1g_3	5.00	5.75	3.63	3.50
n_2g_0	6.13	6.50	4.25	4.50
n_2g_1	6.50	6.25	3.50	4.13
n_2g_2	6.13	4.75	3.50	3.88
n_2g_3	6.88	4.88	3.88	3.88
n_3g_0	5.75	6.50	4.13	4.25
n_3g_1	5.63	5.63	4.13	3.75
n_3g_2	5.50	5.25	3.75	3.50
n_3g_3	5.75	5.38	3.63	3.25
$F_{9,60}$	**1.50**	**0.49**	**1.08**	**1.20**

* Significant at 0.05 level

4.6. Nutrient content of index leaf

The influence of organic inputs, inorganic N and growth regulator on major nutrient contents of index leaf is quantified and presented in Table 42.

Among the organic inputs, the maximum N content (1.04%) was recorded by vermicompost (B_3) and it was significantly superior to *Azospirillum* (B_1), cowpea (B_2) and the control (B_0). The treatment *Azospirillum* (B_1) recorded the highest P content (0.52%). This was significantly superior to the other treatments which were on par. The organic inputs exerted no significant influence on leaf K content but the trend favoured vermicompost (B_3).

Among the N levels, N_2, which received 75 per cent of the recommended dose, recorded the highest N content (1.05 %) but it was significantly superior to the other levels including the control (N_0). The lower level of N (N_1) registered the highest P content (0.50%) in index leaf, and it was significantly superior to N_3 and N_2 which were superior to the control (N_0).

Application of 2-4,D had no significant effect on any of the nutrient content.

The interaction effect of organic inputs and inorganic N was significant on N and P content. The highest N content was recorded by B_3N_2 and it was on par with B_3N_1, B_2N_2 and B_1N_3 (Table 43). The maximum P content was registered by B_1N_3 (0.54) but it was on par with all the treatment combinations except B_0N_2, B_1N_0 and B_3N_0.

Table 42 Effect of organic inputs and applied N on nutrient content of index leaf

Main effect	Nutrient content (%)		
	N	P	K
B_0	0.92	0.38	1.37
B_1	0.89	0.52	1.42
B_2	0.91	0.36	1.38
B_3	1.04	0.33	1.49
$F_{3, 60}$	**4.54****	**5.40****	**1.36**
C.D. (0.05)	**0.09**	**0.11**	-
N_0	0.82	0.33	1.29
N_1	0.94	0.50	1.44
N_2	1.05	0.38	1.45
N_3	0.94	0.38	1.47
$F_{3, 60}$	**8.17****	**3.75***	**3.29***
C.D. (0.05)	**0.09**	**0.11**	**0.13**
G_0	0.95	0.4	1.35
G_1	0.96	0.37	1.42
G_2	0.96	0.43	1.39
G_3	0.89	0.39	1.5
$F_{3, 60}$	**0.95**	**0.43**	**2.11**

* Significant at 0.05 level
** Significant at 0.01 level

Table 43 Interaction of organic inputs and applied N on nutrient content of index leaf

Treatment combination	Nutrient content (%)		
	N	P	K
b_0n_0	0.76	0.34	1.18
b_0n_1	0.91	0.36	1.31
b_0n_2	0.92	0.31	1.48
b_0n_3	0.95	0.34	1.53
b_1n_0	0.76	0.32	1.33
b_1n_1	0.79	0.42	1.53
b_1n_2	0.95	0.41	1.47
b_1n_3	1.06	0.54	1.35
b_2n_0	0.85	0.36	1.31
b_2n_1	0.94	0.35	1.30
b_2n_2	1.08	0.44	1.50
b_2n_3	0.95	0.43	1.41
b_3n_0	0.90	0.31	1.36
b_3n_1	1.13	0.39	1.63
b_3n_2	1.19	0.41	1.36
b_3n_3	0.95	0.40	1.60
$F_{9,60}$	**2.66***	**2.34***	**1.55**
C D (0.05)	**0.197**	**0.208**	--

* Significant at 0.05 level

Table 44 Effect of organic inputs and applied N on weed weight

Main effect	Weed weight (kg ha^{-1})	
	Fresh weight	Dry weight
B_0	1608.8	815.2
B_1	1531.2	778.8
B_2	490.0	280.0
B_3	1557.6	833.2
$F_{3,60}$	**89.06****	**87.23****
C D (0.05)	**161.62**	**80.46**
N_0	945.6	506.2
N_1	1508.2	777.6
N_2	1407.6	740.0
N_3	1366.2	683.2
$F_{3,60}$	**18.51****	**17.85**
C D (0.05)	**161.62**	**80.46**

** Significant at 0.01 level

4.7. Weed weight

The data pertaining to the effect of organic inputs and fertilizer N on fresh and dry weights of weeds are presented in Table 44.

Among the organic inputs, cowpea, (B_2) registering the lowest weight of weeds (both fresh and dry) was significantly superior to the others which were on par.

Applied N favoured weed growth as evidenced by the fresh and dry weights of weeds presented in Table 44. The levels N_1, N_2 and N_3 were on par and significantly superior to N_0 (control) on fresh weight basis and on dry weight basis, N_1 was significantly superior to N_3 and N_0 levels. The levels N_2 and N_3 were on par in their effect. The least weed weight - both fresh and dry - was recorded by N_0 consistently.

4.8. Nutrient status of soil

4.8.1. Chemical properties

The nutrient status of soil in terms of organic carbon, ammoniacal-N, nitrate N, available P and available K are presented in Table 45. The soil analysis after the experiment showed that the effect of organic inputs was significant only for available K (Table 43). The highest K content in soil was recorded by vermicompost (215.6 kg ha^{-1}) followed by *Azospirillum* (200.05 kg ha^{-1}). Though not significant, the organic inputs showed an increasing trend in organic carbon, ammoniacal-N and nitrate N.

The data pertaining to the effect of various levels of N on soil nutrient status showed that there was significant difference between various N levels with

Table 45 Effect of organic inputs and applied N on soil chemical properties at the end of the cropping season (1995-`96)

Main effect	Organic Carbon (%)	NH_4-N (ppm)	NO_3-N (ppm)	Available P (kg ha^{-1})	Available K (kg ha^{-1})
B_0	1.964	328.75	110.00	17.05	109.20
B_1	2.019	333.75	135.00	17.78	200.05
B_2	2.033	351.25	160.00	20.40	123.20
B_3	2.132	340.00	147.50	16.83	215.60
F	**0.04**	**1.884**	**2.15**	**0.56**	**6.70****
C.D. (0.05)	--	--	--	--	**22.04**
N_0	1.689	100.00	92.50	15.53	179.20
N_1	2.109	271.25	138.75	20.73	176.35
N_2	2.075	445.00	163.75	17.80	165.20
N_3	1.985	457.50	157.50	17.99	127.30
F	**0.034**	**16.69****	**4.89****	**0.94**	**1.34**
C.D. (0.05)	--	**43.98**	**15.52**	--	--

Table 46 Interaction of organic and inorganic N on soil chemical properties at the end of the cropping season (1995-'96)

Treatment combination	Organic carbon (%)	NH_4-N (ppm)	NO_3-N (ppm)	Available P (kg ha^{-1})	Available K (kg ha^{-1})
b_0n_0	1.435	110	80	14.1	100.8
b_0n_1	2.105	295	125	21.9	112.0
b_0n_2	2.26	420	125	17.9	100.8
b_0n_3	2.06	570	110	14.3	123.2
b_1n_0	1.56	70	85	17.8	291.2
b_1n_1	2.45	220	150	24.2	235.0
b_1n_2	1.93	310	165	14.7	134.4
b_1n_3	2.15	330	140	14.5	139.6
b_2n_0	1.44	80	110	14.4	123.2
b_2n_1	1.99	220	155	23.4	78.4
b_2n_2	1.96	600	210	24.3	145.6
b_2n_3	1.95	505	165	19.6	145.6
b_3n_0	1.53	140	95	15.9	201.6
b_3n_1	1.90	350	125	13.5	280.0
b_3n_2	2.36	450	155	14.4	280.0
b_3n_3	1.96	420	215	23.6	100.8
F	**2.06**	**0.827**	**0.716**	**0.984**	**2.31**

respect to ammoniacal-N and nitrate-N. The highest ammonical-N was recorded by N_3 level which was on par with N_2 and significantly superior to N_1 and N_0. N_1 was superior to N_0.

The interaction effect of organic inputs and applied N was not significant (Table 46) on the soil chemical properties studied.

4.8.2. Physical properties

The data pertaining to the physical properties of soil in terms of absolute specific gravity, apparent specific gravity, percentage pore space and maximum water holding capacity are presented in Table 47. The effect of organic inputs on soil physical properties was significant only for absolute specific gravity. The highest absolute specific gravity (2.23) was recorded by cowpea (B_2). The pore space and water holding capacity values were high for cowpea (B_2) and vermicompost (B_3). The different levels of applied N influenced only the absolute specific gravity. N_3 recorded the highest absolute specific gravity (2.25) followed by N_0 (2.19).

None of the interaction effects of organic inputs and applied N was significant (Table 48).

4.9. Incubation study

The results of the incubation study (Table 49) showed that the rate of N mineralisation was relatively faster high with vermicompost (B_1) and cowpea (B_2). The NH_4-N content increased from the first week upto the fifth week reaching the peak value in the fifth week (720 ppm) in the case of cowpea. Vermicompost also showed an increase in NH_4-N upto the fourth week and then decreased. *Azospirillum* (B_1) showed only a slight improvement in NH_4-N content. Regarding $N0_3$-N

Table 47 Effect of organic inputs and applied N on soil physical properties at the end of the cropping season(1995-'96)

Main effect	Apparent sp.gravity	Absolute sp.gravity	Porespace (%)	Maximum waterholding capacity (%)
B_0	1.62	2.20	38.59	30.71
B_1	1.63	2.02	36.87	31.71
B_2	1.62	2.23	39.57	33.56
B_3	1.59	2.19	40.04	32.04
F	**0.08**	**4.49****	**0.83**	**1.026**
C.D. (0.05)	--	**0.049**	--	--
N_0	1.64	2.19	37.84	31.26
N_1	1.67	2.12	39.71	31.50
N_2	1.56	2.08	37.45	33.20
N_3	1.61	2.25	40.07	32.05
F	**0.71**	**2.93****	**0.72**	**0.547**
C.D. (0.05)	--	**0.049**	--	--

Table 48 Interaction of organic inputs and applied N on soil physical properties at the end of the cropping season (1995-'96)

Treatment combination	Apparent specific gravity	Absolute specific gravity	Pore space (%)	Maximum water holding capacity (%)
b_0n_0	1.63	2.10	35.14	28.95
b_0n_1	1.63	2.27	39.05	30.93
b_0n_2	1.60	2.21	40.13	31.92
b_0n_3	1.63	2.23	40.05	31.05
b_1n_0	1.65	2.10	34.81	30.65
b_1n_1	1.61	2.01	35.39	30.18
b_1n_2	1.50	1.91	33.22	31.59
b_1n_3	1.46	2.16	44.03	34.41
b_2n_0	1.61	2.20	38.60	34.80
b_2n_1	1.61	2.24	43.46	32.85
b_2n_2	1.54	2.10	38.30	36.23
b_2n_3	1.78	2.40	37.88	30.37
b_3n_0	1.66	2.34	42.78	30.66
b_3n_1	1.52	2.08	40.96	32.06
b_3n_2	1.59	2.08	38.13	33.08
b_3n_3	1.61	2.23	38.30	32.36
F			**1.19**	**0.591**

content also, both cowpea (B_2) and vermicompost (B_3) exhibited increasing trends in mineralisation upto the fifth week. *Azospirillum* did not have any marked effect on NO_3-N content.

4.10. Residual effect of 2,4-D

No residual effect of 2,4-D was detected in any of the treatment combinations.

4.11. Yield response to fertilizer N and 2,4-D

The response of the test crop to applied N and 2,4-D under different organic inputs, viz., *Azospirillum* (B_1), cowpea (B_2), vermicompost (B_3) and the control (B_0) was computed separately for 1994-'95 and 1995-'96 since the seasonal effect on yield performance was highly significant. The response surface function fitted was

$$Y = b_0 + b_1N + b_2G + b_{11}N^2 + b_{22}G^2 + b_{12}NG$$

where:

Y = fruit yield (kg $plant^{-1}$)

N = Nitrogen level (g $plant^{-1}$)

G = 2,4-D level (ppm)

b_0, b_1.................... b_{22} = constants

The estimated response equations are presented in Table 50. The quadratic response equation was found most suited to the data generated under various organic inputs.

Table 49 Effect of organic inputs on NH_4-N and NO_3 N

NH_4-N

	Before experiment-	Weeks after application (ppm)				
		I	II	III	IV	V
Cowpea	170	220	300	360	530	720
Vermicompost	200	250	340	560	400	360
Azospirillum	220	250	250	280	300	280
Control	220	250	280	250	280	250

NO_3 N

Cowpea	110	200	220	220	360	400
Vermicompost	80	250	340	320	340	360
Azospirillum	80	220	250	200	200	170
Control	110	220	300	220	220	200

Table 50 Yield response of banana cv. Nendran to fertilizer N and 2,4-D over different organic inputs

Organic input	Response equation $Y = b_0 + b_1N + b_2G + b_{11}N^2 + b_{22}G^2 + b_{12}NG$	Optimum N (g plant^{-1})	Optimum 2,4-D (ppm)
I Year			
1.*Azospirillum* (B_1)	$Y = 1.6459 + 0.0793\ N + 0.0216\ G - 0.0002\ N^2 + 0.0005\ G^2 - 0.0003\ NG$	147	29
2.Cowpea (B_2)	$Y = 2.6623 + 0.0508\ N + 0.0680\ G - 0.0001\ N^2 - 0.0010\ G^2 - 0.000043\ NG$	182	30
3.Vermicompost (B_3)	$Y = 3.2698 + 0.0647\ N + 0.0370\ G - 0.0002\ N^2 - 0.0002\ G^2 - 0.0003\ NG$	169	--
4.No organic input (B_0)	$Y = 1.8472 + 0.0769\ N + 0.0121\ G - 0.0002\ N^2 + 0.0001\ G^2 + 0.0001\ NG$	158	--
II Year			
1.*Azospirillum* (B_1)	$Y = 1.0249 + 0.0550\ N - 0.0034\ G - 0.002\ N^2 + 0.0008\ G^2 - 0.0004\ NG$	155	7
2.Cowpea (B_2)	$Y = 2.0828 + 0.0428\ N + 0.0629\ G - 0.0001\ N^2 - 0.0005\ G^2 - 0.0003\ NG$	158	24
3.Vermicompost (B_3)	$Y = 2.1218 + 0.0550\ N + 0.0013\ G - 0.0002\ N^2 - 0.003\ G^2 + 0.0001\ NG$	146	31
4.No organic input (B_0)	$Y = 1.5364 + 0.0475\ N + 0.0249\ G - 0.0002\ N^2 - 0.0003\ G^2 + 0.00003\ NG$	150	50

N, nitrogen; G, 2,4-D

Table 51 Economics of banana production

Treatment	Cost of cultivation (Rs.)	Total returns (Rs.)	Net benefit (Rs.)	B:C ratio
POP	91,031	1,68,875	77,844	1.85
$B_1N_2G_1$	98,201	1,95,500	97,299	1.99
$B_1N_2G_3$	98,201	2,07,250	1,09,049	2.11
$B_1N_2G_2$	98,926	1,93,250	94,324	1.95
$B_2N_2G_2$	92,756	2,07,475	1,14,719	2.24
$B_2N_3G_1$	93,481	2,08,500	1,15,019	2.23
$B_2N_3G_2$	93,481	1,98,750	1,05,269	2.12
$B_3N_2G_0$	1,04,819	2,25,500	1,20,681	2.15
$B_3N_2G_1$	1,05,864	2,06250	1,00,386	1.95
$B_3N_3G_1$	1,06,589	2,00750	94,161	1.88
$B_3N_3G_2$	1,06,589	1,99,500	92,911	1.87
Absolute control	88,133	58,500	-29,633	0.66

Fruit @ Rs.11/- kg^{-1} Sucker @ Rs.3/-

Earthworm (from vermicompost (B_3) treatments) @ Rs.500 kg^{-1}

The yield response to fertilizer N varied with the type of organic input. The dose optima was the highest with cowpea (B_2) during both the years of experimentation. However, during the first year, it was conspicuously high (182 g plant^{-1}) as against 158 g plant^{-1} in the second year. The optimum doses of N for maximum bunch yield under vermicompost (B_3), were, 169 and 146 g plant^{-1} during 1994-'95 and 1995-'96, respectively.

The response to the growth regulator was negative in respect of vermicompost (B_3) and the control (B_0) in the first year, but the dose optima were 31 and 50 ppm respectively, in the following year. With cowpea, the optimum doses of 2,4-D for maximum yield were 30 ppm in 1994-'95 and 24 ppm in 1995-'96.

4.12. Economics of production

The economics of banana production was worked out (Appendix IIIa and b) for the treatment which recorded the highest fruit yield on pooled analysis and also for the treatments which were on par with the best treatment.

The cost of cultivation ranged from Rs. 88,133/- (absolute control) to Rs. 1,06,589/- ($B_3N_3G_1$ and $B_3N_3G_2$) ha^{-1} (Table 51). The Package of Practices Recommendations (POP) fetched a net benefit of Rs.77,844/- ha^{-1}. Ten treatment combinations registered higher net returns than that of the POP. They are listed below in the descending order of net returns: $B_3N_2G_0$, $B_2N_3G_1$, $B_2N_2G_2$, $B_1N_2G_3$, $B_2N_3G_2$, $B_3N_2G_1$, $B_1N_2G_1$, $B_1N_2G_2$, $B_3N_3G_1$ and $B_3N_3G_2$. The best B:C ratio (2.24) was in favour of $B_2N_2G_2$. The next best ratio was recorded by $B_2N_3G_1$. All the treatment combinations listed above had B:C ratios above 1.85, the ratio registered by the Package of Practices Recommendations.

DISCUSSION

DISCUSSION

Banana is the most important fruit crop of Kerala. The crop is grown by the marginal and poor farmers in the homesteads and in well drained rice fields. In spite of the large increase in area under the crop, the productivity has remained static during the last decade owing to the excessive use of chemical inputs without adequate organic manure addition. It was, therefore, felt necessary to formulate an Integrated Plant Nutrition System (IPNS) for banana so as to increase and sustain the productivity of the crop. The present investigation was an attempt to develop an IPNS using organic and inorganic sources of nutrients and the growth regulator, 2,4-D. The results generated are being discussed in this chapter.

5.1. Growth characters

The influence of organic inputs on growth characters was only marginal at the initial stages of growth of banana, probably due to the inherently high organic matter content in the experimental soil. Nevertheless, their effect became evident towards the later stages of crop growth. Vermicompost and *Azospirillum* were relatively more effective than cowpea in producing taller plants with higher pseudostem girth during the first year of experimentation. But, in the following year, cowpea had an edge over these inputs in influencing both these characters although the differences amongst the inputs were of little statistical significance. The effect of *Azospirillum* was more pronounced in the case of number of functional leaves plant^{-1} at shooting but this had no bearing on the mean leaf area. Both *Azospirillum* and vermicompost tended to reduce significantly the time interval between the emergence of successive leaves. As compared to these inputs, cowpea prolonged the phylacron. The unmanured control took significantly more number of days for the production of leaves. This is an indication of the fact that *Azospirillum* and vermicompost hastened the vegetative growth by virtue of their nutrient releasing properties (Keshava Murthy, 1978; Pande and Kumar, 1989; Wani, 1990; Tilak and Rao, 1987; Reinecke and Visser, 1980; Verma, 1993). Krishnamoorthy and Vajranabhaiah (1986) attributed the beneficial effect of vermicompost on plant growth to growth promoters like cytokinins and auxins present in the casts.

Cowpea had a depressive effect on pseudostem height and girth during the early stages of crop growth in the first year of experimentation. This may be because it could not release N to banana at the initial phases of crop growth. Later, after the incorporation of cowpea, the growth of plants was accelerated due to the release of nutrients and at the shooting stage, all the organic inputs were on par in their effect on height and girth of pseudostem and leaf area. But in the second year, cowpea was significantly superior to the other inputs on total leaf area. The leguminous green manure crops meet their own N requirement by fixation of atmospheric N_2 and provide some N to the companion and succeeding crops (Tiwari and Bisen, 1975; Saxena and Yadav, 1979; Mahapatra and Sharma, 1989; Grewal *et al.*, 1992; Mishra and Kapoor, 1992). The beneficial effects of growing green manure crops on growth characters of banana have also been reported by Palaniappan *et al.* (1976); Prabhuram (1992) and Indira (1997).

Applied N influenced all the growth characters viz., height and girth of pseudostem, number of functional leaves, leaf area, total leaf area and phylacron. The three levels were equally effective and significantly superior to the control in respect of plant height, girth, mean leaf area and total crop duration. However, the applied N at the highest level (190 g plant^{-1}) had significantly more number of leaves towards the end of the vegetative phase. This trait was observed on total leaf area also. Further, the time interval taken between the successive emergence of leaves was significantly shortened by this level of N. Nitrogen is the chief promoter of growth and it is the element responsible for generating a good vegetative frame which is an essential prerequisite for higher yields in banana (Shanmugham and Velayudham, 1972; Shanmughavelu *et al.*, 1992). The N deficient plants in the untreated control (N_0) were poor in growth with reduced leaf number and leaf area. The time interval taken by these plants between successive leaf emergence was also significantly longer. Kohli *et al.* (1984), Prabhuram (1992) and Sheela (1995) have reported the beneficial influence of applied N on the growth characters of banana.

The effect of organic inputs on crop duration was not significant during the first year of experimentation. But, in the following year, vermicompost tended to prolong the time required for flowering and thereby the total duration. This may be because the physiological maturity of the crop was delayed owing to rank vegetative growth aided by auxins and cytokinins.

The complementary influence of organic inputs on fertilizer N was clearly evident on the number of functional leaves plant^{-1}, mean leaf area and phylacron towards the end of the vegetative phase. This was particularly true for *Azospirillum* and vermicompost. The maximum leaf area was produced at shooting by the combination B_1N_1 (*Azospirillum* x 95 g N plant^{-1}) and the highest leaf number by B_1N_3 (*Azospirillum* x 190 g N plant^{-1}). The phylacron was also shortened by the treatment combinations like B_3N_1, B_1N_1, B_1N_3 and B_1N_2 . The organic manures are known to reduce the loss of N by leaching due to their influence on soil properties. Further, N use efficiency increases by immobilisation of a part of the N into microbial biomass. The immobilised N is released slowly upon the mineralisation of the biomass (Mishra and Kapoor, 1992).

Applied N exerted its effect on total duration of the crop mainly by influencing the days to shooting. There was a reduction of 68-75 days in the total crop duration when N level was increased from zero to 190 g plant^{-1}. Nitrogen reduced the phylacron and increased the leaf area in a short span of time thereby helping the plant to attain early physiological maturity. Thus, shooting occurred early and this reduced the total duration. The effect of N on crop duration was noted as early as 1940 by Croucher and Mitchell. Later, it was confirmed by many workers (Kohli *et al.*, 1984; Nair, 1988; Thankaselvabai, 1989 and Singh and Kashyap, 1992).

The application of 2,4-D on bunches at the end of the female phase reduced the time taken for the maturity of bunches. The highest level of 2,4-D (45 ppm) was the most effective in shortening the maturity period and thereby the total duration. The growth regulators are known to enhance the level of other hormones especially ethylene in fruits which hastens maturity. This effect of 2,4-D on fruit maturity period has been reported by Anbazhakan (1978); Anbazhakan and Shanmughavelu (1980) and Rajendran (1982).

5.2. Yield attributes

The organic inputs exhibited no marked effect on the yield attributing characters such as number of hands bunch^{-1}, number of fingers hand^{-1}, mean girth and weight of fruit. The mean fruit length, however, was significantly influenced by vermicompost (B_3) in the first year of experimentation. The trend was mildly in favour of cowpea (B_2) during the second year. The fruit size is determined during the third stage of growth and development of banana (Simmonds, 1966 and Leopold, 1982). The vegetative growth in the first three to four months sets an upper limit to the number and size of fruit ultimately borne by the shoot. Vermicompost (B_3) might have contributed to this attribute by rapid supply of nutrients and growth promoting substances (Ismail *et al.*, 1991). Similar influence of vermicompost was not evident in the second year probably due to suboptimal weather conditions.

Applied N markedly influenced the yield attributing characters, particularly, the mean fruit weight. It increased with an increase in the N levels although the differences amongst themselves did not touch the level of significance. The increase in weight by N_2 was 59 per cent in the first year and 35.3 per cent in the second year over the control (N_0). This trait, it could be seen, actually contributed to the final bunch weight. The influence of N on girth and length of fruits was also conspicuous. Valsamma (1980), in her N response studies on banana cv. Palayankodan, observed that applied N increased the girth and weight of fingers and that it exerted no significant effect on the number of hands bunch^{-1} and number of fingers bunch^{-1}. On the other hand, Chattopadayay *et al.* (1980) reported that the mean fruit weight, fruit length and circumference, number of hands bunch^{-1} and number of fingers bunch^{-1} increased significantly with an increase in the level of N applied to banana cv. Giant Governor. Similar results have been reported by Ramaswamy and Muthukrishnan (1974); Sheela (1995) and Aravindakshan (1996). The beneficial influence of applied N on fruit girth, was more clear when it was applied in the presence of organic inputs. This may be due to the enhanced availability of nutrients by complementary effects as reported by Jeeva (1987); Thangaselvabai (1989); Prabhuram (1992) and Indira (1997).

The effect of 2,4-D on the yield attributing characters like mean fruit length, fruit girth and weight fruit^{-1} was quite conspicuous. The fruits act as a sink mobilising photosynthates from the other parts of the plant. Auxins play a role in translocation of photosynthates to sink. Being an auxin, 2,4-D enhances endogenous growth substances which result in effective mobilisation of food reserves to the fruit leading to its better development (Rappaport, 1980). Such effects of externally applied auxins have also been observed by Aravindakshan (1981); Rajendran (1982) and Chellappan (1983). Leopold (1982) reported that the regulation of fruit growth might be the result of interactions of multiple hormones. According to Hirate *et al.* (1978), auxins, gibberellins and cytokinins are associated with fruit development in Japanese persimmon. In black currents, Wright (1956) found a significant correlation between fruit growth rate and extractable auxin activity.

5.3. Bunch weight

The bunch weight was significantly influenced by the organic inputs. The highest weight was recorded by vermicompost during the first year and cowpea during the second year. A pooled analysis of the yield data indicated that cowpea (5.85 kg plant^{-1}) and vermicompost (5.80 kg plant^{-1}) were on par and superior to the other treatments. The percentage increases in bunch weight by cowpea and vermicompost over the control were 13.15 and 12.18 per cent, respectively. The impressive influence of cowpea, on bunch weight is attributable to the legume effect. When succulent plants of cowpea are incorporated in to the soil, they undergo rapid decomposition because of low lignin content and in this process enhanced supply of available N is facilitated synchronizing with the demand of the main crop. According to Palaniappan *et al.* (1991), cowpea contributed about 65 kg N ha^{-1} in addition to

500 kg grain ha^{-1}. The studies conducted by John *et al.* (1992) revealed that cowpea as green manure contributed 68 kg N ha^{-1} which was nearly equivalent to 66 kg N ha^{-1} as urea. The cowpea residue, according to these workers was more effective than urea-N, as it had a residual effect equivalent of 70 kg N ha^{-1} for the succeeding wheat crop. In intercropping systems, transfer of N from legume to nonlegume component may take place through root exudate or through root nodules. The residual transfer takes place in intercropping systems, provided the nonlegume component grows for more than 80 days after the harvest of the legume (Narwal and Singh, 1995). Further, cowpea, in the present experiment, suppressed weed growth for about 80 days. This beneficial aspect of cowpea has been reported by Chacko and Reddy (1981); Savithri (1990) and Nybe *et al.* (1991).

In the present study, vermicompost was as effective as cowpea in influencing bunch yield and yield parameters. The nutrients present in vermicompost are readily available. The increase in earthworm population resulting from the application of vermicompost also leads to the easy transfer of nutrients to banana. Thus, the availability of nutrients in soils tilled with earthworms is considerably increased (Robinson *et al.*, 1992). The earthworms are also known to excrete plant growth promoting substances into their casts (Nielson, 1965).

Kale *et al.* (1992) observed that vermicompost enhanced the activity of beneficial microbes like N_2 fixers and colonization by mycorrhizal fungi and hence played a significant role in N_2 fixation and phosphate mobilisation leading to better uptake by the plant. Similar beneficial effects of vermicompost have been reported by a number of workers (Desh and Patra, 1979; Senapathi *et al.*, 1980; Bano *et al.* 1984 and Lunt and Jacobson, 1994).

Both vermicompost and cowpea favoured mineralisation of N as evidenced by the incubation study. The contents of organic carbon and ammoniacal and nitrate N were increased by cowpea and vermicompost. The increased availability of N led to enhanced production of assimilates which were subsequently exported to fruits serving as sink. The overall effect was increase in fruit length, weight finger^{-1} and bunch yield.

The effect of applied N on bunch yield was impressive in this experiment. The three (95, 143, 190 g plant^{-1}) levels improved the yield significantly over the control (N_0). Nevertheless, the highest rate of N (190 g plant^{-1}) had a depressive effect. The maximum bunch weight (7.84 kg in the first year and 5.66 kg in the second year) was produced by N applied at the rate of 143 g plant^{-1} which was significantly superior to 95 g N and on par with 190 g plant^{-1}. Applied N at this level increased the yield by 162.2 per cent. The magnitude of yield increase was 54.8 g of fruit g^{-1} of N. But the yield increase was 74.9 g of fruit g^{-1} of N when the level was enhanced from 0 to 95 g (N_0 to N_1) and 15 g of fruit g^{-1} of N when the N level was increased from 95 to 143 g (N_1 to N_2) plant^{-1}. After that, the fruit weight showed a negative trend.

According to Marshel and Porter (1991), when N is present in just sufficient quantity to sustain maximum growth rate set by the radiative and thermal environment, the amount of mineral N required per unit dry weight declines as the crop increases in size. It indicates that the present recommended dose of N (190 g plant^{-1}) is not required for banana for producing the maximum yield under the conditions existing in the alluvial soils of Kuttanad, Kerala.

In higher plants, the link between the rate of photosynthesis and N supply is not direct as they store nitrate and aminoacids which are absorbed in excess in the vacuoles (Lawlor, 1991). The excess N applied is not utilised by the crop for growth and fruit development. This partly explains the reason for lack of response to the highest dose of N (190 g plant^{-1}) in the present experiment.

The positive response of banana cv. Nendran to applied N has been reported by a number of workers (Pillai *et al.*, 1977; Nair, 1988; Sankar and Rao, 1993 and Aravindakshan *et al.*, 1996).

The interaction effect of organic inputs and applied N on bunch weight was also significant. The yields were higher when the organic inputs and inorganic N were combined than when inorganic N was applied alone. This shows that there was better utilisation of inorganic N when combined with organic inputs. The use of organic manures along with mineral N arrests the declining trend in soil productivity associated with the continuous application of fertilizers alone. The beneficial influence of organic inputs and fertilizer N could be related to increased biological activity in the soil, leading to better soil aggregation and nutrient availability (Manickam, 1993; Palaniappan and Natarajan, 1993).

The graded levels of applied 2,4-D (15, 30, 45 ppm) improved the bunch weight significantly over the control, but there was no marked differences amongst themselves. Thus, a dose in the range of 15-30 ppm was sufficient enough for achieving high bunch yield during both the years of experimentation. The effect of 2,4-D in increasing the bunch weight of banana has been reported by Anbazhagan and Shanmughavelu (1980); Aravindakshan (1981); Rajendran (1982) and Chellappan (1983).

The growth regulators like 2,4-D raises the endogenous levels of auxins, gibberellins, cytokinins and inhibiter like substance during the course of fruit development. The maximum levels of auxins, gibberellins and cytokinins are noticeable in the young fruits and these levels decrease as the maturity of fruit advances. The inhibitor and ethylene contents increase and attain the highest levels at fruit maturity. In black currants, Wright (1956) observed a significant correlation between fruit growth rate and extractable auxin activity. The role of endogenous growth substances may be the mobilisation of nutrients and assimilates from other parts of the plants (Rappaport, 1980). Leopold (1964), however, held the view that the regulation of fruit growth might be the result of the interactions of multiple hormones.

An interesting observation in the present study was that in the absence of applied N (N_0) and at the lower level (95 g N plant^{-1}), the concentration of 2,4-D at 45 ppm exerted the greatest effect on yield increase. With 143 g N (N_2), 2,4-D failed to produce any influence on bunch weight. It suggests that at lower levels of applied N, application of 2,4-D at the rate of 45 ppm or 30 ppm would be of advantage as far as bunch weight is concerned. It is very relevant under poor management situations where sufficient fertilizer N is not applied during the growing season. The growth regulator 2,4-D, thus compensates the deficiency of N. But when N is optimum, the effect of 2,4-D fades away. The highest rate of N had a depressive effect without 2,4-D application. But 2,4-D applied at 15 ppm mitigated the yield depressive effect of excess N. Ashour (1977) suggested that the interactive effect between nutrients and growth regulators is specific depending on the type and concentration of the two components. He also reported that the action of 2,4-D and nutrient elements on plant growth depended on the kind, concentration and form of ingredients as well as the cultivated variety.

5.4. Quality

5.4.1. Quality parameters

The results revealed that the organic inputs had not much effect on fruit quality. But N influenced the fruit quality. It increased the pulp peel ratio, TSS, total sugar, reducing sugar, non-reducing sugar, sugar-acid ratio and ascorbic content and decreased acidity. But the higher dose of N (190 g N plant^{-1}) had a depressive effect on the total reducing and nonreducing sugars. There may be an optimum N level for attaining a high sugar acid ratio by increasing sugar content and reducing acidity. Singh *et al.* (1977) and Asokkumar and Shanmughavelu (1978) reported similar results on banana.

Applied 2,4-D improved all the quality parameters like pulp-peel ratio, TSS, total sugar, reducing sugar and sugar acid ratio and decreased acidity. Aravindakshan (1981) and Chellappan (1983) got similar results with 2,4-D in banana. The higher dose of N and 2,4-D (N_3G_3) together exerted a depressive effect on pulp-peel ratio, TSS, total sugar and sugar-acid ratio. This may be due to the imbalance of other nutrients and endogenous hormone levels. Vermicompost increased the time for fruit ripening in both the years of experimentation. This may be due to increased content of magnesium which is an integral part of chlorophyll. Nitrogen decreased the ripening time and reduced the shelf life of fruits. Further, it accelerated ripening and reduced the keeping quality of fruits. Application of 2,4-D also reduced the ripening time and shelf life of fruits. It hastened biochemical changes. Chellappan (1983) reported that 2,4-D was effective in accelerating fruit ripening in banana cv. Robusta, Nendran and Karpuravalli. The application of 2,4-D hastened ripening of fruits by stimulation of ethylene production and increasing the rate of chlorophyll degradation (Vendrell, 1970 and Chellappan 1983). Frenkel (1975) suggested that there was severalfold increase in peroxidase activity which precedes the onset of the rise of ethylene and respiration rate accompanying ripening of fruits. The increase in its activity could lead to a decrease in endogenous auxin levels.

5.4.2. Nutrient content of fruit

The organic inputs exerted no conspicuous effect on N, K and Mg content in fruits. Nevertheless, cowpea had the highest contents of N and Ca. Vermicompost had the maximum Mg content. The absence of organic inputs favoured increased N uptake. The application of N, particularly in the form of NH_4-N, may impede Mg uptake (Huettl and Fink, 1991). The organic inputs also increased the K content in fruit to some extent. According to Vangoor (1968), low concentration of calcium can have a profound repercussion on the growth of many fruits as it is involved in many physiological processes. The applied N increased the N content of fruits with the N_3 level producing the maximum. The Mg level did not increase commensurating with the N uptake. This upset the N-Mg ratio.

The N content of index leaf was high when the organic inputs were not applied but the K level tended to fall. The applied N levels also showed an increasing trend in leaf N content. Lawlor (1991) suggested that in higher plants, the link between rate of photosynthesis and N supply was not direct as they stored excess nitrates and amino acids in the vacuoles.

The different levels of 2,4-D also increased the nutrient content in fruit. The application of 2,4-D was, thus, effective in mobilising nutrients to the developing fruit.

5.5. Soil properties

After the harvest of the experimental crop, an improvement in the contents of soil organic carbon, NH_4 - N, $N0_3$ - N, available P and available K could be noticed as compared to their initial status in the 0-30 cm soil layer. Cowpea and vermicompost were the most impressive inputs in this regard. The water holding capacity was also improved by the organic inputs. Applied N increased the NH_4 - N and $N0_3$ - N, but it had no appreciable influence on organic carbon and water holding capacity. Reddy (1988) and Sivapal (1989) reported that application of fertilizer N to rice soil, even at higher levels, did not increase the soil organic carbon content.

The increased levels of NH_4 - N and NO_3 - N in the soil indicated better mineralisation of N consequent on the application of organic inputs. The improved availability of soil N is generally attributed to the so called `priming effect' (Jenkinson *et al.*, 1985). Cowpea as green manure released mineral N more quickly and reduced leaching losses of applied N (John *et al.*, 1992; Prasad *et al.*, 1995). Increase in available P was also reported as a result of crop residue incorporation (Nuttal *et al.*, 1986). Cowpea tended to increase the available P content, but the effect was not significant. The legumes are able to extract insoluble forms of soil phosphorus. Leguminous crops have also been reported to produce certain humic substances capable of solubilising soil P resulting in its increased availability (Roysharma, 1967; Sinha, 1977. Thind *et al.*, 1977).

SUMMARY

5.6 Yield response to fertilizer N and 2,4-D

The optimum doses of N and 2,4-D were computed for the different organic inputs separately for each year of experimentation since the season - yield interaction was statistically significant. Among the organic inputs cowpea favoured a conspicuously high response to applied fertilizer N (182 g plant^{-1}) in the first year, but in the succeeding year, it recorded a lower N requirement (158 g plant^{-1}). Vermicompost also exhibited a similar trend in yield response, the optimum doses being, 169 and 146 g plant^{-1} in the respective years of experimentation. This shows that both these organic inputs had considerable residual effects in the soil. The rhizobium legume association can fix atmospheric N_2 in the range of 40-80 kg ha-^{1} one crop season and leave substantial part of it for the succeeding crop (John *et al.*, 1992; Mishra and Kapoor, 1992 and Wani, 1992). Integrated management of organic manures and fertilisers may also mitigate loss of mineralized N (Ito and Watanabe, 1985). *Azospirillum* did not leave any residual effect to the succeeding crop, the organism being an associative symbiotic N fixer. The study clearly indicates that by green manuring *in situ* or by applying organic manures like vermicompost regularly, the dependence on fertilizer N for banana could be reduced to the extent of 15 per cent.

The optimum dose of 2,4-D for the maximum bunch yield depended on the type of organic input and the season. Nevertheless, it was around 30 ppm with cowpea and vermicompost during the second year of experimentation. The optimum dose of 2,4-D, however, depends on the interaction effect between it and the applied nutrients and also on the cultivated variety (Ashour, 1977; Chellappan, 1983).

SUMMARY

Banana is the most popular fruit crop of Kerala. It is grown mainly by marginal and poor farmers. 'Nendran' occupies a prime place among the cultivars grown. The productivity of banana is on the decline owing to the over dependence on chemical inputs without adequate organic manure addition. In order to increase and sustain the productivity of banana, it is necessary to develop an Integrated Plant Nutrition System (IPNS) with an ideal combination of organic inputs, fertilizer nitrogen and growth regulators like 2,4-D. To achieve this objective, an experiment was laid out in the reclaimed alluvial soils of the Regional Agricultural Research Station, Kumarakom, Kerala, during 1994-'95 and 1995-'96. The treatments consisted of factorial combinations of four levels each of organic inputs (*Azospirillum*, cowpea, vermicompost and no organic manure), fertilizer N (0, 95, 143 and 190 g plant^{-1}) and growth regulator, 2,4-D (0, 15, 30 and 45 ppm). The growth regulator was applied only at the end of the female phase of the crop. The design of the experiment was 4^3 confounded factorial RBD with two replications. The salient results emanating from the experiment are summarised in this chapter.

The organic inputs exerted their influence on pseudostem height only in the first year of experimentation. Vermicompost and *Azospirillum* were more effective than cowpea in augmenting growth as indicated by pseudostem height and

girth at all the stages. The influence of applied N on these two growth characters was significant at all the stages of growth during both the years although the differences among the levels 95 (N_1), 143 (N_2) and 190 (N_3) g N plant^{-1} were not significant.

Azospirillum, among the organic inputs and the fertilizer N level 190 g plant^{-1} (N_3), produced the highest number of functional leaves plant^{-1} at shooting stage during both the years of experimentation.

The organic inputs failed to produce any effect on leaf area whereas applied N, exerted its influence significantly with the level N_2 topping the others. But, with regard to total leaf area, cowpea, among the organic inputs, registered the highest values in the second year. Among N levels, N_3 topped the others during both the years of experimentation.

The phylacron was significantly shortened by *Azospirillum* and vermicompost whereas the treatments receiving no organic inputs (B_0) prolonged it significantly. Applied N at the N_3 (190 g plant^{-1}) level significantly shortened the phylacron.

The effect of interaction between organic inputs and fertilizer N was clearly evident in the growth attributes. The maximum leaf area (0.91 m^2) at shooting was recorded by the treatment combinations *Azospirillum* and 95 g N plant^{-1} (B_1 x N_1). Similarly, the highest leaf number plant^{-1} (11.38) was registered by *Azospirillum* x 190 g N plant^{-1} (B_1N_3). The interval between successive emergence of leaves (phylacron) was also shortened by the combinations B_3N_1, B_1N_1, B_1N_3, B_1N_2 and B_3N_1.

The organic inputs failed to produce any conspicuous influence on the number of days to shooting and the total crop duration in the first year of experimentation but vermicompost prolonged the shooting time in the second year by 14 days. Applied N significantly shortened the shooting time and the total duration of the crop. Similarly, 2,4-D at the dose of 45 ppm (G_3) significantly shortened the maturity period of fruits and also the total duration.

The organic inputs had no marked effect on the number of hands and fingers bunch^{-1} and the mean fruit weight. On the other hand, the applied N levels 95 (N_1), 143 (N_2) and 190 g (N_3) plant^{-1} were equally effective in improving the yield attributes, hands and fingers bunch^{-1}. With regard to fruit weight, the N levels, 143 g (N_2) and 190 g (N_3) plant^{-1} were significantly superior to lower level (N_1) and the control (N_0) in the first year and to the control (N_0) in the second year. The influence of fertilizer N was more impressive on fruit weight when it was applied in combination with organic inputs. The application of 2,4-D had significant effect on fruit weight with the doses 30 ppm (G_2), and 45 ppm (G_3) recording higher values as compared to the lower dose of 15 ppm (G_1) and the control (G_0).

Among the organic inputs, vermicompost (B_3) significantly increased the fruit length in the first year. During the second year, cowpea (B_2) tended to increase this trait, but not to a significant extent. The organic inputs alone had no conspicuous effect on fruit girth but, when applied in combination with fertilizer N, they increased the fruit girth significantly over no N during both the years of experimentation. Among the N levels, N_2 and N_3 were on par in their effect on fruit length and superior to N_1 and N_0. The growth regulator applied at the concentrations of 15 (G_1), 30 (G_2) and 45 (G_3) ppm were on par, but significantly superior to the control (G_0) in its effect on fruit length, girth and weight during both the years.

Among the organic inputs, vermicompost (B_3) and cowpea (B_2) produced the highest bunch weights in the first and second year, respectively. The pooled data indicated that both these inputs were on par in their effect on bunch weight and they were superior to *Azospirillum* and the control. During both the years of experimentation, the N level 143 g plant^{-1} (N_2) recorded the highest bunch weight(7.84 and 5.84, respectively). The highest level of N (N_3) showed a depressive effect on bunch yield. The bunch yields were higher whenever mineral N was applied in combination with organic inputs like cowpea and vermicompost. All levels of 2,4-D - G_1, G_2 and G_3 - were on par in their effect on bunch weight and they were superior to the control (G_0). The treatment combinations $B_1N_2G_1$, $B_1N_2G_3$, $B_1N_2G_2$, $B_2N_2G_2$, $B_2N_3G_1$, $B_2N_3G_2$, $B_3N_2G_0$, $B_3N_2G_1$, $B_3N_3G_1$ and $B_3N_3G_2$ which were on par, were most effective in producing higher bunch weights. They were also significantly superior to the rest of the treatment combinations.

In the absence of applied N (N_0) and at lower N level (N_1), 2,4-D at the dose of 45 and 30 ppm exerted the maximum influence on bunch weight. The influence of 2,4-D was not conspicuous at the higher levels of applied N (N_2 and N_3).

The depressive effect of the N_3 level (190 g plant^{-1}) on fruit yield was nullified by 2,4-D applied at 15 ppm.

The influence of organic inputs was significant on TSS, acidity and reducing and nonreducing sugars. Acidity was increased and TSS reduced significantly by *Azospirillum*. Applied N influenced all the quality parameters like pulp peel ratio, TSS, acidity, total sugar and ascorbic acid. Nitrogen at N_2 level recorded the highest sugar content (24.3%) and sugar acid ratio (46.26) and the lowest acidity (0.54%). The N levels - N_1, N_2 and N_3 - were on par in their effect on ascorbic acid content and TSS. The highest pulp peel ratio (2.44) was recorded by the level N_3 but it was on par with N_2.The total sugar content was increased by the levels of 2,4-D with G_3 recording the highest sugar- acid ratio. All the 2,4-D levels - G_1, G_2 and G_3 - were on par in their effect on pulp peel ratio, TSS and ascorbic acid content.

Among the organic inputs, vermicompost took more time for ripening. They had no detectable effect on shelf life. Applied N at N_3 level(190 g plant^{-1}) reduced the ripening time in the first year and shelf life during both the years of experimentation.

The organic inputs had no marked effect on N, K and Mg content in fruits whereas Ca content was increased by cowpea. Applied N levels - N_1, N_2 and N_3 - were on par and superior to the control (N_0) in their effect on N and K content in fruits. The highest Ca and Mg contents were recorded by the level N_2. The growth regulator had no marked influence on nutrient content of fruits. Vermicompost produced the highest N content in index leaf. The P content was increased by *Azospirillum*. The K content was not influenced by any of the organic inputs. The N_2 level of fertilizer N recorded the highest N content, but the P content was the highest with N_1. The N levels - N_1, N_2 and N_3 - were on par and superior to the control (N_0) in their effect on K content. The 2,4-D doses did not influence the nutrient content in index leaf.

The lowest fresh and dry weights of weeds were recorded by cowpea and the treatment receiving no fertilizer N (N_0).

Cowpea and vermicompost recorded an increasing trend in organic carbon, NH_4-N and NO_3 N contents in the soil. They also improved the water holding capacity.

The dose response to applied N varied with the organic input. The optimum dose was the highest with cowpea (B_2) during both the years of experimentation. It was 182 g plant^{-1} in the first year and 158 g plant^{-1} in the second year. With vermicompost (B_3), the dose optima were, 169 g and 146 g plant^{-1} in the respective years. The optimum doses of 2,4-D for maximum yield with cowpea were 30 ppm during 1994-'95 and 24 ppm during 1995-'96.

There were ten treatment combinations fetching higher net benefits (Rs.77,844/- ha^{-1}) than that of the Package of Practices Recommendations. They were, $B_3N_2G_0$, $B_2N_3G_1$, $B_2N_2G_2$, $B_1N_2G_3$, $B_2N_3G_2$, $B_3N_2G_1$, $B_1N_2G_1$, $B_1N_2G_2$, $B_3N_3G_1$

and $B_3N_3G_2$. All these treatments had B C ratios above 1.85 (POP). The best B C ratio of 2.24 was in favour of $B_2N_2G_2$. The next best ratio (2.23) was recorded by $B_2N_3G_1$.

The results of the experiment clearly indicated the need for incorporating organic inputs like cowpea (green manure) or vermicompost for increasing crop productivity and economic returns besides reducing the dependence on chemical N in banana production. It could be concluded that an IPN package for banana cv. Nendran should include an organic input like cowpea (green manure) or vermicompost, eighty five per cent of the present recommended dose (190 g $plant^{-1}$) of fertilizer N and 30 ppm of 2,4-D.

Future line of work

The scope of the experiment may further be extended to elucidate the effects of varying doses of vermicompost and biofertilizers like VAM and phosphobacteria in banana cultivation. The present experiment may be repeated for one more year in same soil, for confirmatory results so as to include the results in the Zonal Package of Practices Recommendations.

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* Original not seen

APPENDICES

APPENDIX I

Climatic parameters during the cropping periods and the previous five years

Months	Temperature (°C)						Relative Humidity (%)			Rainfall (mm)			Evaporaion (mm)		Sunshine (hrs.)	
	Maximum			Minimum			Five year mean	94-95	95-96	Five year mean	94-95	95-96	94-95	95-96	94-95	95-96
	Five year mean	94-95	95-96	Five year mean	94-95	95-96										
November	31.3	32.7	32.1	24.8	24.1	18.1	78.8	75.0	79.0	163.4	188.0	83.6	3.63	3.3	5.8	6.0
December	32.2	33.4	33.1	23.2	21.9	15.7	65.9	69.0	77.0	25.6	33.2	0	4.6	4.2	7.4	7.2
January	32.5	33.5	33. 0	20.8	22.7	16.3	66.3	72.0	66.0	9.1	0.6	8.2	4.1	4.4	7.3	7.2
February	33.4	34.2	32.3	21.8	24.1	18.2	71.7	76.0	69.0	19.3	0	3.4	5.0	4.6	8.0	7.6
March	34.1	35.1	34.4	23.5	24.4	20.9	74.1	79.0	75.0	40.9	134.4	3.4	4.6	5.4	8.7	8.8
April	34.3	34.4	34.5	23.6	25.0	21.4	73.0	78.0	74.0	71.5	188.8	97.4	5.2	4.2	7.8	7.1
May	33.2	33.1	34.0	23.14	25.1	23.0	80.6	85.0	80.0	318.4	525.4	80.0	3.3	3.8	5.0	6.3
June	29.9	31.4	30.8	23.4	24.7	21.0	88.6	85.0	90.0	805.9	526.8	450.2	3.1	2.8	3.0	3.9
July	29.4	30.5	29.9	22.9	23.6	19.1	89.2	91.0	87.0	662.3	457.6	535.4	2.1	2.1	2.3	2.3
August	30.3	30.9	30.5	23.0	24.1	20.2	88.2	87.0	84.0	330.3	518.6	282.0	3.2	3.1	3.6	3.3
September	31.4	31.2	30.6	24.6	23.9	19.9	87.3	84.0	86.0	168.0	494.0	367.2	3.2	2.4	5.8	3.7
October	31.2	32.4	31.2	24.9	22.1	19.5	83.6	83.0	80.0	336.1	213.8	243.6	3.5	3.4	6.4	6.8

APPENDIX II

Details of fertilizer N and organic input application

N - 190, 143, 95 g plant^{-1} (6 splits) P - 115 g plant^{-1} (basal)

K - 300 g plant^{-1} (5 splits)

Time of application	Quantity (g plant^{-1})			Organic input (plant^{-1})		
	N_1	N_2	N_3	*Azospirillum*	Cowpea	Vermicompost
30 DAP	20	30	40	-	-	5 kg
45 DAP	-	-	-	40 g	incorporated	-
60 DAP	15	22.5	30	-	-	-
75 DAP	-	-	-	30 g	-	-
90 DAP	15	22.5	30	-	incorporated	-
105 DAP	-	-	-	30 g	-	-
120 DAP	15	22.5	30	-	-	-
150 DAP	15	22.5	30	-	-	-
Just after shooting	15	22.5	30	-	-	-

APPENDIX III (a)

Cost of cultivation for computing economics of production

General cost	I Year		II Year	
	Men @ Rs.75/-	Women @ Rs.50/-	Men @ Rs.90/-	Women @ Rs.60/-
1. Cleaning the area by weeding		30		30
2. Digging the area	40		40	
3. Taking pits	50		50	
4. Application of cattle manure (10 kg/pit)	10	20	10	20
5. Planting and covering	25		25	
6. Gap filling	2		2	
7. Application of phorate 3 times	15		15	
8. Fertilizer application and earthing up	25	25	25	25
9. Irrigation	60		60	
10. Propping and bunch covering	25		25	
11. Plant protection	5		5	
12. Harvesting	25		25	
13. Desuckering	25		25	
14. Weeding two times (Other than cowpea)		60		60
	307	135	307	135
Total	23,025	6,750	27,630	8,100

APPENDIX III (b)

Cost of inputs and application charges

Input	I Year	II Year
1. Cowdung @ Rs.320 t^{-1}	8000.00	8000.00
2. Planting material	7500.00	7500.00
3. Propping material	32,250.00	30,000.00
4. Mushooriphos (1600 kg)	2,667.00	2,848.00
5. Muriate of potash (1250 kg)	4,640.00	4,575.00
6. Phorate and other PP chemicals	1,300.00	1,480.00
	56,357.00	54,403.00
Treatments		
1. *Azospirillum*		
Cost of *Azospirillum*	7,500.00	3,200.00
Application cost	1,500.00	1,500.00
2. Cowpea		
1. Cost of cowpea seed (40 kg ha^{-1})	800.00	800.00
2. Sowing	300.00	360.00
3. Harvesting and application	1,750.00	2,100.00
4. Weeding	1500.00	1,800.00
Vermicompost		
1. Taking pits, filling with cowdung and organic waste	1,125.00	1450.00
2. Cost of cowdung	12,500.00	11550.00
3. Cost of earthworm	1,750.00	
4. Application of vermicompost	750.00	900.00
2,4-D Cost of 2,4-D and application charge	950.00	1140.00
N level - Cost of urea		
100% recommended dose - N_3 (1056 kg)	3,506.00	2,291.00
75% recommended dose - N_2 (792 kg)	2,629.00	1,718.00
50% recommended dose - N_1 (528 kg)	1753.00	1145.00

Appendix IV

Effect of organic inputs, fertilizer and 2,4-D on bunch weight

Treatment combination	Bunch weight (kg plant^{-1})			Treatment combination	Bunch weight (kg plant^{-1})		
	I Year (1994-'95)	II Year (1995-'96)	Pooled mean		I Year (1994-'95)	II Year (1995-'96)	Pooled mean
$b_0n_0g_0$	1.50	1.85	1.68	$b_2n_0g_0$	2.75	1.97	2.36
$b_0n_0g_1$	2.55	1.92	2.23	$b_2n_0g_1$	3.35	3.4	3.38
$b_0n_0g_2$	2.25	1.82	2.03	$b_2n_0g_2$	3.6	3.47	3.53
$b_0n_0g_3$	1.85	1.83	1.84	$b_2n_0g_3$	3.75	3.75	3.75
$b_0n_1g_0$	6.25	4.01	5.13	$b_2n_1g_0$	6.18	4.71	5.44
$b_0n_1g_1$	6.35	4.89	5.47	$b_2n_1g_1$	7.05	5.5	6.28
$b_0n_1g_2$	6.65	5.08	5.86	$b_2n_1g_2$	7.9	5.67	6.78
$b_0n_1g_3$	8.33	6.00	7.64	$b_2n_1g_3$	7.55	6.3	6.78
$b_0n_2g_0$	6.83	5.08	5.95	$b_2n_2g_0$	7.5	6.35	6.92
$b_0n_2g_1$	7.55	5.21	6.38	$b_2n_2g_1$	7.38	5.83	6.61
$b_0n_2g_2$	7.90	5.74	6.83	$b_2n_2g_2$	8.15	6.04	7.10
$b_0n_2g_3$	7.45	5.55	6.50	$b_2n_2g_3$	7.55	6.35	6.75
$b_0n_3g_0$	6.55	4.80	5.68	$b_2n_3g_0$	7.15	5.63	6.35
$b_0n_3g_1$	6.85	5.17	6.01	$b_2n_3g_1$	8.5	6.98	7.74
$b_0n_3g_2$	7.95	5.51	6.73	$b_2n_3g_2$	8.5	6.2	7.35
$b_0n_3g_3$	8.77	5.10	6.94	$b_2n_3g_3$	8.3	5.66	6.98

$b_1n_0g_0$	2.05	0.69	1.37	$b_3n_0g_0$	3.65	1.67	2.66
$b_1n_0g_1$	2.00	1.70	1.89	$b_3n_0g_1$	3.25	2.2	2.73
$b_1n_0g_2$	2.60	1.20	1.90	$b_3n_0g_2$	3.75	2.3	3.03
$b_1n_0g_3$	3.63	2.54	3.08	$b_3n_0g_3$	5.25	1.59	3.34
$b_1n_1g_0$	6.75	5.20	5.98	$b_3n_1g_0$	6.9	6.48	6.69
$b_1n_1g_1$	6.30	4.38	5.34	$b_3n_1g_1$	7.65	4.49	6.07
$b_1n_1g_2$	6.28	5.25	5.76	$b_3n_1g_2$	8	5.49	6.76
$b_1n_1g_3$	8.00	5.79	6.89	$b_3n_1g_3$	7.75	5.93	6.84
$b_1n_2g_0$	8.25	4.80	6.53	$b_3n_2g_0$	9.73	6.52	8.12
$b_1n_2g_1$	8.60	5.84	7.22	$b_3n_2g_1$	8.2	6.5	7.35
$b_1n_2g_2$	8.50	4.59	6.54	$b_3n_2g_2$	8.4	5.48	6.94
$b_1n_2g_3$	8.27	7.10	7.69	$b_3n_2g_3$	6.2	5.59	5.89
$b_1n_3g_0$	7.95	5.3	6.63	$b_3n_3g_0$	6.75	4.27	5.52
$b_1n_3g_1$	7.55	4.58	6.04	$b_3n_3g_1$	8.25	6.02	7.13
$b_1n_3g_2$	7.75	6.51	7.13	$b_3n_3g_2$	7.85	6.32	7.08
$b_1n_3g_3$	6.4	5.52	5.96	$b_3n_3g_3$	7.15	5.84	6.85
$F_{24, 60}$					**1.51**	**2.82****	**2.55****
C D (0.05)					-	**1.14**	**1.11**

INTEGRATED PLANT NUTRITION SYSTEM (IPNS) FOR MAXIMISING YIELD IN BANANA, *MUSA* (AAB GROUP) 'NENDRAN'

By

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ABSTRACT OF THESIS
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ABSTRACT

Field experiments were conducted at the Regional Agricultural Research Station, Kumarakom during 1994-'95 and 1995-'96, in order to formulate an Integrated Plant Nutrition System (IPNS) for increasing yield and quality of banana cv. Nendran. The optimum combination of various nutrient resources for the crop was arrived at in this study.

The treatments comprised of three types of organic inputs (*Azospirillum*, cowpea and vermicompost) along with a control and four levels each of fertilizer N (0, 95, 143 and 190 g plant^{-1}) and 2,4-D (0, 15, 30 and 45 ppm). The design of the experiment was 4^3 factorial confounding the highest order interaction. There were two replications.

The results revealed that cowpea (green manure) and vermicompost influenced the yield response to applied N significantly. The organic inputs helped to increase the bunch yield and net returns and reduced the chemical N requirement to 85 per cent of the present recommended dose (190 g plant^{-1}). Besides, they

improved the physical and chemical properties of the soil at the end of the experiment. Application of 2,4-D at the rate of 30 ppm was beneficial for higher yield, particularly at the lower doses of fertilizer N. The growth regulator did not give any residue in the fruit.

The effect of interaction between organic inputs and fertilizer N was clearly evident in the growth attributes. The influence of organic inputs was significant on TSS, acidity and reducing and non reducing sugars. Applied N and 2,4-D influenced all the quality parameters.

An IPN package consisting of either cowpea (green manure) or vermicompost, 85 per cent of the present recommended dose of fertilizer N (190 g plant^{-1}) and 30 ppm of 2,4-D is suggested for achieving high economic returns from banana cultivation.