ORGANIC NUTRIENT MANAGEMENT AND INTERCROPPING IN BANANA ORCHARD IN MIZORAM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

ABIGAIL ZOTHANSIAMI
MZU REGN. NO. 1705279
PH. D. REG. NO. MZU/Ph.D./ 1134 of 13.04.2016

DEPARTMENT OF HORTICULTURE, AROMATIC AND MEDICINAL PLANTS
SCHOOL OF EARTH SCIENCES AND NATURAL RESOURCES MANAGEMENT

AUGUST, 2022

ORGANIC NUTRIENT MANAGEMENT AND INTERCROPPING IN BANANA ORCHARD IN MIZORAM

BY

ABIGAIL ZOTHANSIAMI

DEPARTMENT OF HORTICULTURE, AROMATIC AND MEDICINAL PLANTS

SUPERVISOR

DR. DEBASHIS MANDAL

SUBMITTED

IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN HORTICULTURE, AROMATIC AND MEDICINAL PLANTS OF MIZORAM UNIVERSITY, AIZAWL

MIZORAM UNIVERSITY
(A Central University under the Act of Parliament)
Department of Horticulture, Aromatic & Medicinal Plants

Dr. Debashis Mandal

Assistant Professor

No. 9/16/Ph.D. Prog./MZU-HAMP/ **Dated 23.08.2022**

CERTIFICATE

This is to certify that Mrs. Abigail Zothansiami has prepared a Thesis under my Supervision on the topic "Organic Nutrient Management and Intercropping in Banana Orchard in Mizoram" in partial fulfillment for the award of the Degree of Doctor of Philosophy (Ph.D.) in the Department of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl.

This thesis has been the outcome of her original work and it does not form a part of other thesis submitted for the award of any other degrees.

She is duly permitted to submit the Thesis.

(Dr. DEBASHIS MANDAL)

Supervisor

DECLARATION BY THE CANDIDATE

Mizoram University

August, 2022

I, Abigail Zothansiami, hereby declare that the subject matter of the thesis entitled "*Organic Nutrient Management and Intercropping in Banana Orchard in*

Mizoram" **is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge, to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/ Institutes.**

This is being submitted to the Mizoram University for the Degree of Doctor of Philosophy in Horticulture, Aromatic and Medicinal Plants.

(ABIGAIL ZOTHANSIAMI)

Candidate

(Prof. T.K HAZARIKA) **(Dr. DEBASHIS MANDAL)**

Head **Supervisor**

Acknowledgement

"My flesh and my heart may fail;
But God is the strength of my heart,
and my portion forever."

Psalms 73:26

Above all, I am immensely thankful to Almighty God for giving me the opportunity, knowledge, ability and strength to undertake and complete my study successfully.

My most heartfelt thanks goes to my Supervisor, Dr. Debashis Mandal, Assistant Professor, Department of Horticulture, Aromatic & Medicinal Plants, Mizoram University for his impeccable guidance, transcendent suggestions, professional inputs, encouragement and untiring support throughout the years of my research.

I am truly grateful to Dr. T.K. Hazarika, Professor & Head, Department of Horticulture, Aromatic & Medicinal Plants, Mizoram University for providing me with his constant advise, support and guidance. I extend my gratitude to my colleague friends, Dr. Chhungpuii Khawlhring, Dr. Awadhesh Kumar, Prof. Rambir Singh and Dr. Herojit Singh for the help rendered towards me during my research work. I am also grateful to Dr. H.T. Lalmuankima, Mrs. PC. Lalrosiami and Mrs. E. Laldinsangi, non-teaching staffs of the Department of Horticulture, Aromatic

and Medicinal Plants, Mizoram University for all their support during the period of my research work.

Last but not the least, I express my gratitude to my loving and supportive husband who has always been there for me whenever in need and helped me through all the years of my research work. My children have always been a great source of inspiration for me, and for this I am truly grateful. I am also indebted to my mother who had always been my strength and support right from the beginning of my education till today. Her precious prayers have sustained me this far.

With this, I salute my work "Organic Nutrient Management and Intercropping in Banana Orchard in Mizoram" as my contribution to science, for the benefit of mankind in the field of Horticulture.

Place: Aizawl **(ABIGAIL ZOTHANSIAMI)**

Date: 23rd August, 2022

CHAPTER 1

INTRODUCTION

Bananas are grown in all tropical regions and play a key role in the economies of many developing countries. In terms of gross value of production, bananas are the world's fourth most important food crop after rice, wheat and maize. They are a staple food and an export commodity. As a staple, bananas (including plantains and other types of cooking bananas) contribute to the food security of millions of people in much of the developing world, and when traded in local markets they provide income and employment to rural populations. As an export commodity, they are key contributors to the economies of many low income food deficit countries, including Ecuador, Honduras, Guatemala, Cameroon, Ivory Coast and the Philippines. Bananas are the world's most exported fresh fruit in terms of volume and value. Banana production for export is considered a different economic and technological activity to banana production as a staple. Production for export relies on only a few varieties, which were selected for their high yields, durability in long distance transport, consistent quality and unblemished appearance. The volume of bananas exported worldwide in the period 1985-2002 grew at an unprecedented average annual rate of 5.3 percent; twice that of the previous 24 years (2.4 percent between 1960 and 1984). This expansion was accompanied by technological changes and changes in the world trade scenario including: the opening of socialist economies to world markets in the early 1990s; bilateral and multilateral efforts to liberalize trade (General Agreement on Tariffs and Trade-GATT and the World

Trade Organization-WTO); rising environmental awareness (Montreal Protocol in 1987 and the Earth Summit in Rio de Janeiro in 1992); the creation of the Single European Market in 1993; an unprecedented period of economic growth fostered by multimedia technologies and "the new economy" in the developed world; the implementation of structural adjustment policies in banana producing countries; and a significant concentration of trade at retail level.. Bananas (*Musa* spp.) and plantains are staple food crops for millions of people in the tropics and subtropics and belong to the oldest domesticated plant species. It is grown over 130 countries across the world in an area of 10.1m ha and producing 121.85 mt of banana. India is the largest producer of banana contributing 27% of world production (FAO, 2009). In India total area under banana cultivation is 0.796 m ha with production of 28.4 mt and productivity is 35.7 mt ha^{-1}. The consumption pattern of banana is increasing day by day due to its nutritional value and high economic return. Higher productivity in banana is possible through quality planting material, proper nutritional management and other cultural practices. In India banana and plantain are widely grown in both tropical and subtropical regions comprising Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Orissa, Bihar, eastern U.P., West Bengal, Assam and North eastern states with considerable socioeconomic and cultural importance. Banana is the most consumed fruit crop accounting for 36.6% of total fruit production. Bulk of the produce is consumed with in the country with a meagre export share of only 0.1%. There has been a more than tenfold increase in production of banana during the last 25 years while the last decade has witnessed a steep growth due to banana research and development. The area has increased from 0.20 million ha in early 70's to 0.80 million ha in 2014's, while banana production has recorded a giant leap of 9 times from 3 million tonnes to 29.7 million tonnes. The productivity has also increased from a meagre 9 tonnes to 37 tonnes, while in some states; the productivity is as high as 120 tonnes. This significant increase in the production and productivity of banana is due to adoption of improved research technologies and development activities in banana and plantain. This could be achieved due to availability of high yielding genetic material especially Cavendish group of bananas, improved production system and adoption of efficient protection technologies for the control of major pests and diseases under different climatic conditions have contributed to the fast growth of banana industry in the country.

Banana is popular on global scale not only for its nutritional value but also because of its economic importance especially to smallholding farmers in the developing countries. Banana '*Poor man's apple*' is the major staple food crop for millions of people in Central, East and West Africa, Latin America and the Caribbean. It is mainly produced in tropical and sub-tropical regions of the world and recognised as the fourth most important food in terms of gross value after paddy, wheat and milk products (FAO, 2006). Banana is a cheap source of energy like vitamins A, C, B_6 and other minerals with traces of fat. Bananas owing to its large size and rapid growth rate require relatively large amount of nutrients for high yields of quality fruits. It is estimated that 50 tonnes of banana in one hectare removes 320 kg N, 32 kg P_2O_5 and 925 kg K_2O every year (Lahav and Turner, 1983). Application of inorganic fertilizers though increases the yield substantially but could not able to sustain the fertility status of the soil (Bharadwaj and Omanwar, 1994) and have caused several undesirable consequences in the fragile soil eco-system, leading to gradual decline in productivity. Considering the present situation of soil quality and environmental security, it is necessary to go for an integrated nutrient management, involving various sources of organic manures, organic cakes and bio-fertilizers besides using chemical fertilizers in banana. Bananas are extensively grown where they are mainly intercropped with short term crops. There has been an increase in the grower's interest in using intercropping, growing two or more crops simultaneously on the same land in the development of new cropping systems for their land. Intercropping could reduce management inputs and result in sustainable systems that more effectively use and even potentially replenish natural resources used during crop production for long term management of farmland. While intercropping has been practiced more widely in the developing countries of Central America, Asia and Africa, developed countries have not adopted it well. Some benefits of intercropping to the grower are risk minimization, effective use of available resources, efficient use of labour, increased production per unit area of land, erosion control and food security.

Sustainable development has caught the imagination and action all over the world for more than a decade. Sustainable agriculture is necessary to attain the goal of sustainable development. Organic farming is one of the several approaches found to meet the objectives of sustainable agriculture. Many techniques used in organic farming like inter-cropping, mulching and integration of crops and livestock are not alien to various agriculture systems including the traditional agriculture practiced in old countries like India. Adverse effects of modern agricultural practices not only on the farm but also on the health of all living things and thus on the environment have been well documented all over the world.

1.1. Scope of the Study

Banana is one of the most commercially important fruit crops cultivated in Mizoram. Farmers are adopting common method of cultivation which leads to low productivity. Extensive and continuous use of chemicals, both fertilizers and pesticides, has led to several detrimental effects on soil and environments. The soil, water and air got polluted by the use of agrochemicals. The residue of these chemicals entered into the food chain causing health problems to the human as well as animals. Present day modern farming is not sustainable in consonance with economics, ecology, equity, energy and socio-cultural dimensions. It has become a major concern to the consumers and the demand for safe and healthy food is increasing. The demand for organic food from the consumers showed a double digits growth in the last few years particularly from the developed countries like US, Japan, Canada, New Zealand and the EU (Willer and Kilcher, 2009). To make organic farming successful, it is essential that ecofriendly technologies, which can maintain or increase the productivity, have to be developed. The organic farming system relies on large scale application of animal waste or farm yard manure, compost, crop rotation, crop residue, green manure, oil cakes, vermicompost and biofertilizers.

Increasing realization of the ill effects of long sustained, exclusive use of chemical fertilizers, and consistent growing demand from the consumers for fruit quality, coupled with unsustainable productivity of banana, have fostered experimentation with some alternative cultural practices. Organic culture is claimed to be the most benign alternative. Use of organic materials such as farmyard manure, cakes of plant origin, vermicompost, and microbial bio-fertilizers are important components of the bio-organic concept of banana cultivation. Hence, there is need for standardisation of protocol for organic nutrient management to increase the banana production. This will help to maintain or improve soil fertility, limit external inputs to real plant needs, ensure efficient water use to control erosion, avoid water waste and reduce toxicities, utilize cultural practices rather than chemicals, to reduce biotic risks, produce good fruit quality that is as homogeneous as possible and improve traceability and protect the environment.

The improvement of agricultural sustainability favors the maintenance of the intercropping systems. Intercropping can significantly enhance crop productivity as compared with sole cropping since it offers higher land utilization efficiency, efficient acquisition of nutrients, and effective use of water resources. Intercropping is an efficient soil conservation practice due to the increased ground cover that it provides, as well as the exploitation of different soil layers due to the differing depths of the root systems of the two species. Yields are more stable with intercropping than with sole cropping because the yield of one crop compensates for reductions in yield of another.

Following are some important scope of the present investigation:

i. Standardization of organic nutrient management package for banana orchard at Mizoram will enable to optimize and adapt the nutrient management practice for successful cultivation of banana in other growing areas of NEH region.

ii. Findings of the present investigation will help us to figure out the effect of organic nutrient management on soil nutrients and microbial organisms in banana orchard which will definitely help in organic nutrient management of other crops.

iii. Outcome of the present study will depict the most appropriate intercrop for successful organic crop production in banana, which may enhance the economic return of the farmers.

In view of this, there is a need for systematic work to study the organic nutrient management and intercropping in banana orchard. Thus, the present experiments were conducted with the following objectives:

1.2. Objectives

i. To study the effect of organic nutrient management on growth, yield and quality of banana.

ii. To study the effect of intercropping on growth, yield and quality of banana.

iii. To study the economics of banana under organic nutrient management and intercropping.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER-2

REVIEW OF LITERATURE

2.1. Organic nutrient management of fruit crops

Barker (1975) reported that the use of organic manures like farmyard manure, vermicompost, sheep manure, poultry manure and bhumilabh along with chemical fertilizers will reduce the cost of production and also supplement secondary and micronutrient requirement of the crop.

Gomes *et al.* (1988) studied the influence of organic manures on bunch weight of banana cv. Prata and reported that the highest average bunch weight (10.90 kg) was obtained from plants applied with FYM + NPK.

In banana, Jeeva *et al*. (1988) stated that application of *Azospirillum* inoculation + 100% N enhanced height and girth of pseudostem, leaf production, leaf area and increased bunch weight by 8.2% compared to non-inoculated control plants which received 100% N alone.

Kale *et al.* (1992) opined that vermicompost is like any otherorganic manure and depends on the nature of waste used as feed for worms and the nitrogen content varied between 0.5 to 2.0 per cent. Similar variations with respect to phosphorus and potassium content have also been observed.

Pandit *et al.* (1992) reported that the highest yield (35 t/ ha) and number of hands/ bunch were obtained by applying 400 g of Ammonium Sulphate, 300 g of Super Phosphate and 250 g of Muriate of Potash/ plant. Application of 300 g each of

N and K_2O was most effective in increasing the size and weight of bunch and finger, number of hands and fingers per bunch cv. Harichal.

Prabhuram and Sathiamoorthy (1993) stated that less duration was required for banana cv. Rasthali to complete its maturity by application of 25 per cent nitrogen as farmyard manure + 50 per cent nitrogen as neem cake + 25 per cent as urea.

Parida *et al*. (1994) reported that combined application of NPK resulted in increased plant height, pseudostem girth, number of leaves per plant and significantly reduced the time taken for shooting in banana cv. Robusta.

Raju (1996) found that application of 300 g nitrogen with 400 g/ plant recorded significantly better growth in terms of pseudostem height, pseudostem girth, functional leaves, early shooting and harvesting in banana cv. Grand Naine.

Ray and Yadav (1996) reported that higher fruit yield of 72.2 t/ ha was obtained in second ratoon crop by applying 25% FYM + green manures + 75% inorganic fertilizers in Basrai banana.

Parvathareddy *et al.* (1997) observed the dynamic increasing plant growth concerning pseudostem girth of the banana plant infested with *Radopholus similis* by application of Karanj cake + *Glomus massae.* It also increased the number of hands per bunch, number of fingers per hand and finger weight of banana fruits infested with *Radopholus similis*.

The farmyard manure helps directly in increasing the crop yields either by accelerating the respiratory process by increasing cell permeability or by hormonal growth action or by combination of all these processes. It supplies nitrogen, phosphorus, potassium and sulphur in variable forms to the plants through biological decomposition. Indirectly it improves the physical properties of the soil such as aggregation of soil, permeability and water holding capacity (Purakayastha and Bhatnagar, 1997).

Ushakumari *et al.* (1997) stated that organic matter in the form of vermicompost + inorganic fertilizers reduced the total crop duration in banana cv. Poovan and Robusta. However, they recorded significantly maximum bunch weight (15 kg), more number of fingers per bunch, finger weight and finger girth when the plants were applied with vermicompost + inorganic fertilizers.

Smith (1998) studied the benefit of microorganisms on growth and yield of banana and obtained more bunch weight (5.1 kg) with the application of organic manures in banana cv. Israeli Grand Naine compared to control (4.43 kg).

Tiwari *et al.* (1998) reported that inoculation of banana cv. Giant Governor sucker with *Azospirillum* twice resulted in maximum plant height and leaf size in banana plants which were treated with 50% of the recommended N dose. They also reported the highest number of hands per bunch and highest yield of banana (69.15 t ha^{-1}) in *Azospirillum* inoculated plants.

In banana cv. Rajapuri, Athani *et al.* (1999) conducted field investigation and reported that the application of 2 kg vermicompost and 75 per cent recommended inorganic fertilizers (135:81:169 g NPK $plant^{-1}$) has reduced the time for shooting and crop duration. They also observed that with the application of 100% RDF, highest bunch weight, number of finger $hand^{-1}$ and yield (21.29 t ha^{-1}) was recorded.

Chezhiyan *et al.* (1999) reported that the application of inorganic fertilizers (75% NPK) and organic manures along with biofertilizers (*Azospirillum*, *Phosphobacteria and VAM*) and inorganic fertilizers had recorded highest bunch weight in banana.

Abd El-Naby (2000) conducted experimental investigation and found that application of banana compost prepared with 50 % and 25 % chemical fertilizers (NPK) and sulphur has given better bunches with maximum bunch length, circumference, weight, fruits per bunch, fruit length, diameter and weight in Maghrabi banana.

Geetha and Nair (2000) reported that *Azospirillum*, along with cowpea as green manure and vermicompost resulted in increased bunch weight (13.15 and 12.19 % respectively) over control in banana cv. Nendran.

Alvarez et *al.* (2001) carried out a trial to compare the mineral nutrition of organically and normally grown banana plants. Observations were made on growth and yield of organic banana plants, at the Canary Islands. The data were then discussed opposite the results previously reported for conventional plantations. It was observed that the leaf nutrient status of organically grown banana was within normal range for nitrogen and phosphorus nutrients while potassium concentration was low, but not deficient when related to conventionally grown banana.

Athani and Hulamani (2000) conducted a field investigation on banana cv. Rajapuri and revealed that plants treated with in situ vermiculture (1,25,000 earthworms ha^{-1}) has recorded maximum extended shelf life (7.67 days) and noticed highest TSS (27.60°Brix), TSS:Acid ratio (307.67), non-reducing (1.86 %) and total sugars (18.44 %).

Joshi (2000) reported that population growth, rising affluence, technological changes and rising expectation and awareness all lead to higher levels of consumption and waste generation, of which 80% is biodegradable. The end product of the degradable city waste (compost) is consumed by agriculture since it contains sufficient amounts of plant nutrients including micro-elements. If it is properly managed, it could be a valuable resource and alternative for the imported and expensive chemical fertilizers.

Bhuma (2001) stated that, although the organic manures contain plant nutrients in small quantities as compared to chemical fertilizers, they contain growth promoting substances like enzymes and hormones. Besides, they are essential for improvement of soil fertility and productivity by improving soil texture and microbial status.

Jeyabaskaran *et al.* (2001) observed that by adding poultry manure (15 kg) or rice husk ash (15 kg) nearly 20 per cent of NPK could be saved to produce significantly more plant height, pseudostem girth, leaf area and total number of leaves per plant than at 100 per cent NPK + no organic manure in ratoon crop of banana cv. Poovan. They also reported that application of FYM @15 kg per plant + Gypsum @ 2 kg per plant + 120% recommended K to banana cv. Nendran has recorded the highest bunch weight (10.33 kg) over control (5.93 kg).

Suresh and Hasan (2001) noticed that the inoculation of *Azospirillum*, coupled with 50 % N has resulted in the improvement of total soluble solids and reduction in the sugar content of fruits. However, an increase in the total sugar content observed with the combined inoculation of *Azospirillum*, Phosphobacteria and 100% RDF N and K plant^{-1} in Dwarf Cavendish banana.

Abd El-Aziz (2002) carried out physiological studies on bio-fertilization in banana plants and revealed that fruit physical characteristics were improved by the application of organic manure at 75 kg/stool/year on Williams banana plants. Further, it was reported that both farmyard manure and banana compost with 100% chemical fertilizet + sulfur application resulted in higher contents of N, P and K in the banana leaves.

Mustaffa *et al.* (2004) reported that the application of 2.5 kg sludge with 1.0 kg neem cake per plant in three splits recorded the highest plant height (305.40 cm), plant girth (90.60 cm), more number of leaves (14.20), total leaf area (15.12 m2) over control applied with inorganic fertilizers alone (200:50:300 g NPK per plant) in Karpuravalli banana. The lowest quality of fruits were recorded in inorganically fertilized fruits of Rasthali and Karpuravalli cultivars of banana respectively.

Naresh and Anamika (2002) studied the effect of integrated nutrient management in banana and found that banana yield (17.06 kg per bunch) was significantly higher under 100% NPK along with 20 kg FYM.

Sabarad (2002) studied the influence of G. *fasciculatum* on days for shooting after plant was found to be significant. VAM inoculated plants record the minimum number of days for shooting (278.00) when compared to un-inoculated plants (307.54).

Srivastava *et al.* (2002) conducted studies on organic citrus: soil fertility and plant nutrition and claimed that organic culture to be the most benign alternative. Use of organic materials such as farmyard manure, cakes of plant origin, vermicompost, and microbial bio-fertilizers on one hand, and exploiting the synergism between citrus-vesicular arbuscular mycorrhizal fungus on the other hand, are important components of the bio-organic concept of citrus cultivation.

Mycorrhizae were observed to be highly effective in low fertility, coarse textured soils. Mycorrhizal-treated trees had better plant growth and uptake of nutrients like P, Ca, Zn, Cu, and Fe compared to non-mycorrhizal trees. Inoculation of soil with mycorrhizae also helped in regulating the water relations and carbohydrate metabolism of citrus trees. Phosphorus nutrition of mycorrhizal-treated citrus trees was best improved by using rock phosphate as a source of P as opposed to other sources.

According to Tirkey *et al.* (2003), better growth and early cropping in banana cv. Dwarf Cavendish was obtained when inorganic fertilizers (100:100:150 g NPK/ plant) were applied along with organic manures (10 kg poultry manure/plant) as against the application of 300:200:300 g NPK/plant inorganic fertilizers alone.

El-Moniem and Radwan (2003) revealed that application of 75% NPK + PSB significantly improves the leaf macronutrient contents, leaf length, bunch weight, number of fingers per bunch and number of hands per bunch in banana compared with either 25 or 50 % NPK + biofertilizer or the recommended dose of NPK alone.

Hammam (2003) noticed that with the application of 400 g of inorganic N fertilizer along with 200 g microbes (phosphate solubilizing – *Bacillus megatherium* and N fixing *Azotobacter* sp. Bacteria) highest bunch weight (33.0 kg), number of hands per bunch (13.0) and number of fingers per hand (19.0) in banana cv. Williams.

Gogoi *et al.* (2004) reported that banana plants treated with 50% N + RD of PK + *Azospirillum* + PSB rcorded the highest hands/ bunch (9.00), fingers /hand

(22.48), weight of the 2nd hand (3.88 kg), bunch weight (24.28 kg) and yield (74.91 t/ha) followed by 50% + RD of PK + *Azotobacter* + PSB.

Kadam (2004) conducted a study to know the influence of bio-fertilizers on benefit:cost ratio of banana cultivation cv. Rajapuri. Among the different treatments tested, treatment involving 50% RDF + VAM (250g/plant) + *Azospirillum* (50g/plant) + *Trichoderma harzianum* (50g/plant) was found to be superior with respect to net profit and benefit:cost ratio.

Kanamadi *et al.* (2004) reported that in banana cv. Rajapuri, application of 25 % RDF as FYM + green manure (Sunhemp) + 75% RDF (inorganic) has recorded the highest pseudostem girth (19.56 cm), number of functional leaves (16.50), leaf area (10.58 m^2), early shooting (244.80 days), maximum number of fingers per bunch (97.50), highest finger weight (54.84 g) and yield (26.81 t ha^{-1}). Plants supplied with 75% RDF + *Azospirillum* (50g) + PSB (50g) + VAM (250g) + *Trichoderma harzianum* (50g) recorded the highest pseudostem and pseudostem girth whereas, the highest leaf area was observed in the plants applied with 100% RDF + *Azospirillum* (50g) + PSB (50g) + VAM (250g) + *Trichoderma harzianum* (50g) in banana.

Nachegowda *et al*. (2004) reported that, banana plants applied with 15 kg FYM + 180:108:220 g NPK/plant/year recorded the highest bunch weight (49.47 kg), fruit length (25.19 cm), fruit weight (220.21 g), finger/ hand (19.00), Fingers/ bunch (227.94) and the yield (148.41) followed by 2.5 kg sheep manure + 180:108:220 g NPK/plant/year. They also noted that, plants applied with 180:108:220 g NPK + 15 kg of FYM recorded the highest plant height (242.5 cm), plant girth (93.00 cm). Further, plants applied with 15 kg FYM + 180:108:220 g

NPK recorded the highest number of leaves, leaf area, leaf area index and minimum number of days taken for shooting followed by plants supplied with 2.5 kg sheep manure + 180:108:220 g NPK/plant/year in banana.

Sabarad *et al.* (2004) noticed that the banana plants inoculated with VAM-fungus (*Glomus fasciculatum*) shows the highest plant height, plant girth and number of leaves compared with uninoculated plants and also revealed that the plants treated with *in-situ* vermiculture has recorded maximum plant girth, plant height, and leaf area when compared to other treatments.

Balakrishna *et al.* (2005) observed maximum bunch weight, number of fingers per hand, number of hands per bunch and yield of banana fruits with the inoculation of *Glomus fasciculatum* and also reported that the application of 75% RDF combined with vermicompost had recorded maximum bunch weight, number of hands per bunch and yield per hectare. They also reported more number of fingers per hand and the total number of fingers per bunch in plants applied with 75 % RDF along with *Trichoderma harzianum.*

Naresh and Sharma (2005) reported that the highest number of fingers per bunch (60.35) was recorded in 50% NPK + 20 kg FYM + 10 kg *Azolla* and the lowest (36.67) was in control. The highest size of fingers, finger length (13.18 cm) and weight (92.68 g) was observed in 100% NPK + 20 kg FYM treated plants of banana cv. 'Jahajee'. They alos observed that the highest yield was recorded with 50% NPK + 20 kg FYM + 10 kg *Azolla*.

Swamy *et al.* (2005) reported that banana plants inoculated with VAM resulted in highest plant height, plant girth, leaf number, leaf area, sucker number and highest yield when compared to control. Further, maximum plant height, plant girth and leaf area were observed in banana supplied with *in-situ* vermiculture as well as the highest yield with application of 75% RDF + vermicompost.

Sarkar *et al.* (2007) recorded the maximum plant height (2.91 cm), girth (66.39 cm) and green leaves (23.82) in plants applied with *Azospirillum* sp. However, the maximum leaf length (201.57 cm) and leaf breadth (33.12 cm) were recorded in phosphobacterium application on banana cv. Martaman (AAB) under sandy loam soil condition.

Selvabai *et al.* (2007) stated that the application of *Azospirillum* at the rate of 3.3 g/plant along with 100 g inorganic nitrogen in two split doses during 3rd and 5th month of planting increased the quality of (26.3°Brix; 9.3 % over control) of banana.

Eman *et al.* (2008) reported that organic fertilization by using banana compost or FYM was favourable for improving fruit quality in terms of increasing total soluble solids (21.8ºBrix), and decreasing total acidity (0.13%). Further, they also reported that best results with regard to quality of fruits were obtained from plants applied with N through 50% banana compost or farm yard manure + 50% RDF through nitrogen mineral source in banana cv. Williams under silt clay loam situations.

Hazarika and Ansari (2008) revealed that the improvement in the yield and quality of banana by applying both chemical fertilizers and organic manures in combination with biofertilizers and revealed that biochemical constituents such as TSS, reducing sugar, non-reducing sugar, ascorbic acid, and moisture contents of fruit improved by different treatments except sugar acid ratio and titrable acidity.

They also reported that the treatment having organic manure and biofertilizers along with organic fertilizers produced higher values in physical parameters of finger.

Yamano (2008) conducted field trial to study the dairy-banana integration and organic fertilizer use in Uganda and reported that the intensive banana and dairy cropping system is an appropriate farming system where soil degradation is high and mineral fertilization is expensive.

In Maghrabi banana, Ahmed *et al.* (2009) observed improvement in fruit quality with the increase of TSS (°Brix) and decreasing titrable acidity with the application of banana compost mixture at the rate of 25 per cent Cattle manure (CM), El-Katamia compost (KC), El-Eboor compost (EC) and El-Keel compost (NC).

Attia *et al.* (2009) revealed that application of 25% P_2O_5 per plant combined with PSB recorded the highest pseudostem height, girth, number of leaves and leaf area in Maghrabi banana. Further, it also recorded maximum bunch weight, number of hands per bunch and number of fingers per bunch and improved the physical characteristics like finger weight, length and diameter.

Bhalerao *et al.* (2009) reported that application of 100 per cent recommended dose of NPK along with 10 kg FYM per plant and *Azospirillum* and phosphate solubilizing bacteria (25 g each) per plant took minimum days to flower and also crop duration in banana cv. Grand Naine. It also resulted in increased yield of banana fruits. Maximum pseudostem height, pseudostem girth, minimum number of days required for shooting, and minimum crop duration was observed in the same treatment.

Gaikwad *et al*. (2009) stated that maximum banana bunch yield was obtained with the application of 100% RDF + *Azospirillum* (50 g per plant) + PSB (50 g per plant) + VAM (250 g per plant) + *T. harzianum* (50 g per plant).

Kulapati *et al.* (2009) recorded that application of 100% RDF + *Azotobacter* + PSB + *Trichoderma harzianum*recorded the maximum pseudostem height (127.68 cm), pseudostem girth (18.75 cm), number of leaves (22.90) and leaf area (12.34 m^2) in banana cv. Dwarf Cavendish. They also registered the maximum bunch yield of 106.31 t/ha with 125% recommended N, P and K fertilizers when two suckers per hill were retained after harvest of main crop.

Roussos and Gasparatos (2009) conducted a field experiment on apple tree growth and overall fruit quality under organic and conventional orchard management and reported that fruit quality was much better in organically grown apple.

Syed (2009) recorded that, application of 200g N + 150 g P2O5 +200 g K2O per plant combined with organic booster slurry at 6 litres per plant increased the availability of N, P and K in soil and enhanced the nutrient concentration in index leaf tissues in banana cv. Ardhapuri.

Tangaselvabai *et al.* (2009) found that banana plants treated with 100:30:330 g NPK/plant in two split doses + *Azospirillum* recorded the highest pseudostem height (256.13 cm), pseudostem girth (69.95 cm), leaf area (22.52 m^2), less number of days taken for shooting and shooting to harvest (118 days) and the least crop duration (398 days).

Sayed (2009) reported that application of 200g N + 150 g N +150g P_2O_5 + 200g K_2O per plant combined with organic booster slurry at 6 litre per plant was found to be the best and resulted in maximum bunch weight (18.4 kg) and yield per hectare (81.8 t) in banana cv. Ardhapuri.

Hazarika and Ansari (2010) reported that, the highest bunch weight (16.50 kg), number of hands per bunch, fingers per hand, weight of second hand and total yield with 100% RD of NPK (P in the form of rock phosphate) + FYM + *Azospirillum* + PSB was recorded.

Hazarika *et al.* (2011) revealed that apploication of 100% RDF + VAM + *Azospirillum* + PSB + *Trichoderma harrizanum* recorded the best results in post harvest soil characteristics like organic carbon, pH, available N, P and K in tissue cultured Grand Naine banana. They also reported that the least pH was recorded in plants applied with 100% RDF + Vermicompost (4.69) and the highest organic carbon (0.85%), available nitrogen (296.64 kg/ha), available P_2O_5 (37.33 kg/ha) and available K_2O (223.66 kg/ha) were obtained in the same treatment.

Hipparagi *et al.* (2010) reported that the treatment combination of recommended dosage of FYM + 225:135:281 g NPK per hill recorded maximum plant height followed by recommended dose of fertilizer (222:155:251 g per hill) by studying the effect of biofertilizers, organic and inorganic manuring on growth of banana cv. Dwarf Cavendish. Plant provided with recommended dosage of FYM, *Azotobacter*, PSB, *Trichoderma harzianum* recorded the maximum number of leaves and leaf area, whereas plants supplied with only FYM shows minimum values.

In banana cv. Rajapuri, Kanamadi *et al.* (2010) reported that with the application of 100 per cent of RDF + VAM (250 g/plant) + PSB (50 g/ plant) + *Azospirillum* (5 g/plant) + *Trichoderma harzianum* (50 g/ plant) registered the highest leaf area (11.65 m^2) followed by 75 per cent RDF + VAM (250 g/ plant) + PSB (50 g/ plant) + *Azospirillum* (50 g/ plant) + *Trichoderma harzianum* (50 g/ plant). Further, the addition of biofertilizers resulted in early shooting. The treatment combination of *Azospirillum,* VAM, PSB and *Trichoderma harzianum* at different levels of RDF *viz.,* 70 per cent and 75 per cent had registered the highest TSS of 26.16 and 24.91°Brix respectively. Banana treated with 100 per cent RDF along with VAM, PSB, Azospirillum and Trichoderma has recorded early shooting (257.40 days).

Jeyabaskaran *et al.* (2010) studied the influence of inorganic fertilizers and organic manures in combination with biofertilizers on banana nutrient use efficiency and soil physicochemical properties and revealed that application of FYM and gypsum along with potassium had improved the bunch yield in banana.

Fresh chicken manure contains approximately 1.5% nitrogen. One chicken produces approximately 8 to 11 pounds of manure monthly. Chicken manure may be used to create homemade plant fertilizer (Mahamad Amanulla *et al.*, 2010).

Reganold *et al.* (2010) evaluated the fruit and soil quality of organic and conventional strawberry agroecosystems and concluded that the organic strawberry farms produced higher quality fruit and that their higher quality soils may have greater microbial functional capability and resilience to stress. These findings justify additional investigations aimed at detecting and quantifying such effects and their interactions.

Yadav *et al.* (2010) noticed that *Azotobacter* inoculated treatment with 50% nitrogen substitution by FYM and remaining 50 % through inorganic fertilizer in two equal splits at the establishment and before flowering stage gave the maximum benefit:cost ratio (4.97) in strawberry.

Al Busaidi (2012) studied the effect of organic manures on growth and yield of Banana (*Musa* AAA cv. Malindi) and reported that the organic manures significantly increased the yield of banana in saline soils.

Devi and Mitra (2012) conducted an investigation to standardize the organic nutrient management protocol for guava using various organic sources along with various biofertilizer combinations. They reported that plants receiving farm yard manure along with Azotobacter, PSB and KSB produced maximum number of fruits (626.3 fruits/ plant/ year) in guava cv. Sardar.

Singh *et al.* (2012a) reported that the quality parameters like TSS, total sugar, Vitamin C and total phenols were greatly influenced by the application of an organic source of nutrients to aonla in a semi-arid ecosystem.

Singh and Saravanana (2012) observed that the treatment of VAM @ 12 kg/ha + *Azotaobacter* @ 10 kg recorded the maximum net return (Rs.5,18,007 per hactare) and cost:benefit ratio (1:3.21).

Dwivedi (2013) found the maximum profit in guava plants treated with 50 % RDF (250:100:250 g NPK) + 25 kg FYM + 5 kg vermicompost per tree and 100 % RDF (500:200:500 g NPK) + Zn, B, Mn foliar spray + organic mulching 10 cm thick per tree.

Kuttimani *et al.* (2013) observed the maximum number of hands (10.3), number of fingers (145.2), bunch weight (25.3 kg/ plant) and total yield (77.1 t/ ha) in banana with the application of 100 per cent RDF along with 40 per cent Wellgro soil in Grand Naine (AAA) banana cultivar. Highest pseudostem girth

970.10 cm) and numbers of leaves per plant were observed in the plants applied with 100% RDF + 40% Wellgrow soil in Grand Naine (AAA) banana cultivar.

Patil and Shinde (2013) studied nutrient management on growth and yield of banana cv. Ardhapuri (Musa AAA) and found that the application of 50% recommended dose of fertilizer + *Azotobacter* (50gm/ plant) + PSB (50gm/ plant) + VAM g. *Fasciculatum* (250g/ plant) was beneficial for growth and yield of banana cv. Ardhapuri. They observed maximum bunch weight (19.31 kg) and yield (85.80 t/ ha) in banana plants which was applied with 50 per cent recommended dose of fertilizer + FYM + *Azotobacter* (50 g/ plant) + PSB (50 g/ plant) + VAM *Glomus fasciculatum* (250 g/ plant).

Devi *et al.* (2014) conducted an investigation to standardize the organic nutrient management protocol for litchi. Various organic sources viz., farm yard manure at 60 kg/tree/year, poultry manure at 21.4 kg/tree/year, vermicompost at 42.86 kg/tree/year and neem cake at 20.28 kg/tree/year along with various biofertilizer combinations (*Azotobacter, Azospirillum*, phosphorous solubilizers and potash mobilizers each at 100 g/tree/ year) were tested on 32-year-old litchi cultivar 'Bombai'. Application of farm yard manure + *Azotobacter* + phosphorous solubilizers + potash mobilizers resulted in greater fruit weight (24.73 g). The number of fruits (2556) and fruit yield (61.59 kg compared to 23.94 kg in control) per tree were greater with vermicompost + *Azotobacter* + phosphorous solubilizers + potash mobilizers. Treatment combinations with farm yard manure + *Azotobacter* + phosphorous solubilizers + potash mobilizers showed higher total soluble solids (17.79°Brix) and total sugar content (17.57%), whereas vitamin C content (53.48 mg/100 g pulp) was higher where a combination of neem cake + *Azospirillum* +

phosphorous solubilizers + potash mobilizers was applied. Application of nutrients through organic source along with biofertilizers improved soil health by increasing the microbial population in the rhizosphere. Addition of biofertilizers along with organic manure was more effective in enhancing fruit growth parameters in litchi than the use of organic manure alone. Application of vermicompost at (42.86 kg/tree/year) + *Azotobacter* + phosphorous solubilizers + potash mobilizers each at 100 g/tree/year in two split doses (January and July) is recommended for the organic production of the 'Bombai' litchi.

Lenka and Lenka (2014) studied the effect of nutrient management on growth and yield of banana (*Musa spp.*) variety Grand Naine and concluded that the vegetative characters such as pseudostem height, pseudostem girth at the time of shooting and yield attributing characters like days of shooting, weight of bunch, number of hands per bunch, number of fingers per bunch was significantly high in 100% recommended fertilizer dose + PSB+ *Azospirillum.*

Ahmadi *et al*. (2017) noticed maximum number of fruit/ plant (19.07), fruit weight (16.23 g), fruit length (4.28 cm), fruit diameter (2.56 cm), fruit volume (18.83 ml), yield/ plant (309.70 g), yield/ ha (17.20 tons) in the plants treated with 100% RDF + VAM @10 kg/ ha + 0.4% Boron + 0.5% $ZnSO_4$ spray. The highest benefit:cost ratio (2.37) was recorded in the plants treated with 100% RDF + VAM @10 kg/ha + 0.4% Boron + 0.5% Zn SO_4 spray.

Hussain *et al*. (2017) noticed that the maximum number of hands per bunch (10.75), fruits per bunch (156.50), bunch weight (24.53 kg) recorded with the application of 80% RDF + 20% RDF through FYM + *Azospirillum*, PSB and *Frateuria aurantia*.

Rajput *et al.* (2017) carried out a field trial on banana cv. Dwarf Cavendish to study the effect of organic (farm manure and composted pressmud) and inorganic (NPK) sources of nutrients on nutrient composition banana. Application of full NPK (500:250:500 kg ha^{-1}) increased the fruit P (0.08-0.12%), K (0.77-1.50%) and Zn (1.74-2.17 mg kg^{-1}) over full N and the respective values further increased to 0.14 and 0.22%, 2.28 and 1.79% and 2.42 and 2.21% with farm manure and composted pressmud additions. In case of banana fruit, nutrient composition, the inorganic fertilizer application (full NPK) increased P and K contents by 50 and 95% over N alone treatment except in case of N. Addition of farm manure and composted pressmud increased all three nutrients (NPK) by 27.5 and 35.2, 75.0 and 175.0, and 196.1 and 132.5%, respectively over N alone treatment. There was no additional benefit of 1.25 NP (where 25% more than full Nitrogen and Phosphorus). In fact, the higher rates i.e. full NPK and 1.25 NP reduced the micronutrient contents of fruit due to dilution effect. However, the P requirement was same even with application of organic sources. The integrated use of mineral fertilizers and organic amendments resulted in enhanced banana fruit nutrients and highlights the advantage of conjunctive use over their separate applications.

Singh *et al.* (2017) stated that application of 75 % RDF + 20 kg vermicompost + 250 g *Azotobacter* + 250 g PSB/ plant recorded maximum gross income (Rs.10,90,410 and Rs.13,08,346 ha^{-1}), net return (Rs. 8,74,872 and Rs.10,36,240 ha^{-1}) and cost:benefit ratio (1:4.06 and 1:3.08) respectively during the year 2010-11 and 2011-12.

Ganapathi and Dharmati (2018) conducted the field investigation on Integrated nutrient management in banana cv. Grand Naine (AAA) and revealed that application of vermicompost equivalent to 40% recommended dose of nitrogen (RDN) (24.20 t/ ha) + Urea equivalent to 40% RDN (535.73 kg/ ha) + Green manure (Sunhemp @8.88 t/ha) and *Azospirillum* (@ 30.86 kg/ha) equivalent to 20% RDN + PSB (@ 30.86 kg/ha) recorded the highest pseudostem height (205.05 cm), pseudostem girth (27.47 cm), number of leaves (16.00), leaf area (8.87 m^2), leaf area index (2.74), the least number of days taken for shooting (190.65 days) and total crop duration (318.89 days).

Suhasini *et al.* (2018) carried out a research work on the effect of integrated nutrient management practices on banana cv. Rajapuri with commercial formulations of organic fertilizers. The experiment contains six treatments and four replications laid in a randomized block design. The treatment that received 100% recommended dose of fertilizers (RDF) along with Vermicompost (2kg) + Neemcake (250g) + Azospirillum (50g) + PSM (50g) + VAM (250g) recorded the highest plant height, pseudostem girth, number of functional leaves, total leaf production, total leaf area and leaf area index.

Meghwal *et al.* (2021) conducted an experiment at Banana Research Station, Kerala Agricultural University by raising banana (Nendran) under different manurial combinations. Maximum starch (99.61 mg), protein (5.53 mg), crude fibre (3.95%) and tannin content (0.81 g) in mature fruits were obtained in treatment FYM @ 29 kg, lime @ 0.5 kg and wood ash @ 4 kg/ plant as basal dose + fertigation with extract of 14 kg FYM till one month after bunch emergence, once in four days + *in situ* green manuring. This treatment also recorded lowest titrable acidity (0.38%), highest β-carotene content (595.67 μg) in ripe banana fruits. Maximum yield (160.88 kg plot^{-1}) and fruit quality parameters; maximum total sugars (17.55%) and reducing sugars (11.38%), sugars/acid ratio (45.07) of ripe banana fruits were obtained in the treatment where 15 kg FYM and 0.5 kg lime as basal+Poultry manure @ 14 kg plant^{-1}+ash @ 4 kg plant^{-1} applied in two splits *i.e.* one as basal and one 3 MAP+*in situ* green manuring practised. It was evident from the study that application of organic manures improved fruit quality characters in Nendran banana.

2.2. Intercropping in fruit crops

Randhawa and Sharma (1972) suggested that when banana plants planted at 2.5m X 2.5m or 2.5m X 2.0m, two short duration crops with combination of cereal and legume, creal and vegetable, creal and oil seeds can be taken. With closer spacing of 1.6m X 1.6m, as in Maharashtra, only one crop of radish followed by short duration legume like green gram is possible during the initial 3 to 5 months after planting. The most renumerative combination being *moong* – ginger for northern and eastern zone giving a net profit of Rs.7312 and field beans – squashes for southern zone giving Rs.3330 from the intercrops. The growth habit of banana can permit taking only one crop during the early part of growth.

Meenakshi *et al.* (1974) revealed that intercropping of coriander, onion, palak and radish in *rabi* season with solanaceous vegetable crops is always profitable.

Nair *et al.* (1974) found that the basic resource of crop production namely soil and solar energy were not being utilized to the maximum extent possible in a pure stand crop of coconut. Before the coconut plantation become 8 to 20 years of age, the interspaces received filtered sunlight in varying amount, which was adequate to raise various crop.

Subhramanyam (1987) conducted an experiment on papaya orchard, and reported that vegetables like tomato, beans, chillies etc. could be grown when the plants were young during the first year of planting. Growing of intercrops not only utilized the vacant spaces between the plants optimally but also checked the growth of weeds.

Elangovan *et al.* (1980) conducted a trial on intercropping of onion in chilli and revealed that the plant height of chilli was not affected significantly by the growth of onion but yield of sole crop is higher than intercropped chilli.

Subbaiah *et al*. (1980) conducted an experiment to find out a suitable intercrop in banana field with different intercrops like greengram, blackgram, onion, okra, cowpea and revealed that raising an onion as intercrop in banana field did not affect the bunch yield of banana.

Singh and Dahiya (1982) reported that during the pre-bearing stage of papaya, short duration vegetables like cabbage, cauliflower, onion, chillies, radish, tomato etc. could be grown as intercrops which not only kept the soil free from weeds but also added to the income of the growers.

An experiment was conducted by Avilan *et al.* (1983) with avocado, which was intercropped with cocoyam, papaya and cowpeas. The best result was observed in terms of yield, land and labour utilization efficiency when cocoyam was used as an intercrop.

Rao and Edmunds (1984) reported that the intercropping of banana affect the hands per bunch, fingers per bunch and finger weight significantly, but not the bunch weight. The associated growth of intercrops significantly reduces the girth of the pseudostem at five months after planting and increased days to shooting and days to harvesting of the banana. The yield differences within cowpeas and sweet potato were non-significant, but maize interplanted with cowpeas yielded 16.5% higher than with sweet potato.

Studies on intercropping of 'Basrai' banana by Chundawat *et al.* (1984) revealed that when banana is grown alone or intercropped with *Curcuma longa*, C. *amada* or *Dioscorea alata*, it gave average yields of 55195, 54293, 50202 and 49079 kg banana per hectare and the yield of the three intercrops were 5543, 1915 and 1390 kg per hectare respectively. The results suggested that intercropping of banana with turmeric would prove profitable to the banana farmers of South Gujarat.

Rao and Edmunds (1984) studied intercropping of banana with cowpea, maize and sweet potato. They found that all the intercropping treatments significantly reduced the pseudostem girth of banana at 5 months after planting and increased the number of days to shooting and harvesting.

Potentiality of growing cowpea (cv. California Blackeye-5) as an intercrop with one year old grape fruit orchard was studied in South Florida by Stofella *et al.* (1986). It was found that the total yield of fresh marketable pods was 1854 kg/ ha. The result suggested that cowpea could provide a cash crop for growers with newly established citrus (grape fruit) groves.

An investigation carried out by Ashokan *et al.* (1988) to study the relative uptake of ^{32}P by cassava, banana, elephant foor yam and groundnut in intercropping systems. He results showed that the yield and dry matter (gram/plant) production of banana was not affected by intercropping.

Bhuva *et al.* (1988) studied the effect of intercropping on the main crop and the economics of mango cv. 'Rajapuri', planted at 6 m X 6 m and intercropped with banana, cassava, tomato, cluster bean, brinjal and cowpea. They reported that mango grown with tomato and cluster bean as an intercrop gave the highest financial return per hectare with benefit-cost ratio of 1.22.

Singh *et al.* (1988) reported that coconut intercropped with *Dioscorea,* elephant foot yam, tapioca, turmeric and ginger yield much higher as compared to sole crop. The total net income was Rs. 5000, Rs. 7104, Rs.10704, Rs.6570 and Rs.6710 for coconut alone, coconut with *Dioscorea*, coconut with elephant foot yam, coconut with tapioca, coconut with turmeric and coconut with ginger respectively.

Kumar and Pillai (1989) studied the economics of coconut based intercropping system, where mature coconut plantation was intercropped with coconut seedlings, cassava, cowpeas, pineapple or bananas. They found that although intercropping was profitable in all cases, the highest net returns were obtained when the interspaces in the coconut plantation were used for raising quality coconut seedling of the cultivars West Coast Tall and Komadan.

Prabhakar and Shukla (1990) carried out a field experiment on crop land use efficiently in sequential intercropping systems with vegetables. In sequential intercropping systems with vegetables, onion based intercropping system gave higher economic return and crop land use efficiency as compared to other systems.

Nybe *et al.* (1991) studied weed management in banana cv. Nendran with cowpea as an intercrop. Chemical methods of weed control were compared with intercropping with cowpea cv. Kanakamani and hand weeding for the control of weeds in banana orchard. They concluded that intercropping with cowpea was the most effective and economic method of weed control in banana.

Radha *et al.* (1991) conducted an experiment on the effect of intercropping in pineapple cv. Kew which was grown at a spacing of 30cm X 60cm X 180cm and intercropped with ginger, turmeric, cowpea, *Colocasia sp.* They compared the intercropped pineapple with a monocrop planted at a spacing of 30cm X 60cm X 90cm as. It was observed that yield was significantly higher when pineapple was raised as monocrop at higher density, than when intercropped with other crops at lower density.

Berad (1993) carried out an experiment at GAU, Navsari and reported that the sole crop (bottle gourd) showed better performance on various growth parameters such as length of main vine (8.5cm), number of branches from the main vine (29.9), number of flower bud initiation (10.0) at 39 days after sowing, number of male flowers (33.66) and female flowers (14.00). Further, the sole crop treatment recorded the maximum length of fruit (34.25 cm), girth of fruit (26.33 cm) as well as yield of fruits (19.84 t/ha). However, number of flower bud initiated, girth of fruit and yield of sole bottle gourd crop were at par with bottle gourd + onion. The maximum monetary return was fetched in bottle gourd + cabbage which was at par with bottle gourd + cabbage + onion and bottle gourd + onion.

Das and Maharana (1995) worked for profitable intercrops in banana with different intercrops like onion, tomato, potato and chilli. They reported that the intercropped banana gave higher economic return as compared to control and also the onion and chilli were more suitable for intercrop because they uptake less nutrient as compared to other crops. Yield of banana was higher which was intercropped with onion and chilli.

Nayar and Suja (1996) conducted a field experiment for three consecutive seasons at Central Tuber Crop Research Insititute, Trivandrum, India to see the effect of intercropping of four genotypes of dioscorea (Sree Keerthi, Sree Priya and Sree Latha) with banana 'Nendran'. There was no negative effect on growth and productivity of banana due to intercropping with different genotypes of dioscorea. Intercropping banana with Sree Keerthi and Sree Priya was very profitable in comparison to sole cropping.

The effect of different peas as intercrops on growth and yield of ber in sem-arid region was studied by Singh and Nath (1995). They obtained higher fruit yield (16.84 kg / tree) with intercrops than without intercrops (5.10 kg/ tree). Arkel variety of pea produced maximum yield (52.6 qtl./ ha) as compared to other variety.

Sharma *et al*. (1996) conducted experiment in a 30 years old coconut plantation which was spaced at 7.5 m X 7.5 m under rainfed conditions. They reported that among the intercrops *viz*., colocasia, ginger and turmeric, ginger gave the highest value.

Singh *et al*. (1996) studied the effect of intercrops on growth and economic yield of mango cv. Langra. The intercrops selected were (i) chilli as an annual crop (ii) chilli followed by soyabean (iii) okra-gram-okra. It was observed that okra-gram-okra combination gave significantly higher yield than other treatments and net income was obtained considerably higher with the same treatment.

Sairam *et al.* (1997) estimated variable capital requirement and economics of coconut based cropping systems under rainfed and irrigated condition. Various intercrops like elephant foot yam, ginger and turmeric were taken under rainfed condition while banana was taken under irrigated condition. A gross return of Rs.100500 per hectare was obtained for the coconut-ginger system, whereas for the coconut monoculture it was only Rs.31500. Gross return from the banana and coconut system was Rs.69000, profit from the banana alone accounting for Rs.13000.

An investigation was carried out by Singh *et al.* (1998) on economic prospects of vegetable intercropping in young eucalyptus plantation at Pantnagar. The results showed that vegetable intercropping did not cause any adverse effect on the yield and income of eucalyptus. Increased growth of eucalyptus caused marked reduction in yield of all the intercrops during the second year; the maximum being in onion followed by others. Onion as an intercrop gave good net income of Rs.10,527 during the first year but proved a failure in the second year.

An intercropping system (cashew orchard with vegetables, pulses and oil seed under rainfed conditions) was studied by Gupta (1999) under long term evaluation at Jagdalpur to determine the most suitable intercrop for obtaining maximum returns per unit area in the Bastar plateau zone. Cowpea, bush-type French bean, cluster bean, rice bean, moong beans, soyabean and groundnuts were grown in a three year old cashew orchard. Gross and net return per hectare worked out for different models revealed that all the intercrops recorded higher net return than the sole crop of cashew.

An investigation was carried out by Randhawa *et al.* (1999) to study the interactive relationship between growth and yield characters of autumn sugarcane and associated cultures and revealed that among different treatments, sugarcane alone produced the highest cane yield of 149.94 t/ha but it did not differ significantly from that of either lentil or peas or garlic intercropped in sugarcane. But the net income from garlic based intercropped sugarcane gave maximum, while the minimum was observed in the sole crop of sugarcane.

Sharma (1999) studied the effect of intercropping on yield and economic viability of a 6 year old mango orchard (cv. *Langra*) and reported that intercropping with (i) Okra in Kharif, gram in rabi and then okra in summer (ii) soybean in Kharif and chilli in rabi induced high levels of fruit drop of mango that on mango grown alone. However, the intercrops gave additional income to the farmer.

Swaminathan (1999) conducted an experiment at Padukottai, Tamil Nadu on scientific development of tree mixtures in an agro forestry system with two fruits viz. mango and cashew and four tropical nitrogen fixing trees. Growth in cashew was enhanced by 25% when inter-planted with Casuarina and plant girth (10.8 cm) was maximum when inter-planted with Leucaena.

Ghosh (2001) conducted an investigation in guava orchard in watershed area for two years and found that the total returns of guava + groundnut combination proved the best. However, the net profit per hectare was maximum under guava + ridge gourd followed by guava + groundnut combination.

McIntyre *et al.* (2001) studied the effects of legume intercrops on soil-borne pests, biomass, nutrients and soil water in banana and suggested that land use efficiency may be increased by incorporating food and fodder legumes into the banana cropping system. The legume intercrops, although grown as perennials, were pruned at the end of each rainy season. This pruning most likely prevented competition for soil moisture since growth and consequently water uptake by the legumes were limited during the driest periods of the year.

Mishra and Swain (2001) reported that pulse crops like pigeon pea and black gram can be profitably grown as an intercrop in fruit orchards during pre-bearing stage. This was identified during their evaluation of different agri-horti systems in watersheds for eastern Ghats Highland of Orissa.

Singh *et al.* (2001) carried out an experiment to study the suitability and profitability aspects of intercrops in young mango orchard cv. Langra. They reported that among the different vegetable intercrop combinations, the bottle gourd-radish combination increased the mango yield followed by okra-carrot and chilli-onion compared to control. The maximum net income of Rs.88,757.32 ha^{-1} was obtained from the bottle gourd-radish followed by sponge gourd tomato (Rs. 86,397.62ha^{-1}) combination.

Mahadevaswamy and Martin (2003) carried out a field experiment at TNAU, Coimbatore to study the effect of aggregatum onion intercropping in wide spaced sugarcane on the total productivity and economic advantage. They reported that onion did not affect the yield of base crop of sugarcane. The intercropping of aggregatum onion significantly increases the total productivity as well as gross and net returns as compared to sole crop of sugarcane.

Jain and Raut (2004) conducted a comparative study on the performance of different kharif vegetables viz. tomato, French bean, cowpea, brinjal, okra and maize with papaya as filler crop in a mango orchard over two monsoon seasons during 2001 and 2002 at Tihari, Madhya Pradesh. The economics of the intercropping system reveals that gross return of Rs.62760 with net return of Rs.29320 per hectare were found to be highest when tomato was intercropped in mango orchard with filler crop papaya. The cost-benefit analysis of different intercrops resulted with the best cost benefit with tomato (2.60) followed by cowpea (1.90).

Pandey *et al*. (2004) studied the effect of various intercrops in five year old mango orchard 'Amrapalli' and 'Mallika'. During rainy season of the year 2003, 25.75 quintals per hectare cluster bean, 445.24 quintals per hectare okra and 81.9 quintals per hectare cowpea were harvested with additional biomass yield of 161, 142.6, 193, 55.83, 84.54 and 37.3 quintals per hectare respectively.

Lenka *et al*. (2005) studied the feasibility and profitability of intercropping with groundnut, cowpea, turmeric and pineapple in cashew plantation. The results revealed that these were grown successfully as intercrops in 9-10 year old cashew orchard of cashew without affecting the yield of the main crop. The net profit ranges from Rs. 5060 ha^{-1} in cashew + groundnut crop combination to Rs. 30150 ha^{-1} in cashew + turmeric crop combination. Cashew intercropped with cowpea recorded the highest cost benefit ratio (1:4.84) due to low investment and better profitability. Also, there was better retention of soil fertility.

Rahman *et al.* (2006) worked on suitable banana (Ranginsagar) based intercrop combination and reveal that highest yield and all the growth parameters found in the sole banana crop as compared to intercropped banana, but the land equivalent ratio and economic was higher in all intercropping than sole cropping. The combination of banana + potato gave the highest LER (1.68) and BCR (1.95) than the sole crop LER (1) and BCR (1.84).

The result of an intercropping trial conducted by Swain and Patro (2006) in guava orchard showed that cowpea as an intercrop recorded significantly higher plant growth in respect of tree height, girth, canopy area, shoot growth and number of leaves per shoot of guava in watershed area.

An investigation was carried out by Mollah *et al.* (2007) to study the performance of intercropping groundnut with garlic and onion. The results showed that groundnut intercropped with onion and garlic produced higher groundnut equivalent yields (2.67 and 2.94 t/ha respectively) with higher gross margin. It also gave higher B:C ratio.

Nazrul *et al.* (2007) conducted an experiment on multi-location testing of four intercrop combination viz. sole banana, banana + okra, banana + sweet gourd and banana + bitter gourd. The result showed that the highest banana equivalent yield advantage (20%) than sole banana was recorded in the banana + sweet gourd combination. Highest benefit cost ratio (2.41) was also obtained with the same combination.

Pattanaik *et al.* (2007) studied the economics of intercrops in cashew var Vergula-4 plantation with vegetable crops and found that the yield of main crop ranges from 60.1 to 80.70 qtls. ha^{-1} under various crop combinations. Highest returns of Rs.19350 ha^{-1} was obtained from colocasia and lowest recorded in cowpea. Net highest return of Rs. 44,908 ha^{-1} was obtained when cashew was intercropped with colocasia, followed by brinjal. Minimum net return was ontained from the sole crop of cahew.

Ray *et al.* (2007) conducted an experiment with different vegetables and flowers as pre-bearing intercrop in arecanut plantation. They reported that vegetable crops like radish, cabbage, cauliflower and brinjal performed well and resulted in higher net return during winter season. Among the flower crops, marigold and chrysanthemum performed well and resulted in higher B:C ratio (2.05 to 2.43) compared to gladiolus.

The results generated from an experiment conducted at Rajshahi (Bangladesh) indicated that mustard intercropped with garlic and onion gave highest mustard equivalent yield as compared to sole mustard. Mustard blocks intercropped with garlic gave the highest cost:benefit ratio which was followed by onion intercropped blocks. Sole mustard blocks produced lowest cost:benefit ratio in both the seasons (Sarkar *et al.*, 2007).

Srivastava *et al.* (2007) studied the yield prediction in intercropped versus monocropped citrus orchards performance of mandarin orchards. The best results was observed in Abkhaziya (Georgia) was observed with clean cultivation until August then sowing of green manure plus 10 t ha^{-1} farmyard manure followed by green manure during the year.

Swain and Patro (2007) conducted an intercropping experiment in a seven year old bearing mango orchard with filler crop guava. The study revealed that the maximum increase in plant height, girth and canopy area of mango and guava was recorded with cowpea followed by French bean.

Yadukumar (2007) evaluated different annuals, biennials and perennials and inter and mix-cropped with an objective to utilize interspaces and to check soil erosion during initial stages of cashew. Soil erosion could be checked using cover crop. Sustained additional income can be obtained by growing intercrops.

Hipparagi and Chinnapa (2008) revealed that soyabean and red gram could be raised successfully in the interspaces of banana garden without affecting the main crop. Soyabean and red gram were proved to be ideal intercrops in banana garden providing better net income.

Jayakumar *et al.* (2008) studied the influence of intercropping and sources of nitrogen on yield attributes, yield and economics of cotton at Coimbatore and revealed that blackgram based intercropping gave better results in comparison to onion based intercropping.

Biofertilizers are products containing living cells of different types of microorganisms which when applied to seed, plant surface or soil, colonize the rhizosphere or the interior of the plant and promotes growth by converting nutritionally important elements (nitrogen, phosphorus) from unavailable to available form through biological process such as fixation and solubilization of rock phosphate (Rokhzadi *et al.*, 2008).

Jata (2009) carried out an experiment on intercropping of elephant foot yam in orchard crops and reported that the elephant foot yam can be planted between the interspaces of fruit or orchard crops with a recommended spacing of

90cm X 90cm. Depending on the canopy size of fruit and orchard crops, 5000 to 9000 plants of elephant foot yam per hectare can be accommodated and elephant foot yam is not competing for light as this crop is able to tolerate shade.

Karlidag and Yildirim (2009) conducted field experiment was carried out to evaluate the productivity of strawberry–vegetable intercropping systems on the basis of growth, yield, and land equivalent ratio (LER). Strawberry '216' (*Fragariae ananass*a L. Duch.) as main crop was intercropped with Cos lettuce (*Lactuca sativa* L. var. *longifoila*) 'Yedikule 44,' radish (*Raphanus sativus* L.) 'Cherry Belle,' and onion (*Allium cepa* L.) 'Corum.' Additive design technique was employed to formulate mixture populations. Each intercrop was planted between strawberry rows in separate plots. All crops were also grown in pure stands. Results of this study indicated that different intercropping systems compared with sole crop systems did not affect some fruit chemical characteristics and yield of strawberries. The values of LER appeared to be greater than 1 under intercropping systems. The results obtained in this study pointed out that strawberry–vegetable intercropping systems increase total yield and productivity.

Morsy *et al.* (2009) conducted a trial on effect of garlic and onion extracts on their intercropping on suppressing damping off, powdery mildew disease and growth characteristics of cucumber. They reported that intercropped cucumber produced more number of leaves and flowers per plant as compared to sole cucumber during both the years.

Ouma (2009) studied that bananas are extensively grown where they are mainly intercropped with short term crops. There has been an increase in the grower interest in using intercropping, growing two or more crops simultaneously on the same land in the development of new cropping systems for their land. Intercropping could reduce management inputs and result in sustainable systems that more effectively use and even potentially replenish natural resources used during crop production for long term management of farmland. Benefits of intercropping to grower are risk minimization, effective use of available resources, efficient use of labour, increased production per unit area of land, erosion control and food security.

Rodge and Yadlod (2009) conducted a trial to study intercropping in vegetables and reported that intercropping with onion gave higher net profit as compared to sole crop and other intercrops.

Venugopal and Sheela (2009) reported that productivity and income was enhanced in banana variety Nendran by modifying the planting pattern and adopting intercropping. Individual bunch weight did not show any variation with planting pattern. However, maximum yield per hectare was registered in modified system of planting. Combination of modified planting system of cucumber and amaranthus has the highest net profit and benefit cost ratio.

Nedunchenzhiyan *et al.* (2002) conducted an experiment at the Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar to study the suitability of elephant foot yam as an intercrop in banana. The results revealed that intercropping of elephant foot yam in banana did not affect the yield and yield attributing characters of banana and also give high economic returns as compared to sole crop of banana.

Ouma and Jeruto (2010) conducted studies on intercropping and its application to banana production in East Africa and concluded that intercropping is a very beneficial in banana cropping system because of its advantages of increasing food security and reducing poverty and increasing soil fertility. It is increasingly becoming important in East Africa where land scarcity is increasing. Banana is a very important crop in East Africa but due to the fact that small scale farmers also require food security, it should be intercropped with many of the annual crops being grown by farmers to achieve this.

Singh (2010) conducted a trial on evaluation and economics of different intercrops like okra, pumpkin and bitter gourd in banana. He revealed that the yield, yield attributing characters and B:C ratio found higher in intercropped banana as compared to sole banana. Banana + pumpkin gives highest yield (62.19 t/ha) and B:C ratio (2.41) than sole banana yield (51.63 t/ha) and B:C ratio (1.45).

Song *et al.* (2010) conducted field trials on the effects of intercropping with aromatic plants on the diversity and structure of an arthropod community in a pear orchard. Five aromatic plants, *Centaurea cyanus, Saturela hortensis, Nepeta cataria, Agerarum houstonianum,* and *Ocimum basilicum*, were assessed as intercrops in a pear orchard, and all significantly reduced the pest population compared with that in the plot natural grasses. The decrease was particularly marked for *C. cyanus, S. hortensis,* and A. *houstonianum*, and plots intercropped with these aromatic plants also had significantly higher values of ratios of natural enemies to pests. Intercropping with aromatic plants in pear orchards proved beneficial to the main crop by repelling pests and regulating the structure of the arthropod community in the pear orchard ecosystem.

Asten *et al.* (2011) studied the profitability of intercropping in coffee-banana system in Arabica and Robusta coffee in Uganda. They reported that coffee-banana intercropping is much more beneficial that sole crop of either banana or coffee.

Ghosh and Hore (2011) in their study on economics of a coconut-based intercropping system as influenced by spacing and seed rhizome size of ginger reported that the maximum net return was realized from closest spacing with smaller seed rhizome in 20cm X 15cm spacing. Hence, intercropping coconut with ginger may be recommended for maximizing yield in coconut plantation.

Girija Devi *et al*. (2011) conducted a study on performance of various crops in coconut based cropping system compared to sole cropping, and reported that Nendran banana, elephant foot yam, ginger can be grown as suitable intercrops in coconut plantation in different combinations. All these crops produced significantly at par with the sole crops in coconut garden and by adjusting the plant population of intercrops, renumeration from the coconut garden can be increased sufficiently.

Mahanta *et al.* (2012) conducted a field experiment on intercropping in banana and has found that banana intercropped with onion was more profitable under drip irrigation system. This recorded higher banana equivalent yield, land equivalent ratio and net realization, while benefit cost ratio was maximum under banana intercropped with garlic.

Singh *et al.* (2012b) reported that if mandarin is intercropped with soyabean in kharif and coriander in rabi, there may be income for almost six months as against 1-3 months under sole cropping system.

Sit and Roybarman (2012) studied the performance of different turmeric cultivars under coconut plantation for sub-Himalayan Teria regions of west

Bengal and reported that cultivars like Suguna, Suraniana and Suvarna performed well when planted as an intercrop in coconut plantation.

Koko *et al.* (2013) studied the Cacao-fruit tree intercropping effects on cocoa yield, plant vigour and light interception in Ivory Coast and their results showed that the planting distance between the cacao and the intercropped tree had a noteworthy effect on cacao vigour and yield and that, at equal distances, it depended on the intercropped species.

A field experiment was conducted by Swadija *et al.* (2013) in the Western Ghat region of Kerala for deriving an organic nutrient schedule for sustained yield of arrowroot intercropped in coconut garden. Seven treatments were laid out, and the results indicated that arrowroot can be profitably intercropped in coconut gardens.

Krishnakumar *et al.* (2013) in their study on integrated nutrient management for elephant foot yam intercropped in coconut gardens concluded that elephant foot yam (var. Gajendra) can be successfully intercropped in coconut gardens with the application of 50% recommended dose of NPK fertilizers along with biofertilizers (*Azospirillum* and Phosphobacteria) @5 kg per hectare and vermicompost @1 kg per plant.

Nayak *et al.* (2014) carried out a study on economics and yield performance of some short duration fruit and medicinal crops under agri-silvicultural syatem in rainfed uplands of Odisha. They reported that *Acacia magium* with pineapple based agri-silvicultural system recorded the highest gross return, net return and BCR as compared to other agri-silvicultural systems and sole crops.

Netsere and Kufa (2015) in their investigation on intercropping of *Arabica* coffee with turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) at Tepi, South-west Ethiopa revealed that coffee intercropped with turmeric and ginger was found to be agronomically and economically beneficial. Therefore, depending upon the suitability of area and priority of farmers, coffee intercropped with turmeric and ginger can be practiced as an important remedy to increase crop production and economic returns, as coffee can be grown with turmeric and ginger without significant yield reduction.

Patil *et al.* (2015) conducted an experiment to find out the effect of different intercropping on growth and yield of banana cv. Grand Naine. The growth parameters *viz.* plant height, girth of pseudostem, number of leaves and leaf area of banana reduced due to intercropping 3 to 5 months after planting. However, banana intercropped with onion, garlic and cauliflower showed similar growth to that of sole banana. The days required for inflorescence emergence and harvesting did not influence significantly due to various treatments. However, intercropping remain non-significant for yield attributes, *viz.* number of hands/ bunch, average weight of fingers, number of fingers/ bunch, and length and girth of fingers. Among the intercrops, cauliflower caused severe reduction in banana yield under all planting patterns.

An experiment was conducted by Alam *et al.* (2021) to determine the yield and profitability of bananas for winter crops. The winter vegetables intercropped with bananas were sweet gourd, bitter gourd, red amaranth and radish. Significant effects were found in yield contributing characters. Banana intercropped with bitter gourd gave the highest gross return with a benefit cost ratio of 3.22. BCR (benefit cost ratio) of banana intercropped with red amaranth, banana intercropped with sweet gourd and banana intercropped with radish was 2.77, 2.69 and 2.66 respectively. Sole banana recorded the lowest BCR of 2.35.

CHAPTER-3

MATERIALS AND METHODS

The details of the materials used and methods adopted during the course of the investigation are described below:

3.1. Experimental Site

The experiments were carried out at farmer's field situated at Kelsih, Aizawl district, Mizoram, situated at 23.64°N latitude and 92.71°E longitude having an attitude of 791 m above mean sea level (MSL).

3.2. Soil status of the experimental site

Before undertaking the experiments, composite soil samples of the experimental sites were taken from the depth of 15 - 45 cm. The soil texture is loam to clay loam soil. The estimated values of initial soil composition are as follows:

Table 3.1: Initial soil composition of the experimental plot 1

Depth of soil (cm)	Soil pH	Organic Carbon (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
0-15	4.92	0.31	402.18	33.48	386.24
15-30	4.95	0.28	382.25	23.82	372.34
30-45	4.86	0.26	374.38	28.42	378.57

Table 3.2: Initial soil composition of the experimental plot 2

Depth of soil (cm)	Soil pH	Organic Carbon (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
0-15	4.78	0.32	412.36	34.65	392.12
15-30	4.85	0.27	378.85	24.18	368.48
30-45	4.69	0.25	366.82	26.25	372.14

Table 3.3: Methods employed for soil analysis

Soil pH	pH meter with glass electrode (Jackson,1973)
Organic Carbon	Walkey and Black method (Jackson, 1973)
Available N	Micro-Kjeldahl's method (Jackson, 1973)
Available P_2O_5	Colorimetric method (Dickman and Bray,1940)
Available K_2O	Flame photometric method (Jackson, 1973)
Fe	Atomic Absorption Spectrophotometry
Mn	Atomic Absorption Spectrophotometry
Cu	Atomic Absorption Spectrophotometry
Zn	Atomic Absorption Spectrophotometry
B	Atomic Absorption Spectrophotometry

3.3. Meteorological observations during the period of experimentations.

The climate of the site usually is subtropical and humid.

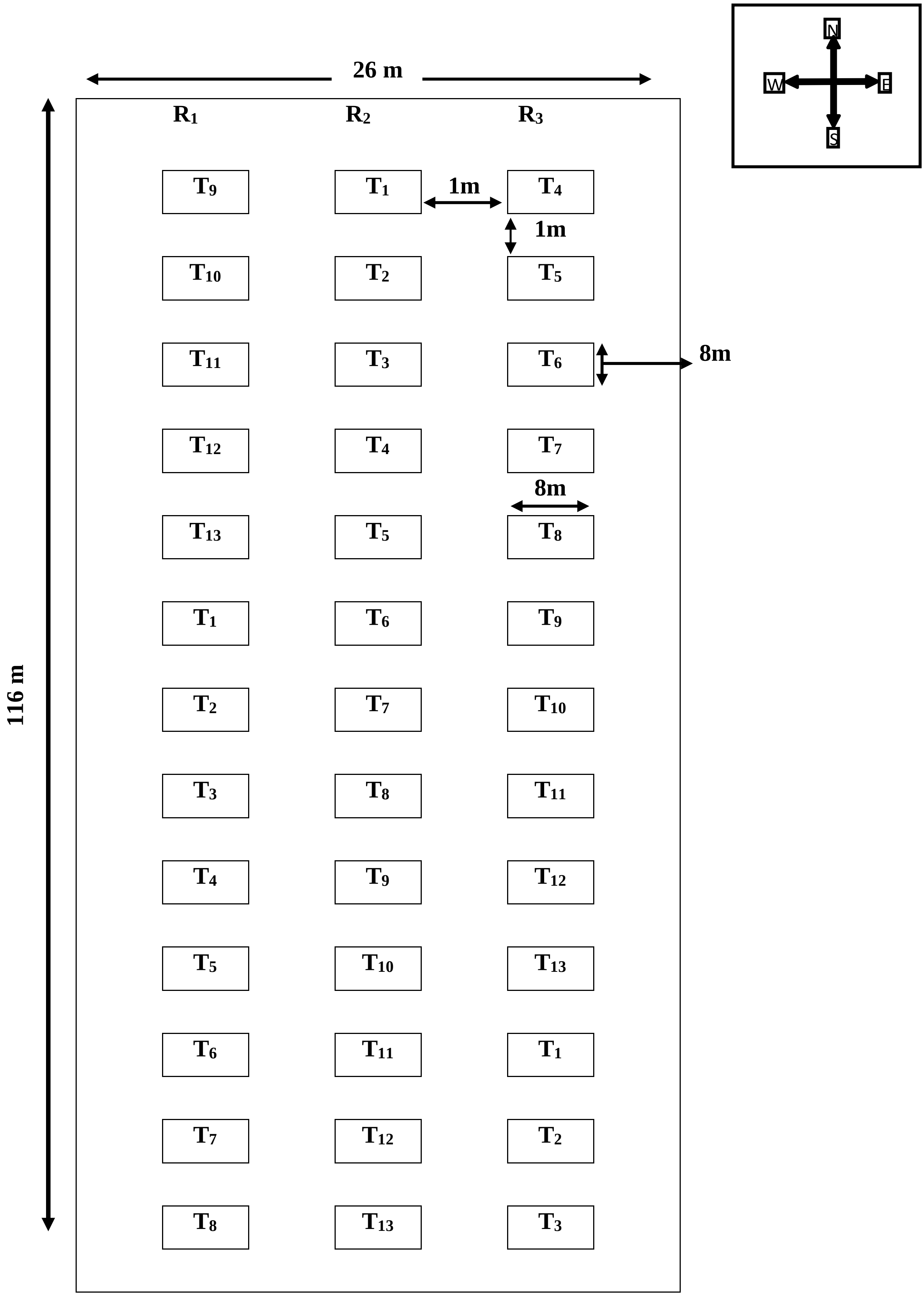
Table 3.4.: Monthly records of temperature, relative humidity and total rainfallduring the period of experimentation (June 2016 to October, 2018)

Year &Month	Average temperature (°C)		Average relative humidity (%)		Monthly Annual total rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
2016					
June	27.8	14.1	95.2	90.4	
July	27.2	12.2	96.7	93.2	9.4
August	28.5	12.8	95	90	10.6
September	28.0	12.3	97.1	92.9	12.7
October	28.4	12.0	96.2	89.2	3.4
November	25.7	8.2	94.2	85.3	3.0
December	24.9	7.0	91	81.4	0.0
2017					
January	26.3	5.7	89.3	79.6	0.0
February	28.4	8.2	79.9	89.1	0.7
March	27.1	8.5	90.7	82.0	3.1
April	30.0	10.6	91.1	84.5	4.8
May	30.3	13.8	92.7	86.4	7.0
June	28.4	12.2	96.5	93.6	24.8
July	29.1	12.6	97.5	95.1	12.1
August	29.4	12.613	97.8	96.7	15.5

September	29.9	14.1	97.5	95.9	8.0
October	29.7	15.6	96.0	92.4	10.6
November	28.8	13.9	92.1	85.3	0.3
December	25.3	11.4	91.7	84.4	1.2
2018					
January	25.7	7.3	92.1	84.7	0.3
February	28.6	11.1	93.4	81.1	0.3
March	30.0	14.3	91.7	80.4	1.5
April	29.6	12.0	88.0	76.8	3.8
May	30.2	10.5	85.5	74.7	7.4
June	30.0	12.0	96.5	93.1	15.4
July	30.0	13.0	97.3	95.0	7.5
August	29.9	13.8	96.4	94.0	13.5
September	30.4	18.3	96.2	93.0	4.4
October	29.9	16.1	95.1	91.2	2.9

Source: State Meteorological Centre, Directorate of Science & Technology

Fig.3.1. Layout of the Experimental Plot 1



3.4. Experiment 1: Organic Nutrient management of banana

Table 3.5: Details of the Experiment

a.	**Plant/ variety**	**:**	**Banana (Giant Cavendish)**
b.	**Planting material**	**:**	**Suckers**
c.	**Spacing**	**:**	**3m X 3m**
d.	**Design of experiment**	**:**	**Randomised Block Design**
e.	**Number of treatments**	**:**	**13**
f.	**Number of replications**	**:**	**3**
g.	**Plants per replication**	**:**	**9**
h.	**Total no of Plants**	**:**	**351**
i.	**Plot size**	**:**	**3016 sq.m**
j.	**Total experimental area**	**:**	**4628 sq.m**

3.4.1. Treatment details

T_1: Farm Yard Manure (FYM)

T_2: Vermi compost (VC)

T_3: Neem Cake (NC)

T_4: Poultry Manure (PM)

T_5: *Azotobacter* (AZ)

T_6: Phosphate Solubilizing Bacteria (PSB)

T_7: Potash Solubilizing Bacteria (KSB)

T_8: FYM +AZ+PSB+ KSB

T_9: VC +AZ+PSB+ KSB

T_{10}: NC +AZ+PSB+ KSB

T_{11}: PM +AZ+PSB+ KSB

T_{12}: AZ+PSB+ KSB

T_{13}: Control (no fertilizer)

Table 3.6: Nutrient composition of the various organic matters before application

Organic matter	N (%)	P (%)	K (%)
Farm yard manure	0.68	0.23	0.38
Vermicompost	1.48	0.21	0.78
Neem cake	4.15	1.02	1.82
Poultry manure	3.21	0.62	1.38

3.4.2. Time and method of application of manures and biofertilizers

RDF: Nitrogen: Phosphorus: Potassium (N:P:K): 300:100:300 g $plant^{-1}$ $year^{-1}$

Dose of Manures: Different dose of organic manures *viz*. FYM, VC, NC and PM was calculated based on the 50% of Potash (K) requirement of RDF.

Dose of Azotobacter (AB): 100 g $plant^{-1}$ $year^{-1}$

Dose of PSB: 100 g $plant^{-1}$ $year^{-1}$

Dose of KSB: 100 g $plant^{-1}$ $year^{-1}$

Application Time: Biofertilizer (AZ, PSB & KSB) and manures was applied one month prior to planting.

3.4.3. Intercultural Operations

3.4.3.1. Land preparation

Before starting of the experiment, the experimental plot was cleared from big trees, pits were dug and filled with the required organic manures.

3.4.3.2. Plant protection

Spraying with neem kernel oil extract was done once every month to protect the crops from insects and pests.

3.4.3.3. Harvesting

Harvesting of fruits was done when the banana hands have attained full maturity stage. After harvesting the trunk was cut at the base.

3.4.4. Observations

3.4.4.1. Plant growth and development

a) **Pseudostem height [at small (90 days after planting), at large (150 days after planting), shooting and harvesting stage**]

   The pseudostem height was measured from 15 cm above the ground to the point of intersection of the youngest first and second leaf axis with the help of measuring tape. Finally the 15 cm length was added to obtain the pseudostem height and expressed in centimeters.

b) **Pseudostem girth (at large, shooting and harvesting stage)**

   It was measured at 15 cm above the ground level with measuring tape and expressed in centimeters.

c) **Phyllochron**

   The time interval between the production of two successive leaves was recorded in days and mean value for each plant was determined.

d) **No. of functional leaves**

   It was recorded by counting the green and healthy leaves at 3 months (at small), 5 months after planting (at large), shooting and harvesting stage.

e) **Total leaf production**

   The number of leaves produced by plants during the entire growth period was counted from the first leaf emergence up to the shooting stage.

f) Leaf area (at small, at large, shooting and harvesting stage)

The leaf area was calculated based on the dimension of the third leaf from the apex *i.e.* by multiplying the leaf length and breadth of lamina along with the common factor 0.8 as the method given by Murray (1960). The leaf area was recorded at small (90 days after planting), at large (150 days after planting), shooting and harvesting stage and expressed in square meter.

g) Leaf area index (LAI: at large, shooting and harvesting stage)

It was calculated by using the method given by Williams (1946). Leaf area index was recorded at small (90 days after planting), at large (150 days after planting), shooting and harvesting stage.

$$\text{LAI} = \frac{\text{Leaf area of three plants}}{\text{Area of land occupied by three plants}}$$

h) Days taken for shooting

The date of shooting was noted on the first day of emergence of first whorl of inflorescence and the days taken for shooting from planting was counted.

i) Shooting to harvesting interval

The days from the date of shooting to harvest was counted in days.

j) Crop duration

It was counted by the days taken from the date of planting to the date of harvest.

k) Sucker production (at small, at large, shooting and harvesting stage)

The total number of sucker produced per plant during the whole crop cycle was counted at different stages viz., at small (90 days after planting), at large (150 days after planting), shooting and harvesting stage.

l) Total biomass

It was determined by taking the weight of corm with roots, pseudostem, leaves and bunch and finally they were added and expressed in kg.

m) Net assimilation rate (NAR)

NAR was calculated at shooting stage as per the method given by Radford (1967).

$$NAR = \frac{dw}{A.\ dt} \quad (g/\ m^2/\ day)$$

where,

dw = difference between weight of plants at two stages

dt = difference between time at two stages

A = difference between leaf area at two stages

n) Harvest index (HI)

HI was calculated by using the methods of Donald (1962).

$$HI = \frac{\text{Economic yield (bunch weight / plant) in kg}}{\text{Total biomass production in kg}}$$

3.4.4.2. Fruit growth and development

a) Bunch weight

It was taken at harvest by measuring the weight of all the hands and the peduncle and expressed in kg.

b) Bunch length

At harvesting, the length of the peduncle was measured and expressed in cm.

c) Hands per bunch

Total number of hands per bunch was calculated by counting the total number of fully developed hands per bunch.

d) Second hand weight

The weight of the second hand from the bunch was taken at harvest.

e) Fingers per hand

Total numbers of fingers per hand was counted from the second hand.

f) Finger length

It was measured from the base of the pedicle to the tip along with dorsal curve and expressed in centimeter (cm).

g) Finger diameter

It was measured in the middle portion of the fruit finger by using a thread and expressed in cm.

h) Finger volume

The fruit volume was calculated by using the methods of Simmonds (1953).

$$\text{Volume} = 0.3537 + 0.0616\ LC^2$$

where,

V = finger volume in cc
L = length of finger
C = circumference of finger

i) Finger weight

The second hand was taken and from it middle finger was weighed out as representative fruit for finding out average weight of the finger (Gottreich *et al.*, 1964).

j) Yield per hectare

It was calculated by multiplying the average bunch weight with the total number of plants per hectare and expressed in tonnes per hectare.

k) Days taken for ripening after harvest

The number of days required for fruits to ripen after harvest and expressed in days.

l) Shelf life

Shelf life of the fruits was determined on the basis of appearance and texture as per the scales of Bhowmik and Pann (1992).

3.4.4.3. Fruit quality parameters

a) Pulp – peel ratio

Mean weight of pulp and peel of ripe fruit was recorded separately and expressed in grams and ratio was calculated by dividing the pulp weight by the peel weight.

b) Moisture

Moisture content of the fruit was determined by the oven dry method as described by Rangana (1986).

$$\text{Moisture \%} = \frac{\text{Initial sample weight} - \text{Final sample weight}}{\text{Initial sample weight}} \times 100$$

c) Total soluble solids (TSS)

Total Soluble Solids content of ripe fruit was measured by Hand Refractrometer which was calibrated at 20°C and expressed in terms of °Brix.

d) Titratable acidity

It was determined by adopting the standard method by titration against NaOH and using phenolphthalein as indicator (AOAC, 2012).

e) Total Sugar

The total sugar was determined by using the methods of AOAC (2012).

$$\% \text{ Total sugar} = \frac{\text{mg of dextrose X volume made up X 100}}{\text{Titre X weight of sample taken X 100}}$$

f) Reducing sugar

The reducing sugar was determined by using the methods of AOAC (2012).

$$\% \text{ Reducing sugar} = \frac{\text{mg of dextrose X volume made up X 100}}{\text{Titre X weight of sample taken X 100}}$$

g) TSS-acid ratio

The TSS acid ratio was calculated by dividing the value of total soluble solids by titratable acidity.

$$\text{TSS:Acid ratio} = \frac{\text{TSS }^{o}\text{Brix}}{\text{Titable acidity \%}}$$

h) Ascorbic Acid

2,6 – dichlorophenol indophenol dye titration method was used to estimate the ascorbic acid content of the fruit (AOAC, 2012; Rangana, 1986) and expressed as mg/ 100 mg of fruit pulp.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre X Factor X Volume made up X 100}}{\text{Volume of filtrate taken X weight or volume of sample taken}}$$

Dye Factor = 0.5/ titre

i) Protein

Protein content of the fruits was estimated by following Lowry's method (Lowrey *et al*., 1951).

j) Starch

Starch content of the fruits was estimated by anthrone method as described by Hodge and Hofreiter (1962).

k) Amylose

Amylose content of the fruit was estimated by using the method as described by McCready *et al.* (1950).

l) Carbohydrate

The amount of fruit carbohydrate was measured by anthrone method as described by Hodge and Hofreiter (1962).

3.4.4.4. Soil analysis (Soil pH, moisture, organic and inorganic carbon, C: N ratio and nutrients viz. N, P, K, Fe, Mn, Cu, Zn)

a) Soil pH was determined by potentiometric method (Jackson, 1973) or by using digital pH meter.

b) Soil organic carbon content of the sample was estimated by 'wet digestion method' as described by Walkley and Black (1934).

c) Total nitrogen content of soil was determined by micro-Kjeldahl's method (Jackson, 1973).

d) C: N ration of soil was estimated by dividing the organic carbon by the total nitrogen.

e) Available phosphorus of soil sample was determined colorimetrically following the procedure of Dickman and Bray (1940).

f) Available potassium of soil sample was determined by leaching the soil with neutral ammonium acetate and estimated by flame photometer (Jackson, 1973).

g) Micro nutrient viz. Fe, Mn, Cu and Zn of the soil sample was measured using Atomic Absorption Spectrophotometer.

Preparation of soil samples

Soil samples from each experimental plot were collected at 0-30 cm depth with the help of a soil auger. The samples were thoroughly mixed, dried in shade, pulverized, to pass through 0.2 mm sieve and kept in brown paper bag for chemical analysis. Soil samples were collected before the initiation of the research work, one year and two years after installation of the treatment.

3.4.4.5. Soil Microbial analysis (AZ, PSB and KSB)

Soil samples taken from the rhizosphere were used for microbial count of *Azotobacter*, phosphate solubilising bacteria and potash mobilizers' population. Serial dilution plating method was followed for microbial population count (Vincent, 1970).

a) Isolation of *azotobacter* from treated soil

Isolation of *Azotobacter* was done by serial dilution up to 10^6 of soil samples with sterilized distilled water. Melted warm Jehnson's agar media was poured, solidified and1ml of the diluted aliquot was added on the petriplates and incubated at 28± 2^o C for 3 days and observations were taken by counting the colonies and expressed in colony forming units (cfu) per g of soil.

b) Isolation of phosphate solubilising bacteria and potash mobilizers from treated soil

Soil samples were serially diluted up to 10^6 and then plated in the respective media for solubilisation test and identification and incubated at 28 ± 2 ^{o} C for 3 days and observations were taken by counting the colonies and expressed in colony forming units (cfu) per g of soil.

Composition of different media used for microbial count

3.7. Jehnson's agar media for identification of *Azotobacter* colonies

1	Sucrose	20g
2	K_2HPO_4	1.0g
3	$MgSO_4.7H_2O$	0.5g
4	NaCl	0.5g
5	$FeSO_4$	0.1g
6	$CaCO_3$	2.0g
7	Agar	15.0g
8	Distilled Water	1litre

3.8. Sreber's media for solubilisation test and identification of phosphate solubilising bacteria

1	Glucose	10 g
2	Soil extract/ tap water	250 ml
3	Stock solution A (K_2HPO_4 10%)	20 ml
4	Stock solution B ($CaCl_2$ 10%)	30 ml
5	$CaCl_2$	0.1 g
6	$MgSO_4$	0.2 g
7	Yeast extract	0.5 g
8	Agar Agar	20 g
9	Distilled water	750 ml

Note: Stock solution A and B are prepared separately, autoclaved and added to the medium while plating at 60^{o}C.

3.9. Media for potash mobilizers identification

1	D – glucose	2.0 g
2	Yeast extract	0.8 g
3	Peptone	0.5 g
4	Ethanol	0.3 ml
5	Calcium carbonate ($CaCO_3$)	0.3 g
6	Agar agar	2.0 g

3.4.4.6. Leaf analysis (N,P,K, Fe, Mn, Cu, Zn, and C:N ratio)

3.4.4.6.1. Digestion of leaf samples

The digestion of leaf samples (1 g) for the estimation of total nitrogen was carried out in concentrated H_2S0_4 in the presence of a digestion mixture of following chemicals: Potassium sulphate - 400 parts, Copper sulphate - 20 parts, Mercuric oxide - 3 parts, Selenium powder - 1 part. For estimation of P, K, Fe, Cu, Zn and Mn, the leaf samples (0.5 g) were digested in di-acid mixture prepared by mixing HNO_3 and $HC1O_4$ in the ratio of 4: 1 taking all precautions as suggested by Piper (1966).

3.4.4.6.2. Analysis

a) The total nitrogen content (% dry weight basis) of the leaf sample was estimated by Micro-Kjeldahl method as described by Black (1965).

b) Phosphorus content of leaf sample was estimated by Vanadomolybdate yellow colour method (Chapman and Pratt, 1961).

c) Potassium content was determined by standard procedure using flame photometer (Jackson, 1973).

d) Micro nutrient viz. Fe, Mn, Cu and Zn of the leaf sample was measured using Atomic Absorption Spectrophotometer.

e) Determination of carbohydrate content of leaf: The leaf samples were kept in an oven and dried. Dried leaves were then crushed and 100 mg taken into a boiling tube and hydrolysed in boiling water bath for three hours with 5 ml of 2.5 N HCl and then cooled in room temperature. The hydrolysed sample was then neutralized with solid carbonate until the effervescence ceases. The volume is made up to 100 ml and centrifuged. The supernatant was collected and 0.5 and 1 ml aliquots were taken for analysis. Standard curve was prepared by taking 0, 0.2, 0.4, 0.6 0.8 and 1.0 ml of the working standard. 0 served as blank. Volume was made up to 1 ml in all the tubes including the sample tubes by adding distilled water. 4 ml of the anthrone reagent was added and the samples were heated for eight minutes in a boiling water bath and then made to cool. Readings of the green to dark green coloured samples was taken at 630nm in a spectrophotometer. Standard graph was drawn by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. The amount of carbohydrate present in the sample tube was determined from the graph and calculation was done as:

$$\text{Amount of carbohydrate present in 100 mg of the sample} = \frac{\text{mg. of glucose}}{\text{Volume of the test sample}} \times 100$$

3.4.4.7. Cost Benefit analysis

The economics of different treatments and net return was calculated considering the present rates of field worker wages, manures, fertilizers, biofertilizers, plant protection botanicals and market sale value of the harvested fruits and the net out return per rupee of investment was worked out.

3.4.4.8. Statistical analysis

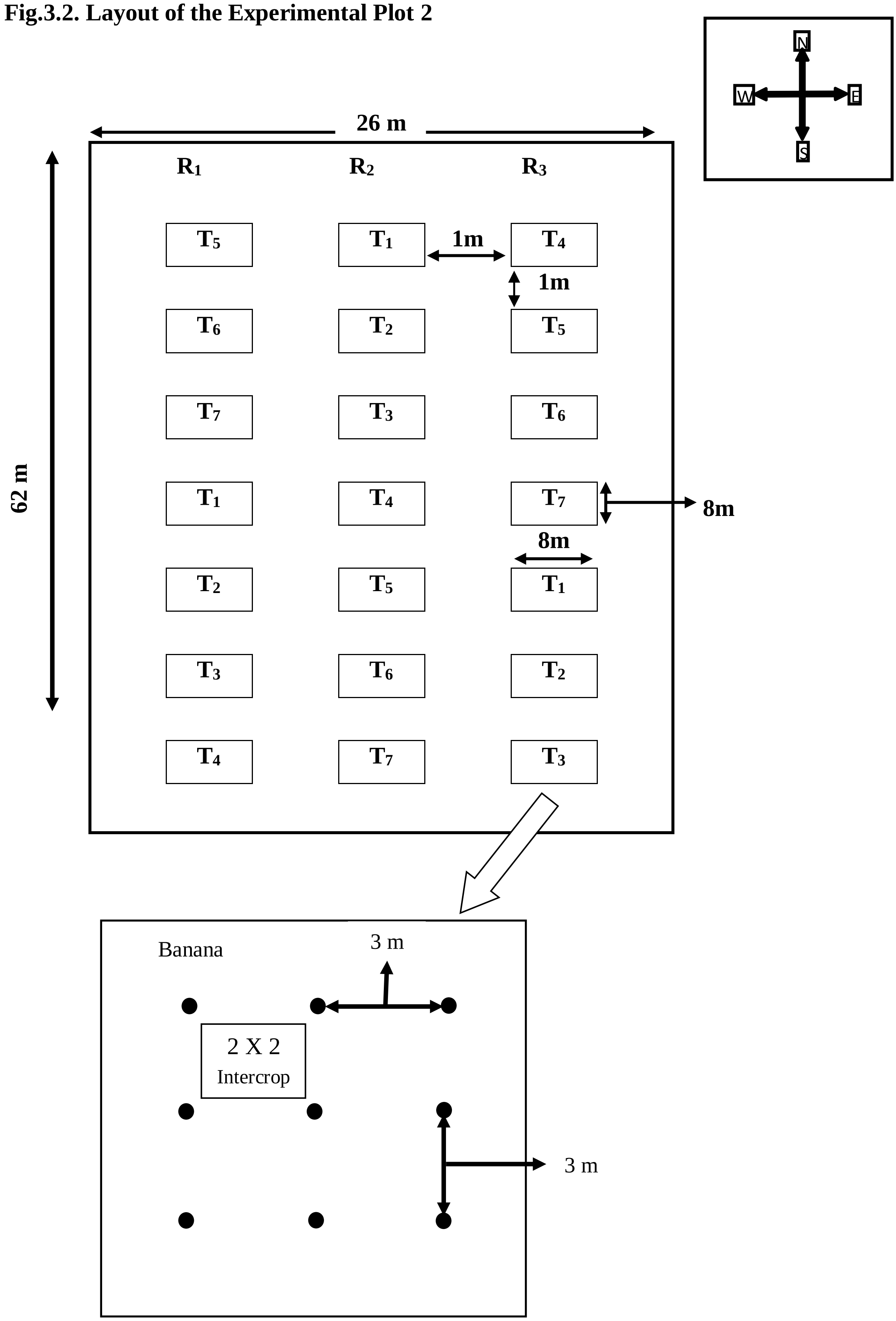
Data was analyzed for statistical inference following the statistical method for Randomized Block Design (RBD) described by Gomez and Gomez (1983).

3.5. Experiment 2: Intercropping in Banana

Table 3.10. Details of the experiment

a.	Plant/variety	:	Banana Giant Cavendish
b.	Planting material used	:	Suckers
c.	Spacing	:	3m X 3m
d.	Plot size of the intercrop	:	2m X 2m
e.	Design of experiment	:	Randomised Block Design
f.	Number of treatments	:	7
g.	Number of replications	:	3
h.	Plants per replication	:	9
i.	Total no. of Plants	:	189
j.	Plot size	:	1612 sq.m
g.	Total experimental area	:	4628 sq.m

Fig.3.2. Layout of the Experimental Plot 2



3.5.1. Treatment details

T_1: Banana intercropped with ginger

T_2: Banana intercropped with turmeric

T_3: Banana intercropped with colocasia

T_4: Banana intercropped with cowpea and french bean

T_5: Banana intercropped with brinjal + cabbage

T_6: Banana intercropped with chilli + broccoli

T_7: Control (No intercrop, only banana plants)

3.5.2. Varieties and recommended nutrient dose of intercrops

Varieties

Ginger – Thinglaidum

Turmeric – Lakadong

Colocasia – Local

Cowpea – Local

French Bean – Local

Brinjal – Local

Cabbage – Quisto (Syngenta)

Chilli – Mizo Chilli

Broccoli – Green Magic (Sakata)

Recommended nutrient dose applied for intercrops

Ginger – N:P: K 100:90:90 Kg/ha

Turmeric – N:P: K 100:80:80 Kg/ha

Colocasia – N:P: K 80:25:80 Kg/ha

Cowpea – N:P: K 30:75:50 Kg/ha

French Bean – N:P: K 50:75:75 Kg/ha

Brinjal – N:P: K 100:60:60 Kg/ha

Cabbage – N:P: K 120:60:60 Kg/ha

Chilli – N:P: K 90:60:60 Kg/ha

Broccoli – N:P: K 120:60:60 Kg/ha

3.5.3. Time and method of application of fertilizer

RDF Banana: 300:100:300 g plant^{-1} year^{-1}, fertilizer dose for intercrops as per mentioned.

Application Time: RDF was applied on two splits during June and September by placement method to all the plants. Fertilizers for intercrops were also applied at base and second dose one month after planting or during earthing up.

3.5.4. Intercultural Operations

3.5.4.1. Land preparation

Before starting of the experiment, the experimental plot was cleared from big trees, pits were dug and filled with the required organic manures. Basal dose of fertilizers were also applied for the intercrops.

3.5.4.2. Plant protection

Spraying with neem kernel oil extract was done once every month to protect the crops from insects and pests.

3.5.4.3. Harvesting

Harvesting of fruits was done when the banana hands have attained full maturity stage. After harvesting the trunk was cut at the base.

3.5.5. Observations

Observation was taken only on the main crop banana for plant growth and development, fruit growth and development, fruit quality, soil and leaf nutrition. Besides, yield of the intercrops were recorded separately.

3.5.5.1. Plant growth and development

a) **Pseudostem height [at small (90 days after planting), at large (150 days after planting), shooting and harvesting stage**]

   The pseudostem height was measured from 15 cm above the ground to the point of intersection of the youngest first and second leaf axis with the help of measuring tape. Finally the 15 cm length was added to obtain the pseudostem height and expressed in centimeters.

b) **Pseudostem girth (at large, shooting and harvesting stage)**

   It was measured at 15 cm above the ground level with measuring tape and expressed in centimeters.

c) **Phyllochron**

   The time interval between the production of two successive leaves was recorded in days and mean value for each plant was determined.

d) No. of functional leaves

It was recorded by counting the green and healthy leaves at 3 months (at small), 5 months after planting (at large), shooting and harvesting stage.

e) Total leaf production

The number of leaves produced by plants during the entire growth period was counted from the first leaf emergence up to the shooting stage.

f) Leaf area (at small, at large, shooting and harvesting stage)

The leaf area was calculated based on the dimension of the third leaf from the apex i.e. by multiplying the leaf length and breadth of lamina along with the common factor 0.8 as the method given by Murray (1960). The leaf area was recorded at small (90 days after planting), at large (150 days after planting), shooting and harvesting stage and expressed in square meter.

g) Leaf area index (LAI: at large, shooting and harvesting stage)

It was calculated by using the method given by Williams (1946). Leaf area index was recorded at small (90 days after planting), at large (150 days after planting), shooting and harvesting stage.

$$LAI = \frac{\text{Leaf area of three plants}}{\text{Area of land occupied by three plants}}$$

h) Days taken for shooting

The date of shooting was noted on the first day of emergence of first whorl of inflorescence and the days taken for shooting from planting was counted.

i) Shooting to harvesting interval

The days from the date of shooting to harvest was counted in days.

j) Crop duration

It was counted by the days taken from the date of planting to the date of harvest.

k) Sucker production (at small, at large, shooting and harvesting stage)

The total number of sucker produced per plant during the whole crop cycle was counted at different stages viz., at small (90 days after planting), at large (150 days after planting), shooting and harvesting stage.

l) Total biomass

It was determined by taking the weight of corm with roots, pseudostem, leaves and bunch and finally they were added and expressed in kg.

m) Net assimilation rate (NAR)

NAR was calculated at shooting stage as per the method given by Radford (1967).

n) Harvest index (HI)

HI was calculated by using the methods of Donald (1962).

$$HI = \frac{\text{Economic yield (bunch weight / plant) in kg}}{\text{Total biomass production in kg}}$$

3.5.5.2. Fruit growth and development

a) Bunch weight

It was taken at harvest by measuring the weight of all the hands and the peduncle and expressed in kg.

b) Bunch length

At harvesting, the length of the peduncle was measured and expressed in cm.

c) Hands per bunch

Total number of hands per bunch was calculated by counting the total number of fully developed hands per bunch.

d) Second hand weight

The weight of the second hand from the bunch was taken at harvest.

e) Fingers per hand

Total numbers of fingers per hand was counted from the second hand.

f) Finger length

It was measured from the base of the pedicle to the tip along with dorsal curve and expressed in centimeter (cm).

g) Finger diameter

It was measured in the middle portion of the fruit finger by using a thread and expressed in cm.

h) Finger volume

The fruit volume was calculated by using the methods of Simmonds (1953).

$$\text{Volume} = 0.3537 + 0.0616\ LC^2$$

where,

V = finger volume in cc

L = length of finger

C = circumference of finger

i) Finger weight

The second hand was taken and from it middle finger was weighed out as representative fruit for finding out average weight of the finger (Gottreich *et al.*, 1964).

j) Yield per hectare

It was calculated by multiplying the average bunch weight with the total number of plants per hectare and expressed in tonnes per hectare.

k) Days taken for ripening after harvest

The number of days required for fruits to ripen after harvest and expressed in days.

l) Shelf life

Shelf life of the fruits was determined on the basis of appearance and texture as per the scales of Bhowmik and Pann (1992).

3.5.5.3. Fruit quality parameters

a) Pulp – peel ratio

Mean weight of pulp and peel of ripe fruit was recorded separately and expressed in grams and ratio was calculated by dividing the pulp weight by the peel weight.

b) Moisture

Moisture content of the fruit was determined by the oven dry method as described by Rangana (1986).

$$\text{Moisture \%} = \frac{\text{Initial sample weight} - \text{Final sample weight}}{\text{Initial sample weight}} \times 100$$

c) Total soluble solids (TSS)

Total Soluble Solids content of ripe fruit was measured by Hand Refractrometer which was calibrated at 20°C and expressed in terms of °Brix.

d) Titratable acidity

It was determined by adopting the standard method by titration against NaOH and using phenolphthalein as indicator (AOAC, 2012).

e) Total Sugar

The total sugar was determined by using the methods of AOAC (2012).

$$\text{\% Total sugar} = \frac{\text{mg of dextrose} \times \text{volume made up} \times 100}{\text{Titre} \times \text{weight of sample taken} \times 100}$$

f) Reducing sugar

The reducing sugar was determined by using the methods of AOAC (2012).

$$\% \text{ Reducing sugar} = \frac{\text{mg of dextrose} \times \text{volume made up} \times 100}{\text{Titre} \times \text{weight of sample taken} \times 100}$$

g) TSS-acid ratio

The TSS acid ratio was calculated by dividing the value of total soluble solids by titratable acidity.

$$\text{TSS:Acid ratio} = \frac{\text{TSS }^{\circ}\text{Brix}}{\text{Titable acidity \%}}$$

h) Ascorbic Acid

2,6 – dichlorophenol indophenol dye titration method was used to estimate the ascorbic acid content of the fruit (AOAC, 2012; Rangana, 1986) and expressed as mg/ 100 mg of fruit pulp.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{Factor} \times \text{Volume made up} \times 100}{\text{Volume of filtrate taken} \times \text{weight or volume of sample taken}}$$

Dye Factor = 0.5/ titre

i) Protein

Protein content of the fruits was estimated by following Lowry's method (Lowrey *et al*., 1951).

j) Starch

Starch content of the fruits was estimated by anthrone method as described by Hodge and Hofreiter (1962).

k) Amylose

Amylose content of the fruit was estimated by using the method as described by McCready *et al.* (1950).

l) Carbohydrate

The amount of fruit carbohydrate was measured by anthrone method as described by Hodge and Hofreiter (1962).

3.5.5.4. Soil analysis (organic carbon, C: N ratio and nutrients viz. N, P, K)

a) Soil organic carbon content of the sample was estimated by 'wet digestion method' as described by Walkley and Black (1934).

b) Total nitrogen content of soil was determined by micro-Kjeldahl's method (Jackson, 1973).

c) C: N ration of soil was estimated by dividing the total carbon by the total nitrogen. The total carbon was calculated by adding organic carbon with inorganic carbon.

d) Available phosphorus of soil sample was determined colorimetrically following the procedure of Dickman and Bray (1940).

e) Available potassium of soil sample was determined by leaching the soil with neutral ammonium acetate and estimated by flame photometer (Jackson, 1973).

Preparation of soil samples:

Soil samples from each experimental plot were collected at 0-30 cm depth with the help of a soil auger. The samples were thoroughly mixed, dried in shade, pulverized, to pass through 0.2 mm sieve and kept in brown paper bag for chemical analysis. Soil samples were collected before the initiation of the research work, one year and two years after installation of the treatment.

3.5.5.5. Leaf analysis (N,P,K and C:N ratio)

Digestion of leaf samples

The digestion of leaf samples (1 g) for the estimation of total nitrogen was carried out in concentrated H_2S0_4 in the presence of a digestion mixture of following chemicals: Potassium sulphate - 400 parts, Copper sulphate - 20 parts, Mercuric oxide - 3 parts, Selenium powder - 1 part. For estimation of P, K, the leaf samples (0.5 g) were digested in di-acid mixture prepared by mixing HNO_3 and $HClO_4$ in the ratio of 4: 1 taking all precautions as suggested by Piper (1966).

Analysis

a) The total nitrogen content (% dry weight basis) of the leaf sample was estimated by Micro-Kjeldahl method as described by Black (1965).

b) Phosphorus content of leaf sample was estimated by Vanadomolybdate yellow colour method (Chapman and Pratt, 1961).

c) Potassium content was determined by standard procedure using flame photometer (Jackson, 1973).

d) Determination of carbohydrate content of leaf: The leaf samples were kept in an oven and dried. Dried leaves were then crushed and 100 mg taken into a boiling tube and hydrolysed in boiling water bath for three hours with 5 ml of 2.5 N HCl and then cooled in room temperature. The hydrolysed sample was then neutralized with solid carbonate until the effervescence ceases. The volume is made up to 100 ml and centrifuged. The supernatant was collected and 0.5 and 1 ml aliquots were taken for analysis. Standard curve was prepared by taking 0, 0.2, 0.4, 0.6 0.8 and 1.0 ml of the working standard. 0 served as blank. Volume was made up to 1 ml in all the tubes including the sample tubes by adding distilled water. 4 ml of the anthrone reagent was added and the samples were heated for eight minutes in a boiling water bath and then made to cool. Readings of the green to dark green coloured samples was taken at 630nm in a spectrophotometer. Standard graph was drawn by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. The amount of carbohydrate present in the sample tube was determined from the graph and calculation was done as:

$$\text{Amount of carbohydrate present in 100 mg of the sample} = \frac{\text{mg. of glucose}}{\text{Volume of the test sample}} \times 100$$

3.5.5.6. Cost Benefit analysis

The economics of different treatments and net return will be calculated considering the present rates of field worker wages, manures, fertilizers, plant protection chemicals and market sale value of the harvested fruits of main crop and yield of intercrops; the net out turn per rupee of investment was worked out.

3.5.5.7. Statistical analysis

Data was analyzed for statistical inference following the statistical method for Factorial Randomized Block Design (RBD) described by Gomez and Gomez (1983).

CHAPTER 4

RESULTS AND DISCUSSIONS

Experiment 1: Organic Nutrient Management of Banana

4.1. Results

4.1.1. Plant growth and development

Plant growth and development parameters *viz.* pseudostem height, pseuodstem girth, phyllocron, number of functional leaves, leaf area, leaf area index, sucker production were recorded both for main as well as ratoon crop at different stages of plant growth *viz.* at small (90 days after planting), large (150 days after planting), shooting and harvesting stages. Besides, parameters like total leaf production, days taken for shooting, shooting to harvesting and crop duration as influenced by different treatments were also recorded.

4.1.1.1. Pseudostem height

Perusal of the data presented at Table 4.1.1, Fig. 4.1.1 and 4.1.2 suggested that pseudostem height of the banana plant had significantly varied among the different organic treatments. A significant increase in pseudostem height was observed in both main as well ratoon crop. For the main crop, it was found that at small stage, highest pseudostem height (95.94 cm) was recorded in case of the plants treated with poultry manure along with biofertilizers *viz.* *Azotobacter* (AZ), phosphate solubilizing bacteria (PSB) and potassium solubilizing bacteria (KSB) (T_{11}) followed by plants treated with neem cake along with AZ, PSB & KSB (95.03 cm) compared with control (67.67 cm). After 150 days of planting *i.e.* at large stage, maximum height (210.47 cm) was attained in plants treated with neem cake+AZ+PSB+KSB (T_{10})

followed by T_{11} (208.33 cm) against control (160.67 cm). However, at shooting and harvesting stage of main crop, maximum pesudostem height (255.67 cm and 267.10 cm) was recorded in plants at T_{11} followed by T_{10} (250.02 cm and 261.76 cm) compared with control (201.67 cm and 216.58 cm, respectively).

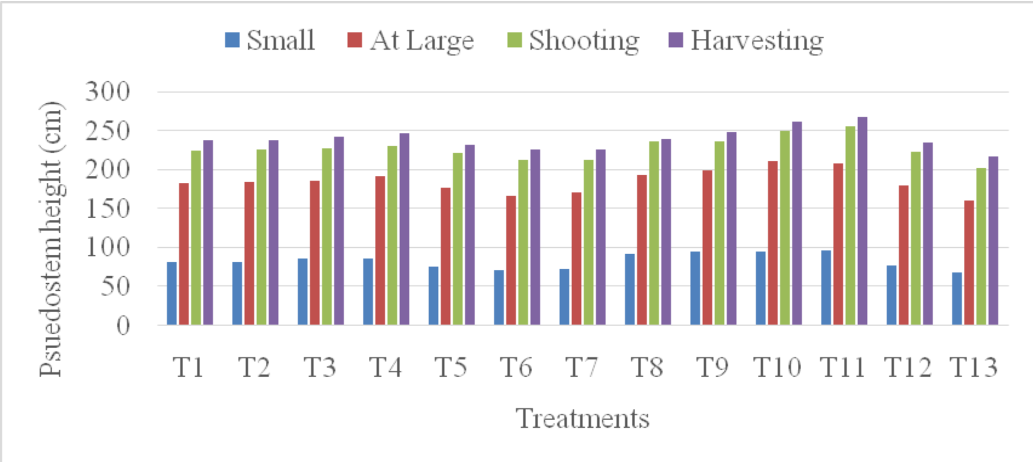


Figure 4.1.1.: Effect of organic nutrition on pseudostem height of the main crop in banana

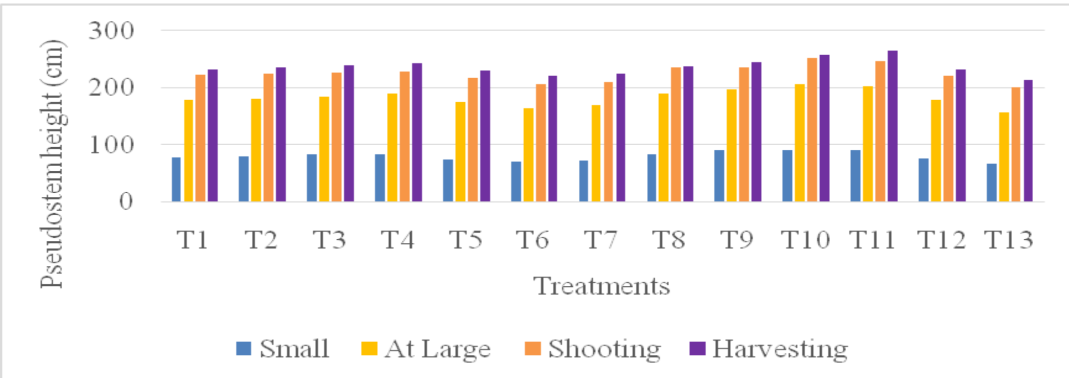


Figure 4.1.2: Effect of organic nutrition on pseudostem height of the ratoon crop in banana

For ratoon crop, pseudostem height was consistently high in T_{10} up to shooting stage. Plants treated with neem cake along with AZ, PSB & KSB had maximum pesudostem height at small (90.17 cm), large (205.63 cm) as well as at shooting (252.43 cm) stage compared with control (65.46 cm, 156.92 cm and 200.24 cm).

Table 4.1.1.: Effect of organic nutrition on pseudostem height of main and ratoon crop in banana

Treatments	Pseudostem Height (cm)							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Farm Yard Manure	81.02	182.00	224.67	237.62	77.63	179.19	223.40	232.13
T_2 - Vermi compost	81.33	183.89	225.90	237.64	79.85	180.91	224.28	236.39
T_3 - Neem Cake	85.67	185.33	227.93	241.37	83.13	184.23	225.71	239.54
T_4 - Poultry Manure	85.96	191.67	230.02	246.18	83.43	189.03	227.73	242.12
T_5 - Azotobacter	75.03	176.01	220.67	231.32	73.48	174.74	217.57	229.78
T_6 - Phosphate Solubilizing Bacteria	71.07	166.32	211.67	225.07	69.44	163.85	206.57	221.57
T_7 - Potash Solubilizing Bacteria	73.33	171.33	212.32	225.85	71.37	168.94	209.67	224.40
T_8 - FYM +AZ+PSB+ KSB	92.33	193.33	235.93	238.40	83.57	189.19	234.87	237.12
T_9 - VC +AZ+PSB+ KSB	94.33	198.97	236.67	247.31	89.33	197.64	235.16	245.38
T_{10} - NC +AZ+PSB+ KSB	95.03	210.47	250.02	261.76	90.17	205.63	252.43	258.20
T_{11} - PM +AZ+PSB+ KSB	95.94	208.33	255.67	267.10	89.43	202.45	247.40	264.12
T_{12} - AZ+PSB+ KSB	77.67	180.33	223.33	234.90	75.34	178.69	221.05	231.50
T_{13} - Control	67.67	160.67	201.67	216.58	65.46	156.92	200.24	213.21
SEm±	**1.3201**	**4.6201**	**4.5395**	**4.2079**	**0.3669**	**0.4567**	**0.4948**	**0.5236**
CD at 5%	**3.8532**	**13.4857**	**13.2506**	**12.2826**	**1.0709**	**1.3332**	**1.4444**	**1.5285**

However, at harvesting stage plants treated with poultry manure along with AZ, PSB & KSB (T_{11}) had highest pseudostem height (264.12 cm) among all.

4.1.1.2. Pseudostem girth

It is evident from the Table 4.1.2. that pseudostem girth of the banana plants varied significantly among the different treatments. From small stage *i.e.* 90 days after planting (DAP) to harvesting stage, plant girth increased across all the treatments in main as well as in case of ratoon crops. For the main crop, it was found that up to large stage, plants treated with neem cake along with AZ, PSB & KSB (T_{10}) had maximum plant girth (small stage: 36.83 cm and 64.17 cm) whereas, from shooting to harvesting stage, girth was found maximum (shooting at large stage: 69.33 cm and at harvesting: 73.96 cm) in case of the plant treated with poultry manure along with AZ, PSB & KSB (T_{11}) compared with control (small: 24.61 cm; large: 54.36 cm; shooting: 55.50 cm and harvesting : 62.35 cm, respectively).

In case of ratoon crop, plants treated with poultry manure along with AZ, PSB & KSB (T_{11}) had maximum girth at small (32.60 cm) and shooting stage (67.41 cm), whereas, plants manured with neem cake and AZ, PSB & KSB (T_{10}) had maximum girth at large (62.89 cm) and harvesting stage (71.95 cm). For all the stages, plant girth was found minimum (small: 23.01 cm; large: 52.16 cm; shooting: 54.12 cm and harvesting : 60.71 cm, respectively) at control.

4.1.1.3. Phyllocron

Mean days interval between production of two successive leaves *i.e.* phyllocron varied significantly among the treatments both in main and for ratoon crop. However, it was noted that mean phyllocron value was significantly lower in ratoon crop than

Table 4.1.2: Effect of organic nutrition on pseudostem girth of main and ratoon crop in banana

Treatments	Pseudostem Girth (cm)							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Farm Yard Manure	28.83	60.34	62.90	67.85	24.66	56.12	59.42	65.36
T_2 - Vermi compost	27.83	59.51	61.67	67.53	26.32	56.47	60.32	66.14
T_3 - Neem Cake	29.67	61.17	65.17	68.99	26.66	58.79	61.47	67.57
T_4 - Poultry Manure	32.67	62.50	63.17	70.26	27.39	59.41	62.18	68.09
T_5 - *Azotobacter*	26.16	57.53	59.83	66.97	23.85	55.07	57.41	64.58
T_6 - Phosphate Solubilizing Bacteria	25.50	56.18	57.33	65.26	23.22	53.18	55.74	62.18
T_7 - Potash Solubilizing Bacteria	25.67	56.50	58.17	66.82	23.39	54.26	56.62	63.61
T_8 - FYM +AZ+PSB+ KSB	34.33	61.50	66.17	69.73	29.71	60.12	65.41	68.12
T_9 - VC +AZ+PSB+ KSB	35.34	62.83	67.50	72.21	31.54	60.34	65.89	70.45
T_{10} - NC +AZ+PSB+ KSB	36.83	64.17	67.67	73.41	31.96	62.89	66.34	71.95
T_{11} - PM +AZ+PSB+ KSB	36.67	63.50	69.33	73.96	32.60	62.18	67.41	71.28
T_{12} - AZ+PSB+ KSB	26.50	58.36	60.66	67.08	23.86	55.18	58.34	64.98
T_{13} - Control	24.61	54.36	55.50	62.35	23.01	52.16	54.12	60.71
SEm±	**1.4804**	**1.5729**	**1.4311**	**2.1736**	**1.5411**	**0.5574**	**0.8624**	**0.6896**
CD at 5%	**4.3212**	**4.5913**	**4.1772**	**6.3447**	**4.4983**	**1.6270**	**2.5172**	**2.0130**

Table 4.1.3: Effect of organic nutrition on phyllocron of main and ratoon crop in banana

Treatments	Phyllocron (Days)					
	Main Crop			Ratoon Crop		
	Small	At Large	Shooting	Small	At Large	Shooting
T_1 - Farm Yard Manure	8.16	8.01	8.83	7.31	7.26	8.19
T_2 - Vermi compost	8.04	7.98	8.78	7.26	7.18	7.98
T_3 - Neem Cake	7.93	7.54	8.75	7.29	7.12	8.36
T_4 - Poultry Manure	7.74	7.52	8.69	7.18	7.09	8.24
T_5 - Azotobacter	8.41	8.18	8.96	7.56	7.36	8.27
T_6 - Phosphate Solubilizing Bacteria	8.89	8.21	8.98	7.94	7.58	8.38
T_7 - Potash Solubilizing Bacteria	8.48	8.23	8.97	7.68	7.42	8.25
T_8 - FYM +AZ+PSB+ KSB	7.89	7.41	8.71	7.04	6.89	8.21
T_9 - VC +AZ+PSB+ KSB	7.62	7.35	8.63	6.95	6.42	7.74
T_{10} - NC +AZ+PSB+ KSB	7.58	7.21	8.54	6.74	6.21	7.52
T_{11} - PM +AZ+PSB+ KSB	7.21	6.87	8.27	6.87	6.24	7.68
T_{12} - AZ+PSB+ KSB	8.32	8.09	8.93	7.42	7.31	8.23
T_{13} - Control	9.84	8.65	9.08	8.16	8.02	8.52
SEm±	**0.1880**	**0.1706**	**0.0917**	**0.2451**	**0.2136**	**0.0928**
CD at 5%	**0.5488**	**0.4979**	**0.2677**	**0.7153**	**0.6236**	**0.2708**

main crop. The highest phyllocron value was recorded in plant at control for small (main crop: 9.84 days, ratoon crop: 8.16 days), at large (main crop: 8.65 days, ratoon crop: 8.02 days) and at shooting stage (main crop: 9.08 days, ratoon crop: 8.52 days) for both main and ratoon crop,

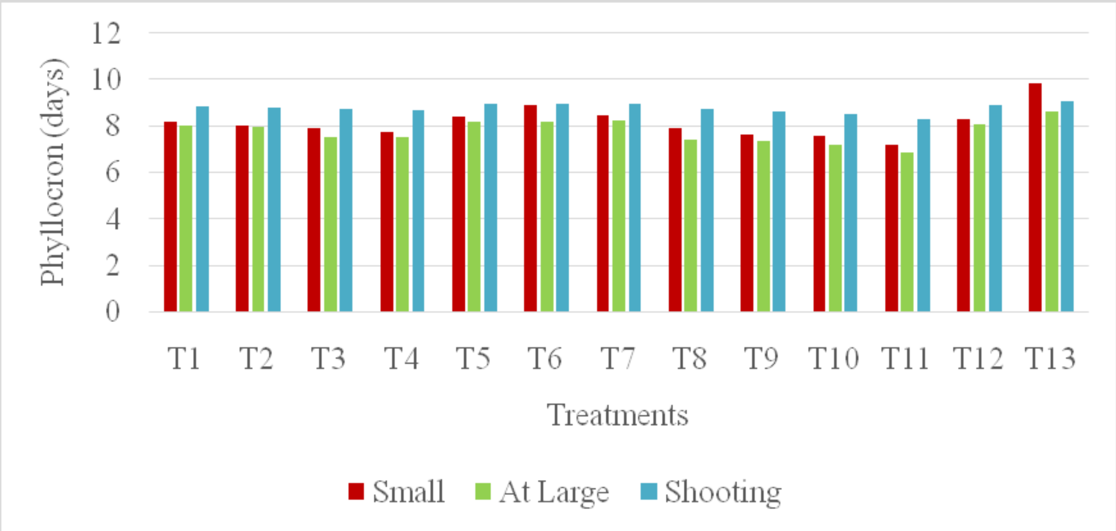


Figure 4.1.3.: Effect of organic nutrition on phyllocron of the main crop in banana

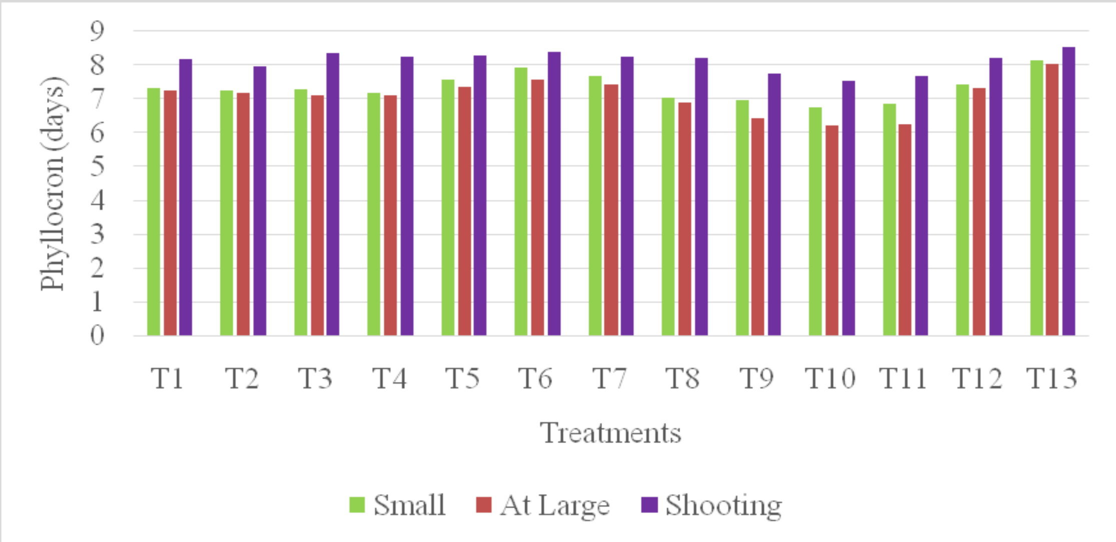


Figure 4.1.4.: Effect of organic nutrition on phyllocron of the ratoon crop in banana

whereas, plants treated with poultry manure + AZ, PSB & KSB (T_{11}) had minimum phyllocron value (small:7.21 days; at large: 6.87 days and shooting: 8.27 days) followed by plant treated with neem cake + AZ, PSB & KSB (small: 7.58 days; at large: 7.21 days and shooting: 8.54 days) at main crop and it was found minimum in T_{10} (small: 6.74 days; at large: 6.21 days and shooting: 7.52 days) followed by T_{11} (small: 6.87 days; at large: 6.24 days and shooting: 7.68 days) in ratoon crop (Table: 4.1.3, Fig: 4.1.3 and 4.1.4).

4.1.1.4. Number of functional leaves

Results of the effect of different organic treatments on banana revealed that the number of functional leaves in the plant varied significantly across the treatments and with increment in growth stages the number also got increased, however, the number of functional leaves were found less in ratoon crop compared with main crop in all the growth stages under record. For the main crop, at small (6.81), large (13.48) and shooting (14.15) stages plants treated with poultry manure +AZ, PSB & KSB (T_{11}) had maximum number of leaves followed by plant treated with neem cake + AZ, PSB & KSB (small: 6.70, large: 12.56, shooting: 13.04) whereas it was maximum in T_{10} (10.81) followed by T_{11} (10.44) at harvesting stage compared with control (small: 4.48, large: 8.26, shooting: 9.03 and harvesting stage: 6.62) (Table: 4.1.4).

For the ratoon crop at small stage, maximum number of leaves (6.24) was recorded in case of the plants treated with poultry manure +AZ, PSB & KSB (T_{11}) followed by T_{10} (5.98) compared with control (4.12). At large as well as shooting stage, maximum number of leaves were recorded in T_{10} (11.67 and 11.98) followed by T_{11} (11.43 and 11.72) whereas, at harvesting stage it was highest in T_{11} (10.14) followed by T_{10} (9.78) compared with control (at large: 8.05, shooting: 8.13, harvesting: 6.23).

Table 4.1.4: Effect of organic nutrition on number of leaves of main and ratoon crop in banana

Treatments	Number of functional leaves (No.)							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Farm Yard Manure	5.48	10.67	11.07	9.37	4.86	9.38	10.02	8.02
T_2 - Vermi compost	5.59	11.04	11.92	9.48	4.98	9.67	10.17	8.18
T_3 - Neem Cake	5.67	11.26	11.67	9.51	5.08	9.76	10.34	8.47
T_4 - Poultry Manure	6.26	11.30	12.04	9.59	5.12	9.89	10.67	8.97
T_5 - *Azotobacter*	4.92	9.10	10.70	7.84	4.63	9.08	9.52	7.45
T_6 - Phosphate Solubilizing Bacteria	4.63	8.92	10.26	7.55	4.51	8.74	9.27	6.78
T_7 - Potash Solubilizing Bacteria	4.78	9.04	10.65	7.59	4.58	8.98	9.41	7.12
T_8 - FYM +AZ+PSB+ KSB	6.37	12.15	12.22	9.81	5.48	10.42	10.78	9.12
T_9 - VC +AZ+PSB+ KSB	6.59	12.18	12.29	10.26	5.67	10.56	11.34	9.34
T_{10} - NC +AZ+PSB+ KSB	6.70	12.56	13.04	10.81	5.98	11.67	11.98	9.78
T_{11} - PM +AZ+PSB+ KSB	6.81	13.48	14.15	10.44	6.24	11.43	11.72	10.14
T_{12} - AZ+PSB+ KSB	5.29	10.33	10.81	7.92	4.71	9.12	9.85	7.78
T_{13} - Control	4.48	8.26	9.03	6.62	4.12	8.05	8.13	6.23
SEm±	**0.3835**	**0.5904**	**0.4973**	**0.4268**	**0.1263**	**0.2220**	**0.2441**	**0.1450**
CD at 5%	**1.1194**	**1.7234**	**1.4516**	**1.2459**	**0.3687**	**0.6481**	**0.7126**	**0.4232**

4.1.1.5. Total leaf production

It is evident from the data presented in Table 4.1.5 and Fig. 4.1.5 that total number of leaves produced by the banana plants varied significantly among the different treatments. It was observed that the total number of leaves produced were less in number in ratoon crops than the main crop in all the treatments under study and plants at control has minimum number of total leaves in main (24.47) as well as ratoon crop (23.12). For both main and ratoon crop, maximum number of leaves were recorded in case of the plants treated with poultry manure + AZ, PSB & KSB (34.15, 32.34) followed by plants treated with neem cake + AZ, PSB & KSB (32.67, 30.74) and vermi compost + AZ, PSB & KSB (30.84, 29.64).

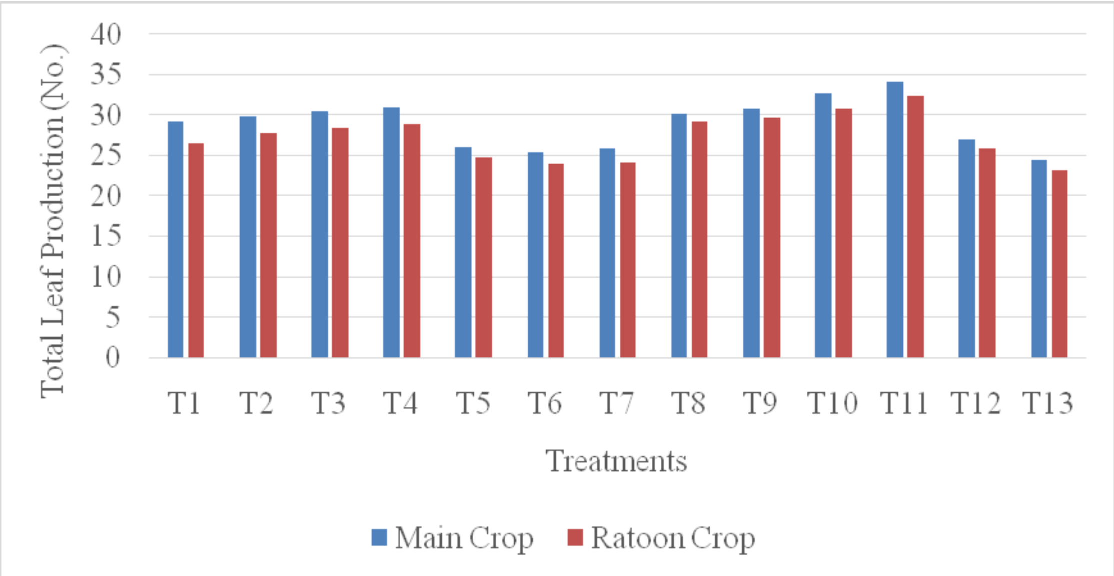


Figure 4.1.5: Effect of organic nutrition treatments on total number of leaves of main and ratoon crop in banana

4.1.1.6. Leaf area

Leaf area of the banana plants under study got increased with the stages of development *i.e.* from small (90 days after planting) to shooting stage but dropped slightly at harvesting stage in both main and ratoon crop across different treatments.

Table 4.1.5: Effect of organic nutrition on total leaf production of main and ratoon crop in banana

Treatments	Total Leaf Production (No.)	
	Main Crop	**Ratoon Crop**
T_1 - Farm Yard Manure	29.14	26.46
T_2 - Vermi compost	29.88	27.75
T_3 - Neem Cake	30.55	28.37
T_4 - Poultry Manure	30.89	28.85
T_5 - *Azotobacter*	26.02	24.76
T_6 - Phosphate Solubilizing Bacteria	25.47	24.01
T_7 - Potash Solubilizing Bacteria	25.88	24.12
T_8 - FYM +AZ+PSB+ KSB	30.14	29.13
T_9 - VC +AZ+PSB+ KSB	30.84	29.64
T_{10} - NC +AZ+PSB+ KSB	32.67	30.74
T_{11} - PM +AZ+PSB+ KSB	34.15	32.34
T_{12} - AZ+PSB+ KSB	26.92	25.86
T_{13} - Control	24.47	23.12
SEm±	**0.8433**	**0.3517**
CD at 5%	**2.4615**	**1.0267**

Table 4.1.6: Effect of organic nutrition on leaf area of main and ratoon crop in banana

Treatments	Leaf Area (m^2)							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Farm Yard Manure	3.86	7.85	9.58	8.53	3.34	7.34	9.12	8.32
T_2 - Vermi compost	4.11	8.56	9.63	8.92	3.52	7.51	9.46	8.78
T_3 - Neem Cake	4.13	8.58	10.63	9.29	3.76	7.94	10.21	8.93
T_4 - Poultry Manure	4.21	8.68	10.81	9.79	3.81	8.37	10.19	9.67
T_5 - *Azotobacter*	3.30	7.05	9.15	8.03	2.98	6.98	8.75	7.89
T_6 - Phosphate Solubilizing Bacteria	2.47	6.99	8.35	7.34	2.32	6.54	8.29	7.12
T_7 - Potash Solubilizing Bacteria	3.01	7.02	8.99	8.01	2.98	6.92	8.82	7.91
T_8 - FYM +AZ+PSB+ KSB	4.14	9.08	11.21	10.10	3.89	8.78	10.52	9.83
T_9 - VC +AZ+PSB+ KSB	4.15	9.29	11.41	10.51	3.83	8.81	10.41	10.04
T_{10} - NC +AZ+PSB+ KSB	4.48	9.68	11.48	10.70	4.08	8.85	11.56	10.18
T_{11} - PM +AZ+PSB+ KSB	4.38	9.41	12.01	11.02	4.02	8.82	11.12	10.16
T_{12} - AZ+PSB+ KSB	3.44	7.31	9.44	8.21	3.23	7.19	9.09	8.09
T_{13} - Control	2.31	6.47	8.06	7.13	2.14	6.44	7.89	7.02
SEm±	**0.1777**	**0.4065**	**0.3872**	**0.4289**	**0.1072**	**0.0608**	**0.1511**	**0.1462**
CD at 5%	**0.5186**	**1.1866**	**1.1302**	**1.2520**	**0.3129**	**0.1773**	**0.4410**	**0.4268**

For the main crop, plants treated with neem cake along with AZ, PSB & KSB (T_{10}) had maximum leaf area at small (4.48 m^2) and at large (9.68 m^2) stage followed by T_{11} (4.38 m^2 and 9.41 m^2), whereas, at shooting and harvesting stage mean leaf area was maximum (12.01 m^2 and 11.02 m^2) in T_{11} followed by T_{10} (11.48 m^2 and 10.70 m^2) compared with control (small: 2.31, at large: 6.47, shooting: 8.06 and harvesting: 7.13 m^2) (Table: 4.1.6).

In case of ratoon crop, plant treated with neem cake along with biofertilizers (AZ, PSB & KSB) (T_{10}) had maximum mean leaf area at small (4.08 m^2), large (8.85 m^2), shooting (11.56 m^2) and harvesting stage (10.18 m^2) followed by plants at T_{11} (small: 4.02 m^2, large: 8.82 m^2, shooting: 11.12 m^2 and harvesting stage: 10.16 m^2) compared with control (small: 2.14 m^2, large: 6.44 m^2, shooting: 7.89 m^2 and harvesting stage: 7.02 m^2).

4.1.1.7. Leaf area index

It is clear from the data presented in Table 4.1.7; Fig. 4.1.6 and 4.1.7 that leaf area index varied significantly among the different organic nutrition treatment both in case of main and ratoon crop. For the main crop, at small and large stage, maximum leaf area index (1.41 and 3.18) was recorded in case of the plants treated with neem cake along with biofertilizers *viz.* AZ, PSB & KSB (T_{10}) followed by plants treated with poultry manure +AZ, PSB & KSB (T_{11}; 1.38 and 3.08) compared with control (0.81 and 2.08). Subsequently at shooting and harvesting stage, leaf area index was recorded maximum (4.02 and 3.69) in T_{11} followed by T_{10} (3.79 and 3.59) compared with control (2.72 and 2.31).

While in case of ratoon crop, plants which were manured with neem cake along with AZ, PSB & KSB (T_{10}) had maximum leaf area index in small (1.32), large

(2.93), shooting (3.83) and harvesting (3.40) stage followed by plants treated with poultry manure + AZ, PSB & KSB (small: 1.30, large: 2.92, shooting: 3.69 and harvesting: 3.37) compared with control (small: 0.69, large: 2.02, shooting: 2.61 and harvesting: 2.29, respectively).

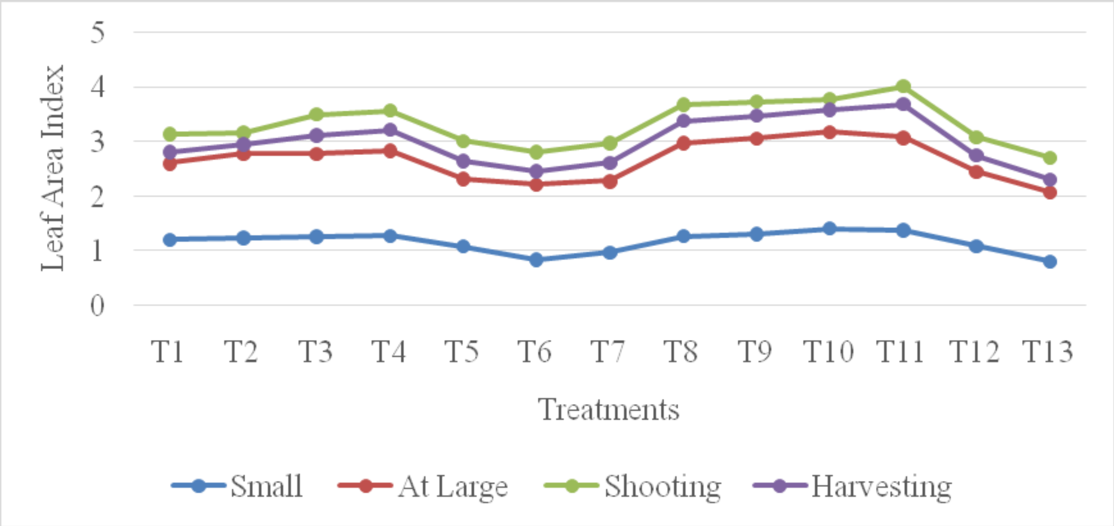


Figure 4.1.6: Effect of organic nutrition on leaf area index of the main crop in banana

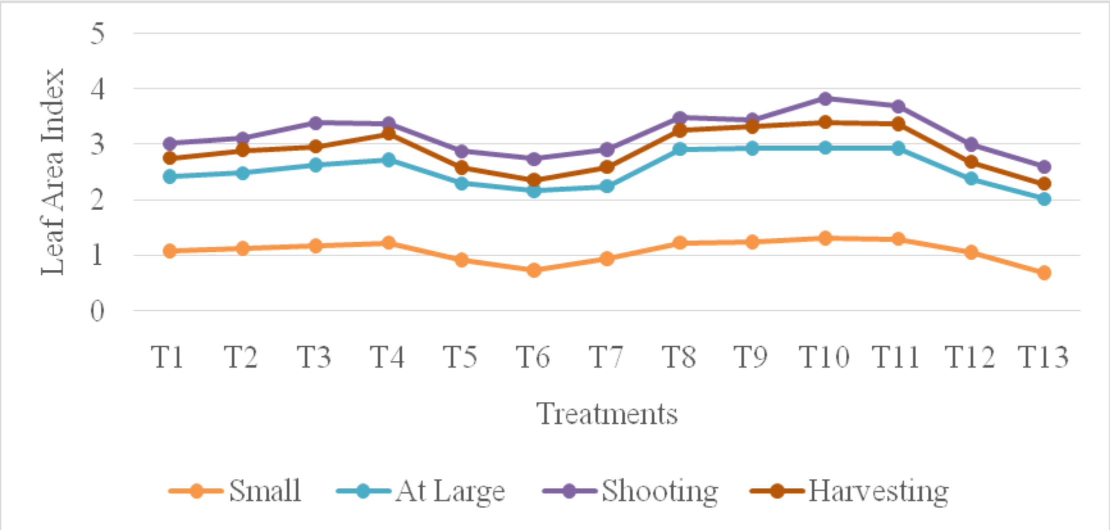


Figure 4.1.7: Effect of organic nutrition on leaf area index of the ratoon crop in banana

Table 4.1.7: Effect of organic nutrition on leaf area index of main and ratoon crop in banana

Treatments	Leaf Area Index							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Farm Yard Manure	1.21	2.61	3.15	2.81	1.09	2.42	3.02	2.75
T_2 - Vermi compost	1.24	2.78	3.17	2.95	1.13	2.48	3.12	2.90
T_3 - Neem Cake	1.26	2.79	3.51	3.12	1.18	2.63	3.39	2.96
T_4 - Poultry Manure	1.28	2.84	3.58	3.22	1.23	2.72	3.38	3.19
T_5 - *Azotobacter*	1.08	2.32	3.02	2.65	0.93	2.29	2.89	2.58
T_6 - Phosphate Solubilizing Bacteria	0.84	2.21	2.82	2.46	0.74	2.16	2.74	2.35
T_7 - Potash Solubilizing Bacteria	0.97	2.28	2.98	2.61	0.95	2.24	2.92	2.59
T_8 - FYM +AZ+PSB+ KSB	1.27	2.98	3.69	3.39	1.23	2.91	3.48	3.25
T_9 - VC +AZ+PSB+ KSB	1.31	3.06	3.74	3.48	1.25	2.92	3.45	3.32
T_{10} - NC +AZ+PSB+ KSB	1.41	3.18	3.79	3.59	1.32	2.93	3.83	3.40
T_{11} - PM +AZ+PSB+ KSB	1.38	3.08	4.02	3.69	1.30	2.92	3.69	3.37
T_{12} - AZ+PSB+ KSB	1.09	2.45	3.09	2.75	1.06	2.38	3.01	2.68
T_{13} - Control	0.81	2.08	2.72	2.31	0.69	2.02	2.61	2.29
SEm±	**0.0402**	**0.0665**	**0.0965**	**0.0992**	**0.0679**	**0.0601**	**0.0680**	**0.0944**
CD at 5%	**0.1172**	**0.1940**	**0.2815**	**0.2894**	**0.1981**	**0.1755**	**0.1986**	**0.2754**

Table 4.1.8: Effect of organic nutrition on days taken for shooting, shooting to harvesting and crop duration of main and ratoon banana

Treatments	Days Taken for Shooting		Shooting to Harvesting Interval (Days)		Crop Duration (days)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	304.33	297.67	91.67	90.33	396.00	388.00
T_2 - Vermi compost	295.33	289.33	91.33	89.67	386.67	379.00
T_3 - Neem Cake	289.33	283.67	90.67	88.67	380.00	372.34
T_4 - Poultry Manure	288.67	281.33	90.33	87.67	379.00	369.00
T_5 - *Azotobacter*	316.67	307.67	92.67	91.33	409.33	399.00
T_6 - Phosphate Solubilizing Bacteria	326.33	318.67	94.33	92.33	420.67	411.00
T_7 - Potash Solubilizing Bacteria	324.33	310.33	93.33	91.67	417.67	402.00
T_8 - FYM +AZ+PSB+ KSB	286.33	278.33	89.33	87.33	375.67	365.66
T_9 - VC +AZ+PSB+ KSB	284.33	274.33	88.67	87.00	373.00	361.33
T_{10} - NC +AZ+PSB+ KSB	277.67	268.67	86.67	85.33	365.00	354.00
T_{11} - PM +AZ+PSB+ KSB	259.33	254.67	87.33	83.33	346.00	338.00
T_{12} - AZ+PSB+ KSB	315.33	305.33	92.33	91.00	407.67	396.33
T_{13} - Control	330.67	319.33	99.33	93.67	430.00	413.00
SEm±	**9.5716**	**6.8110**	**1.6168**	**0.7475**	**9.4436**	**1.7028**
CD at 5%	**27.9389**	**19.8808**	**4.7193**	**2.1819**	**27.5652**	**4.9704**

4.1.1.8. Days taken for shooting

In this experiment it was found that average days taken for shooting varied significantly among the different treatments. For both main and ratoon crop, highest number of days (330.67 days and 319.33 days) were taken by control plant for shooting, whereas it was minimum in case of the plants treated with poultry manure along with AZ, PSB & KSB (259.33 days and 254.67 days) followed by in case of the plants treated neem cake + AZ, PSB & KSB (277.67 days and 268.67 days) and treated with vermi compost + AZ, PSB & KSB (284.33 days and 274.33 days) both in main and ratoon crop (Table 4.1.8).

4.1.1.9. Shooting to harvesting interval

It was evident from the present experiment that plants at control had taken maximum days interval (99.33 days and 93.67 days) from shooting to harvesting both in case of main and ratoon crop (Table: 4.1.8). It was found that the plants treated with neem cake along with AZ, PSB & KSB (T_{10}) had minimum days interval (86.67 days) from shooting to harvesting in main crop followed by T_{11} (87.33 days) and T_9 (88.67 days), while in case of ratoon crop minimum days interval from shooting to harvesting was recorded in T_{11} (83.33 days) followed by T_{10} (85.33 days) and T_9 (87.00 days).

4.1.1.10. Crop duration

Data presented at Table 4.1.8 and Fig.4.1.8 showed that maximum duration of crop was recorded in control plants (430.00 days and 413.00 days) for both main and ratoon crop. It was found that the crop duration of ratoon crop was significantly lower than main crop. In case of main crop, the minimum crop duration (346.00 days) was recorded in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11})

followed by plants treated with neem cake + AZ, PSB & KSB (365.00 days), similarly, in ratoon crop the minimum duration of cropping was recorded in T_{11} (338.00 days) followed by T_{10} (354.00 days) and T_9 (361.33 days) compared with other treatments.

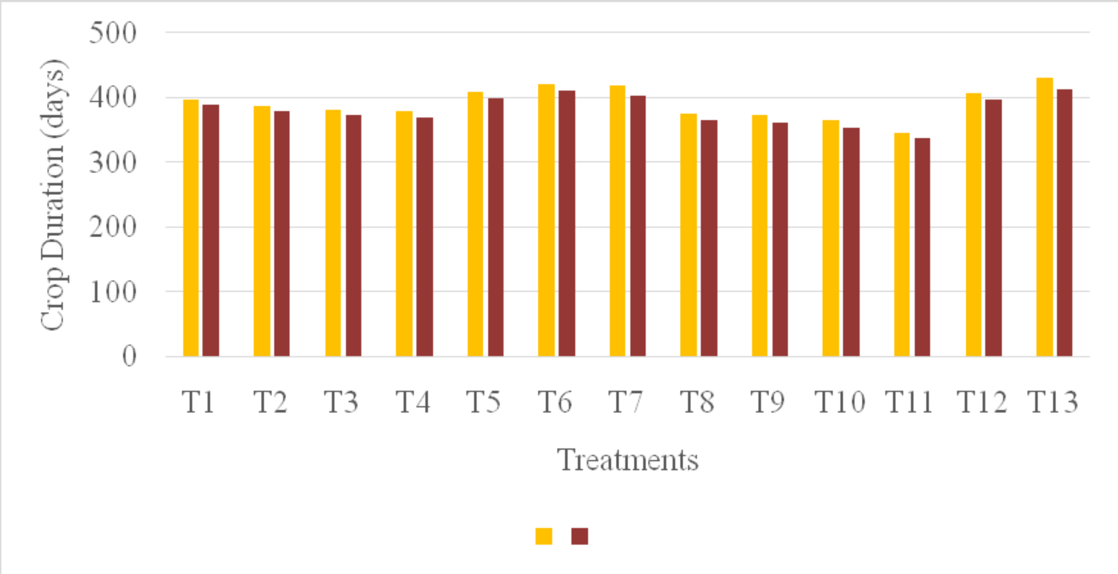


Figure 4.1.8: Effect of organic nutrition on crop duration of the main and ratoon crop in banana

4.1.1.11. Sucker production

Perusal of the data presented at Table 4.1.9; Fig. 4.1.9 and 4.1.10 it was found that throughout the period of growth banana plants produced suckers and thus the number gradually increased from small stage to harvesting stage, both in main as well as in ratoon crops. However, it was recorded that number of suckers in ratoon crops were lesser than in main crops for all the treatments. There were few treatments in both main and ratoon crop, where no suckers were developed at small stage, however no significant variation was observed in sucker production at small stage in both main and ratoon crops. For the main crop, plants treated with neem cake along with biofertilizer viz. AZ, PSB & KSB (T_{10}) had maximum number of suckers at large (4.78) and shooting stage (7.83), however, it was recorded maximum (10.89) for the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) at harvesting stage compared with control (large: 2.89, shooting: 4.23, harvesting: 6.11).

For the ratoon crop, plants at T_{11} had maximum number of suckers (4.56) at large stage however, it was found highest in T_{10} at shooting stage (4.57) and harvesting stage (6.07) compared with control (large: 2.64, shooting: 3.66 and harvesting stage: 4.04).

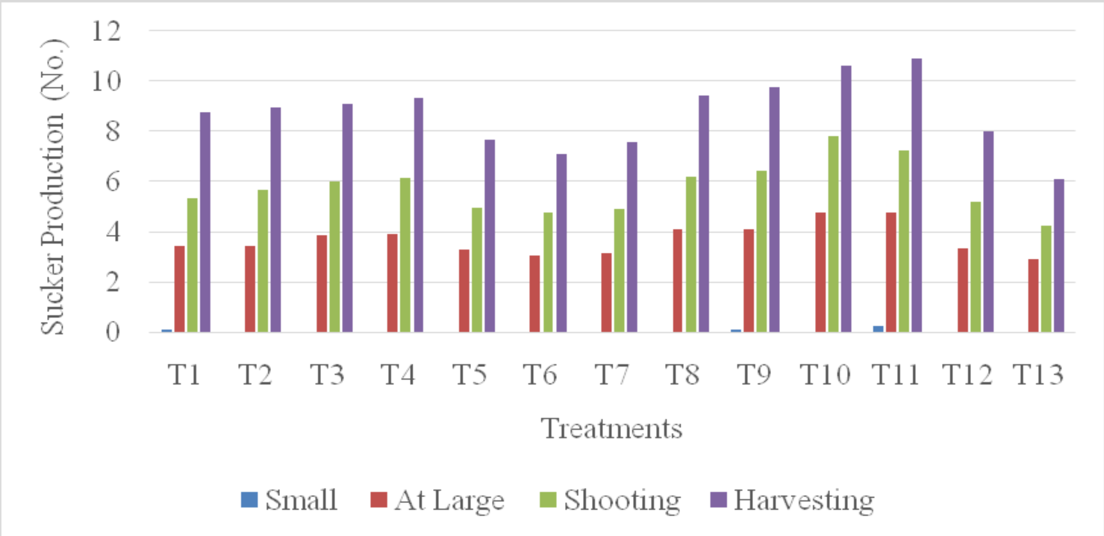


Figure 4.1.9: Effect of organic nutrition on sucker production of the main crop in banana

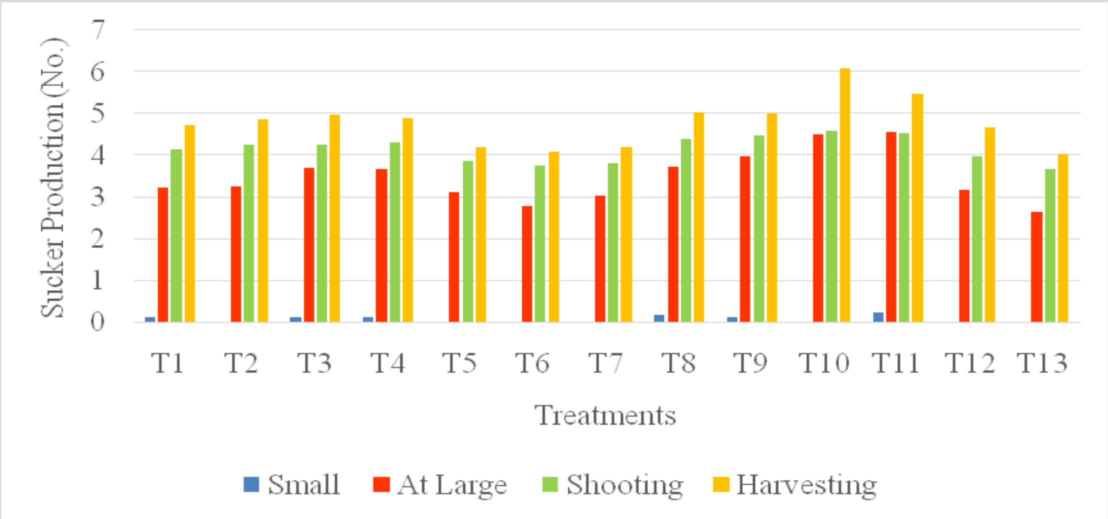


Figure 4.1.10: Effect of organic nutrition on sucker production of the ratoon crop in banana

Table 4.1.9: Effect of organic nutrition on sucker production of main and ratoon crop in banana

Treatments	Sucker production (Number)							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Farm Yard Manure	0.11	3.42	5.32	8.78	0.11	3.21	4.15	4.73
T_2 - Vermi compost	0.00	3.45	5.67	8.95	0.00	3.24	4.25	4.85
T_3 - Neem Cake	0.00	3.84	5.98	9.11	0.11	3.70	4.26	4.97
T_4 - Poultry Manure	0.00	3.89	6.13	9.33	0.11	3.68	4.31	4.90
T_5 - *Azotobacter*	0.00	3.28	4.96	7.67	0.00	3.11	3.87	4.19
T_6 - Phosphate Solubilizing Bacteria	0.00	3.04	4.74	7.11	0.00	2.78	3.74	4.07
T_7 - Potash Solubilizing Bacteria	0.00	3.12	4.89	7.55	0.00	3.02	3.81	4.19
T_8 - FYM +AZ+PSB+ KSB	0.00	4.11	6.21	9.44	0.17	3.72	4.40	5.02
T_9 - VC +AZ+PSB+ KSB	0.11	4.11	6.45	9.78	0.11	3.97	4.48	5.00
T_{10} - NC +AZ+PSB+ KSB	0.00	4.78	7.83	10.62	0.00	4.49	4.57	6.07
T_{11} - PM +AZ+PSB+ KSB	0.22	4.74	7.24	10.89	0.22	4.56	4.53	5.48
T_{12} - AZ+PSB+ KSB	0.00	3.31	5.21	8.01	0.00	3.16	3.97	4.66
T_{13} - Control	0.00	2.89	4.23	6.11	0.00	2.64	3.66	4.04
SEm±	**NS**	**0.1110**	**0.2291**	**0.3329**	**NS**	**0.1083**	**0.0844**	**0.1942**
CD at 5%		**0.3241**	**0.6687**	**0.9716**		**0.3162**	**0.2464**	**0.5668**

4.1.1.12. Total biomass

The present experiment showed that total biomass was found highest (78.14 Kg) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by the plants treated with neem cake + AZ, PSB & KSB (T_{10}) (76.48 Kg) compared with control (64.17 Kg) for main crop. However, in case of ratoon crop, the total biomass was recorded highest (73.24 Kg) in case of the plants at T_{10} followed by T_{11} (71.64 Kg) and T_9 (69.87 Kg) compared with control (60.14 kg) (Table 4.1.10).

4.1.1.13. Net assimilation rate (NAR)

Data presented at Table 4.1.10 and Fig. 4.1.11 clearly showed that net assimilation rate (NAR) significantly varied among the plants under different treatments. For both main and ratoon crop, it was recorded highest (4.15 and 3.95 g m^{-2} day^{-1}) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by plants treated with neem cake +AZ, PSB & KSB (3.98 and 3.72 g m^{-2} day^{-1}) compared with control (2.08 and 1.91 g m^{-2} day^{-1}).

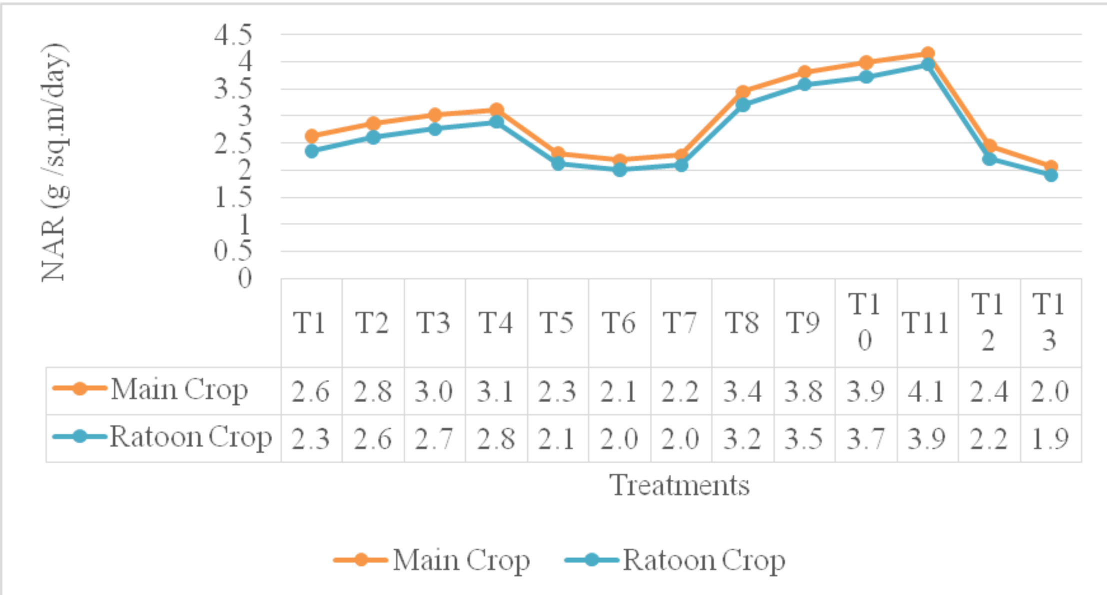


Figure 4.1.11: Effect of organic nutrition on net assimilation rate (NAR) of the main and ratoon crop in banana

Table 4.1.10: Effect of organic nutrition on total biomass, net assimilation rate and harvest index of main and ratoon crop in banana

Treatments	Total Biomass (kg)		Net assimilation rate/NAR ($g\ m^{-2} day^{-1}$)		Harvest Index (HI)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	70.53	64.58	2.64	2.35	0.21	0.19
T_2 - Vermi compost	72.66	66.87	2.86	2.61	0.23	0.21
T_3 - Neem Cake	73.36	67.42	3.02	2.76	0.25	0.25
T_4 - Poultry Manure	75.05	68.85	3.12	2.89	0.26	0.25
T_5 - *Azotobacter*	67.88	62.89	2.31	2.12	0.16	0.15
T_6 - Phosphate Solubilizing Bacteria	65.16	61.65	2.19	2.01	0.15	0.13
T_7 - Potash Solubilizing Bacteria	66.22	62.14	2.28	2.09	0.15	0.14
T_8 - FYM +AZ+PSB+ KSB	73.79	68.26	3.45	3.21	0.27	0.25
T_9 - VC +AZ+PSB+ KSB	75.96	69.87	3.81	3.58	0.29	0.27
T_{10} - NC +AZ+PSB+ KSB	76.48	73.24	3.98	3.72	0.29	0.27
T_{11} - PM +AZ+PSB+ KSB	78.14	71.64	4.15	3.95	0.33	0.32
T_{12} - AZ+PSB+ KSB	68.93	63.15	2.45	2.21	0.18	0.16
T_{13} - Control	64.17	60.14	2.08	1.91	0.14	0.12
SEm±	**0.9721**	**1.6898**	**0.0941**	**0.0728**	**0.0100**	**0.0059**
CD at 5%	**2.8374**	**4.9325**	**0.2745**	**0.2126**	**0.0292**	**0.0172**

4.1.1.14. Harvest index

For the main crop, harvest index was recorded maximum (0.33) for the plants treated with poultry manure + AZ, PSB & KSB followed by the plants treated with neem cake + AZ, PSB & KSB (0.29) and vermi compost + AZ, PSB & KSB (0.29), which were found statistically at par (Table 4.1.10). In ratoon crop, harvest index was found highest in T_{11} (0.32) followed by T_{10} (0.27) which was statistically at par with T_9 (0.27). The harvest index was found minimum in control plant for both main (0.14) and ratoon crop (0.12).

4.1.2. Fruit growth and development

Different parameters of fruit growth and development *viz.* bunch weight, bunch length, hands per bunch, second hand weight, number of fingers per hand, finger length, fingers diameter, finger volume, finger weight and yield were recorded. Besides, treatment wise record was made on days taken for ripening after harvest and shelf life.

4.1.2.1. Bunch weight

Present experiment on organic nutrient management of banana revealed that bunch weight of the fruits under different treatments significantly varied among themselves. For the main crop, it was found that highest weight of fruit bunch (25.47 Kg) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by the plants treated with neem cake + AZ, PSB & KSB (22.37 Kg) and plants treated with vermi compost + AZ, PSB & KSB (21.90 Kg) compared with control (9.08 Kg). It was observed that the weight of fruit bunch was low in case of ratoon crop among all the treatments under study (Table 4.1.11 and Fig. 4.1.12). However, plants at T_{11} had maximum bunch weight (23.32 Kg) followed by T_{10} (20.08 Kg) in comparison with control (6.28 Kg).

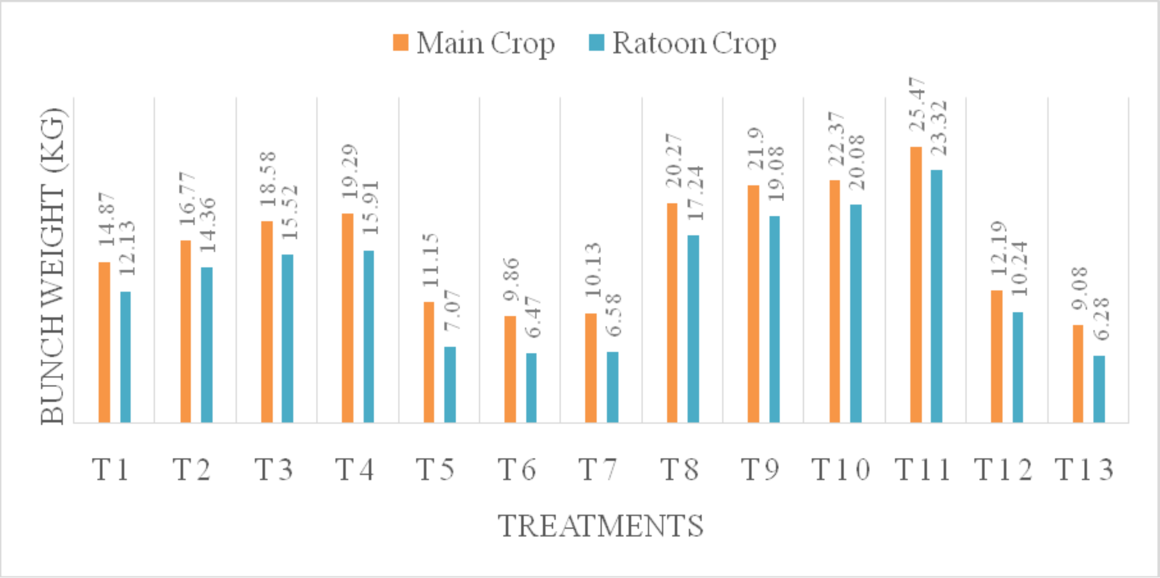


Figure 4.1.12: Effect of organic nutrition on bunch weight of the main and ratoon crop in banana

4.1.2.2. Bunch length

It was evident form the Table 4.1.11 that the bunch length was varied significantly both in main as well as ratoon crop due to the influence of organic nutrient treatments under the present study. For the main crop, the maximum length of the bunch (127.10 cm) was recorded in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by the plants treated with neem cake + AZ, PSB & KSB (126.54 cm) compared with control (84.18 cm). However, for the ratoon crop, maximum length of fruit bunch was found in T_{10} (121.48 cm) followed by T_{11} (119.23 cm) against control (80.26 cm).

4.1.2.3. Hands per bunch

Number of hands per bunch was found significantly different among the treatments. For both main and ratoon crop, plants treated with poultry manure and biofertilizer

Table 4.1.11: Effect of organic nutrition on bunch weight, bunch length and hands per bunch of main and ratoon crop in banana

Treatments	Bunch Weight (Kg)		Bunch Length (cm)		Hands per Bunch (Number)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	14.87	12.13	94.25	91.67	6.56	6.10
T_2 - Vermi compost	16.77	14.36	96.11	92.93	6.67	6.50
T_3 - Neem Cake	18.58	15.52	99.08	94.56	6.78	6.63
T_4 - Poultry Manure	19.29	15.91	109.55	104.20	6.89	6.67
T_5 - *Azotobacter*	11.15	7.07	87.38	85.37	5.55	5.43
T_6 - Phosphate Solubilizing Bacteria	9.86	6.47	86.47	83.78	5.11	5.03
T_7 - Potash Solubilizing Bacteria	10.13	6.58	86.73	84.93	5.33	5.17
T_8 - FYM +AZ+PSB+ KSB	20.27	17.24	111.51	107.32	7.11	6.67
T_9 - VC +AZ+PSB+ KSB	21.90	19.08	121.35	118.77	7.33	6.93
T_{10} - NC +AZ+PSB+ KSB	22.37	20.08	126.54	121.48	7.44	7.17
T_{11} - PM +AZ+PSB+ KSB	25.47	23.32	127.10	119.23	7.89	7.73
T_{12} - AZ+PSB+ KSB	12.19	10.24	89.24	87.23	5.78	5.70
T_{13} - Control	9.08	6.28	84.18	80.26	5.33	4.63
SEm±	**0.9357**	**0.3394**	**2.9636**	**0.5255**	**0.4050**	**0.5299**
CD at 5%	**2.7312**	**0.9907**	**8.6506**	**1.5340**	**1.1822**	**1.5466**

(AZ, PSB & KSB) had maximum number of hands (7.89 and 7.73) followed by plants treated with neem cake + AZ, PSB & KSB (7.44 and 7.17) and vermi compost + AZ, PSB & KSB (7.33 and 6.93) compared with control (5.33 and 4.63) (Table 4.1.11).

4.1.2.4. Second hand weight

It was clear from the data presented at Table 4.1.12 and Fig. 4.1.13 that second hand weight of the fruits got significant variation among the different treatments. Further, it was found that second hand weight of the main crop was significantly higher than ratoon crop, among all the treatments. In case of the main crop, second hand weight of the fruit ranged between 1.39 Kg and 3.18 Kg whereas, it was ranged between 1.03 Kg and 2.82 Kg in ratoon crops. For both main and ratoon crop, plants treated with poultry manure + AZ, PSB & KSB (T_{11}) had maximum second hand weight (3.18 and 2.82 Kg) followed by the plants treated with neem cake + AZ, PSB & KSB (2.86 and 2.65 Kg) and vermi compost + AZ, PSB & KSB (2.78 and 2.57 Kg) compared with control (1.39 and 1.03 Kg).

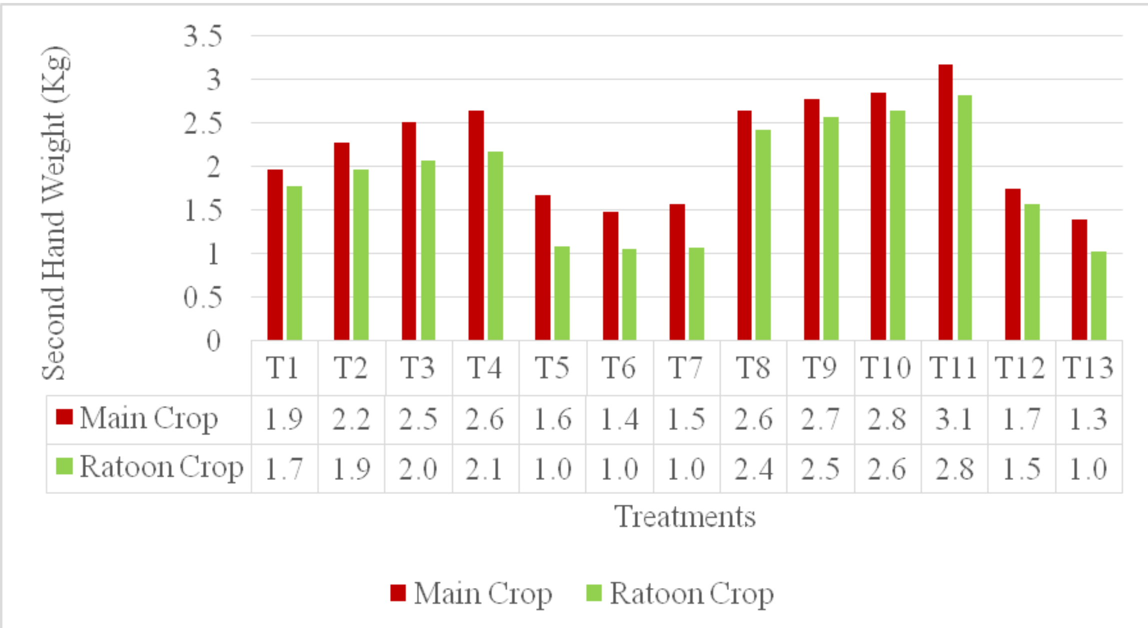


Figure 4.1.13: Effect of organic nutrition on second hand weight of the main and ratoon crop in banana

4.1.2.5. Number of fingers per hand

There was significant variation in number of fingers per hand of banana among the plants under different organic nutrition treatments along with control. Highest number of fingers per fruiting hand (main crop: 14.11 and ratoon crop: 13.44) was recorded in case of the plant treated with poultry manure along with biofertilizers viz. AZ, PSB & KSB followed by the plants treated with neem cake along with AZ, PSB & KSB (main crop: 13.33 and ratoon crop: 12.89), for both main and ratoon crop compared with control (main crop: 10.55 and ratoon crop: 8.26) (Table 4.1.12).

4.1.2.6. Finger length

Perusal of the data presented at Table 4.1.12 revealed that the length of banana fruit finger got significant variation under different treatments. For the main crop, the maximum finger length (23.63 cm) was observed in case of the plants treated with poultry manure along with biofertilizers (AZ, PSB & KSB) followed the plants treated with neem cake + AZ, PSB & KSB (T_{10}; 23.37 cm) compared with control (17.30 cm) whereas, in case of ratoon crop maximum finger length (22.57 cm) was recorded in T_{10} followed by T_{11} (21.43 cm) against control (16.20 cm).

4.1.2.7. Finger diameter

It was evident from the data presented at Table 4.1.13 that diameter of the banana fingers got significant variation among the different treatments under study. Plants treated with poultry manure + AZ, PSB & KSB (T_{11}) had maximum finger diameter (14.13 cm) followed by the plants treated with neem cake + AZ, PSB & KSB (T_{10}; 13.47 cm) compared with control (10.83 cm) in case of main crop; while in ratoon

Table 4.1.12: Effect of organic nutrition on second hand weight, number of finger per hand and finger length of main and ratoon crop in banana

Treatments	Second Hand Weight (Kg)		Number of fingers per hand		Finger Length (cm)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	1.97	1.78	11.67	11.56	19.27	18.20
T_2 - Vermi compost	2.28	1.97	12.33	11.67	19.93	19.13
T_3 - Neem Cake	2.51	2.08	12.56	11.73	20.93	20.23
T_4 - Poultry Manure	2.64	2.17	12.67	11.94	21.67	20.77
T_5 - *Azotobacter*	1.67	1.09	11.56	8.67	18.90	16.97
T_6 - Phosphate Solubilizing Bacteria	1.48	1.06	10.67	8.44	18.37	16.40
T_7 - Potash Solubilizing Bacteria	1.58	1.08	11.11	8.39	18.67	16.47
T_8 - FYM +AZ+PSB+ KSB	2.65	2.43	12.89	12.33	21.73	21.33
T_9 - VC +AZ+PSB+ KSB	2.78	2.57	13.44	12.67	22.03	21.33
T_{10} - NC +AZ+PSB+ KSB	2.86	2.65	13.33	12.89	23.37	22.57
T_{11} - PM +AZ+PSB+ KSB	3.18	2.82	14.11	13.44	23.63	21.43
T_{12} - AZ+PSB+ KSB	1.75	1.57	11.66	11.11	19.17	17.17
T_{13} - Control	1.39	1.03	10.55	8.26	17.30	16.20
SEm±	**0.1343**	**0.1446**	**0.7210**	**0.5511**	**0.4947**	**0.6293**
CD at 5%	**0.3919**	**0.4222**	**2.1046**	**1.6086**	**1.4440**	**1.8370**

crop it was recorded highest in T_{10} (12.83 cm) followed by T_{11} (12.53 cm) and T_9 (12.23 cm) compared with control (10.30 cm).

4.1.2.8. Finger volume

There was significant variation in the finger volume across the different treatments under study. It was found that for both main and ratoon crops, the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) had maximum finger volume (248.62 and 233.81 cc) followed by the plants treated with neem cake + AZ, PSB & KSB (231.46 and 220.04 cc) compared with control (149.38 and 140.46 cm) (Table 4.1.13 and Fig. 4.1.14).

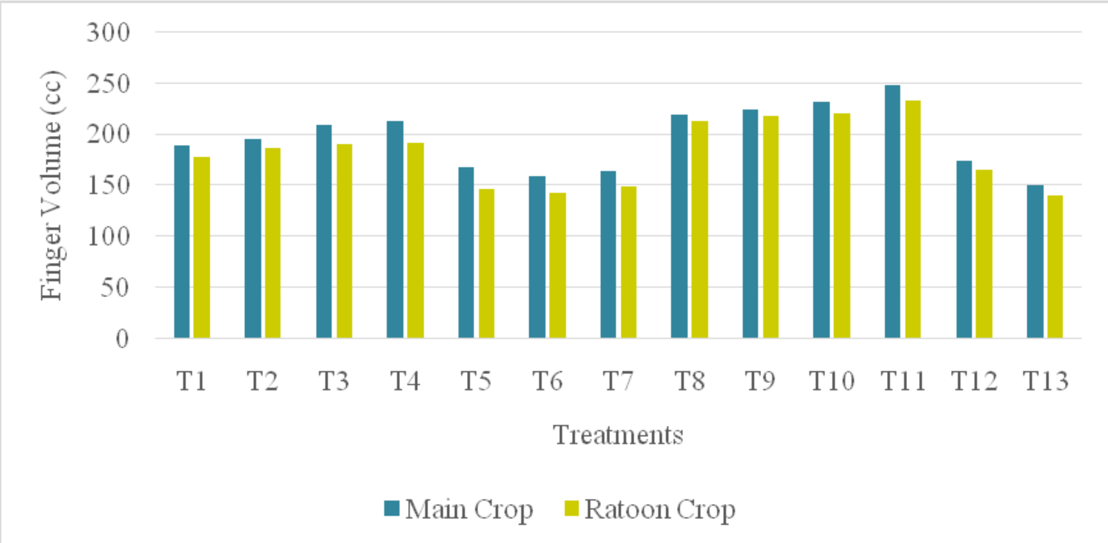


Figure 4.1.14: Effect of organic nutrition on finger volume of the main and ratoon crop in banana

4.1.2.9. Finger weight

For both main and ratoon crops, plants treated with poultry manure + AZ, PSB & KSB (T_{11}) had maximum finger weight (main crop: 221.93 g and ratoon crop: 209.47 g) followed by the plants treated with neem cake + AZ, PSB & KSB (main crop: 216.20 g and ratoon crop: 204.37 g) and vermi compost + AZ, PSB & KSB (main

Table 4.1.13: Effect of organic nutrition on finger diameter, finger volume and finger weight of main and ratoon crop in banana

Treatments	Finger Diameter (cm)		Finger Volume (cc)		Finger Weight (gm)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	11.93	11.47	188.93	177.17	159.83	154.83
T_2 - Vermi compost	12.13	11.97	195.64	186.59	177.03	169.38
T_3 - Neem Cake	12.73	12.13	209.37	190.43	198.57	176.12
T_4 - Poultry Manure	12.80	12.17	212.74	191.77	202.47	179.43
T_5 - *Azotobacter*	11.27	10.53	167.47	146.06	140.30	124.68
T_6 - Phosphate Solubilizing Bacteria	11.20	10.43	158.46	142.75	137.87	123.52
T_7 - Potash Solubilizing Bacteria	11.23	11.07	164.21	148.74	139.07	126.62
T_8 - FYM +AZ+PSB+ KSB	12.90	12.20	219.28	212.77	203.37	198.45
T_9 - VC +AZ+PSB+ KSB	13.00	12.23	224.72	217.45	205.43	200.67
T_{10} - NC +AZ+PSB+ KSB	13.47	12.83	231.46	220.04	216.20	204.37
T_{11} - PM +AZ+PSB+ KSB	14.13	12.53	248.62	233.81	221.93	209.47
T_{12} - AZ+PSB+ KSB	11.53	11.03	173.62	164.82	148.67	142.48
T_{13} - Control	10.83	10.30	149.38	140.46	130.23	122.78
SEm±	**0.1377**	**0.4010**	**3.0597**	**3.6355**	**3.9526**	**4.3670**
CD at 5%	**0.4020**	**1.1704**	**8.9310**	**10.6119**	**11.5375**	**12.7471**

crop: 205.43 g and ratoon crop: 200.67 g) compared with control (main crop: 130.23 g and ratoon crop: 122.78 g) (Table 4.1.13).

4.1.2.10. Yield

Data presented in the Table 4.1.14 and Fig. 4.1.15 showed that the yield of the banana plants varied significantly among the different treatments under study. Further, it was observed that the yield of the main crop was recorded high than ratoon crop in case of all the treatments. In case of main crop, the yield was ranged between 10.09 and 28.30 tonnes per hectare whereas, it ranged between 6.98 and 25.91 tonnes per hectares in case of ratoon crops. For the main crop, the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) had the maximum yield (28.30 tonnes/ hectare) followed by the plants treated with neem cake + AZ, PSB & KSB (24.85 tonnes/ hectare), similarly in case of ratoon crop highest yield was recorded in T_{11} (25.91tonnes/ hectare) followed by T_{10} (22.31 tonnes/ hectare) and T_9 (21.20 tonnes/ hectare). For both main and ratoon crop, lowest yield was found in control (10.09 and 6.98 tonnes/ hectare).

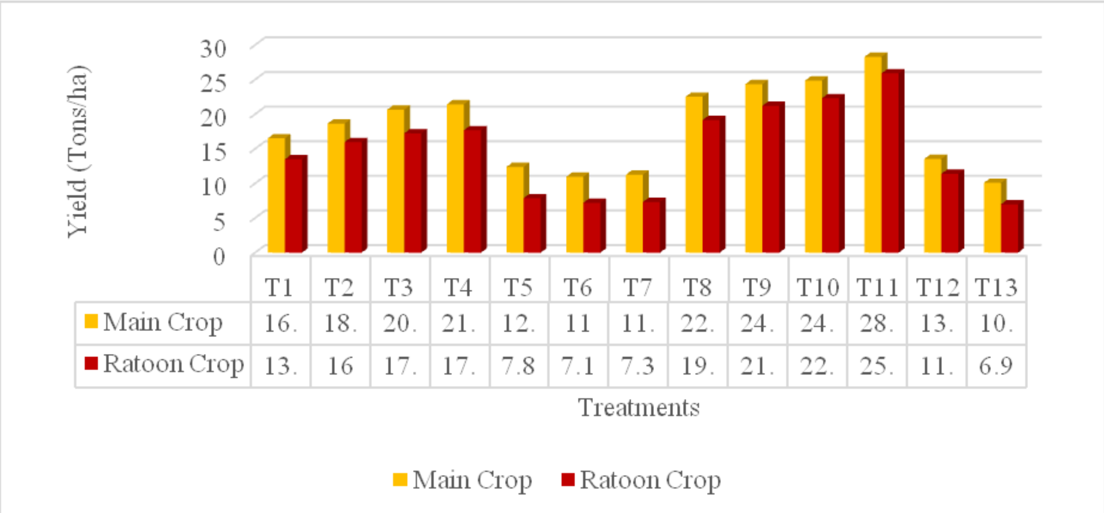


Figure 4.1.15: Effect of organic nutrition on yield of the main and ratoon crop in banana

Table 4.1.14: Effect of organic nutrition on yield, days taken for ripening and shelf life of main and ratoon crop in banana

Treatments	Yield (tonnes per hectare)		Days taken for ripening after harvest		Shelf-life (days)	
	Main Crop	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**
T_1 - Farm Yard Manure	16.52	13.48	6.44	6.33	9.22	7.78
T_2 - Vermi compost	18.64	15.96	7.11	7.00	9.33	7.89
T_3 - Neem Cake	20.65	17.24	6.89	6.67	9.44	8.11
T_4 - Poultry Manure	21.43	17.68	7.33	7.22	9.56	8.33
T_5 - *Azotobacter*	12.39	7.86	5.89	5.78	8.89	7.56
T_6 - Phosphate Solubilizing Bacteria	10.95	7.19	5.78	5.56	8.78	7.44
T_7 - Potash Solubilizing Bacteria	11.26	7.31	6.33	5.89	9.00	7.67
T_8 - FYM +AZ+PSB+ KSB	22.52	19.16	7.89	7.67	9.67	8.56
T_9 - VC +AZ+PSB+ KSB	24.33	21.20	8.89	8.22	10.56	9.11
T_{10} - NC +AZ+PSB+ KSB	24.85	22.31	8.00	8.11	9.67	8.56
T_{11} - PM +AZ+PSB+ KSB	28.30	25.91	8.11	7.78	9.78	8.44
T_{12} - AZ+PSB+ KSB	13.54	11.38	6.56	6.11	9.11	7.67
T_{13} - Control	10.09	6.98	5.67	5.11	8.67	7.22
SEm±	**1.0396**	**0.3771**	**0.2441**	**0.3108**	**0.2778**	**0.2577**
CD at 5%	**3.0346**	**1.1008**	**0.7125**	**0.9072**	**0.8107**	**0.7522**

4.1.2.11. Days taken for ripening after harvest

The present experiment revealed that minimum days for ripening of fruits after harvest (main crop: 5.67 days and ratoon crop: 5.11days) was recorded in control plants for both main and ratoon crop (Table 4.1.14). For both main and ratoon crop, maximum days (8.89 and 8.22 days) were recorded for ripening of fruits after harvest in case of the plants treated with vermi compost + AZ, PSB & KSB (T_9). Besides, plants treated with neem cake + AZ, PSB & KSB (8.00 and 8.11 days) and poultry manure + AZ, PSB & KSB (8.11 and 7.78 days) had also comparatively taken more days for ripening than other treatments.

4.1.2.12. Shelf life

In case of main crop, the maximum shelf life (10.56 days) was recorded in case of the plants treated with vermi compost + AZ, PSB & KSB (T_9) followed by the plants treated with poultry manure + AZ, PSB & KSB (T_{11}; 9.78 days). In case of ratoon crops, the shelf life was found maximum (9.11 days) in T_9 followed by the plants treated with neem cake + AZ, PSB & KSB (8.56 days). For both main and ratoon crop, shelf life was found minimum (8.67 days and 7.22 days) in control plants (Table 4.1.14).

4.1.3. Fruit quality parameters

Fruit quality parameters like pulp-peel ratio, moisture content, ascorbic acid content, Total Soluble Solids (TSS) content, titratable acidity content, TSS:acid ratio, total sugar content, reducing sugar content, protein, starch, amylose and total carbohydrate content was measured in fruits of main crop and ratoon crop for different treatment.

4.1.3.1. Pulp and peel ratio

It is evident from the Table 4.1.15 and Fig. 4.1.16 that pulp: peel ratio of the banana fruit varied significantly among the different treatments. For the main crop, it was recorded highest (2.61) in case of the plant treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by the plants treated with vermi compost + AZ, PSB & KSB (2.54) compared with control (2.05). For the ratoon crops, maximum pulp: peel ratio of fruit was recorded in case of T_9 (2.23) followed by T_{11} (2.21) which was statistically at par with T_{10} (2.21) against control (1.88).

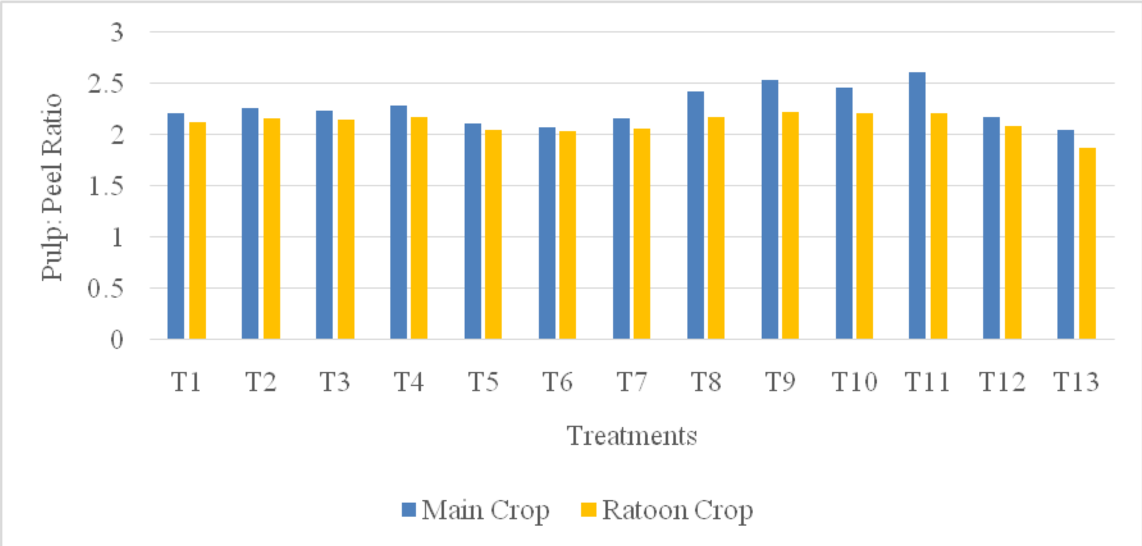


Figure 4.1.16: Effect of organic nutrition on fruit pulp:peel ratio of the main and ratoon crop in banana

4.1.3.2. Moisture content

In case of the main crop, the moisture content of the fruit was found maximum (80.18%) in control followed by plants applied with PSB (T_7, 79.62%) whereas, it was recorded minimum (75.49%) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by the plants treated with vermi compost + AZ, PSB & KSB (76.83%).

For the ratoon crop, lowest moisture (76.17%) was recorded in fruits at T_9 (Vermi compost + AZ, PSB &KSB) followed by T_{11} (76.27%) compared with control (78.75%) (Table 4.1.15).

4.1.3.3. Ascorbic acid content

Data presented at Table 4.1.15 and Fig. 4.1.17 showed that ascorbic acid content of the fruit varied significantly among the different treatments under study. For both main and ratoon crop, it was recorded highest (9.48 and 8.78 mg/100g) in case of the plants treated with vermi compost + AZ, PSB & KSB followed by plants treated with poultry manure + AZ, PSB & KSB (T_{11}; 9.21 and 8.76 mg/100g). Plants at control had the minimum fruit ascorbic acid content both in main crop (6.28 mg/100g) and for ratoon crop (7.02 mg/100g).

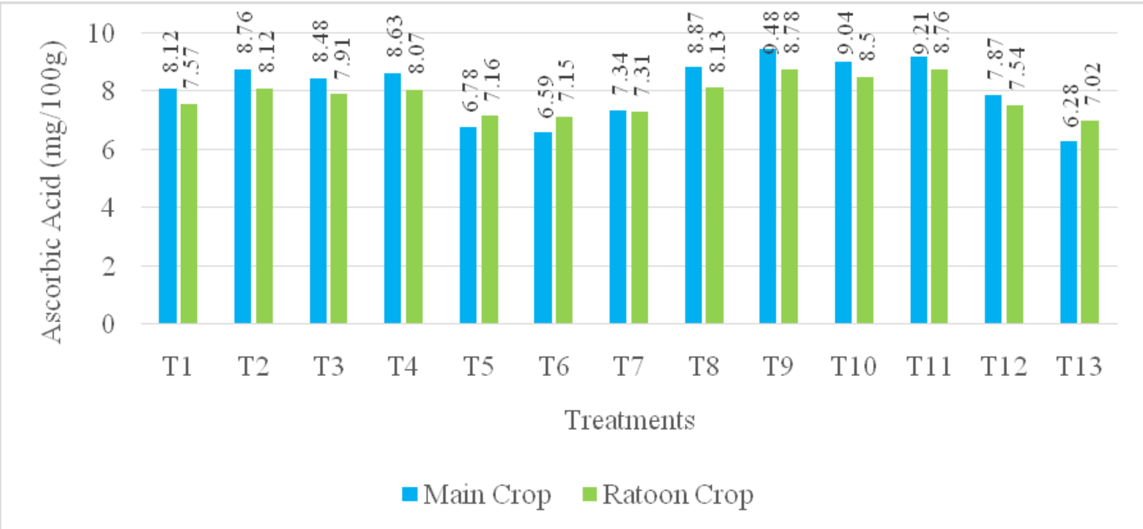


Figure 4.1.17: Effect of organic nutrition on fruit ascorbic acid content of the main and ratoon crop in banana

4.1.3.4. Total Soluble Solids (TSS) content

Perusal of the data presented at Table 4.1.16 showed that for the main crop TSS content of the banana fruit was maximum (25.75ºBrix) in case of the plant treated with poultry manure + AZ, PSB and KSB followed by the plants treated with vermi

Table 4.1.15: Effect of organic nutrition on pulp: peel ratio, moisture content and ascorbic acid content of fruits of main and ratoon crop in banana

Treatments	Pulp: Peel		Moisture (%)		Ascorbic acid (mg/100g)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	2.21	2.13	78.84	77.61	8.12	7.57
T_2 - Vermi compost	2.26	2.16	78.26	76.89	8.76	8.12
T_3 - Neem Cake	2.24	2.15	78.45	77.46	8.48	7.91
T_4 - Poultry Manure	2.29	2.17	77.94	77.23	8.63	8.07
T_5 - *Azotobacter*	2.11	2.05	79.22	78.33	6.78	7.16
T_6 - Phosphate Solubilizing Bacteria	2.08	2.04	79.62	78.49	6.59	7.15
T_7 - Potash Solubilizing Bacteria	2.16	2.06	79.09	77.90	7.34	7.31
T_8 - FYM +AZ+PSB+ KSB	2.42	2.18	77.17	76.64	8.87	8.13
T_9 - VC +AZ+PSB+ KSB	2.54	2.23	76.83	76.17	9.48	8.78
T_{10} - NC +AZ+PSB+ KSB	2.46	2.21	77.02	76.51	9.04	8.50
T_{11} - PM +AZ+PSB+ KSB	2.61	2.21	75.49	76.27	9.21	8.76
T_{12} - AZ+PSB+ KSB	2.18	2.09	78.87	77.77	7.87	7.54
T_{13} - Control	2.05	1.88	80.18	78.75	6.28	7.02
SEm±	**0.0563**	**0.0567**	**0.5038**	**0.3154**	**0.2700**	**0.3384**
CD at 5%	**0.1645**	**0.1656**	**1.4704**	**0.9206**	**0.7881**	**0.9877**

Table 4.1.16: Effect of organic nutrition on Total Soluble Solids (TSS), titratable acidity content and TSS:acid ratio of fruits of main and ratoon crop in banana

Treatments	TSS (°Brix)		Titratable Acidity (%)		TSS: Acid ratio	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	22.83	21.79	0.25	0.26	91.33	83.79
T_2 - Vermi compost	23.92	22.89	0.24	0.24	99.65	95.36
T_3 - Neem Cake	23.33	22.34	0.24	0.25	97.22	89.36
T_4 - Poultry Manure	24.08	22.46	0.23	0.24	104.71	93.58
T_5 - *Azotobacter*	20.42	19.37	0.26	0.27	78.53	71.73
T_6 - Phosphate Solubilizing Bacteria	19.58	18.33	0.27	0.28	72.53	65.48
T_7 - Potash Solubilizing Bacteria	21.58	20.82	0.26	0.26	83.01	80.08
T_8 - FYM +AZ+PSB+ KSB	24.33	22.90	0.23	0.24	105.80	95.40
T_9 - VC +AZ+PSB+ KSB	24.83	23.55	0.22	0.22	112.88	107.05
T_{10} - NC +AZ+PSB+ KSB	24.67	23.03	0.22	0.23	112.12	100.12
T_{11} - PM +AZ+PSB+ KSB	25.75	23.04	0.21	0.22	122.62	104.73
T_{12} - AZ+PSB+ KSB	22.08	21.62	0.25	0.26	88.33	83.17
T_{13} - Control	17.42	16.32	0.29	0.28	60.06	58.29
SEm±	**0.6654**	**0.8455**	**0.0092**	**0.0028**	**5.5936**	**0.5893**
CD at 5%	**1.9423**	**2.4680**	**0.0269**	**0.0081**	**16.3273**	**1.7203**

compost + AZ, PSB and KSB (24.83°Brix) compared with control (17.42°Brix) whereas, for ratoon crop maximum TSS content (23.55°Brix) was found in T_9 followed by T_{11} (23.04°Brix) and T_{10} (23.03°Brix) against control (16.32°Brix).

4.1.3.5. Titratable acidity

For both main and ratoon crop, titratable acidity was found maximum (0.29% and 0.28%) in control whereas, it was minimum (main crop: 0.21% and ratoon crop: 0.22%) in case of the plant treated with poultry manure + AZ, PSB & KSB (T_{11}). Titratable acidity value (0.22%) in fruits from the plants treated with vermi compost + AZ, PSB & KSB (T_9) was statistically at par with T_{11} for ratoon crop (Table 4.1.16).

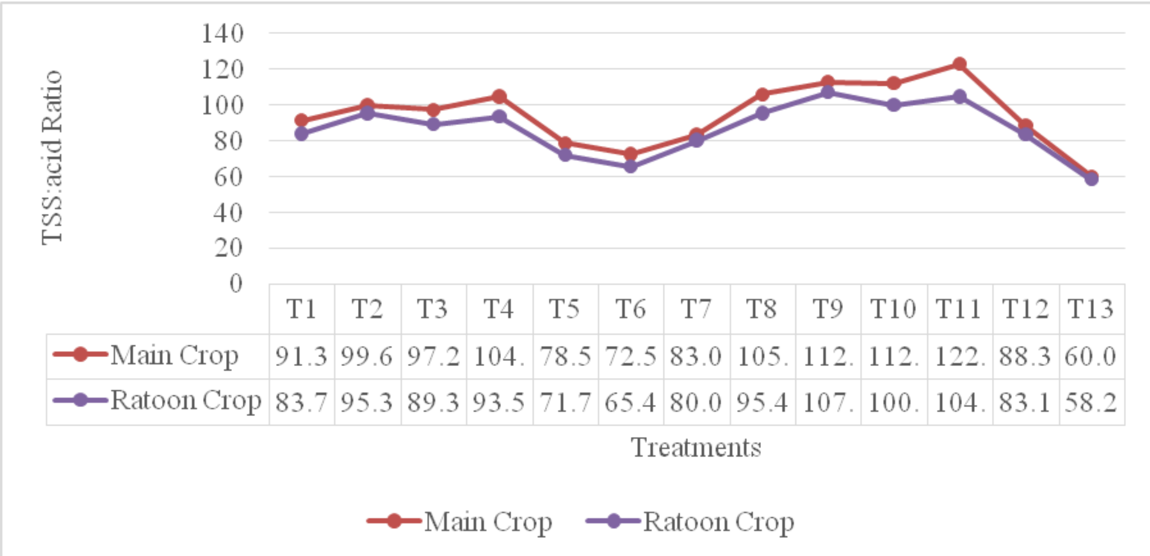


Figure 4.1.18: Effect of organic nutrition on fruit TSS:acid ratio of the main and ratoon crop in banana

4.1.3.6. TSS: acid ratio

The TSS:acid ratio of the banana fruit varied significantly among the different treatment at main as well as ratoon crop (Table 4.1.16 and Fig. 4.1.18). For the main crop, maximum TSS:acid ratio (122.62) was recorded in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by the plants treated with vermi compost + AZ, PSB & KSB (112.88) and neem cake + AZ, PSB & KSB (112.12) compared with control (60.06). For the ratoon crop, minimum TSS:acid ratio (58.29) was found in fruits from the plants at control, whereas, it was recorded highest (107.05) in case of the plants treated with vermi compost + AZ, PSB & KSB followed by T_{11} (104.73).

4.1.3.7. Total sugar content

Total sugar content of the fruit was found highest (22.78%) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by the plants treated with vermi compost + AZ, PSB & KSB (21.67%) compared with control (15.76%) in main crop, however, in case of ratoon crop maximum total sugar content (19.78%) was recorded in T_9 (vermi compost + AZ, PSB & KSB) followed by T_{11} (18.87%) against control (14.56%) (Table 4.1.17).

4.1.3.8. Reducing sugar content

From the data presented at Table 4.1.17, it was found that the reducing sugar content of the fruit was maximum (19.12%) in T_{11} (poultry manure + AZ, PSB & KSB) followed by T_9 (18.62%) compared with control (13.96%) for main crop. For the ratoon crop, maximum reducing sugar content (16.81%) was recorded in fruit from the plants under T_9 (vermi compost + AZ, PSB & KSB) followed by T_{11} (16.78%) against control (12.13%).

4.1.3.9. Protein content

It was evident from the Table 4.1.17 that for both main and ratoon crop, the highest fruit protein content (13.11 and 12.51 mg/g) was recorded in case of the fruits from T_9

Table 4.1.17: Effect of organic nutrition on total sugar content, reducing sugar and protein content of fruits of main and ratoon crop in banana

Treatments	Total Sugar (%)		Reducing Sugar (%)		Protein (mg g^{-1})	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	18.95	16.82	16.42	14.41	11.12	10.08
T_2 - Vermi compost	20.18	17.94	17.18	15.25	12.22	11.92
T_3 - Neem Cake	19.63	16.98	16.72	14.72	11.69	11.44
T_4 - Poultry Manure	20.72	17.86	17.35	14.98	12.37	11.94
T_5 - *Azotobacter*	17.89	15.96	15.34	13.18	10.85	10.62
T_6 - Phosphate Solubilizing Bacteria	17.17	15.12	14.93	12.56	10.72	10.25
T_7 - Potash Solubilizing Bacteria	18.56	15.82	15.83	13.42	10.92	10.76
T_8 - FYM +AZ+PSB+ KSB	21.09	18.28	18.14	15.46	12.54	12.15
T_9 - VC +AZ+PSB+ KSB	21.67	19.78	18.62	16.81	13.11	12.51
T_{10} - NC +AZ+PSB+ KSB	21.16	18.34	18.21	15.75	12.67	12.19
T_{11} - PM +AZ+PSB+ KSB	22.78	18.87	19.12	16.78	12.72	12.36
T_{12} - AZ+PSB+ KSB	18.78	16.42	16.17	13.85	10.96	10.85
T_{13} - Control	15.76	14.56	13.96	12.13	10.08	9.80
SEm±	**0.9781**	**0.2728**	**0.3808**	**0.2983**	**0.2206**	**0.5580**
CD at 5%	**2.8551**	**0.7963**	**1.1115**	**0.8707**	**0.6439**	**1.6288**

Table 4.1.18: Effect of organic nutrition on starch content, amylose and carbohydrate content of fruits of main and ratoon crop in banana

Treatments	Starch (mg/g)		Amylose (%)		Carbohydrate (g/ 100)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	10.22	9.84	23.42	22.67	25.46	23.56
T_2 - Vermi compost	10.34	9.97	23.85	22.99	26.28	24.30
T_3 - Neem Cake	10.28	9.85	23.75	22.84	25.84	23.74
T_4 - Poultry Manure	10.46	10.20	24.51	23.17	26.54	24.41
T_5 - Azotobacter	9.73	9.68	22.77	22.05	24.27	22.60
T_6 - Phosphate Solubilizing Bacteria	9.69	9.60	22.56	22.01	23.78	22.32
T_7 - Potash Solubilizing Bacteria	9.81	9.79	23.13	22.49	24.84	22.95
T_8 - FYM +AZ+PSB+ KSB	10.47	10.39	24.68	23.18	26.78	24.67
T_9 - VC +AZ+PSB+ KSB	10.84	11.02	24.79	24.61	28.76	26.64
T_{10} - NC +AZ+PSB+ KSB	10.71	10.51	24.71	23.33	27.39	25.28
T_{11} - PM +AZ+PSB+ KSB	11.18	10.57	24.82	23.78	28.24	25.83
T_{12} - AZ+PSB+ KSB	10.19	9.80	23.31	22.65	24.98	23.12
T_{13} - Control	9.53	9.16	21.41	21.04	23.12	21.72
SEm±	**0.2553**	**0.1059**	**0.5208**	**0.2863**	**0.3931**	**0.4213**
CD at 5%	**0.7453**	**0.3090**	**1.5201**	**0.8357**	**1.1474**	**1.2298**

(vermi compost + AZ, PSB & KSB) followed by T_{11} (12.72 and 12.36 mg/g) compared with control (10.08 and 9.80 mg/g).

4.1.3.10. Starch content

From the present study it was clear that starch content of the banana fruits varied significantly among the treatment both in main as well as in ratoon crop. For main crop, maximum starch content (11.18 mg/g) was found in T_{11} (poultry manure + AZ, PSB & KSB) followed by T_9 (10.84 mg/g) compared with control (9.53 mg/g). However, in ratoon crop, maximum fruit starch (11.02 mg/g) was recorded in T_9 (vermi compost + AZ, PSB & KSB) followed by T_{11} (10.57 mg/g) and T_{10} (10.51 mg/g) compared with control (9.16 mg/g) (Table 4.1.18).

4.1.3.11. Amylose content

Table 4.1.18 showed that the amylose content of the banana fruit varied significantly across the treatments for both main and ratoon crop. It was found that amylose content was maximum (24.82%) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by T_9 (24.79%) against control (21.41%) for the main crop; whereas, it was found maximum (24.61%) in case of the plants treated with vermi compost + AZ, PSB & KSB (T_9) followed by T_{11}(23.78%) compared with control (21.04%) for the ratoon crop.

4.1.3.12. Total carbohydrate content

Perusal of the data presented at Table 4.1.18 revealed that total carbohydrate content of the banana fruit got significant variation due to different organic nutrient treatments. For both main and ratoon crops, maximum amount of fruit carbohydrate content (28.76 and 26.64 g/100g) was found in case of the plants treated with vermi compost +AZ, PSB & KSB (T_9) followed by the plants treated with poultry manure + AZ, PSB & KSB (28.24 and 25.83 g/100g) compared with control (23.12 and 21.72 g/100g).

4.1.4. Soil analysis

Soil analysis was done to measure soil pH, organic carbon, nitrogen, phosphorus, potassium, iron, manganese, copper, zinc and C:N ratio.

4.1.4.1. Soil pH

Application of organic inputs had caused significant variation in soil pH under different treatment in the present study. It was observed that in case of main crop, the soil pH was lowest (4.96) in control whereas, it was found highest (5.85) in case of the plants treated with neem cake + AZ, PSB & KSB (T_{10}) followed by the plants treated with poultry manure + AZ, PSB & KSB (5.84). For the ratoon crop, soil pH was recorded maximum in T_{11} (6.12) followed by T_{10} (6.03) compared with control (4.95) (Table 4.1.19).

4.1.4.2 Soil organic carbon

Perusal of the data presented in Table 4.1.19 revealed that organic carbon content of the soil under different treatments got significant variation. For both main and ratoon crop, it was found highest (1.02% and 0.94%) in T_{11} (Poultry manure + AZ, PSB & KSB) followed by T_{10} (0.96% and 0.89%) compared with control (0.28% and 0.25%).

4.1.4.3. Soil nitrogen (N)

Data presented in Table 4.1.20 and Fig. 4.1.19 manifested that nitrogen content of soil varied significantly due to different organic nutrition treatments. For the main crop,

Table 4.1.19: Effect of organic nutrition on soil pH and soil organic carbon content of main and ratoon crop in banana

Treatments	Soil pH		Organic Carbon (%)	
	Main Crop	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**
T_1 - Farm Yard Manure	5.58	5.62	0.65	0.59
T_2 - Vermi compost	5.64	5.68	0.68	0.62
T_3 - Neem Cake	5.68	5.69	0.76	0.71
T_4 - Poultry Manure	5.72	5.78	0.78	0.73
T_5 - Azotobacter	5.35	5.37	0.40	0.38
T_6 - Phosphate Solubilizing Bacteria	5.17	5.19	0.31	0.28
T_7 - Potash Solubilizing Bacteria	5.21	5.24	0.34	0.31
T_8 - FYM +AZ+PSB+ KSB	5.78	5.81	0.89	0.83
T_9 - VC +AZ+PSB+ KSB	5.81	5.89	0.92	0.85
T_{10} - NC +AZ+PSB+ KSB	5.85	6.03	0.96	0.89
T_{11} - PM +AZ+PSB+ KSB	5.84	6.12	1.02	0.94
T_{12} - AZ+PSB+ KSB	5.48	5.49	0.42	0.39
T_{13} - Control	4.96	4.95	0.28	0.25
SEm±	**0.0611**	**0.1165**	**0.0310**	**0.0421**
CD at 5%	**0.1783**	**0.3402**	**0.0906**	**0.1229**

Table 4.1.20: Effect of organic nutrition on soil nitrogen, phosphorus and potassium content of main and ratoon crop in banana

Treatments	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	948.67	919.87	47.12	43.16	784.52	756.87
T_2 - Vermi compost	985.73	956.47	58.86	52.37	821.37	804.39
T_3 - Neem Cake	1097.34	1071.32	62.34	56.78	849.78	811.27
T_4 - Poultry Manure	1104.62	1089.78	68.67	61.32	864.38	825.48
T_5 - Azotobacter	598.47	572.38	41.26	35.32	564.34	534.58
T_6 - Phosphate Solubilizing Bacteria	491.23	473.48	43.54	37.72	546.16	512.35
T_7 - Potash Solubilizing Bacteria	523.46	508.97	40.28	34.68	596.45	583.48
T_8 - FYM +AZ+PSB+ KSB	1254.41	1232.46	74.24	69.43	896.52	881.28
T_9 - VC +AZ+PSB+ KSB	1276.54	1246.94	76.54	71.38	960.34	945.67
T_{10} - NC +AZ+PSB+ KSB	1296.81	1267.87	88.32	80.29	981.67	978.45
T_{11} - PM +AZ+PSB+ KSB	1345.78	1321.38	87.21	82.48	986.78	982.35
T_{12} - AZ+PSB+ KSB	627.21	609.34	45.13	39.24	672.45	656.78
T_{13} - Control	474.43	457.89	37.28	32.41	489.75	471.23
SEm±	**22.6857**	**20.0178**	**1.6516**	**1.5127**	**10.6405**	**10.7329**
CD at 5%	**66.2181**	**58.4308**	**4.8209**	**4.4154**	**31.0590**	**31.3286**

soil nitrogen content was recorded maximum (1345.78 Kg/ha) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by the plants treated with neem cake + AZ, PSB & KSB (1296.81 Kg/ha) compared with control (474.43 Kg/ha). Similarly, in case of ratoon crop, nitrogen content of the experimental soil was found highest in T_{11} (1321.38 Kg/ha) followed by T_{10} (1267.87 Kg/ha) against control (457.89 Kg/ha).

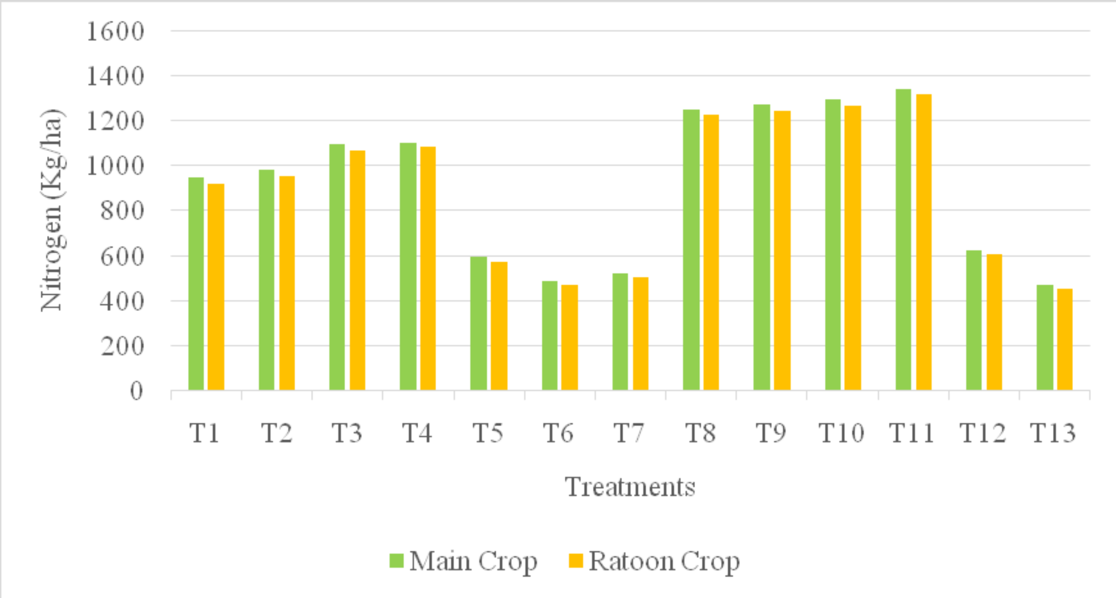


Figure 4.1.19: Effect of organic nutrition on soil nitrogen content of the main and ratoon crop in banana

4.1.4.4. Soil phosphorus (P)

Soil phosphorus content varied significantly among the different treatments. Table 4.1.20 suggested that for main crop, phosphorus content of soil was found maximum (88.32 Kg/ha) under T_{10} (neem cake + AZ, PSB & KSB) followed by T_{11} (87.21 Kg/ha) compared with control (37.28 Kg/ha). In case of ratoon crop, soil phosphorus content recorded highest in T_{11} (82.48 Kg/ha) followed by T_{10} (80.29 Kg/ha) against control (32.41 Kg/ha).

4.1.4.5. Soil potassium (K)

It was evident from the data presented at Table 4.1.20 that for both main and ratoon crop soil potassium content was recorded maximum (986.78 and 982.35 Kg/ha) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by plants treated with neem cake + AZ, PSB & KSB (T_{10}; 981.67 and 978.45 Kg/ha) compared with control (489.75 and 471.23 Kg/ha).

4.1.4.6. Soil iron (Fe)

Data presented at Table 4.1.21 manifested that soil iron content was recorded highest (112.78 and 104.56 mg/Kg) in control for both main and ratoon crops, whereas, it was recorded lowest (102.85 mg/Kg) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by T_{10} (103.78 mg/Kg) in main crop and for ratoon crop, it was found minimum (95.79 mg/Kg) in T_{10} (neem cake + AZ, PSB & KSB) followed by T_{11} (95.98 mg/Kg).

4.1.4.7. Soil manganese (Mn)

Manganese content in experimental soil varied significantly among the different treatments under study (Table 4.1.21). For both main and ratoon crop, it was found that plants treated with neem cake + AZ, PSB & KSB (T_{10}) had maximum soil manganese (58.15 and 56.78 mg/kg) followed by plants treated with poultry manure + AZ, PSB & KSB (T_{11}, 53.06 and 52.82 mg/Kg) compared with control (36.58 and 34.74 mg/Kg).

4.1.4.8. Soil copper (Cu)

It was found that maximum soil copper content (1.57 mg/Kg) was recorded in case of the plants at T_{11} (poultry manure + AZ, PSB & KSB) followed by T_{10} (1.49 mg/Kg)

Table 4.1.21: Effect of organic nutrition on soil iron (Fe), manganese (Mn) and copper (Cu) content of main and ratoon crop in banana

Treatments	Fe (mg/Kg)		Mn (mg/Kg)		Cu (mg/Kg)	
	Main Crop	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**
T_1 - Farm Yard Manure	106.85	98.43	43.21	41.63	1.12	1.01
T_2 - Vermi compost	105.36	96.48	44.18	42.37	1.27	1.17
T_3 - Neem Cake	104.98	98.25	45.04	44.12	1.32	1.21
T_4 - Poultry Manure	104.67	97.89	45.24	44.75	1.34	1.24
T_5 - Azotobacter	108.27	100.57	39.76	38.21	1.05	0.86
T_6 - Phosphate Solubilizing Bacteria	111.32	102.34	38.73	35.48	0.98	0.84
T_7 - Potash Solubilizing Bacteria	109.94	101.32	39.44	36.72	1.02	0.82
T_8 - FYM +AZ+PSB+ KSB	104.12	97.24	49.76	48.81	1.42	1.27
T_9 - VC +AZ+PSB+ KSB	103.98	96.19	50.07	49.56	1.45	1.32
T_{10} - NC +AZ+PSB+ KSB	103.78	95.79	58.15	56.78	1.49	1.42
T_{11} - PM +AZ+PSB+ KSB	102.85	95.98	53.06	52.82	1.57	1.38
T_{12} - AZ+PSB+ KSB	107.72	99.73	40.61	39.78	1.09	0.83
T_{13} - Control	112.78	104.56	36.58	34.74	0.92	0.76
SEm±	**0.5044**	**0.3730**	**0.4658**	**0.5011**	**0.0494**	**0.0564**
CD at 5%	**1.4724**	**1.0888**	**1.3595**	**1.4626**	**0.1441**	**0.1646**

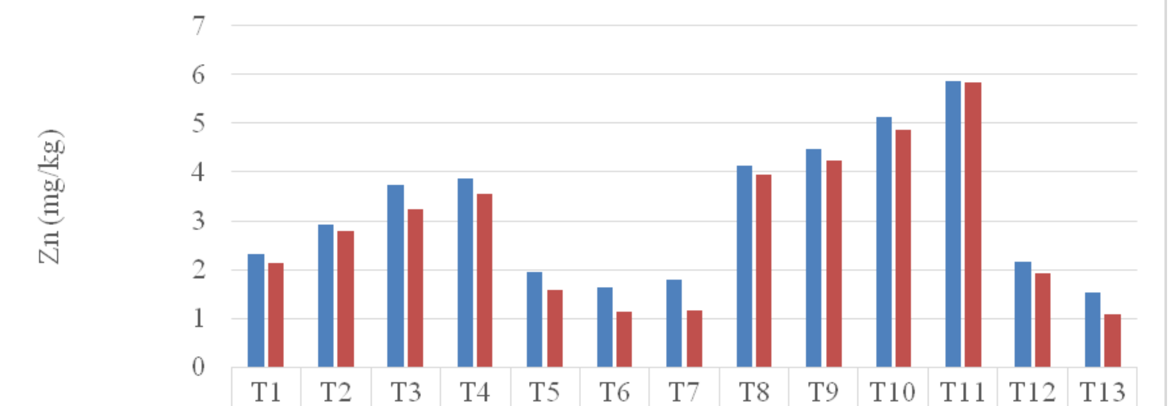
Table 4.1.22: Effect of organic nutrition on soil zinc (Zn) and Carbon: Nitrogen (C:N) ratio of main and ratoon crop in banana

Treatments	Zn (mg/kg)		C:N ratio	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	2.32	2.12	15.35	14.37
T_2 - Vermi compost	2.92	2.78	15.45	14.52
T_3 - Neem Cake	3.74	3.23	15.51	14.85
T_4 - Poultry Manure	3.86	3.54	15.82	15.00
T_5 - Azotobacter	1.96	1.57	14.97	14.87
T_6 - Phosphate Solubilizing Bacteria	1.64	1.12	14.14	13.25
T_7 - Potash Solubilizing Bacteria	1.79	1.15	14.55	13.64
T_8 - FYM +AZ+PSB+ KSB	4.12	3.95	15.89	15.09
T_9 - VC +AZ+PSB+ KSB	4.47	4.24	16.14	15.27
T_{10} - NC +AZ+PSB+ KSB	5.12	4.87	16.58	15.72
T_{11} - PM +AZ+PSB+ KSB	5.86	5.83	16.98	15.93
T_{12} - AZ+PSB+ KSB	2.17	1.91	15.00	14.34
T_{13} - Control	1.53	1.07	13.22	12.23
SEm±	**0.1231**	**0.1313**	**0.3645**	**0.1514**
CD at 5%	**0.3594**	**0.3831**	**1.0641**	**0.4420**

compared with control (0.92 mg/Kg) in main crop. For the ratoon crop, plants treated with neem cake + AZ, PSB & KSB (T_{10}) recorded the maximum soil copper (1.42 mg/Kg) followed by T_{11} (1.38 mg/Kg) against control (0.76 mg/kg) (Table 4.1.21).

4.1.4.9. Soil zinc (Zn)

Perusal of the data presented at Table 4.1.22 and Fig.4.1.20 revealed that for both main and ratoon crop, soil zinc content was recorded highest (5.86 and 5.83 mg/Kg) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by plants treated with neem cake + AZ, PSB & KSB (T_{10}; 5.12 and 4.87 mg/Kg) compared with control (1.53 and 1.07 mg/Kg).



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13
Main Crop	2.32	2.92	3.74	3.86	1.96	1.64	1.79	4.12	4.47	5.12	5.86	2.17	1.53
Ratoon Crop	2.12	2.78	3.23	3.54	1.57	1.12	1.15	3.95	4.24	4.87	5.83	1.91	1.07

Figure 4.1.20: Effect of organic nutrition on soil zinc content of the main and ratoon crop in banana

4.1.4.10. Soil organic carbon: nitrogen (C:N) ratio

Organic carbon and nitrogen ratio (C:N) was varied significantly among the different treatments (Table 4.1.22 and Fig.4.1.21). For both main and ratoon crop, it was found maximum (16.98 and 15.93) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by T_{10} (16.58 and 15.72) compared with control (13.22 and 12.23).

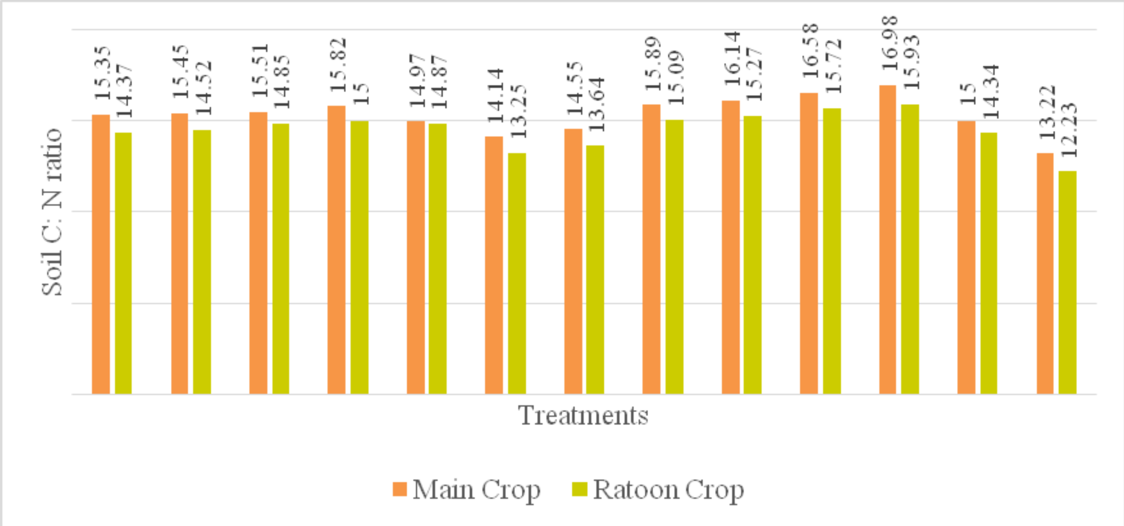


Figure 4.1.21: Effect of organic nutrition on soil organic carbon : nitrogen (C:N) ratio content of the main and ratoon crop in banana

4.1.5. Leaf analysis

Leaf analysis was done to measure leaf nitrogen, phosphorus, potassium, iron, manganese, copper, zinc, carbohydrate content and carbohydrate with nitrogen ratio.

4.1.5.1. Leaf nitrogen (N)

Data presented in Table 4.1.23 and Fig. 4.1.22 suggested that nitrogen content in leaf varied significantly among the different treatments. For the main crop, it was found that the plants treated with poultry manure along with biofertilizers (AZ, PSB & KSB) had highest leaf nitrogen content (2.24%) followed by the plants treated with neem cake along with AZ, PSB & KSB (2.21%) compared with control (1.39%). Similarly, in case of ratoon crops also plants at T_{11} (Poultry manure + AZ, PSB & KSB) had maximum leaf nitrogen (2.19%) followed by T_{10} (2.16%) compared with control (1.17%).

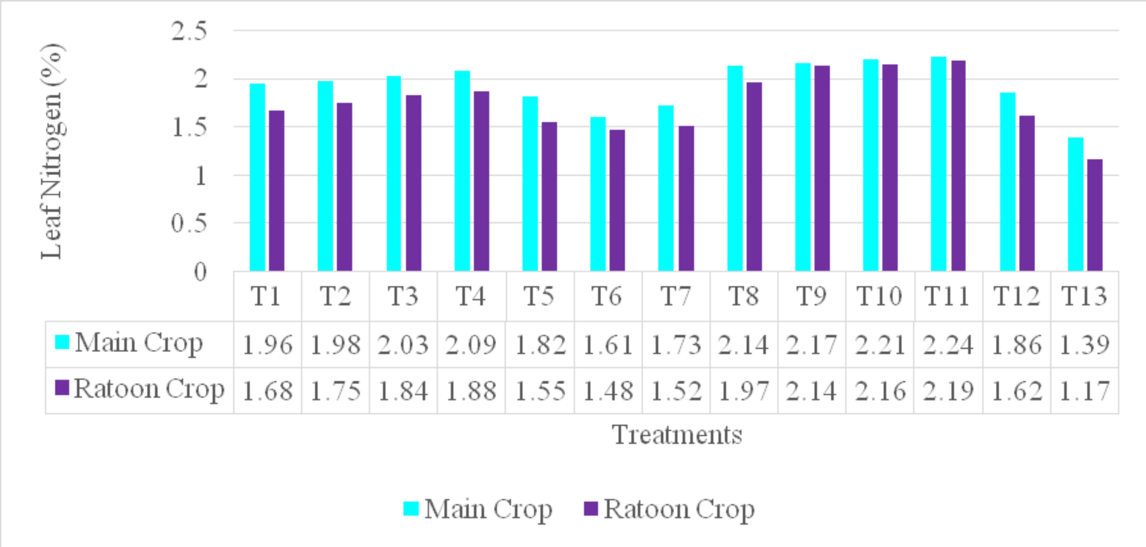


Figure 4.1.22: Effect of organic nutrition on leaf nitrogen content of the main and ratoon crop in banana

4.1.5.2. Leaf phosphorus (P)

Result of the present study revealed that phosphorus content of leaf got decreased in ratoon crop than in main crop for all the treatments. It was found that the leaf phosphorus content ranged between 0.14% to 0.38% in main crop which got reduced and ranged between 0.11% to 0.29% in ratoon crop (Table 4.1.23). For the main crop, highest leaf phosphorus content (0.38%) was recorded in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by the plants treated with neem cake + AZ, PSB & KSB (T_{10}: 0.34%) compared with control (0.14%) whereas, in ratoon crop highest leaf phosphorus content was found in T_{10} (0.29%) followed by T_{11} (0.26) against control (0.11%).

4.1.5.3. Leaf potassium (K)

Perusal of the data presented in Table 4.1.23 and Fig. 4.1.23 revealed that leaf potassium content significantly varied both in main and ratoon crops under the different treatments. In case of main crop, leaf potassium was recorded highest (2.83%) in case of the plants treated with poultry manure along with biofertilizers viz.

AZ, PSB & KSB (T_{11}) followed by the plants treated with neem cake and biofertilizers (T_{10}: 2.74%) and vermi compost along with biofertilizers (2.68%) compared with control (T_9: 1.26%). Similarly, in ratoon crop, leaf potassium content was found highest in T_{11} (2.81%) followed by the plants treated with neem cake along with biofertilizers (T_{10}: 2.65%) and farmyard manure along with biofertilizers (T_8: 2.43%) compared with control (1.18%).

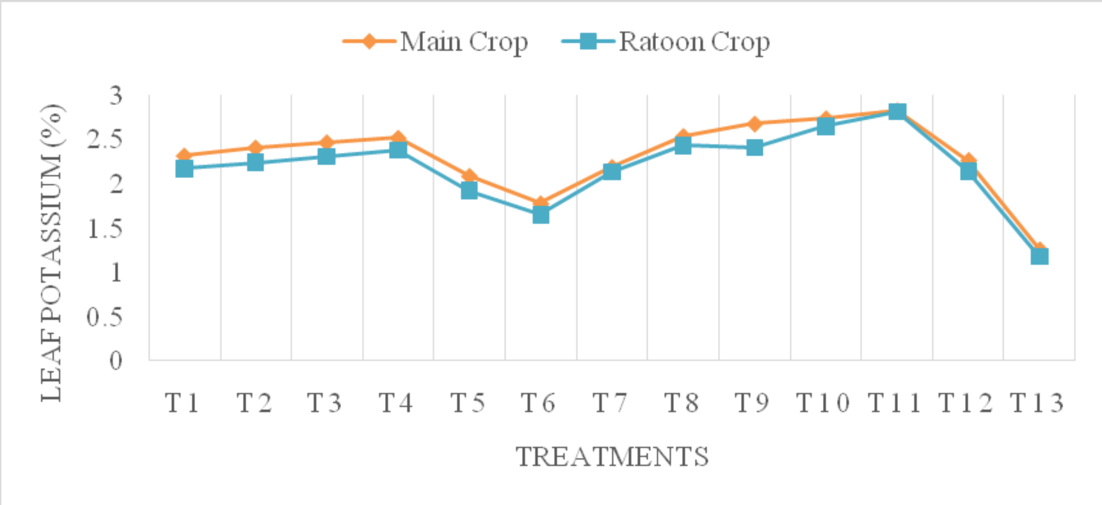


Figure 4.1.23: Effect of organic nutrition on leaf potassium content of the main and ratoon crop in banana

4.1.5.4. Leaf iron (Fe)

Iron content of the banana leaves got significant variation among the treatments. For the main crop, highest leaf iron content was recorded in plants at control (181.23 ppm) whereas, it was recorded minimum (117.72 ppm) in case of the plants treated with poultry manure along with AZ, PSB & KSB (T_{11}) followed by T_{10} (119.28 ppm) (Table 4.1.24). In case of ratoon crop, leaf iron content was found minimum in case of the plants treated with neem cake along with biofertilizers viz. AZ, PSB & KSB (112.37 ppm) compared with control (176.52 ppm).

Table 4.1.23: Effect of organic nutrition on leaf nitrogen, phosphorus and potassium content of main and ratoon crop in banana

Treatments	Leaf Nitrogen (%)		Leaf Phosphorus (%)		Leaf Potassium (%)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	1.96	1.68	0.19	0.16	2.32	2.17
T_2 - Vermi compost	1.98	1.75	0.22	0.18	2.41	2.24
T_3 - Neem Cake	2.03	1.84	0.24	0.19	2.47	2.31
T_4 - Poultry Manure	2.09	1.88	0.27	0.19	2.52	2.38
T_5 - Azotobacter	1.82	1.55	0.16	0.14	2.09	1.92
T_6 - Phosphate Solubilizing Bacteria	1.61	1.48	0.17	0.12	1.78	1.65
T_7 - Potash Solubilizing Bacteria	1.73	1.52	0.16	0.13	2.19	2.13
T_8 - FYM +AZ+PSB+ KSB	2.14	1.97	0.29	0.21	2.54	2.43
T_9 - VC +AZ+PSB+ KSB	2.17	2.14	0.31	0.22	2.68	2.41
T_{10} - NC +AZ+PSB+ KSB	2.21	2.16	0.34	0.29	2.74	2.65
T_{11} - PM +AZ+PSB+ KSB	2.24	2.19	0.38	0.26	2.83	2.81
T_{12} - AZ+PSB+ KSB	1.86	1.62	0.18	0.15	2.27	2.14
T_{13} - Control	1.39	1.17	0.14	0.11	1.26	1.18
SEm±	**0.0701**	**0.0417**	**0.0116**	**0.0068**	**0.0518**	**0.0629**
CD at 5%	**0.2047**	**0.1217**	**0.0339**	**0.0198**	**0.1511**	**0.1836**

Table 4.1.24: Effect of organic nutrition on leaf Iron (Fe), Manganese (Mn) and Copper (Cu) content of main and ratoon crop in banana

Treatments	Leaf Fe (ppm)		Leaf Mn (ppm)		Leaf Cu (ppm)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	158.91	156.35	391.21	384.38	5.25	5.12
T_2 - Vermi compost	142.32	138.48	412.84	398.46	5.26	5.78
T_3 - Neem Cake	136.54	131.27	432.35	422.37	5.27	6.04
T_4 - Poultry Manure	135.16	128.62	441.32	425.48	5.36	6.23
T_5 - Azotobacter	172.62	169.34	316.58	312.21	4.39	4.34
T_6 - Phosphate Solubilizing Bacteria	174.65	172.42	304.52	294.38	4.08	4.28
T_7 - Potash Solubilizing Bacteria	173.84	171.28	309.34	298.87	4.13	4.32
T_8 - FYM +AZ+PSB+ KSB	134.82	126.49	474.78	464.37	5.87	6.32
T_9 - VC +AZ+PSB+ KSB	128.36	124.52	519.67	521.34	5.93	6.85
T_{10} - NC +AZ+PSB+ KSB	119.28	112.37	634.58	633.25	6.14	7.45
T_{11} - PM +AZ+PSB+ KSB	117.72	116.26	667.12	632.45	6.84	7.42
T_{12} - AZ+PSB+ KSB	164.32	158.27	327.56	367.54	4.94	4.69
T_{13} - Control	181.23	176.52	298.76	287.45	3.35	3.72
SEm±	**2.3230**	**3.7022**	**5.8707**	**4.9798**	**0.2265**	**0.1192**
CD at 5%	**6.7807**	**10.8065**	**17.1362**	**14.5357**	**0.6611**	**0.3478**

4.1.5.5. Leaf manganese (Mn)

Data presented in Table 4.1.24 manifested that manganese content of banana leaf got significant variation among the treatments. For the main crop, highest leaf manganese was recorded in case of the plants treated with poultry manure plus AZ, PSB & KSB (T_{11}: 667.12 ppm) followed by T_{10} (634.58 ppm) compared with control (298.76 ppm). Whereas, in case of ratoon crop, leaf manganese content was found highest in case of the plant treated with neem cake along with AZ, PSB & KSB (T_{10}: 633.25 ppm) followed by T_{11} (632.45) compared with control (287.45 ppm).

4.1.5.6. Leaf copper (Cu)

It is evident from the data presented in Table 4.1.24 and Fig. 4.1.24, that leaf copper content in banana got significant variation among the different fertilizer treatments. It was found that in case of main crop, leaf copper content was recorded highest (6.84 ppm) for the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed T_{10}

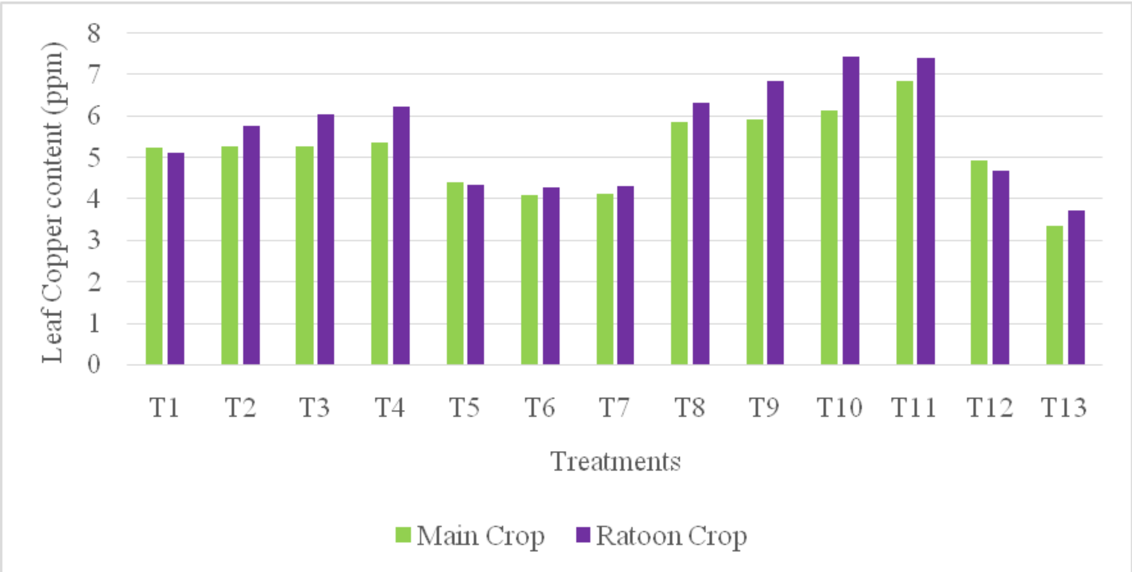


Figure 4.1.24: Effect of organic nutrition on leaf copper content of the main and ratoon crop in banana

(6.14 ppm) compared with control (3.35 ppm). However, in ratoon crop, it was recorded highest in case of the plants treated with neem cake + AZ, PSB & KSB (T_{10}:7.45 ppm) followed by T_{11} (7.42 ppm) compared with control (3.72 ppm).

4.1.5.7. Leaf zinc (Zn)

Perusal of the data presented at Table 4.1.25 suggested that zinc content of the banana leaf got significant variation among the treatments. For the main crop, the highest amount of leaf zinc was found in case of the plants treated with poultry manure along with bio-fertilizers viz. AZ, PSB & KSB (16.19 ppm) followed by the plants treated with neem cake + AZ, PSB & KSB (15.61 ppm) compared with control (11.69 ppm). Whereas, in case of ratoon crop leaf zinc content was found highest (15.36 ppm) in T_{10} i.e. application of neem cake + AZ, PSB & KSB followed by T_{11} (15.07 ppm) against control (11.21 ppm).

4.1.5.8. Leaf carbohydrate

Carbohydrate content of the leaves of banana under the present experiment got significant variation. For the main crop, the highest percentage (7.82%) of leaf carbohydrate was recorded in case of the plants treated with poultry manure + AZ, PSB & KSB (Table 4.1.25). Banana plants treated with neem cake +AZ, PSB & KSB (7.45%) and vermi compost + AZ, PSB & KSB (7.28%) had high leaf carbohydrate percentage compared with control (4.12%). While in case of ratoon crop, leaf carbohydrate content reduced significantly than main crop. It was found that the plants at T_{11} i.e. manured with poultry manure+ AZ, PSB & KSB had highest leaf carbohydrate (7.12%) followed by T_{10} (6.93%) and T_9 (6.78%) compared with control (3.21%).

Table 4.1.25: Effect of organic nutrition on leaf zinc (Zn), carbohydrate content and C:N ratio of main and ratoon crop in banana

Treatments	Leaf Zn (ppm)		Carbohydrate (%)		Carbohydrate:N Ratio	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	12.71	12.24	6.09	5.17	3.11	3.08
T_2 - Vermi compost	13.06	12.35	6.21	5.41	3.14	3.09
T_3 - Neem Cake	13.07	12.51	6.48	5.78	3.19	3.14
T_4 - Poultry Manure	13.14	12.82	6.78	5.94	3.24	3.16
T_5 - Azotobacter	12.43	12.03	5.54	4.61	3.04	2.97
T_6 - Phosphate Solubilizing Bacteria	12.26	11.76	4.81	4.12	2.99	2.78
T_7 - Potash Solubilizing Bacteria	12.38	11.86	5.21	4.34	3.01	2.86
T_8 - FYM +AZ+PSB+ KSB	13.25	12.93	7.01	6.26	3.28	3.18
T_9 - VC +AZ+PSB+ KSB	13.43	13.12	7.28	6.78	3.35	3.17
T_{10} - NC +AZ+PSB+ KSB	15.61	15.36	7.45	6.93	3.37	3.21
T_{11} - PM +AZ+PSB+ KSB	16.19	15.07	7.82	7.12	3.49	3.25
T_{12} - AZ+PSB+ KSB	12.54	12.17	5.74	4.92	3.09	3.04
T_{13} - Control	11.69	11.21	4.12	3.21	2.96	2.74
SEm±	**0.1687**	**0.1367**	**0.1254**	**0.1635**	**0.0398**	**0.0431**
CD at 5%	**0.4924**	**0.3989**	**0.3661**	**0.4773**	**0.1162**	**0.1258**

4.1.5.9. Leaf carbohydrate and nitrogen (C:N) ratio

It was found that the leaf C:N ratio significantly varied among the treatments in main as well as in case of ratoon crops (Table 4.1.25 and Fig. 4.1.25). Leaf C:N ratio was recorded highest in case of the banana plants treated with poultry manure + AZ, PSB & KSB (3.49) followed by the plants treated with neem cake along with AZ, PSB & KSB (3.37) compared with control (2.96) similarly, in case of ratoon crop it was found highest (3.25) in T_{11} i.e. manured with poultry manure and AZ, PSB & KSB followed by T_{10} (3.21) against control (2.74).

Figure 4.1.25: Effect of organic nutrition on leaf carbohydrate: nitrogen ratio of the main and ratoon crop in banana

4.1.6. Soil microbial analysis

Soil samples taken from the rhizosphere were used for microbial count of azotobacter, phosphate solubilising bacteria and potash solubilizers' population. Serial dilution plating method was followed for microbial population count.

4.1.6.1. Azotobacter

Azotobacter count in the soil was gradually got increased from main crop to ratoon crop. The count was significantly high in case of the plants treated with poultry manure + AZ, PSB & KSB; neem cake + AZ, PSB & KSB and vermi compost +AZ, PSB & KSB both in main as well as in ratoon crop soil (Table 4.1.26). For main crop, plants treated with poultry manure + AZ, PSB & KSB had highest Azotobacter count (9.81 X 10^6cfu g^{-1}) followed by plants treated with neem cake + AZ, PSB & KSB (9.68 X 10^6cfu g^{-1}) compared with control (4.72 X 10^6cfu g^{-1}). In ratoon crop, similarly, the soil Azotobacter count was maximum (9.97 X 10^6cfu g^{-1}) in T_{11} followed by T_{10} (9.85X 10^6cfu g^{-1}) against control (4.21X 10^6cfu g^{-1}).

4.1.6.2. Phosphate Solubilizing Bacteria (PSB)

Phosphate Solubilizing Bacteria (PSB) count in the experimental soil varied significantly among the treatments both in main as well as in ratoon crop (Table 4.1.26). For the main crop the soil PSB count was found maximum (7.81 X 10^6cfu g^{-1}) in plants treated with poultry manure +AZ, PSB & KSB (T_{11}) followed by plants treated with neem cake + AZ, PSB & KSB (7.65 X 10^6cfu g^{-1}) compared with control (3.51 X 10^6cfu g^{-1}), whereas, in ratoon crops soil PSB count was highest in T_{10} (7.89 X 10^6cfu g^{-1}) followed by T_{11} (7.84 X 10^6cfu g^{-1}) compared with control (3.22 X 10^6cfu g^{-1}).

4.1.6.2. Potash Solubilizing Bacteria (KSB)

KSB count of soil got significant variation among the different treatments. For the main crop, the KSB count was found highest (7.51 X 10^6cfu g^{-1}) in T_{11} i.e. treated with poultry manure along with bio-fertilizers viz. AZ, PSB & KSB followed by T_{10} (6.89 X 10^6cfu g^{-1}) compared with control (3.06 X 10^6cfu g^{-1}). Similarly, in case of

Table 4.1.26: Effect of organic nutrition on soil Azotobacter(AZ), Phosphate Solubilizing Bacteria (PSB), Potash Solubilizing Bacteria (KSB) count of main and ratoon crop in banana

Treatments	AZ count X 10^6cfu g^{-1}		PSB count X 10^6cfu g^{-1}		KSB count X 10^6cfu g^{-1}	
	Main Crop	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**
T_1 - Farm Yard Manure	5.12	5.01	4.09	3.89	4.18	4.05
T_2 - Vermi compost	5.29	5.11	4.32	3.97	4.32	4.22
T_3 - Neem Cake	5.42	5.32	4.45	4.13	4.67	4.51
T_4 - Poultry Manure	5.87	5.36	4.87	4.35	4.84	4.78
T_5 - Azotobacter	7.58	7.48	3.64	3.23	3.18	3.07
T_6 - Phosphate Solubilizing Bacteria	4.78	4.68	7.03	6.85	3.09	2.98
T_7 - Potash Solubilizing Bacteria	4.82	4.45	3.59	3.14	6.43	6.51
T_8 - FYM +AZ+PSB+ KSB	8.77	8.86	7.26	7.35	6.72	6.97
T_9 - VC +AZ+PSB+ KSB	9.54	9.68	7.62	7.72	6.77	7.04
T_{10} - NC +AZ+PSB+ KSB	9.68	9.85	7.65	7.89	6.89	7.17
T_{11} - PM +AZ+PSB+ KSB	9.81	9.97	7.81	7.84	7.51	7.53
T_{12} - AZ+PSB+ KSB	7.88	7.82	7.18	6.88	6.56	6.47
T_{13} - Control	4.72	4.21	3.51	3.22	3.06	2.74
SEm±	**0.2842**	**0.0915**	**0.2335**	**0.1023**	**0.3098**	**0.1562**
CD at 5%	**0.8296**	**0.2670**	**0.6815**	**0.2986**	**0.9043**	**0.4558**

Table 4.1.27: Cost of cultivation and benefit: cost ratio in organic nutrient management of main and ratoon crop in banana per hectare

Treatments	Gross Expenditure		Gross Income		Net Income		Benefit: Cost Ratio	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Farm Yard Manure	354883.38	232961.23	825925.10	673888.22	471041.72	440926.99	1.33	1.89
T_2 - Vermi compost	436662.75	313730.60	931850.92	797776.98	495188.17	484046.38	1.13	1.54
T_3 - Neem Cake	362648.38	239716.23	1032406.38	862000.00	669758.00	622283.77	1.85	2.60
T_4 - Poultry Manure	238711.33	115779.18	1071480.41	884000.00	832769.08	768220.82	3.49	6.64
T_5 - Azotobacter	194556.30	71624.15	619443.83	393000.00	424887.53	321375.85	2.18	4.49
T_6 - Phosphate Solubilizing Bacteria	194556.30	71624.15	547592.05	359443.99	353035.75	287819.84	1.81	4.02
T_7 - Potash Solubilizing Bacteria	194556.30	71624.15	562962.40	365500.00	368406.10	293875.85	1.89	4.10
T_8 - FYM +AZ+PSB+ KSB	405378.33	282446.18	1125924.80	957776.82	720546.47	675330.64	1.78	2.39
T_9 - VC +AZ+PSB+ KSB	487157.70	364225.55	1216665.45	1059998.94	729507.75	695773.39	1.50	1.91
T_{10} - NC +AZ+PSB+ KSB	413143.33	290211.18	1242591.35	1115554.44	829448.02	825343.26	2.01	2.84
T_{11} - PM +AZ+PSB+ KSB	289206.28	166274.13	1414813.40	1295500.00	1125607.12	1129225.87	3.89	6.79
T_{12} - AZ+PSB+ KSB	228219.60	105287.45	677036.36	568888.32	448816.76	463600.87	1.97	4.40
T_{13} - Control	173179.65	50247.50	504443.94	349000.00	331264.29	298752.50	1.91	5.95

ratoon crop, the KSB count was recorded highest in T_{11}(7.53X 10^6cfu g^{-1}) compared with control (2.74X 10^6cfu g^{-1}) (Table 4.1.26).

4.1.7. Cost benefit analysis

The gross expenditure, gross income for different treatments along net return was calculated considering the present rates of field worker wages, manures, fertilizers, biofertilizers, plant protection botanicals and market sale value of the harvested fruits and the net out turn per rupee of investment was worked out for one hectare and in case of the present experiment, the gross expenditure was found highest in case of the plants treated with vermi compost along with bio-fertilizers viz. AZ, PSB & KSB for both main crop (Rs.487157.70) and in ratoon crop (Rs.364225.55) compared with control (Rs.173179.65 in main crop and Rs.50247.50 in ratoon crop).

Gross income was found highest in case of the plants treated with poultry manure along with bio-fertilizers viz. AZ, PSB & KSB both in main crop (Rs.1414813.40) and ratoon crop (Rs.1295500.00) compared with control (Rs.504443.94 in main and Rs.349000.00 in ratoon crop). Similarly, the net income was found highest in case of the plants treated with poultry manure + AZ, PSB & KSB in main (Rs.1125607.12) and ratoon crop (Rs.1129225.87) compared with control (main crop: Rs.331264.29 and ratoon crop: Rs.298752.50).

In case of main crop, the benefit: cost ratio was found maximum (3.89) in case of the plants treated with poultry manure + AZ, PSB & KSB (T_{11}) followed by T_4 (3.49) whereas, it was found minimum (1.13) in case of the plants treated with vermi compost (T_2). In ratoon crop, the benefit: cost ratio was highest (6.79) in T_{11} while it was minimum (1.54) in plants treated with vermi compost (T_2). However, the benefit:cost ratio which was calculated low (1.91) , was reasonably found high (5.95) in ratoon crop for plants at control (Table 4.1.27).

Experiment 2: Intercropping in Banana

4.2. Results

4.2.1. Plant growth and development

Following plant growth and development parameters like pseudostem height, pseuodstem girth, phyllocron, number of functional leaves, leaf area, leaf area index, sucker production were recorded both for main as well as ratoon crop at different stages of plant growth viz. at small (90 days after planting), large (150 days after planting), shooting and harvesting stages. Furthermore, parameters like total leaf production, days taken for shooting, shooting to harvesting and crop duration as influenced by different treatments were also recorded.

4.2.1.1. Pseudostem height

Results from the study on different intercropping treatments in banana showed significant variation in pseudostem height. In case of the main crop, it was found that at small stage pseudostem height was maximum (92.75 cm) in T_5 (banana intercropped with brinjal + cabbage), whereas, it was recorded minimum (88.20 cm) in T_3 (banana intercropped with colocasia) (Table 4.2.1). Pseudostem height at large and shooting stage was found highest (215.70 cm and 250.52 cm) in T_6 (banana intercropped with chilli + broccoli) while, it was found lowest (204.88 cm and 239.78 cm) in T_3 (banana intercropped with colocasia). Again, at harvesting, the pseudostem height was recorded maximum (262.43 cm) in T_6 (banana intercropped with chilli + broccoli) against T_3 (banana intercropped with colocasia) which was recorded minimum (258.70 cm).

Table 4.2.1: Effect of different intercropping treatments on pseudostem height of main and ratoon crop in banana

Treatments	Pseudostem Height (cm)							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Banana intercropped with ginger	90.05	205.84	243.39	259.56	86.78	198.78	230.58	243.81
T_2 - Banana intercropped with turmeric	89.90	205.05	242.90	258.91	85.32	194.27	229.71	242.37
T_3 - Banana intercropped with colocasia	88.20	204.88	239.78	258.70	83.47	191.23	226.48	239.41
T_4 - Banana intercropped with cowpea + french bean	90.33	210.70	248.43	260.62	87.28	199.75	232.48	246.32
T_5 - Banana intercropped with brinjal + cabbage	92.75	214.77	250.45	261.58	89.31	202.45	242.52	251.68
T_6 - Banana intercropped with chilli + broccoli	91.00	215.70	250.52	262.43	88.46	203.48	241.37	254.78
T_7 - Control (No intercrop, only banana plants)	90.30	205.90	247.43	259.93	89.76	201.48	235.76	245.72
SEm±	**0.4330**	**0.3565**	**0.3298**	**0.1887**	**0.4026**	**0.3810**	**0.4162**	**0.5675**
CD at 5%	**1.3345**	**1.0987**	**1.0162**	**0.5815**	**1.2406**	**1.1741**	**1.2826**	**1.7487**

For ratoon crop, plants at control had maximum pseudostem height (89.76 cm) followed by plants at T_5 (89.31 cm) compared with T_3 (banana intercropped with colocasia) which got the minimum pseudostem height (83.47 cm) at small stage. Ratooned banana plants at large stage showed maximum pseudostem height (203.48 cm) in T_6 (banana intercropped with chilli + broccoli) whereas, at shooting stage it was scored highest (242.52 cm) in T_5 (banana intercropped with brinjal + cabbage) and for both the stages, pseudostem height was found minimum (191.23 cm and 226.48 cm) in T_3 (banana intercropped with colocasia). At harvesting stage, maximum pseudostem height (254.78 cm) was observed in T_6 followed by T_5 (251.68 cm) and it was found minimum (239.41 cm) in T_3.

4.2.1.2. Pseudostem girth

It is evident from the Table 4.2.2; Fig. 4.2.1and 4.2.2 that pseudostem girth of banana plants got significant variation across different stages both for main as well as in case of ratoon crop under different intercropping treatments. In case of main crop, it was found that at small stage the pseudostem girth was recorded maximum (38.12 cm) in T_6 (banana intercropped with chilli + broccoli) followed by T_4 i.e. banana intercropped with cowpea + french bean (37.07 cm), whereas, it was minimum (35.21 cm) in T_3 (banana intercropped with colocasia). Banana plants intercropped with cowpea and french bean (T_4) had maximum pseudostem girth (63.77 cm) compared with T_3 (banana intercropped with colocasia) which had scored minimum (60.51 cm) at large stage. At shooting stage, pseudostem girth was recorded maximum (70.16 cm) in T_5 (banana intercropped with brinjal + cabbage) followed by T_6 (69.86 cm) whereas, it was found minimum (65.67 cm) in T_3 (banana intercropped with colocasia). Banana plants intercropped with chilli + broccoli (T_6) had maximum

Table 4.2.2: Effect of different intercropping treatments on pesudostem girth of main and ratoon crop in banana

Treatments	Pseudostem Girth (cm)							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Banana intercropped with ginger	36.65	63.10	68.42	70.67	34.29	59.34	65.16	68.92
T_2 - Banana intercropped with turmeric	36.11	62.12	66.18	68.34	33.38	58.92	65.23	67.87
T_3 - Banana intercropped with colocasia	35.21	60.51	65.67	66.67	32.52	58.21	64.52	67.34
T_4 - Banana intercropped with cowpea + french bean	37.07	63.77	69.68	73.08	34.87	60.25	67.18	69.43
T_5 - Banana intercropped with brinjal + cabbage	37.00	63.36	70.16	73.19	36.95	61.94	69.17	71.28
T_6 - Banana intercropped with chilli + broccoli	38.12	63.33	69.86	74.83	35.42	62.12	68.34	72.97
T_7 - Control (No intercrop, only banana plants)	36.84	63.21	69.32	72.13	36.25	59.87	65.78	68.82
SEm±	**0.3513**	**0.2396**	**0.3464**	**0.3049**	**0.4572**	**0.4394**	**0.3414**	**0.3597**
CD at 5%	**1.0825**	**0.7382**	**1.0676**	**0.9394**	**1.4090**	**1.3540**	**1.0521**	**1.1085**

pseudostem girth (74.83 cm) compared with T_3 (banana intercropped with colocasia) which had minimum (66.67 cm) at harvesting stage.

In case of ratoon crop, at small stage, maximum pseudostem girth (36.95 cm) was found in T_5 (banana intercropped with brinjal + cabbage) whereas it was recorded minimum (32.52 cm) in T_3 (banana intercropped with colocasia).

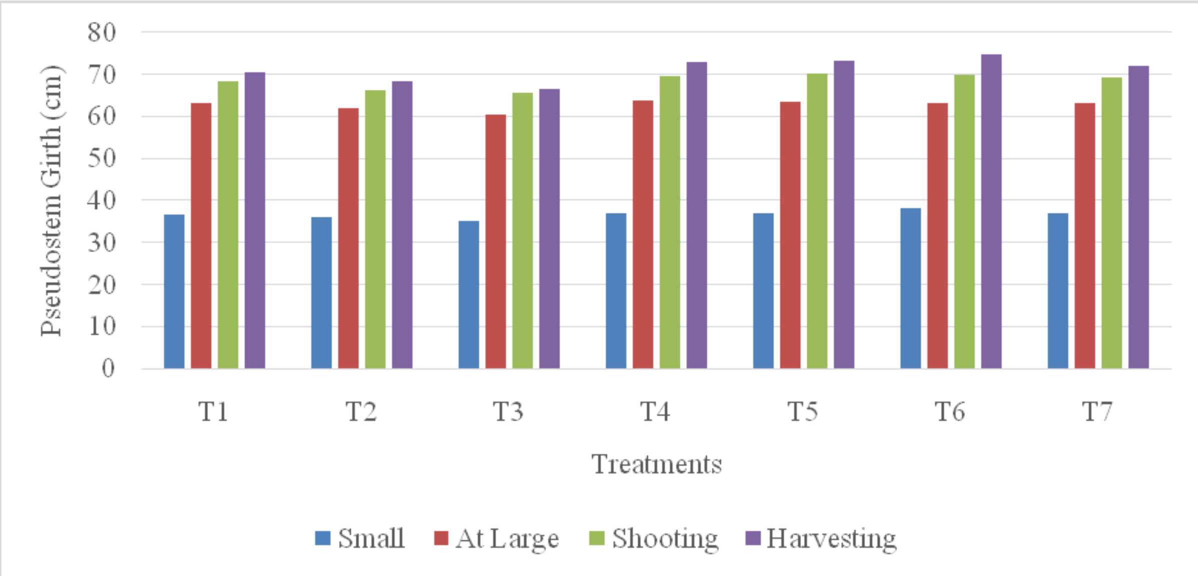


Figure 4.2.1: Effect of intercropping treatments on pseudostem girth of main crop in banana

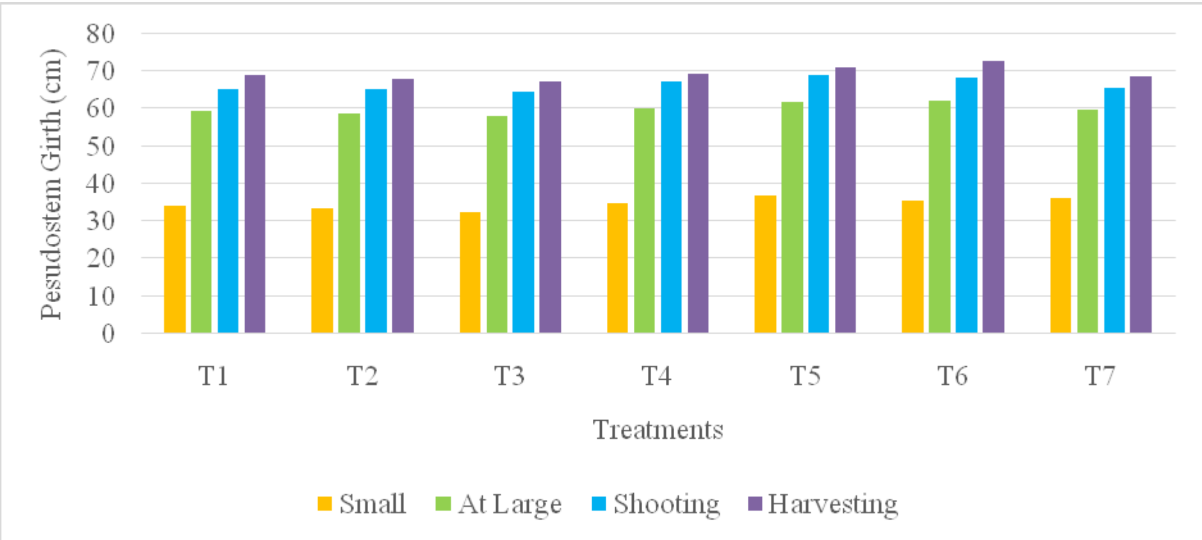


Figure 4.2.2: Effect of intercropping treatments on pseudostem girth of ratoon crop in banana

At large stage, pseudostem girth was found maximum (62.12 cm) in T_6 whereas it was minimum in T_3 (58.21 cm). Banana intercropped with brinjal + cabbage (T_5) has maximum pesudostem girth (69.17 cm) at shooting stage, while plants at T_3 had minimum (64.52 cm) pseudostem girth. Further, at harvesting stage, banana plants intercropped with chilli + broccoli (T_6) had highest pesudostem girth (72.97 cm) compared with T_3 (banana intercropped with colocasia) where it was recorded lowest (67.34 cm).

4.2.1.3. Phyllocron

Significant variation in phyllocron value (days) was observed in main as well as in ratooned banana plants under different intercropping treatments. For the main crop, banana plants intercropped with colocasia (T_3) had highest phyllocron value for all the stages viz. small (9.32 days), large (8.25 days) and shooting (9.02 days), respectively. However, banana plants intercropped with chilli + broccoli (T_6) had minimum phyllocron value at small (7.13 days) and shooting (8.21 days) stage (Table 4.2.3). Whereas, intercropping banana plants with brinjal + cabbage (T_5) had minimum phyllocron (6.56 days) at large stage.

Similarly, for ratoon crop, highest phyllocron value was recorded in case of the banana plants intercropped with colocasia (T_3) for small (8.67 days), large (7.62 days) and shooting (8.56 days) stage. However, lowest phyllocron value was recorded in case of banana plants intercropped with brinjal and chilli (T_5) at small stage (6.73 days), while it was lowest for the banana plants intercropped with chilli +broccoli (T_6) at large (5.98 days) and shooting stage (7.52 days).

Table 4.2.3: Effect of different intercropping treatments on phyllocron of main and ratoon crop in banana

Treatments	Phyllocron (Days)					
	Main Crop			Ratoon Crop		
	Small	At Large	Shooting	Small	At Large	Shooting
T_1 - Banana intercropped with ginger	8.85	7.84	8.70	8.31	7.18	8.21
T_2 - Banana intercropped with turmeric	9.08	8.12	8.74	8.42	7.56	8.32
T_3 - Banana intercropped with colocasia	9.32	8.25	9.02	8.67	7.62	8.56
T_4 - Banana intercropped with cowpea + french bean	8.09	7.12	8.38	7.52	6.58	7.61
T_5 - Banana intercropped with brinjal + cabbage	7.42	6.56	8.25	6.73	6.23	7.65
T_6 - Banana intercropped with chilli + broccoli	7.13	6.94	8.21	6.85	5.98	7.52
T_7 - Control (No intercrop, only banana plants)	8.37	7.23	8.43	7.81	6.67	7.92
SEm±	**0.1397**	**0.3234**	**0.0832**	**0.0950**	**0.0851**	**0.1426**
CD at 5%	**0.4306**	**0.9965**	**0.2564**	**0.2928**	**0.2623**	**0.4394**

Table 4.2.4: Effect of different intercropping treatments on number of leaves of main and ratoon crop in banana

Treatments	Number of functional leaves							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Banana intercropped with ginger	6.12	9.90	13.03	8.56	5.79	8.23	12.02	7.12
T_2 - Banana intercropped with turmeric	5.78	8.78	12.60	7.94	5.35	8.19	11.33	6.78
T_3 - Banana intercropped with colocasia	5.34	8.54	12.07	7.38	4.92	8.09	11.30	6.47
T_4 - Banana intercropped with cowpea + french bean	6.82	10.21	13.57	9.87	6.12	8.68	12.22	9.12
T_5 - Banana intercropped with brinjal + cabbage	6.87	10.73	13.75	10.32	6.52	9.04	12.34	9.44
T_6 - Banana intercropped with chilli + broccoli	7.23	10.53	13.77	10.74	6.32	9.24	12.52	10.02
T_7 - Control (No intercrop, only banana plants)	6.65	10.03	13.17	9.21	5.96	8.48	12.17	8.26
SEm±	**0.1887**	**0.2225**	**0.1084**	**0.2136**	**0.2382**	**0.1960**	**0.2304**	**0.1981**
CD at 5%	**0.5814**	**0.6855**	**0.3340**	**0.6583**	**0.7341**	**0.6041**	**0.7100**	**0.6105**

4.2.1.4 Number of functional leaves

Data enumerated in Table 4.2.4; Fig. 4.2.3 and 4.2.4 clearly showed that the number of leaves got significant variation among the intercropping treatments.

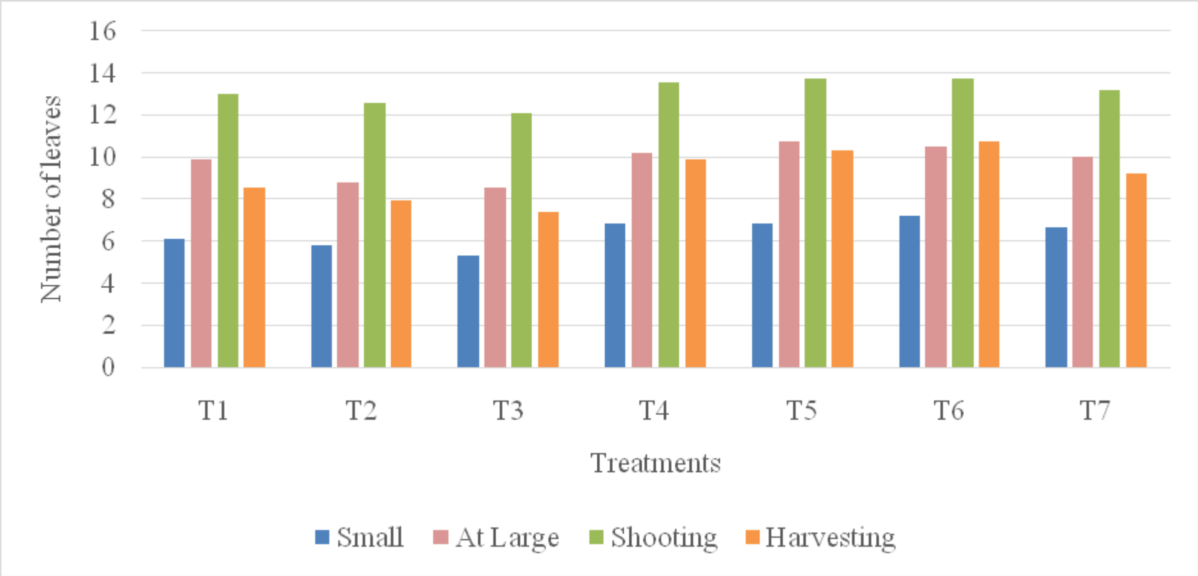


Figure 4.2.3: Effect of intercropping treatments on number of functional leaves of main crop in banana

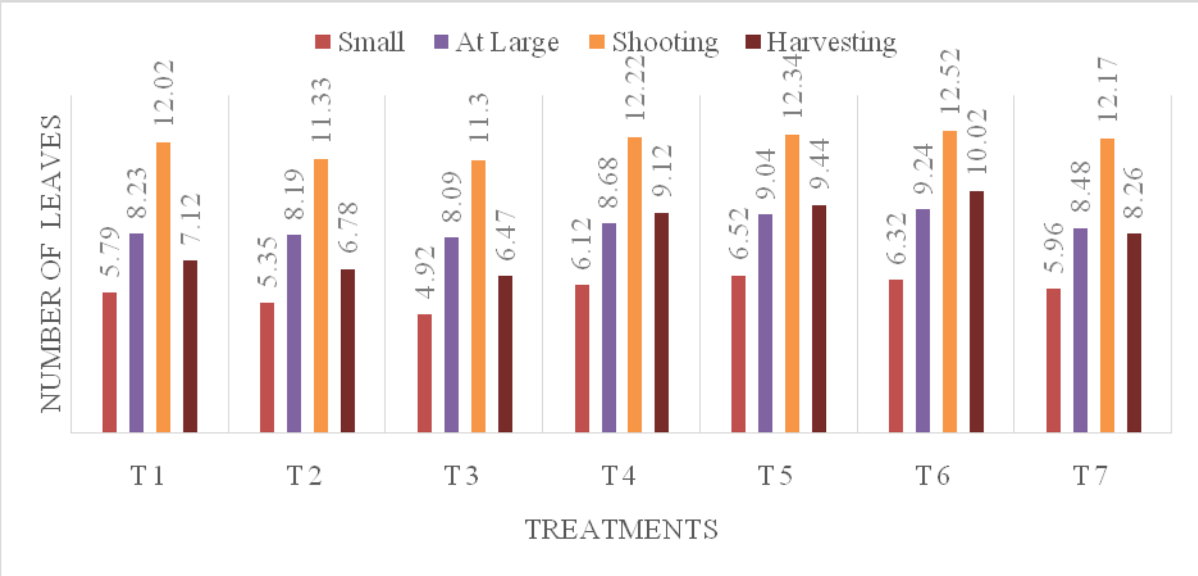


Figure 4.2.4: Effect of intercropping treatments on number of functional leaves of ratoon crop in banana

For the main crop, at small stage it was found that highest number of functional leaves (7.23) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by intercropping with brinjal and cabbage (T_5: 6.87). During banana plants at large, the highest number of leaves (10.73) was recorded in case of the banana plants intercropped with brinjal and cabbage (T_5). However, for both shooting and harvesting stage, it was found that the banana plants intercropped with chilli and broccoli had maximum number of functional leaves (13.77 and 10.74, respectively). For all the growth stages, banana plants inter cropped with colocasia (T_3) had minimum number of functional leaves (small: 5.34, at large: 8.54, shooting: 12.07, harvesting: 7.38).

For the ratoon crop, at small stage highest number of functional leaves (6.52) were found for the banana plants intercropped with brinjal and cabbage (T_5). Whereas, at large, shooting and harvesting stage; banana plants intercropped with chilli and broccoli (T_6) had highest number of functional leaves (at large: 9.24, shooting: 12.52 and harvesting:10.02; respectively). Whereas the ratoon banana plants intercropped with colocasia (T_3) had the least number of leaves at small (4.92), large (8.09), shooting (11.30) and harvesting stage (6.47), respectively.

4.2.1.5. Total leaves production

For both main and ratoon crop, total leaves production was recorded highest (34.67 and 32.23) in banana plants intercropped with chilli and broccoli (T_6), followed by intercropping with brinjal and cabbage (main crop: 33.18, ratoon crop: 31.74), and cowpea and french bean (main crop: 32.27, ratoon crop: 30.55). Whereas total number of leaves was found lowest (main crop: 26.78, ratoon crop: 24.85) in case of the

Table 4.2.5: Effect of different intercropping treatments on total leaf production of main and ratoon crop in banana

Treatments	Total Leaf Production (No.)	
	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	29.61	27.46
T_2 - Banana intercropped with turmeric	27.12	25.75
T_3 - Banana intercropped with colocasia	26.78	24.85
T_4 - Banana intercropped with cowpea + french bean	32.27	30.55
T_5 - Banana intercropped with brinjal + cabbage	33.18	31.74
T_6 - Banana intercropped with chilli + broccoli	34.67	32.23
T_7 - Control (No intercrop, only banana plants)	31.06	28.89
SEm±	**0.3573**	**0.6029**
CD at 5%	**1.1009**	**1.8579**

Table 4.2.6: Effect of different intercropping treatments on leaf area of main and ratoon crop in banana

Treatments	Leaf Area (m^2)							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Banana intercropped with ginger	4.26	8.85	10.32	9.78	3.66	8.06	9.94	9.32
T_2 - Banana intercropped with turmeric	4.19	8.79	9.98	8.93	3.62	7.87	9.52	8.47
T_3 - Banana intercropped with colocasia	3.98	7.97	9.54	8.21	3.49	7.38	9.17	8.02
T_4 - Banana intercropped with cowpea + french bean	4.41	9.25	11.61	10.01	3.89	8.37	10.74	9.76
T_5 - Banana intercropped with brinjal + cabbage	4.56	9.43	11.82	10.61	4.11	8.52	11.13	10.08
T_6 - Banana intercropped with chilli + broccoli	4.49	9.51	11.96	10.82	4.09	8.68	11.42	10.12
T_7 - Control (No intercrop, only banana plants)	4.35	8.85	11.16	9.96	3.75	8.19	10.38	9.48
SEm±	**0.0556**	**0.1163**	**0.3911**	**0.1752**	**0.1142**	**0.0674**	**0.1506**	**0.0994**
CD at 5%	**0.1715**	**0.3583**	**1.2052**	**0.5399**	**0.3518**	**0.2077**	**0.4640**	**0.3064**

banana plants intercropped with colocasia (T_3) both for main crop and ratoon condition (Table 4.2.5).

4.2.1.6. Leaf area

Perusal of the data presented in Table 4.2.6; Fig. 4.2.5 and 4.2.6 showed that leaf area of the banana plants got significant variation under different intercropping treatments. In case of the main crop, at small stage, it was found that the banana plants intercropped with brinjal and cabbage recorded maximum leaf area (4.56 m^2) followed by the plants intercropped with chilli + broccoli (T_6: 4.49 m^2) compared with the plants intercropped with colocasia (T_3: 3.98 m^2). At large stage, leaf area was recorded highest at T_6 (9.51 m^2) followed by T_5 (9.43 m^2) compared with T_3 (7.97 m^2). Similarly, at shooting and harvesting stage, leaf area was found maximum in T_6 (11.96 m^2, 10.82 m^2) followed by T_5 (11.82 m^2, 10.61 m^2) compared with T_3 (9.54 m^2, 8.21 m^2).

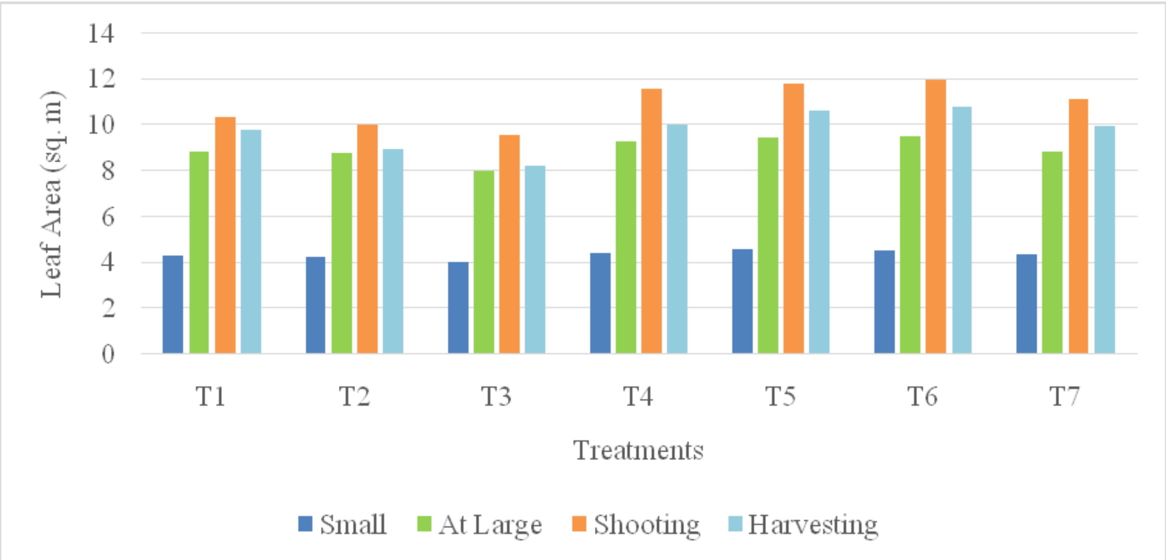


Figure 4.2.5: Effect of intercropping treatments on leaf area of main crop in banana

At ratoon crop condition, the leaf area was recorded highest (4.11 m^2) in case of the banana plants intercropped with brinjal and cabbage (T_5) compared with other treatments at small stage. However, banana plants intercropped with chilli and broccoli had maximum leaf area at large (8.68 m^2), shooting (11.42 m^2) and harvesting (10.12 m^2) stage compared with the banana plants intercropped with colocasia (at large: 7.38 m^2, shooting: 9.17 m^2 and harvesting stage: 8.02 m^2).

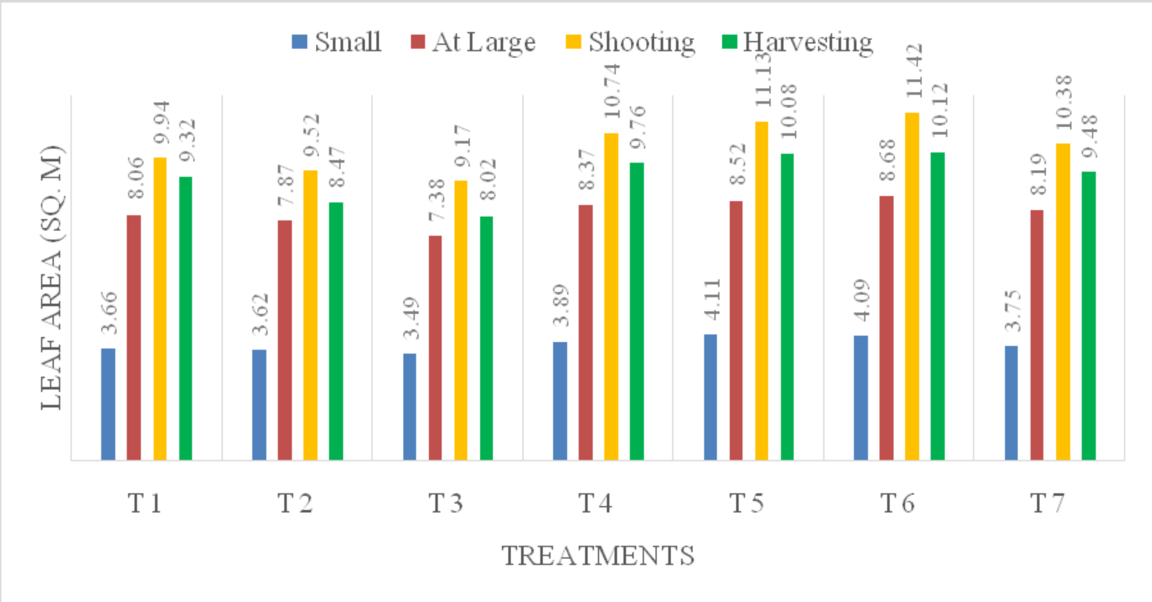


Figure 4.2.6: Effect of intercropping treatments on leaf area of ratoon crop in banana

4.2.1.7. Leaf area index

Leaf area index of banana leaves had significant variation under different intercropping treatments (Table 4.2.7). For the main crop, at small stage, leaf area index was found maximum (1.48) in case of the banana plants intercropped with brinjal+ cabbage (T_5) followed by plants intercropped with chilli + broccoli (T_6: 1.41) compared with the banana plants intercropped with colocasia (T_3: 1.19). Whereas, banana plants intercropped with chilli + broccoli had maximum leaf area index at large (3.15), shooting (3.96) and harvesting (3.58) stage compared with T_3 (at large: 2.59, shooting: 3.14 and harvesting: 2.72, respectively).

Table 4.2.7: Effect of different intercropping treatments on leaf area index of main and ratoon crop in banana

Treatments	Leaf Area Index							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Banana intercropped with ginger	1.28	2.81	3.21	3.19	1.21	2.65	3.18	3.02
T_2 - Banana intercropped with turmeric	1.21	2.76	3.18	2.91	1.18	2.58	3.12	2.72
T_3 - Banana intercropped with colocasia	1.19	2.59	3.14	2.72	1.12	2.41	2.89	2.49
T_4 - Banana intercropped with cowpea + french bean	1.38	3.02	3.84	3.32	1.28	2.72	3.51	3.18
T_5 - Banana intercropped with brinjal + cabbage	1.48	3.12	3.91	3.49	1.34	2.82	3.67	3.27
T_6 - Banana intercropped with chilli + broccoli	1.41	3.15	3.96	3.58	1.32	2.91	3.78	3.32
T_7 - Control (No intercrop, only banana plants)	1.32	2.89	3.64	3.28	1.22	2.68	3.38	3.08
SEm±	**0.0431**	**0.0556**	**0.1334**	**0.0800**	**0.0263**	**0.0736**	**0.0770**	**0.0875**
CD at 5%	**0.1329**	**0.1714**	**0.4110**	**0.2464**	**0.0811**	**0.2269**	**0.2374**	**0.2696**

Table 4.2.8: Effect of different intercropping treatments on days taken for shooting,shooting to harvesting interval and crop duration of main and ratoon crop in banana

Treatments	Days Taken for Shooting		Shooting to Harvesting Interval (Days)		Crop Duration (days)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	290.89	284.76	89.37	87.12	380.26	369.74
T_2 - Banana intercropped with turmeric	294.01	288.52	91.53	89.33	385.54	378.92
T_3 - Banana intercropped with colocasia	296.15	289.37	94.40	92.17	390.55	381.95
T_4 - Banana intercropped with cowpea + french bean	282.87	275.38	87.80	84.73	370.67	358.18
T_5 - Banana intercropped with brinjal + cabbage	279.15	269.83	86.17	81.67	365.32	344.17
T_6 - Banana intercropped with chilli + broccoli	271.59	263.46	84.73	82.33	356.32	345.29
T_7 - Control (No intercrop, only banana plants)	287.59	282.18	88.12	86.33	375.71	362.92
SEm±	**2.5049**	**1.9578**	**1.010**	**0.7214**	**3.4520**	**2.0676**
CD at 5%	**7.7189**	**6.0330**	**3.112**	**2.2230**	**10.6375**	**6.3715**

For the ratoon crop, it was found that the banana plants intercropped with brinjal + cabbage (T_5) had maximum leaf area index (1.34) followed by intercropping with chilli + broccoli (T_6: 1.32) compared with the banana plants intercropped with colocasia (T_3: 1.12) during small stage. Whereas banana plants intercropped with chilli + broccoli (T_6) had maximum leaf are index at large (2.91), shooting (3.78) and harvesting (3.32) stage, respectively. Banana plants intercropped with colocasia (T_3) had minimum leaf area index at large (2.41), shooting (2.89) and harvesting (2.49) stage, respectively.

4.2.1.8. Days taken for shooting

Table 4.2.8 and Fig. 4.2.7 clearly showed that days taken for shooting got significant variation among the banana plants under different intercropping treatments. It was found that for the main crop as well as for the ratoon crop banana plants intercropped with colocasia (T_3) had taken maximum number of days (main crop: 296.15 , ratoon crop: 289.37) for shooting. Whereas for main and ratoon crop, it was found minimum (main crop: 271.59 days, ratoon crop: 263.46 days) in case of the banana plants intercropped with chilli and broccoli (T_6) followed by the plants intercropped with brinjal and cabbage (T_5; main crop: 279.15 days, ratoon crop: 269.83 days).

4.2.1.9. Shooting to harvesting interval

In the present experiment it was observed that shooting to harvesting interval got significant variation among the banana plants under different intercropping treatments. For both main and ratoon crop, the interval was found minimum number of days (main crop 84.73 and ratoon crop: 82.33) for the banana plants intercropped with chilli+broccoli (T_6) followed by the intercropping treatment with brinjal+cabbage (T_5; main crop: 86.17 days and ratoon crop: 81.67 days). However, banana plants intercropped with colocasia (T_3) had maximum days interval between shooting to harvesting both for main (94.40 days) as well as ratoon crop (92.17 days) (Table 4.2.8).

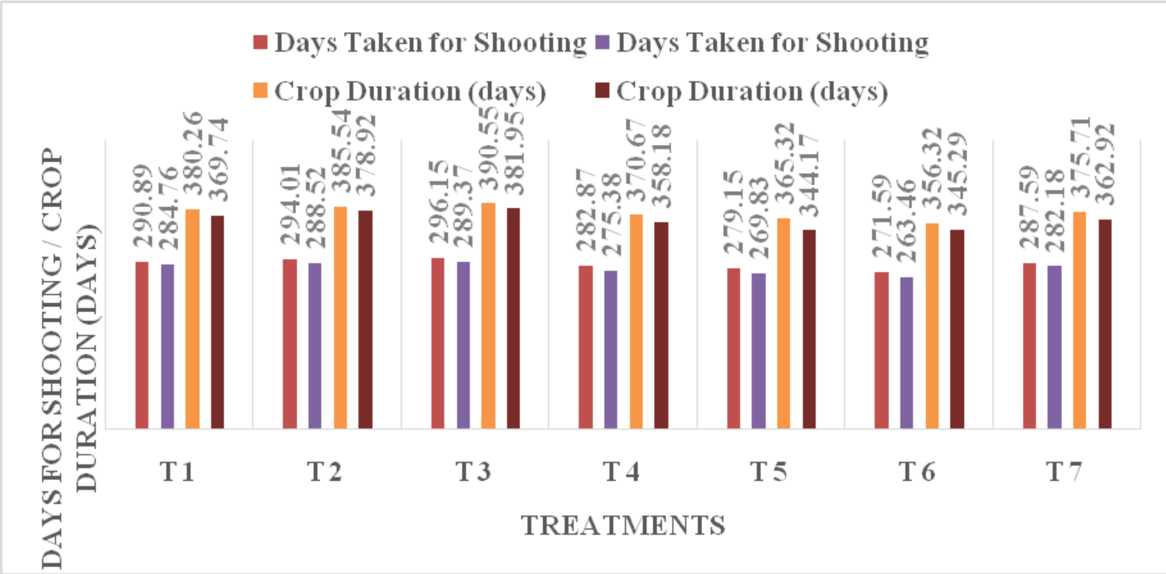


Figure 4.2.7: Effect of intercropping treatments on days for shooting and crop duration in main and ratoon crop in banana

4.2.1.10. Crop duration

Present intercropping experiment in banana revealed that the total duration of crop varied significantly among the different treatments. It was found that the banana plants intercropped with colocasia (T_3) had maximum duration of crop both in main (390.55 days) as well as in ratoon crop (381.95 days) condition (Table 4.2.8 and Fig. 4.2.7). Crop duration for both main and ratoon crop, was found minimum (main crop: 356.32 days and ratoon crop: 345.29 days) in case of the banana plants intercropped with chilli + broccoli (T_6). Besides, the banana plants intercropped with brinjal + cabbage (T_5) also had low crop duration for main (365.32 days) and ratoon crop conditions (345.29 days).

4.2.1.11. Sucker production

Number of suckers per plant in banana was highly varied under different intercropping treatments for main and for the ratoon crop condition (Table 4.2.9). For the main crop, during small stage, four of the intercropping treatments did not show any development of suckers *viz.* banana intercropped with ginger, intercropped with turmeric, intercropped with colocasia and control. Whereas it was also very less (ranging between 0.11 to 0.22) for other three intercropping treatments *i.e.* cowpea + french bean; brinjal + cabbage and chilli + broccoli, at this stage. For the main crop, maximum number of sucker production was recorded in case of the banana plants intercropped with chilli + broccoli (T_6) for rest of the stages viz. at large (3.09), shooting (7.56) and at harvesting stage (10.22). Banana intercropped with colocasia (T_3) had minimum number of suckers per plant at these stages (large:1.92, shooting: 4.67, harvesting: 8.45).

For the ratoon crop, during small stage, there was no significant variation in number of suckers per plant under different intercropping treatments. At large stage, banana plants intercropped with chilli+broccoli (T_6) had maximum number of suckers per plant (2.83) compared with the banana plants intercropped with colocasia (T_3: 1.68). Banana plants intercropped with brinjal and cabbage (T_5) had highest number of suckers per plants in shooting (4.48) as well as at harvesting stage (6.19) whereas, it was found lowest in case of the banana plants intercropped with colocasia (T_3: shooting 3.74, harvesting: 4.62) at these stages.

4.2.1.12. Total biomass

For the main crop, total biomass content of banana plant was found maximum (75.25 Kg) in case of the plants intercropped with chilli + broccoli (T_6) followed by

Table 4.2.9: Effect of different intercropping treatments on sucker production of main and ratoon crop in banana

Treatments	Sucker production (Number)							
	Main Crop				Ratoon Crop			
	Small	At Large	Shooting	Harvesting	Small	At Large	Shooting	Harvesting
T_1 - Banana intercropped with ginger	0.00	2.33	6.44	9.11	0.00	2.12	3.89	4.89
T_2 - Banana intercropped with turmeric	0.00	2.09	5.22	8.78	0.00	1.87	3.83	4.78
T_3 - Banana intercropped with colocasia	0.00	1.92	4.67	8.45	0.00	1.68	3.74	4.62
T_4 - Banana intercropped with cowpea + french bean	0.11	2.78	6.78	9.45	0.04	2.57	4.15	5.44
T_5 - Banana intercropped with brinjal + cabbage	0.11	2.89	7.22	9.89	0.07	2.68	4.48	6.19
T_6 - Banana intercropped with chilli + broccoli	0.22	3.09	7.56	10.22	0.11	2.83	4.38	5.89
T_7 - Control (No intercrop, only banana plants)	0.00	2.65	6.67	9.22	0.04	2.36	3.97	5.02
SEm±	**NS**	**0.2459**	**0.2258**	**0.2358**	**NS**	**0.2418**	**0.1431**	**0.1240**
CD at 5%	**-**	**0.7577**	**0.6959**	**0.7266**	**-**	**0.7451**	**0.4409**	**0.3820**

Table 4.2.10: Effect of different intercropping treatments on total biomass, net assimilation rate and harvest index of main and ratoon crop in banana

Treatments	Total Biomass (kg)		Net assimilation rate/NAR (g $m^{-2}day^{-1}$)		Harvest Index (HI)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	71.25	65.87	2.78	2.51	0.25	0.21
T_2 - Banana intercropped with turmeric	70.99	65.12	2.67	2.34	0.24	0.20
T_3 - Banana intercropped with colocasia	70.53	64.38	2.43	2.19	0.21	0.19
T_4 - Banana intercropped with cowpea + french bean	72.04	68.55	3.21	2.98	0.28	0.23
T_5 - Banana intercropped with brinjal + cabbage	73.53	67.61	3.89	3.67	0.27	0.25
T_6 - Banana intercropped with chilli + broccoli	75.25	69.47	4.02	3.83	0.31	0.28
T_7 - Control (No intercrop, only banana plants)	71.40	67.39	3.13	2.87	0.27	0.21
SEm±	**0.6873**	**0.4355**	**0.1080**	**0.1073**	**0.0105**	**0.0059**
CD at 5%	**2.1179**	**1.3420**	**0.3328**	**0.3306**	**0.0322**	**0.0183**

intercropping with brinjal + cabbage (T_5: 73.53 kg) compared with intercropping with colocasia (T_3: 70.53). Whereas in ratoon crop, highest total biomass was observed in T_6 (69.47 kg) followed by the banana plants intercropped with cowpea + french bean (T_4: 68.55 kg) compared with T_3 (64.38 kg) (Table 4.2.10, Fig. 4.2.8).

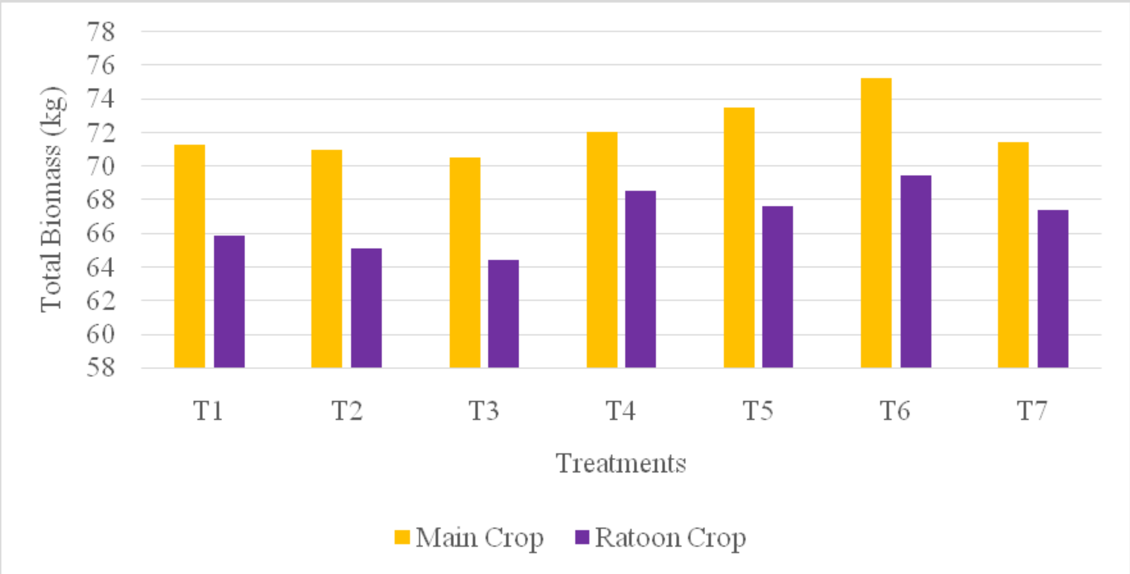


Figure 4.2.8: Effect of intercropping treatments on total biomass in main and ratoon crop in banana

4.2.1.13. Net assimilation rate (NAR)

Net assimilation rate (NAR) varied significantly in banana plants for both main and at ratoon condition under different intercropping treatments (Table 4.2.10). For the main crop, NAR was recorded highest (4.02 $gm^{-2}day^{-1}$) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by intercropping with brinjal +cabbage (T_5: 3.89 $gm^{-2}day^{-1}$) compared with intercropping by colocasia (T_3: 2.43 $gm^{-2}day^{-1}$). Similarly, in ratoon crop, NAR was measured lowest (2.19 $gm^{-2}day^{-1}$) in T_3 compared with T_6 where it was found highest (3.83 $gm^{-2}day^{-1}$).

4.2.1.14. Harvest index

Present experiment revealed that there was significant variation in harvest index under different intercropping treatments in banana. It was found that for both main as well as ratoon crop, the harvest index was recorded highest (main crop: 0.31 and ratoon crop: 0.28) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by intercropping with brinjal and cabbage (T_5, main crop: 0.27, ratoon crop: 0.25) compared with banana plants intercropping with colocasia (T_3, main crop: 0.21, ratoon crop: 0.19) (Table 4.2.10). However, harvest index (0.27) of main crop at control was statistically at par with T_5.

4.2.2. Fruit growth and development

Following parameters of fruit growth and development *viz.* bunch weight, bunch length, hands per bunch, second hand weight, number of fingers per hand, finger length, fingers diameter, finger volume, finger weight and yield were recorded. Furthermore, treatment wise record was made on days taken for ripening after harvest and shelf life.

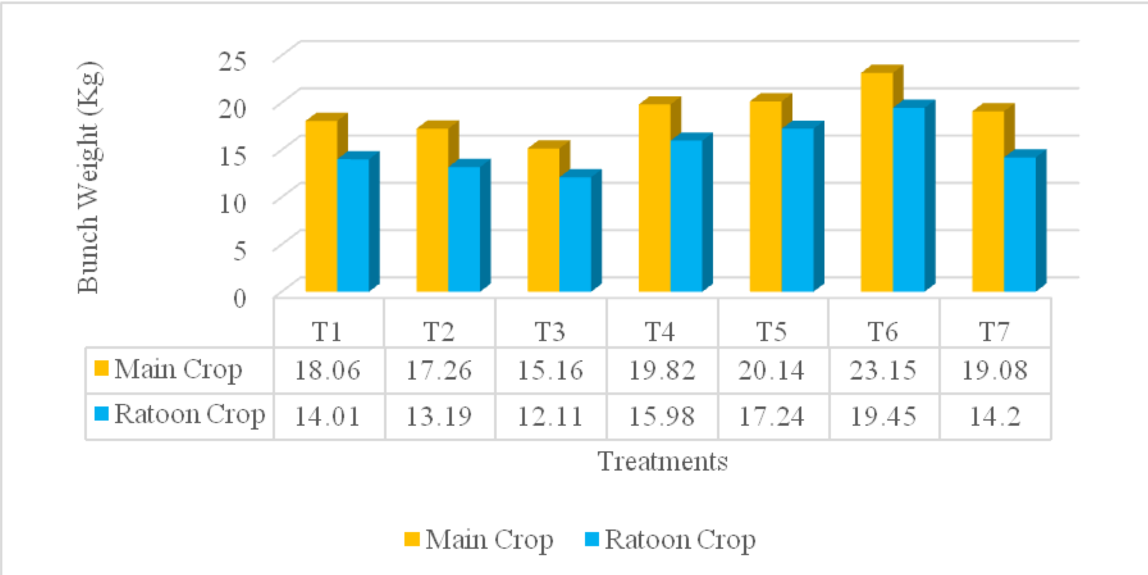


Figure 4.2.9: Effect of intercropping treatments on bunch weight in main and ratoon crop in banana

Table 4.2.11: Effect of different intercropping treatments on bunch weight, bunch length and hands per bunch of main and ratoon crop in banana

Treatments	Bunch Weight (Kg)		Bunch Length (cm)		Hands per Bunch (Number)	
	Main Crop	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**
T_1 - Banana intercropped with ginger	18.06	14.01	99.85	92.81	7.21	6.73
T_2 - Banana intercropped with turmeric	17.26	13.19	96.39	89.08	7.11	6.63
T_3 - Banana intercropped with colocasia	15.16	12.11	94.87	86.72	6.89	6.43
T_4 - Banana intercropped with cowpea + french bean	19.82	15.98	109.67	102.38	7.28	6.97
T_5 - Banana intercropped with brinjal + cabbage	20.14	17.24	117.43	108.27	7.35	7.17
T_6 - Banana intercropped with chilli + broccoli	23.15	19.45	124.21	114.76	7.47	7.11
T_7 - Control (No intercrop, only banana plants)	19.08	14.20	107.82	100.12	7.26	6.78
SEm±	**0.4169**	**0.5060**	**0.6798**	**0.4992**	**0.0815**	**0.1046**
CD at 5%	**1.2846**	**1.5593**	**2.0949**	**1.5383**	**0.2512**	**0.3222**

4.2.2.1. Bunch weight

It is evident from the data presented in Table 4.2.11 and Fig. 4.2.9 that the bunch weight of banana got significant variation among the different intercropping treatments. For the main crop, maximum bunch weight (23.15 Kg) was recorded in case of the banana plants intercropped with chilli + broccoli (T_6) followed by intercropping with brinjal+ cabbage (T_5: 20.14 Kg) compared with the banana plants intercropped with colocasia (T_3) where the bunch weight was recorded minimum (15.16 Kg).

Similarly, for the ratoon crop also the highest bunch weight was found in T_6 (19.45 Kg) followed by T_5 (17.24 Kg) as compared to with T_3 (12.11 Kg).

4.2.2.2. Bunch length

For both main as well as ratoon crop, the maximum length of the fruit bunch (main crop: 124.21 cm, ratoon crop: 114.76 cm) was recorded in case of the banana plants intercropped with chilli + broccoli (T_6) followed by intercropping with brinjal + cabbage (T_5, main crop: 117.43 cm, ratoon crop: 108.27 cm) compared with banana plants intercropped with colocasia (T_3), where the length of the fruit bunch was recorded minimum both in main (94.87 cm) and ratoon crop (86.72 cm) (Table 4.2.11).

4.2.2.3. Hands per bunch

Present experiment on intercropping in banana revealed that the average number of hands per fruit bunch had significant variation among the different treatments. For the main crop, maximum number of hands per fruit bunch (7.47) was recorded in case of the banana plants intercropped with chilli and broccoli (T_6) followed by the plants intercropped with brinjal and cabbage (T_5: 7.35), whereas it was found minimum in case of the banana plants intercropped with colocasia (T_3: 6.89).

In case of ratoon crop, maximum number of hands per bunch (7.17) was found in case of the banana plants intercropped with brinjal and cabbage (T_5) followed by intercropping with chilli and broccoli (T_6: 7.11) compared with intercropping by colocasia where it was found minimum (T_3: 6.43) (Table 4.2.11, Fig. 4.2.10).

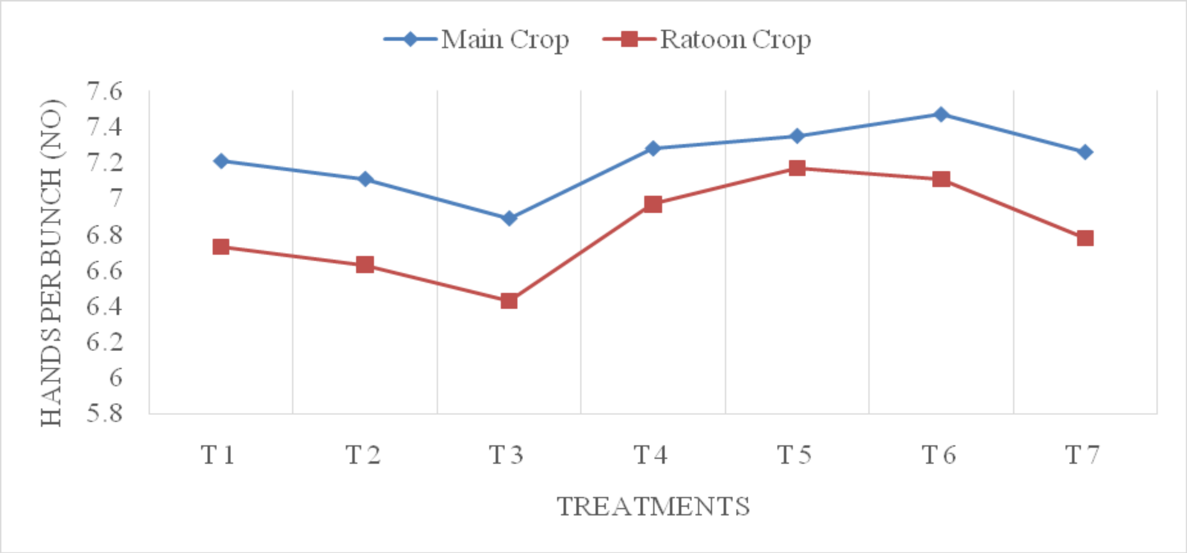


Figure 4.2.10: Effect of intercropping treatments on number of hand per bunch in main and ratoon crop in banana

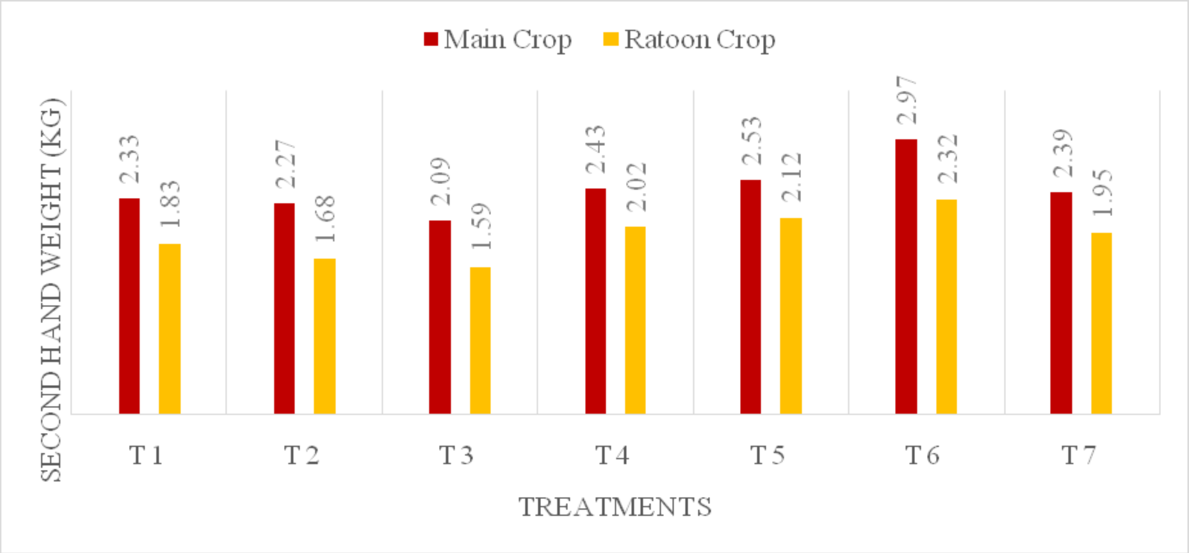


Figure 4.2.11: Effect of intercropping treatments on second hand weight in main and ratoon crop in banana

4.2.2.4. Second hand weight

Perusal of the data presented in the Table 4.2.12 and Fig. 4.2.11 showed that weight of the 2nd most hand from the top of the banana bunch had significant variation among the different intercropping treatments. For the main crop, it was found that the maximum weight of the second most hand of the bunch (2.97 Kg were recorded in banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5: 2.53 Kg), whereas it was found minimum (2.09 Kg) in case of the banana plants intercropped with colocasia (T_3).

For the ratoon crop, similarly maximum weight of the second hand of the fruit bunch (2.32 Kg) was recorded in banana plant intercropped with chilli + broccoli (T_6), whereas it was recorded minimum in banana plants intercropped with colocasia (T_3: 1.59 Kg).

4.2.2.5. Number of fingers per hand

Number of fingers per hand was significantly different among the banana plants under different intercropping treatments (Table 4.2.12). For the main crop, maximum number of fingers per hand (13.57) was recorded in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the plants intercropped with brinjal + cabbage (T_5:12.57). The minimum number of finger per hand (11.17) was recorded in banana plants intercropped with colocasia (T_3).

For the ratoon crop, minimum number of fingers per hand was recorded in T_3 (9.44) whereas, it was found maximum in T_6 (11.89) followed by T_5 (11.33).

4.2.2.6. Finger length

Data presented in Table 4.2.12 manifested that the length of the banana fruit fingers got significant variation under different intercropping treatments. For the main crop, maximum length of the finger (23.67 cm) was recorded in case of the banana plants intercropped with chilli + broccoli (T_6) followed by intercropping with brinjal + cabbage (T_5: 23.10 cm). Fruits from the banana plants intercropped with colocasia (T_3) had minimum length of finger (19.98 cm).

For the ratoon crop, maximum length of finger (21.58 cm) was recorded in the fruits from the banana plants intercropped with brinjal + cabbage (T_5), whereas it was found minimum (17.39 cm) in the banana plants intercropped with colocasia (T_3).

4.2.2.7. Finger diameter

Diameter of the fruit finger had significant variation under different intercropping treatments. For the main crop, maximum diameter of fruit finger (13.48 cm) was recorded in case of the fruits from the banana plants intercropped with chilli + broccoli (T_6) whereas it was found minimum (12.28 cm) in case of the fruit from the banana plants intercropped with colocasia (T_3) (Table 4.2.13).

For the ratoon crop, maximum diameter of finger (12.43 cm) was recorded in case of the fruit from the banana plants intercropped with brinjal + cabbage (T_5) whereas it was recorded minimum (11.23 cm) in case of the fruits from the banana plants intercropped with colocasia (T_3).

Table 4.2.12: Effect of different intercropping treatments on second hand weight, fingers per hand and finger length of main and ratoon crop in banana

Treatments	Second Hand Weight (kg)		Number of fingers per hand		Finger Length (cm)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	2.33	1.83	12.10	10.11	21.12	18.58
T_2 - Banana intercropped with turmeric	2.27	1.68	11.57	9.52	20.17	18.23
T_3 - Banana intercropped with colocasia	2.09	1.59	11.17	9.44	19.98	17.39
T_4 - Banana intercropped with cowpea + french bean	2.43	2.02	12.33	10.89	22.92	19.39
T_5 - Banana intercropped with brinjal + cabbage	2.53	2.12	12.57	11.33	23.10	21.58
T_6 - Banana intercropped with chilli + broccoli	2.97	2.32	13.57	11.89	23.67	20.93
T_7 - Control (No intercrop, only banana plants)	2.39	1.95	12.27	10.67	22.58	19.21
SEm±	**0.1029**	**0.0381**	**0.2973**	**0.2752**	**0.5077**	**0.2359**
CD at 5%	**0.3172**	**0.1173**	**0.9160**	**0.8480**	**1.5645**	**0.7271**

Table 4.2.13: Effect of different intercropping treatments on finger girth, finger volume and finger weight of main and ratoon crop in banana

Treatments	Finger Diameter (cm)		Finger Volume (cc)		Finger Weight (gm)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	12.52	11.72	210.81	199.66	196.58	180.68
T_2 - Banana intercropped with turmeric	12.39	11.54	207.74	192.18	195.62	177.62
T_3 - Banana intercropped with colocasia	12.28	11.23	201.42	182.57	186.24	171.79
T_4 - Banana intercropped with cowpea + french bean	12.83	12.11	213.92	203.13	200.62	186.81
T_5 - Banana intercropped with brinjal + cabbage	13.07	12.43	218.72	206.31	202.60	189.10
T_6 - Banana intercropped with chilli + broccoli	13.48	12.21	219.79	215.46	214.58	207.79
T_7 - Control (No intercrop, only banana plants)	12.75	11.98	221.35	201.60	198.05	183.37
SEm±	**0.0508**	**0.0527**	**3.3910**	**1.2789**	**3.6187**	**1.4036**
CD at 5%	**0.1564**	**0.1623**	**10.4496**	**3.9410**	**11.1512**	**4.3253**

4.2.2.8. Finger volume

Present experiment revealed that volume of finger got significant variation in fruit from the banana plants under different intercropping treatments (Table 4.2.13). For the main crop, highest volume of finger (219.79 cc) was recorded in fruits from the banana plants intercropped with chilli + broccoli (T_6), whereas it was lowest (201.42 cc) in fruits from the banana plants intercropped with colocasia (T_3). Similarly for the ratoon crop, finger volume was recorded maximum (215.46 cc) in T_6 compared with T_3 (182.57 cc).

4.2.2.9. Finger weight

For both main and ratoon crop, it was found that the maximum weight of finger (main crop: 214.58 g; ratoon crop: 207.79 g) was recorded in the fruits from the banana plants intercropped with chilli + broccoli (T_6) followed the banana plants intercropped with brinjal+ cabbage (T_5; main crop: 202.60 g and ratoon crop: 189.10 g) compared with the fruits from the banana plants intercropped with colocasia (T_3) where it was recorded minimum (main crop: 186.24 g and ratoon crop: 171.79 g) (Table 4.2.13, Fig. 4.2.12).

Figure 4.2.12: Effect of intercropping treatments on fruit finger weight in main and ratoon crop in banana

4.2.2.10. Yield

Significant yield variation was observed in banana plants under different intercropping treatments. For the main crop, the yield was found highest (25.72 t ha^{-1}) in case of the banana plants intercropped with chilli + broccoli (T_6), followed by banana plants intercropped with brinjal + cabbage (T_5: 22.38 t ha^{-1}) and cowpea + french bean (T_4: 22.02 t ha^{-1}) compared with the yield of the banana plants intercropped with colocasia (T_3: 16.84 t ha^{-1}).

Similarly, in case of ratoon crop, the highest yield (21.61t ha^{-1}) was obtained in case of the banana plants intercropped with chilli + broccoli (T_6) followed by T_5 (19.16 t ha^{-1}) and T_4 (17.76 t ha^{-1}) compared with T_3 (13.46 t ha^{-1}) where it was found lowest (Table 4.2.14, Fig. 4.2.13).

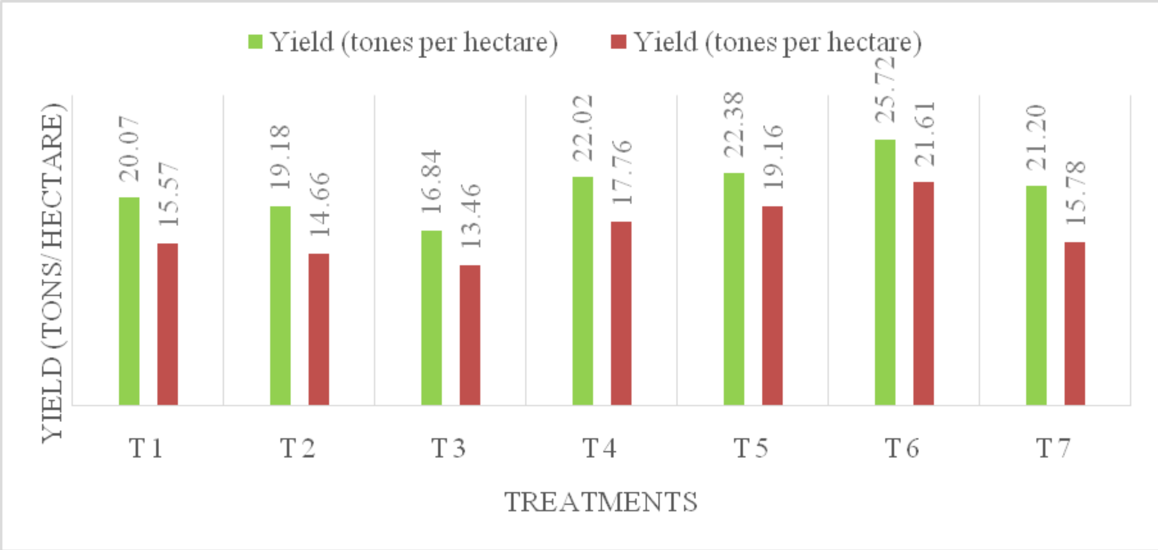


Figure 4.2.13: Effect of intercropping treatments on yield in main and ratoon crop in banana

4.2.2.11. Days taken for ripening after harvest

Table 4.2.14 manifested that for main crop, fruits from the banana plants intercropped with colocasia (T_3) had taken minimum days (7.11 days) for ripening after harvest, whereas, fruits from the plants intercropped with chilli and broccoli (T_6) had taken maximum days (8.33 days) for ripening of fruits after harvesting.

In case of the ratoon crop, fruits from the banana plants intercropped with brinjal and cabbage (T_5) took maximum number of days (8.02 days) for ripening of fruits after harvesting compared with the fruits from the banana plants intercropped with colocasia (T_3: 6.81 days).

Table 4.2.14: Effect of different intercropping treatments on yield, days taken for ripening and shelf life of banana

Treatments	Yield (tones per hectare)		Days taken for ripening after harvest		Shelf-life (days)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	20.07	15.57	7.56	7.13	8.56	7.33
T_2 - Banana intercropped with turmeric	19.18	14.66	7.33	7.10	8.44	7.11
T_3 - Banana intercropped with colocasia	16.84	13.46	7.11	6.81	8.11	6.89
T_4 - Banana intercropped with cowpea + french bean	22.02	17.76	8.00	7.89	9.11	7.78
T_5 - Banana intercropped with brinjal + cabbage	22.38	19.16	8.11	8.02	9.56	8.78
T_6 - Banana intercropped with chilli + broccoli	25.72	21.61	8.33	7.99	9.89	8.74
T_7 - Control (No intercrop, only banana plants)	21.20	15.78	7.89	7.26	8.89	7.44
SEm±	**0.4632**	**0.6946**	**0.2089**	**0.2759**	**0.3443**	**0.3203**
CD at 5%	**1.4273**	**2.1404**	**0.6439**	**0.8501**	**1.0608**	**0.9869**

4.2.2.12. Shelf life

Present study on intercropping in banana revealed that shelf life of the banana fruits had significant variation due to different intercropping treatments. Shelf life of banana fruits was found maximum (9.89 days) in case of the plants intercropped with chilli + broccoli (T_6) in main cropping season, while it was maximum (8.78 days) in case of the plants intercropped with brinjal + cabbage (T_5) during ratoon condition (Table 4.2.14, Fig. 4.2.14). Whereas banana fruits from the plants intercropped with colocasia (T_3) had minimum shelf life both at main crop (8.11 days) as well as at ratoon crop (6.89 days) condition.

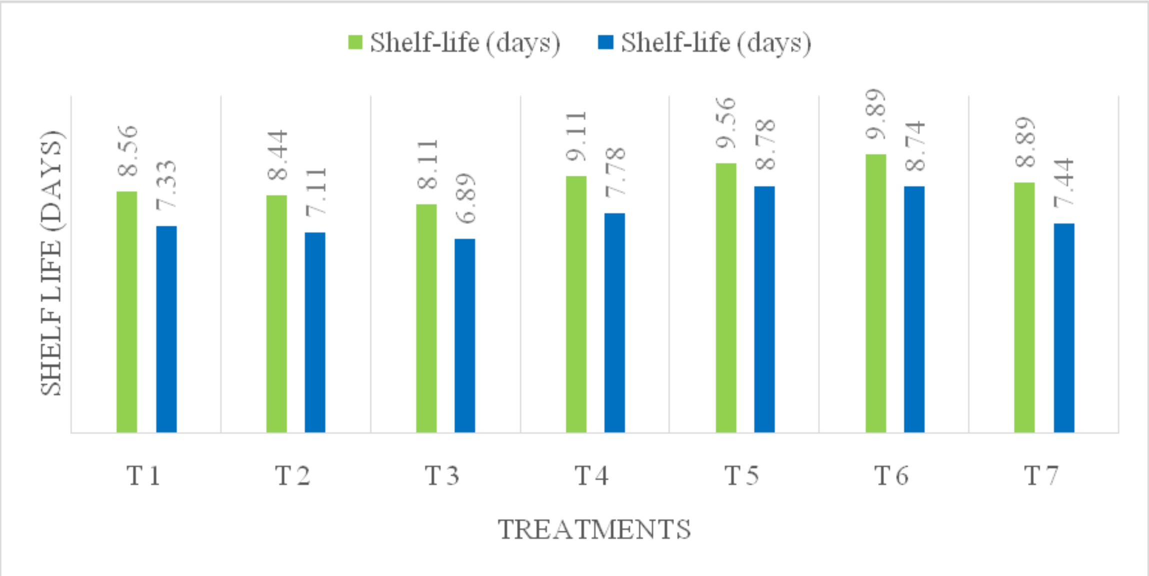


Figure 4.2.14: Effect of intercropping treatments on fruit shelf life in main and ratoon crop in banana

4.2.3. Fruit quality parameters

Different fruit quality parameters of the banana fruits under intercropping treatments were analyzed *viz.* pulp: peel ratio, fruit moisture content, ascorbic acid content, TSS, titratable acidity, TSS:acid ratio, total sugar, reducing sugar, protein content, starch content, amylose content and total carbohydrate content.

4.2.3.1. Pulp and peel ratio

Present experiment revealed that the pulp and peel ratio of the banana fruits got significant variation under the different intercropping treatments (Table 4.2.15). For the main crop, the ratio was recorded maximum (2.45) in case of the fruits from the banana plants intercropped with chilli and broccoli (T_6) followed by banana plants intercropped with brinjal + cabbage (T_5: 2.32). The ratio was found minimum (2.09) in case of the fruits from the plants intercropped with colocasia (T_3).

Similarly, in case of the ratoon crop, the pulp and peel ratio was found maximum (2.34) in case of the fruit from the banana plants intercropped with chilli+broccoli (T_6) whereas, it was minimum (2.02) in case of the banana plants intercropped with colocasia (T_3).

4.2.3.2. Moisture content

Significant variation was recorded in fruit moisture content of banana under different intercropping treatments. For the main crop, highest moisture content (78.55%) was recorded in case of the fruits from the banana plants intercropped with colocasia (T_3) whereas, it was found minimum (74.77%) in case of the fruits intercropped with chilli + broccoli (T_6) compared with other treatments (Table 4.2.15).

For the ratoon crop, highest fruit moisture content (77.26%) was recorded in case of the banana plants intercropped with turmeric (T_2), whereas it was found minimum (73.18%) in case of the banana plants intercropped with brinjal + broccoli (T_5).

4.2.3.3. Ascorbic acid content

Perusal of the data presented in Table 4.2.15 and Fig. 4.2.15 manifested that the ascorbic acid content of banana fruits got significant variation among the different intercropping treatments. For the main crop, ascorbic acid content was recorded

Table 4.2.15: Effect of different intercropping treatments on pulp: peel ratio, moisture and ascorbic acid content of main and ratoon crop in banana

Treatments	Pulp: Peel ratio		Fruit Moisture Content (%)		Ascorbic acid (mg/100g)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	2.18	2.11	76.64	75.67	8.25	8.05
T_2 - Banana intercropped with turmeric	2.12	2.06	77.43	77.26	8.08	7.95
T_3 - Banana intercropped with colocasia	2.09	2.02	78.55	76.22	8.12	7.57
T_4 - Banana intercropped with cowpea + french bean	2.28	2.21	75.73	74.21	8.46	8.17
T_5 - Banana intercropped with brinjal + cabbage	2.32	2.27	75.71	73.18	8.84	8.27
T_6 - Banana intercropped with chilli + broccoli	2.45	2.34	74.77	73.21	8.78	8.34
T_7 - Control (No intercrop, only banana plants)	2.21	2.12	76.43	75.12	8.39	8.20
SEm±	**0.0474**	**0.0346**	**0.4239**	**0.3355**	**0.0973**	**0.1330**
CD at 5%	**0.1461**	**0.1067**	**1.3064**	**1.0337**	**0.2998**	**0.4099**

highest (8.84 mg 100g^{-1}) in case of the fruits from the banana plants intercropped with brinjal and cabbage (T_5) followed by the banana plants intercropped with chilli + broccoli (T_6: 8.78 mg 100g^{-1}), whereas it was found minimum (8.08 mg 100g^{-1}) in case of the banana plants intercropped with turmeric (T_2).

In case of ratoon crop, the fruit ascorbic acid content was maximum (8.34 mg 100g^{-1}) in case of banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5: 8.27 mg 100g^{-1}) compared with the plants intercropped with colocasia (T_3), where it was rerecorded minimum (7.57 mg 100g^{-1}).

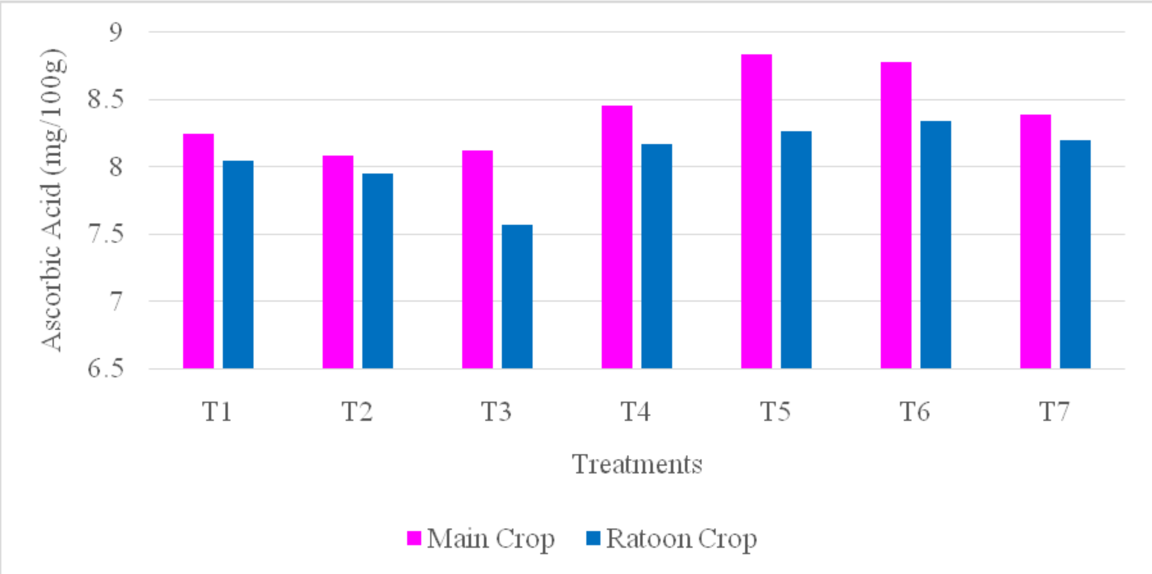


Figure 4.2.15: Effect of intercropping treatments on fruit ascorbic acid content in main and ratoon crop in banana

4.2.3.4. Total Soluble Solids (TSS) content

zPresent study showed significant variation in total soluble solids (TSS) content of banana fruits under different intercropping treatments (Table 4.2.16). For main crop, it was found highest (24.32 °Brix) in case of the banana plants intercropped with chilli + broccoli (T_6), followed by the banana plants intercropped with brinjal + cabbage

(T_5: 24.08 °Brix) compared with the banana plants intercropped with colocasia (T_3) where the TSS content of the banana fruits was found lowest (22.37 ºBrix).

For the ratoon crop, TSS content of the banana fruits was found highest (22.89 °Brix) in T_6 (banana intercropped with chilli + broccoli) compared with T_3 (banana intercropped with colocasia) where it was recorded lowest TSS value (20.92 ºBrix).

4.2.3.5. Titratable acidity

Titratable acidity content of the banana fruits had significant variation across the intercropping treatment. For both main as well as ratoon crop, the titratable acidity content of banana fruits was found highest (main crop: 0.26 %, ratoon crop: 0.25 %) in case of the banana plants intercropped with colocasia (T_3) whereas, it was recorded lowest (both main and ratoon crop: 0.21 %) in case of banana fruits from the plants intercropped with chilli + broccoli (T_6) (Table 4.2.16).

4.2.3.6. TSS: acid ratio

Data presented in Table 4.2.16, Fig. 4.2.16 clearly revealed that TSS:acid ratio of the banana fruit got significant variation among the different intercropping treatments. For the main crop, TSS: acid ratio was maximum (115.81) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5: 109.45), whereas it was found minimum (86.04) in case of the banana plants intercropped with colocasia (T_3).

Similarly, for the ratoon crop, maximum TSS:acid ratio of banana fruits (109.00) was recorded in case of the plants intercropped with chilli+broccoli (T_6) while it was minimum (83.68) in case of the banana plants intercropped with colocasia (T_3).

Table 4.2.16: Effect of different intercropping treatments on TSS, titratable acidity and TSS:acid ratio of main and ratoon crop in banana

Treatments	TSS (°Brix)		Titratable Acidity (%)		TSS: acid ratio	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	22.89	21.67	0.24	0.23	95.38	94.22
T_2 - Banana intercropped with turmeric	22.52	21.38	0.25	0.24	90.08	89.08
T_3 - Banana intercropped with colocasia	22.37	20.92	0.26	0.25	86.04	83.68
T_4 - Banana intercropped with cowpea + french bean	23.55	22.25	0.23	0.22	102.39	101.14
T_5 - Banana intercropped with brinjal + cabbage	24.08	22.42	0.22	0.22	109.45	101.91
T_6 - Banana intercropped with chilli + broccoli	24.32	22.89	0.21	0.21	115.81	109.00
T_7 - Control (No intercrop, only banana plants)	23.04	21.92	0.23	0.23	100.17	95.30
SEm±	**0.2940**	**0.2434**	**0.0053**	**0.0041**	**1.5769**	**2.2304**
CD at 5%	**0.9060**	**0.7501**	**0.0165**	**0.0126**	**4.8593**	**6.8732**

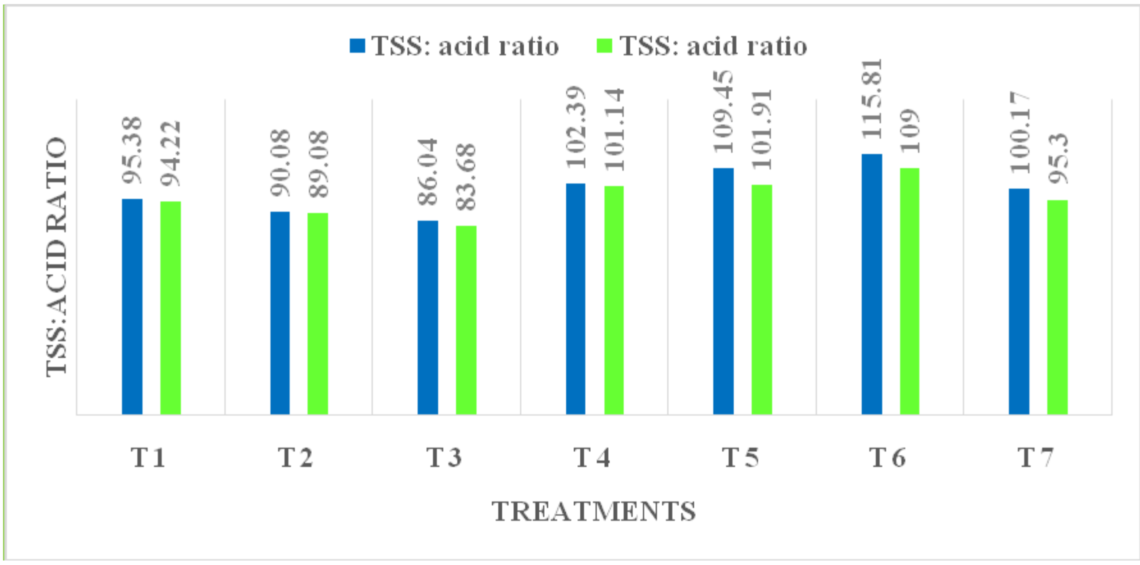


Figure 4.2.16: Effect of intercropping treatments on fruit TSS:acid ratio in main and ratoon crop in banana

4.2.3.7. Total sugar content

Perusal of the data presented in Table 4.2.17 manifested that total sugar content of the banana fruits under different intercropping treatments got significant variation. For both main as well as ratoon crop, total sugar content of banana fruits was recorded highest (main crop: 21.32% and ratoon crop: 18.42%) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5; main crop: 21.06% and ratoon crop: 18.28%), while it was recorded lowest (main crop: 18.67% and ratoon crop:15.92%) in case of the banana plants intercropped with colocasia (T_3).

4.2.3.8. Reducing sugar content

Significant variation of reducing sugar was found in banana fruits under different intercropping treatments. For the main crop, reducing sugar content was found highest (19.06%) in case of the banana plants intercropped with brinjal + cabbage (T_5) followed by the banana plants intercropped with chilli + broccoli (T_6:18.65%)

whereas it was found lowest (16.36%) in case of the banana plants intercropped with colocasia (T_3).

For the ratoon crop, reducing sugar content of the banana fruits was recorded highest (17.09%) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5: 17.01%) whereas it was recorded lowest (14.72%) in case of the banana plants intercropped with turmeric (T_2) (Table 4.2.17).

4.2.3.9. Protein content

Table 4.2.17 clearly manifested that for the main crop, protein content of the banana fruits was found highest (12.18 mg g^{-1}) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5:12.23 mg g^{-1}) compared with the banana plants intercropped with colocasia (T_3), where the fruit protein content was found lowest (11.58 mg g^{-1}).

For the ratoon crop, highest fruit protein (12.01 mg g^{-1}) was recorded in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the plants intercropped with cowpea + french bean (T_4: 11.94 mg g^{-1}) whereas it was recorded lowest (10.62 mg g^{-1}) in case of the banana plants intercropped with turmeric (T_2).

4.2.3.10. Starch content

Starch content of banana fruits got significant variation in the present experiment in banana with different intercropping treatments (Table 4.2.18, Fig. 4.2.17). For the main crop, starch content of the banana fruits was found maximum (11.10 mg/g) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants in intercropped with brinjal + cabbage (T_5: 11.05 mg/g) whereas it was

Table 4.2.17: Effect of different intercropping treatments on total sugar, reducing sugar and protein content of main and ratoon crop in banana

Treatments	Total Sugar (%)		Reducing Sugar (%)		Protein (mg g^{-1})	
	Main Crop	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**
T_1 - Banana intercropped with ginger	19.32	17.21	17.36	15.79	11.62	10.85
T_2 - Banana intercropped with turmeric	18.83	16.85	16.94	14.72	11.41	10.62
T_3 - Banana intercropped with colocasia	18.67	15.92	16.36	14.96	11.58	10.76
T_4 - Banana intercropped with cowpea + french bean	20.81	17.98	18.32	16.91	11.82	11.94
T_5 - Banana intercropped with brinjal + cabbage	21.06	18.28	19.06	17.01	12.23	11.57
T_6 - Banana intercropped with chilli + broccoli	21.32	18.42	18.65	17.09	12.18	12.01
T_7 - Control (No intercrop, only banana plants)	20.16	17.43	18.15	16.82	11.94	10.96
SEm±	**0.3463**	**0.3410**	**0.3773**	**0.3992**	**0.1278**	**0.1114**
CD at 5%	**1.0672**	**1.0509**	**1.1627**	**1.2301**	**0.3937**	**0.3431**

Table 4.2.18: Effect of different intercropping treatments on starch, amylose and carbohydrate content of main and ratoon crop in banana

Treatments	Starch (mg/g)		Amylose (%)		Carbohydrate (g/ 100 g)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	10.82	10.21	19.48	18.76	22.49	21.23
T_2 - Banana intercropped with turmeric	10.74	9.89	18.78	17.62	21.63	20.58
T_3 - Banana intercropped with colocasia	10.35	10.02	18.25	17.23	21.12	19.78
T_4 - Banana intercropped with cowpea + french bean	11.03	10.41	20.38	19.94	23.01	21.97
T_5 - Banana intercropped with brinjal + cabbage	11.05	10.95	20.67	20.13	23.47	22.21
T_6 - Banana intercropped with chilli + broccoli	11.10	10.58	21.75	20.42	23.55	22.14
T_7 - Control (No intercrop, only banana plants)	10.91	10.34	19.89	18.98	22.63	21.65
SEm±	**0.1380**	**0.1254**	**0.3516**	**0.1820**	**0.2560**	**0.4095**
CD at 5%	**0.4251**	**0.3865**	**1.0835**	**0.5610**	**0.7888**	**1.2619**

recorded minimum (10.35 mg/g) in case of the banana plants intercropped with colocasia (T_3).

For the ratoon crop, fruit starch content was found highest (10.95 mg/g) in case of the banana plants intercropped with brinjal + cabbage (T_5) followed by the banana plants intercropped with chilli + broccoli (T_6: 10.58 mg/g) compared with banana plants intercropped with turmeric (T_2), where starch content of banana fruits was found lowest (9.89 mg/g).

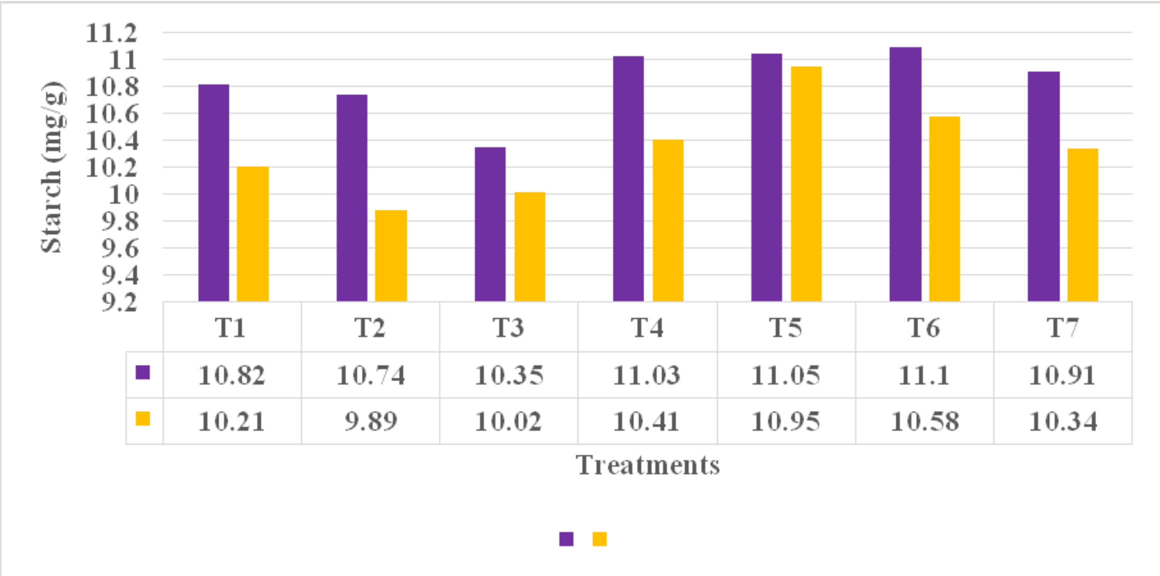


Figure 4.2.17: Effect of intercropping treatments on fruit starch content in main and ratoon crop in banana

4.2.3.11. Amylose content

For the main crop, amylose content of banana fruit was found highest (21.75%) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5: 20.67%) whereas it was found lowest (18.25%) in case of the banana plants intercropped with colocasia (T_3) (Table 4.2.18).

Similarly for the ratoon crop, amylose content of the banana fruit was found highest (20.42%) in case of the banana plants intercropped with chilli+broccoli (T_6) compared with T_3 (banana intercropped with colocasia) where the fruit amylose content was found lowest (17.23%).

4.2.3.12. Total carbohydrate content

Perusal of the data presented in Table 4.2.18 showed that carbohydrate content banana fruits had significant variation among the different intercropping treatments. For the main crop, total carbohydrate content of banana fruits was recorded highest (23.55 g/100g) in case of the banana plants intercropped with chilli and broccoli (T_6) followed by the banana plants intercropped with brinjal and cabbage (T_5: 23.47 g/100g) whereas it was recorded lowest (21.12 g/100g) in case of the banana plants intercropped with colocasia (T_3).

For the ratoon crop, total carbohydrate content of the banana fruits was found highest (22.21 g/100g) in case of the banana plants intercropped with brinjal+ cabbage (T_5) followed by the banana plants intercropped with chilli+broccoli (T_6: 22.14 g/100g) whereas it was found lowest in case of the banana plants intercropped with colocasia (T_3: 19.78 g/100g).

4.2.4. Soil analysis

Analysis of the soil samples collected from each treatment were carried out for the following parameters *viz.* nitrogen content, phosphorus content, potassium content, organic carbon, and C:N ratio.

4.2.4.1. Soil nitrogen (N)

Data presented in Table 4.2.19, Fig. 4.2.18 showed that for the main crop, soil nitrogen content was found maximum (1114.24 Kg/ha) in case of the banana plants intercropped with chilli+ broccoli (T_6) followed by the plants intercropped with brinjal+cabbage (T_5: 1066.27 Kg/ha) compared with the banana plants intercropped with colocasia (T_3: 816.56 Kg/ha).

For the ratoon crop, nitrogen content of the soil was recorded maximum (1098.67 Kg/ha) in case of the banana plants intercropped with chilli + broccoli (T_6) whereas, it was found minimum (792.38 Kg/ha) in case of the banana plants intercropped with colocasia (T_3).

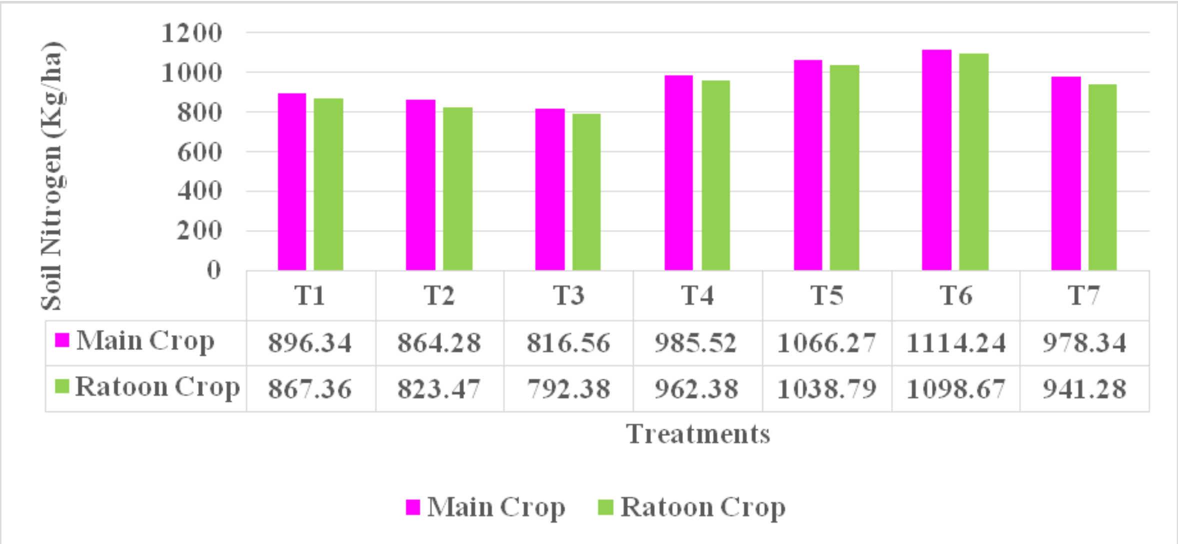


Figure 4.2.18: Effect of intercropping treatments on soil nitrogen content in main and ratoon crop in banana

4.2.4.2. Soil phosphorus (P)

Phosphorus content of the soil of banana plants got significant variation under different intercropping treatments (Table 4.2.19). For the main crop, phosphorus content of the soil of banana plants recorded maximum (81.24 Kg/ha) in case of the banana plants intercropped with brinjal + cabbage (T_5) followed by the banana plants intercropped with chilli + broccoli (T_6: 78.39 Kg/ha) whereas it was recorded minimum (43.67 Kg/ha) in case of the banana plants intercropped with colocasia (T_3).

Similarly, for ratoon crop, maximum phosphorus content of soil (74.26 Kg/ha) was recorded in case of the banana plants intercropped with brinjal + cabbage (T_5) while it was found minimum (39.71 Kg/ha) in case of the banana plants intercropped with colocasia (T_3).

4.2.4.3. Soil potassium (K)

For both main as well as ratoon crop, the soil potassium content of banana plants was found maximum (main crop: 864.98 Kg/ha, ratoon crop: 831.67 Kg/ha) in case it was intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5, main crop: 826.13 Kg/ha and ratoon crop:798.58 Kg/ha) whereas it was found minimum (main crop: 562.48 Kg/ha and ratoon crop: 528.76 Kg/ha) in case of the banana plants intercropped with colocasia (T_3) (Table 4.2.19, Fig. 4.2.19).

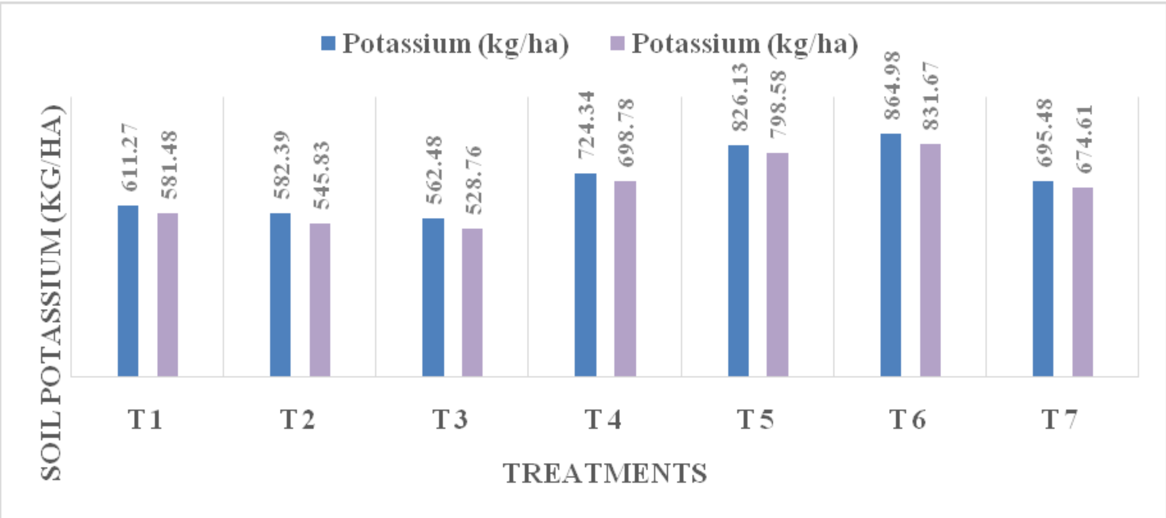


Figure 4.2.19: Effect of intercropping treatments on soil potassium content in main and ratoon crop in banana

4.2.4.4. Soil organic carbon

Perusal of the data presented in Table 4.2.20 showed that for the main crop, soil organic carbon content was recoded maximum (0.87%) in case of the banana plants

Table 4.2.19: Effect of different intercropping treatments on soil Nitrogen, Phosphorus and Potassium of main and ratoon crop in banana

Treatments	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	896.34	867.36	51.32	46.76	611.27	581.48
T_2 - Banana intercropped with turmeric	864.28	823.47	47.36	44.28	582.39	545.83
T_3 - Banana intercropped with colocasia	816.56	792.38	43.67	39.71	562.48	528.76
T_4 - Banana intercropped with cowpea + french bean	985.52	962.38	64.18	59.78	724.34	698.78
T_5 - Banana intercropped with brinjal + cabbage	1066.27	1038.79	81.24	74.26	826.13	798.58
T_6 - Banana intercropped with chilli + broccoli	1114.24	1098.67	78.39	72.85	864.98	831.67
T_7 - Control (No intercrop, only banana plants)	978.34	941.28	59.86	55.37	695.48	674.61
SEm±	**11.5692**	**2.4615**	**0.9414**	**0.7104**	**10.3752**	**0.3833**
CD at 5%	**35.6512**	**7.5852**	**2.9011**	**2.1891**	**31.9719**	**1.1811**

Table 4.2.20: Effect of different intercropping treatments on soil organic carbon content and C:N ratio of main and ratoon crop in banana

Treatments	Soil Organic Carbon (%)		C:N ratio	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	0.63	0.55	15.74	14.20
T_2 - Banana intercropped with turmeric	0.59	0.52	15.29	14.15
T_3 - Banana intercropped with colocasia	0.56	0.49	15.36	13.85
T_4 - Banana intercropped with cowpea + french bean	0.74	0.65	16.82	15.13
T_5 - Banana intercropped with brinjal + cabbage	0.81	0.74	17.02	15.96
T_6 - Banana intercropped with chilli + broccoli	0.87	0.79	17.49	16.11
T_7 - Control (No intercrop, only banana plants)	0.69	0.61	15.80	14.52
SEm±	**0.0221**	**0.0295**	**0.2559**	**0.4602**
CD at 5%	**0.0681**	**0.0910**	**0.7886**	**1.4181**

intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5: 0.81%) whereas it was recorded minimum (0.56%) in case of the banana plants intercropped with colocasia (T_3).

For the ratoon crop, soil organic carbon content was found highest (0.79%) in case of the banana plants intercropped with chilli + broccoli (T_6) compared with T_3 (banana intercropped with colocasia) where it was found lowest (0.49%).

4.2.4.5. Soil organic carbon: nitrogen (C:N) ratio

Present experiment showed significant variation in soil organic carbon with nitrogen (C:N) ratio in banana plants under different intercropping treatments (Table 4.2.20, Fig. 4.2.20). For the main crop, the C:N ratio was maximum (17.49) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by banana plants intercropped with brinjal + cabbage (T_5: 17.02) compared with banana plants intercropped with colocasia (T_3: 15.36).

For the ratoon crop soil C:N ratio was recorded maximum (16.11) in case of the banana plants intercropped with chilli + broccoli (T_6) whereas, it was found minimum in case of the banana plants intercropped with colocasia (T_3: 13.85)

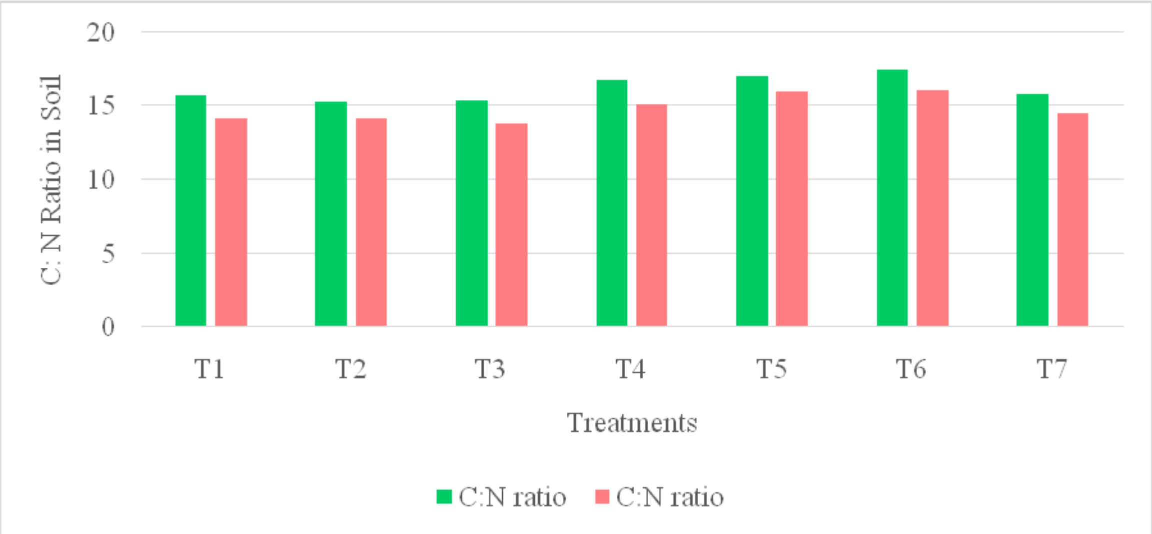


Figure 4.2.20: Effect of intercropping treatments on soil organic carbon : nitrogen (C:N) ratio in main and ratoon crop in banana

4.2.5. Leaf analysis

Leaf samples were collected from the banana plants under different intercropping treatments and were analyzed for the following parameters *viz*. nitrogen, phosphorus, potassium, carbohydrate content and carbohydrate: nitrogen (C:N) ratio.

4.2.5.1. Leaf nitrogen (N)

It is evident from the Table 4.2.21, Fig. 4.2.21 that the leaf nitrogen content of the banana plants under different intercropping treatments had significant variation. For the main crop, the leaf nitrogen content was found maximum (2.37%) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5: 2.34%) compared with T_3 (banana plants intercropped with colocasia) where the leaf nitrogen content was found minimum (1.98%).

For the ratoon crop, nitrogen content of the leaf was recorded highest (2.16%) in case of the banana plants intercropped with chilli + broccoli (T_6) whereas it was recorded lowest (1.71%) in case of the banana plants intercropped with colocasia (T_3).

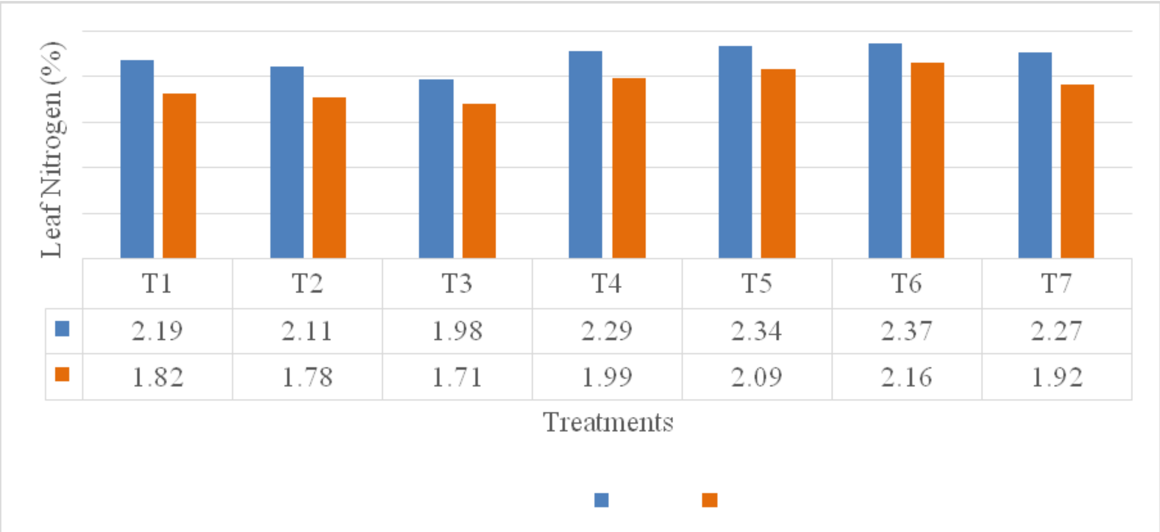


Figure 4.2.21: Effect of intercropping treatments on leaf nitrogen content in main and ratoon crop in banana

4.2.5.2. Leaf phosphorus (P)

Data furnished in the Table 4.2.21 showed that for that main crop the phosphorus content of the leaf was found highest (0.28%) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the plants intercropped with brinjal + cabbage (T_5: 0.26%) whereas it was found lowest (0.15%) in case of the banana plants intercropped with colocasia (T_3).

For the ratoon crop, highest leaf phosphorus content (0.21%) was recorded in case of the banana plants intercropped with brinjal + cabbage (T_5) whereas it was recorded lowest (0.11%) in case of the banana plants intercropped with turmeric (T_2).

Figure 4.2.22: Effect of intercropping treatments on leaf potassium content in main and ratoon crop in banana

4.2.5.3. Leaf potassium (K)

Different intercropping treatments had influenced the leaf potassium content of the banana plants under present experiment (Table 4.2.21, Fig. 4.2.22). For the main crop, potassium content of the leaf was recorded maximum (2.89%) incase of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants

Table 4.2.21: Effect of different intercropping treatments on leaf Nitrogen, Phosphorus and Potassium of main and ratoon crop in banana

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Main Crop	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**
T_1 - Banana intercropped with ginger	2.19	1.82	0.18	0.13	2.38	2.15
T_2 - Banana intercropped with turmeric	2.11	1.78	0.16	0.11	2.24	1.98
T_3 - Banana intercropped with colocasia	1.98	1.71	0.15	0.12	2.14	1.85
T_4 - Banana intercropped with cowpea + french bean	2.29	1.99	0.24	0.18	2.71	2.56
T_5 - Banana intercropped with brinjal + cabbage	2.34	2.09	0.26	0.21	2.76	2.62
T_6 - Banana intercropped with chilli + broccoli	2.37	2.16	0.28	0.19	2.89	2.77
T_7 - Control (No intercrop, only banana plants)	2.27	1.92	0.22	0.16	2.55	2.48
SEm±	**0.0445**	**0.0290**	**0.0118**	**0.0181**	**0.0852**	**0.0615**
CD at 5%	**0.1372**	**0.0895**	**0.0362**	**0.0558**	**0.2625**	**0.1894**

Table 4.2.22: Effect of different intercropping treatments on leaf Carbohydrate and C:N ratio of main and ratoon crop in banana

Treatments	Carbohydrate (%)		Leaf Carbohydrate: N Ratio	
	Main Crop	**Ratoon Crop**	**Main Crop**	**Ratoon Crop**
T_1 - Banana intercropped with ginger	6.32	5.12	2.89	2.81
T_2 - Banana intercropped with turmeric	6.01	4.89	2.85	2.75
T_3 - Banana intercropped with colocasia	5.56	4.46	2.81	2.61
T_4 - Banana intercropped with cowpea + french bean	6.82	5.89	2.98	2.96
T_5 - Banana intercropped with brinjal + cabbage	7.08	6.31	3.03	3.02
T_6 - Banana intercropped with chilli + broccoli	7.36	6.68	3.11	3.09
T_7 - Control (No intercrop, only banana plants)	6.74	5.42	2.97	2.82
SEm±	**0.1075**	**0.1936**	**0.0421**	**0.0807**
CD at 5%	**0.3312**	**0.5965**	**0.1298**	**0.2488**

intercropped with brinjal + cabbage (T_5: 2.76%) whereas it was recorded minimum (2.14%) in T_3 (banana plants intercropped with colocasia).

For the ratoon crop maximum leaf potassium content (2.77%) was recorded in case of the banana plants intercropped with chilli + broccoli (T_6) whereas it was found minimum (1.85%) in case of the banana plants intercropped with colocasia (T_3).

4.2.5.4. Leaf carbohydrate

It is revealed from the data presented at Table 4.2.22 that for both main as well as for ratoon crop highest amount of leaf carbohydrate (main crop: 7.36% and ratoon crop: 6.68%) was recorded in case of the banana plants intercropped with chilli+broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5; main crop: 7.08% and ratoon crop: 6.31%) whereas, it was found lowest (main crop: 5.56% and ratoon crop: 4.46%) in case of the banana plants intercropped with colocasia (T_3).

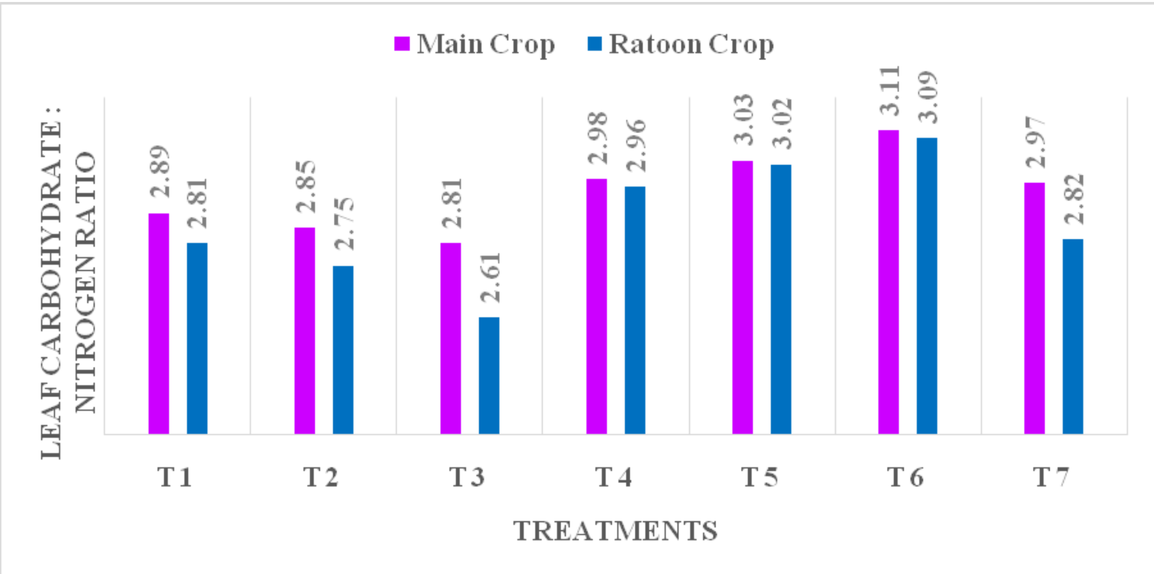


Figure 4.2.23: Effect of intercropping treatments on leaf carbohydrate: nitrogen ratio in main and ratoon crop in banana

4.2.5.5. Leaf carbohydrate and nitrogen (C:N) ratio

C:N ratio of the banana leaves got significant variation under the present intercropping experiment. For the main crop, leaf C:N ration was recorded maximum

(3.11) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5: 3.03) compared with the banana plants intercropped with colocasia (T_3: 2.81).

Similarly, for the ratoon crop, C:N ratio of the leaf was recorded maximum (3.09) in case of the banana plants intercropped with chilli + broccoli (T_6) whereas it was recorded minimum (2.61) in case of the banana plants intercropped with colocasia (T_3) (Table 4.2.22, Fig. 4.2.23).

4.2.6. Yield of intercrops

Nine different intercrops were cultivated in the banana orchard under different intercropping treatments. Data presented in Table: 4.2.23 showed that during main cropping season of banana highest yield was obtained from cabbage as intercrop (17.68 t/ha) followed by turmeric (16.58 t/ha) whereas chilli is having the lowest yield (6.45 t/ha). Similarly, in ratoon season yield of cabbage as intercrop was found maximum (20.93 t/ha) followed by broccoli (13.78 t/ha) whereas yield of chilli as intercrop was least (5.95 t/ha).

Table 4.2.23: Yield of different intercrops in banana orchard

Name of the Intercrops	Yield at Main Crop (1^{st} Year) T/ha	Yield at Ratoon Crop (2^{nd} Year) T/ha
Ginger	15.47	12.97
Turmeric	16.58	11.72
Colocasia	9.25	6.91
Cowpea	10.56	9.03
French Bean	12.97	9.22
Brinjal	13.25	10.50
Cabbage	17.68	20.93
Chilli	6.45	5.95
Broccoli	14.37	13.78

4.2.7. Cost benefit analysis

Cost benefit analysis for each treatment under the current experiment was done based on the gross expenditure, gross income, and net income (Table 4.2.24).

For the main crop, the gross expenditure was found highest (Rs. 552051.93) in case of the banana plants intercropped with cowpea and french bean (T_4) followed by the banana plants intercropped with brinjal + cabbage (T_5: Rs.541535.71) whereas it was found lowest in case of control (T_7: Rs.232524.01) followed banana plants intercropped with colocasia (T_3: Rs.344706.50). Similarly, for the ratoon crop, gross expenditure was found minimum (Rs.104945.86) in control (T_7) whereas, it was found maximum (Rs.435583.78) in case of the banana plants intercropped with cowpea and french bean (T_4) followed by banana plants intercropped with brinjal + cabbage (Rs.425067.56).

For main crop, gross income was highest (Rs.3834200.00) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by banana plants intercropped with cowpea and french bean (T_4: Rs.3242785.01) whereas it was found lowest (Rs.1059998.94) in case of control (T_7). For ratoon crop, gross income reduced than the main crop and it was recorded highest (Rs.3488800.00) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with brinjal + cabbage (T_5: Rs.2738800.00) compared with control (Rs.789000.00).

For the main crop, net income was highest (Rs.3293015.60) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by the banana plants intercropped with cowpea + french bean (T_4: Rs.2690733.08) compared with control (Rs.827474.93). Similarly, net income for ratoon crop was found highest

Table 4.2.24: Cost of cultivation and benefit : cost ratio under different intercropping treatments

Treatments	Gross Expenditure		Gross Income		Net Income		Benefit: Cost Ratio	
	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop	Main Crop	Ratoon Crop
T_1 - Banana intercropped with ginger	429147.37	307124.22	2859732.33	2334732.56	2430584.96	2027608.33	5.66	6.60
T_2 - Banana intercropped with turmeric	377189.27	255166.12	2202387.93	1612058.30	1825198.66	1356892.18	4.84	5.32
T_3 - Banana intercropped with colocasia	344706.50	222683.35	1304721.38	1018089.61	960014.88	795406.25	2.79	3.57
T_4 - Banana intercropped with cowpea + french bean	552051.93	435583.78	3242785.01	2531951.89	2690733.08	2096368.11	4.87	4.81
T_5 - Banana intercropped with brinjal + cabbage	541535.71	425067.56	2842300.00	2738800.00	2300764.29	2313732.44	4.25	5.44
T_6 - Banana intercropped with chilli + broccoli	541184.40	424716.25	3834200.00	3488800.00	3293015.60	3064083.75	6.08	7.21
T_7 - Control (No intercrop, only banana plants)	232524.01	104945.86	1059998.94	789000.00	827474.93	684054.14	3.56	6.52

***Gross expenditure, gross income, net income and B:C ratio was calculated for the banana along with intercrops.**

(Rs. 3064083.75) in T_6 (banana intercropped with chilli + broccoli) followed by T_5 i.e. banana intercropped with brinjal + cabbage (Rs.2313732.44) whereas, it was lowest in control (Rs.684054.14).

Benefit: cost ratio of the main cropping season was highest (6.08) in case of the banana plants intercropped with chilli + broccoli (T_6) followed by banana intercropped with ginger (T_1: 5.66) whereas it was lowest in case of banana plants intercropped with colocasia (T_3: 2.79) followed by control (3.56). For the ratoon crop, highest benefit:cost ratio (7.21) was obtained in case of the banana plants intercropped with chilli + broccoli (T_6) followed by banana plants intercropped with ginger (T_1: 6.60) whereas it was found lowest (3.57) in case of the banana plants intercropped with colocasia (T_3).

4.3. Discussion

Banana is one of the leading fruit crops of Mizoram and performing very well under the soil and climatic condition of Mizoram and other Northeastern states. It has increased in both area and production in few past decade. Cavendish group is the most popular and commercially cultivated banana in this region, mostly under traditional cultivation or using some inorganic inputs. However, in recent times, production of horticultural crops under organic nutrient management become emphasized in this region. Banana, being a luxuriant nutrient loving crop, it is difficult to undergo organic cultivation without proper scientific management of organic nutrition of the crop. Besides, systematic information on organic nutrient management protocol for cavendish banana at Mizoram condition was not available, so that the benchmark information can suitably be used for farmers' practice. Thus, the present experiment was conducted on organic nutrient management of banana. Further, the crop though under extensive commercial cultivation in Mizoram but no systematic research information is available on suitable intercrops for better economic return. Therefore, the experiment on intercropping was taken up to assess the performance of selected intercrops under banana orchard.

4.3.1. Experiment No. 1: Organic Nutrient Management of Banana

For the organic nutrient management of Giant Cavendish banana in Mizoram condition, different organic manures *viz.* farm yard manure (FYM), vermi compost (VC), neem cake (NC), poultry manure (PM) and biofertilizers like *Azotobacter* (AZ), Phosphate Solubilizing Bacteria (PSB) and Potash Solubilizing Bacteria (KSB) were used as sole or in different combination to check the performance of banana.

It was found that the pseudostem height had significantly increased from small stage to harvesting stage both in main as well as ratoon crop manifested its continuous growth. Lenka and Lenka (2014) reported that banana pseudostem had significant growth increase as recorded up to shooting stage. It was found that banana plants applied with poultry manure along with biofertilizer *viz. Azotobacter,* Phosphate Solubilizing Bacteria and Potash Solubilizing Bacteria had performed best in terms of attaining pseudostem height, pseudostem girth, number of leaves, total leaf production , leaf area and leaf area index followed by the banana plants applied with neem cake along with biofertilizers (AZ+PSB+KSB) and vermicompost along with biofertilizers. Plants under treatment with poultry manure along with biofertilizers (AZ+PSB+KSB) had lowest phyllocron in main crop, while neem cake along with biofertilizers *viz.* AZ+PSB+KSB had lowest phyllocron days in ratoon banana. Rivera-Cruz *et al.* (2008) found that poultry manure combined with *Azospirillum, Azotobacter* and P-solubilizers stimulated the growth of AAA banana cv. Simmonds. Saravanan *et al.*

(2020) had reported that neem cake had enhanced plant growth *viz.* plant height, pseudostem girth, number of leaves and root characters in banana cv. Robusta. Banana plant height, pseudostem girth, number of leaves, total leaf production, leaf area and leaf area index was positively influence by application of vermicompost along with biofertilizers and inorganic fertilizer (Suhasini *et al*., 2018; Hazarika and Ansari, 2010). Banana plants manured with poultry litter along with biofertilizers had recorded high number of suckers at harvesting both in main as well as in ratoon crop and gained high total biomass. Aba *et al.* (2011) found that application of poultry manure on banana cv. PITA 24 and Mbi-Egome (AAB) had increased the sucker production and total biomass. Further, present study revealed that banana plants applied with poultry manure along with biofertilizers had minimum days for shooting and harvesting with lowest crop duration. Mensah *et al.* (2012) found that *in vitro* propagated hybrid dessert banana cv. FHIA-01 had minimum days to flowering with shorter crop duration when plants were fertilized with poultry manure. Soni *et al*. (2018) found that poultry manure along with vermi compost and biofertilizer had significantly increased plant height, number of leaves, plant spread in strawberry cv. Sweet Charlie.

Significant variation was recorded in fruit growth and development parameters under different organic nutrient treatments. It was found that the banana plants applied with poultry manure along with biofertilizers (AZ+PSB+KSB) had significantly high bunch weight, hands per bunch, second hand weight, fingers per hand, finger length, finger volume and finger weight. Aba *et al.* (2011) found that banana plants applied with poultry manure had significantly higher number of hands and finger per bunch and bunch yield. Singh *et al*. (2018) reported that banana variety G-9 and Dwarf Cavendish have high bunch weight, number of fingers per bunch and fruit weight when applied with poultry manure. Panelo and Diza (2017) found that application of chicken manure significantly increased fruit weight, finger length and diameter in banana cv. Latundan. Florence *et al.* (2021) observed that application of chicken manure in apple orchard increased the fruit weight and yield. Poultry manure when applied along with *Azotobacter* and inorganic fertilizer gave encouraging fruit growth in terms of high fruit length, diameter, volume and weight in guava cv. L 49 (Sharma *et al.*, 2016). Banana plants manured with neem cake along with biofertilizers (AZ+PSB+KSB) have also given good bunch weight, hands per bunch, second hand weight and finger weight. Besides, banana plants applied with vermi compost and biofertilizers (AZ+PSB+KSB) had good fruit growth and development as recorded in terms of bunch weight, second hand weight and finger weight. Mitra *et al*. (2012) reported that guava cultivar 'Sardar' when applied with neem cake along with *Azotobacter* significantly increased fruits size and yield. Furthermore, Dheware *et al*. (2020) found that mango (cv. Alphonso) plants manured with vermi compost along with *Azotobacter* and PSB had given good fruit weight, number of fruits per plant and yield. Present study showed that the banana plants applied with poultry manure along with biofertilizers (AZ+PSB+KSB) had maximum fruit yield followed by the banana plants treated with neem cake along with biofertilizers compared with control. Mamatha *et al.* (2021) obtained highest yield in banana when applied poultry manure along with *Azospirillum* and arbuscular mycorrhizal fungi. Poultry manure when applied two months after planting of banana cv. PITA 17 and French Reversion resulted high bunch yield (Ndukwe *et al*., 2011). Devi and Mitra (2018) found that pineapple cv. Kew given best yield of quality fruits when fertilized with poultry manure along with *Azospirillum,* phosphorus solubilizers and potash mobilizers. Turemis (2002) obtained high yield on strawberry fruits with application of poultry manure along with wheat mulch. Hema *et al.* (2016) reported that yield of the banana cultivar Grand Naine was high when manured with neem cake and poultry manure. Guava plants manured with neem cake and Azotobacter gave highest yield (Mitra *et al.*, 2012). It was found in our study that banana plants manured with vermi compost along with biofertilizer (AZ+PSB+KSB) had maximum shelf life of the fruit. Application of vermi compost along with biofertilizer provided maximum shelf life in strawberry cv. Camarosa fruits (Reddy *et al*. 2021).

Study on the fruit biochemical parameters of banana revealed that in case of main crop pulp and peel ratio, total soluble solids (TSS), TSS:acid ratio was recorded highest in case of the banana plants treated with poultry manure along with biofertilizers *viz. Azotobacter,* phosphate solubilizing bacteria (PSB) and potash solubilizing bacteria (KSB), whereas, for ratoon banana crop better result was obtained for these parameters when fertilized with vermi compost along with biofertilizers (AZ+PSB+KSB). Hema *et al*. (2016) reported that poultry manure had increased banana fruit TSS when applied along with neem cake. Poultry manure along with cow pat pit and BD 500 and BD 501 had highest pulp:peel ratio and high total sugar in Khasi mandarin fruits (Hazarika *et al.* 2022). Application of poultry manure proved to be best in influencing juice quality of yellow passion fruit in terms of TSS, sugar, vitamin C (Ani and Baiyeri, 2008). Chicken manure (equivalent to 9 g nitrogen/plant) caused high fresh fruit weight, TSS and vitamin C in pineapple cv. Pattavia (Isuwan, 2014). Devadas and Kuriakose (2005) reported that pineapple plants applied with poultry manure along with *Azospirillum,* phospho bacteria and inorganic fertilizer caused high juice percentage and excellent quality fruits. Athani and Hulamani (2000) obtained high TSS, TSS:acid ratio and total sugar of ratoon banana crop with application of vermicompost. Vermicompost along with inorganic fertilizer yielded high quality fruits in guava cv. Sardar with high TSS and ascorbic acid content (Athani *et al.,* 2007). It was found in the present study that banana plants applied with vermi compost along with biofertilizers *viz. Azotobacter,* PSB and potash solubilizing bacteria resulted highest ascorbic acid content both in main as well as in ratoon crop. Subramanian *et al*. (2019) reported that ratoon banana crop when provided with vermicompost gave highest ascorbic acid content in banana cv. Grand Naine. Application of vermi compost along with **Azospirillium** and PSB resulted in highest ascorbic acid content in guava (Rani *et al*., 2021). Ascorbic acid content of cashew apple was found to be the highest when vermicompost was applied along with *Azotobacter*, *Azospirillium* and PSB (Mohapatra *et al*., 2016).

Present study revealed that application of poultry manure along with biofertilizer i.e. *Azotobacter,* PSB and KSB had resulted in maximum soil organic carbon, nitrogen and potassium. Besides, neem cake along with biofertilizer (AZ+PSB+KSB) also reasonable increased the organic carbon, nitrogen and potassium content of the soil of banana orchard. Ewulo *et al*. (2008) found that application of poultry manure in tomato field had increased the organic matter content along with highest amount of available soil nitrogen. Choudhary *et al*. (2011) opined that poultry manure with multi-inoculation of biofertilizers might have enhanced mineralization of soil nitrogen thus helped to higher buildup of available soil nitrogen. Application of poultry manure had increased the plant availability of potassium and nitrogen in potato (Oustani *et al*., 2015). Further, the soil of banana orchard were provided with poultry manure and biofertilizer (AZ+PSB+KSB) resulted in high C:N ratio. In acid soil having high microbial activity had resulted in high C:N with applied chicken manure (Khalil *et al.,* 2005). Bindiya *et al*. (2012) found that application of neem cake along with biofertilizers had increased the uptake of nitrogen and potassium. In case of soil micronutrients it was found that soil of the banana plants applied with poultry manure along with biofertilizers (AZ+PSB+KSB) had high soil Mn, Cu and Zn. Abbasi and Yousra (2012) obtained high soil manganese, copper and zinc with application of poultry manure mixed with *Pseudomonas*, *Azospirillium* and *Agrobacterium* strains. Application of poultry manure and biofertilizers (AZ+PSB+KSB) caused high leaf nitrogen, phosphorus, potassium, Mn, Cu, Zn and carbohydrate: nitrogen ratio. Poultry manure augmented with *Azospirillium* and *Azotobacter* caused maximum leaf nitrogen, phosphorus, potassium, calcium and magnesium in Sardar guava (Sharma *et al.*, 2011). Fawzy *et al.* (2007) found that poultry manure significantly increased Fe, Cu, Mn and Pb in leaf tissue. Poultry manure along with biofertilizer resulted in increased leaf carbohydrate content with high nitrogen which may have caused high carbohydrate : nitrogen ratio. Al-Hadethi (2019) found that poultry manure along with biofertilizer had significantly increased leaf carbohydrate content. Furthermore, it was observed leaf micronutrients viz. Mn, Cu, Zn and macro nutrients like N, P and K were significantly high in case of the banana plants fertilized with neem cake along with biofertilizer (AZ+PSB+KSB). Devi *et al*. (2014) found that application of neem cake along with *Azotobacter* + phosphorus solubilizers + potash mobilizers cause high percentage of leaf nitrogen, phosphorus and potassium in case of 'Bombai' litchi plants. Neem cake along with cow dung and *Trichoderma* mixture increased the available Cu, Fe and Mn (Suja *et al.*, 2011). Present study revealed that application of poultry manure with biofertilizer had maximum AZ, PSB and KSB count in the experimental banana orchard. Talwar *et al*. (2017) observed that application of poultry manure and biofertilizer as organic nutrient caused higher microbial count in the experimental soil.

Economic analysis of the treatments in present experiment manifested that for both main and ratoon crop, poultry manure along with biofertilizer (AZ+PSB+KSB) resulted highest benefit:cost ratio. Bakshi *et al*. (2018) reported that poultry manure along with *Azotobacter* and inorganic nitrogen caused maximum benefit: cost ratio in Kinnow mandarin cultivation. Jaipaul *et al*. (2011a) reported to have highest B:C ratio with application of poultry manure along with biofertilizer in capsicum and garden pea production. Similarly, highest benefit cost ratio for application of chicken manure along with biofertilizer was found in case of organic production of potato under rainfed condition (Jaipaul *et al*. 2011b).

4.3.2. Experiment No. 2: Intercropping in Banana

In the intercropping experiment of the banana plants both for main as well as ratoon crop seven treatments were utilized *viz.* T_1: intercropping with ginger; T_2: intercropping with turmeric; T_3: intercropping with colocasia ; T_4: intercropping with cowpea and french bean; T_5: intercropping with brinjal and cabbage; T_6: intercropping with chilli and broccoli and T_7: no intercrops (control).

Observation on the plant growth and development parameters manifested that significant variation was found in banana plants under different intercropping treatments. It was found that banana plants intercropped with chilli and broccoli had reasonably high pseudostem height, girth, number of functional leaves, leaf area, total leaf production. Besides, in this intercropping treatment, crop duration was minimum with maximum sucker production. Maji and Das (2013a) found chilli as the best intercrop influencing growth and yield in guava cv. L-49. Bakshi *et al*. (2019) suggested broccoli as suitable intercrops in young orchard. Besides chilli and broccoli, it was found that brinjal and cabbage also performed as better intercrop than others in terms of plant growth and development parameters of banana. Singh *et al*. (2015) obtained good growth and yield of mango under cabbage and brinjal intercropping in mango cv. Dashehari.

Observation on fruit growth and development parameters revealed that banana plants intercropped with chilli and broccoli had high bunch weight, hands per bunch, second hand weight, number of fingers per hand, finger weight and yield. Chilli and amaranthus found to be the best intercrop resulted in high yield of sweet orange in Southwestern Nigeria (Aiyelaagbe, 2001). Hussain *et al.* (2016) found yield increase in tomato fruits when intercropped with chilli. Besides, banana intercropped with brinjal and cabbage also scored high bunch weight, finger weight and yield. Maji and Das (2013a,b) found that beside chilli, cabbage and brinjal are also potential intercrops influencing higher floral shoot formation and yield in guava cv. L-49. Potential use of chilli, eggplant, cabbage and broccoli as intercrops were emphasized for extra income in horticultural crops (Blair *et al*., 2016). Karlidag and Yildirim (2009) reported to have good plant growth and yield in strawberry when intercropped with vegetables. Vegetable intercropping had resulted high yield in guava by influencing soil health (Swain, 2016).

For the fruit biochemical quality parameters, banana intercropped with chilli and broccoli had high pulp:peel ratio, ascorbic acid, TSS, TSS:acid ratio, total sugar and starch content. It was reported that intercropping with vegetables in guava had improved the fruit quality in terms of TSS, ascorbic acid and total sugar content (Singh *et al*., 2016a). Gill *et al.* (2018) reported to have high yield Kinnow mandarin with high TSS as influenced by the intercrops. Intercropping in Nagpur mandarin influenced fruit quality in terms of TSS, acidity and TSS:acid ratio (Shirgure, 2012).

Present study on intercropping in banana revealed that it has significant effect of the soil-plant nutrition of the orchard. Determination of nitrogen, phosphorus, potassium in soil and plant along with C: N ratio manifested that intercropping had marked influence on these parameters. It was found that banana intercropped with chilli and broccoli had high soil and leaf nitrogen, phosphorus and potassium content along with high C:N ratio in leaf and soil which may have resulted high yield of quality fruits in banana. Use of intercrops had influenced bulk density, electric conductivity and water holding capacity of soil and therefore increased organic carbon, available nitrogen, phosphorus, potassium content and C:N ratio in soil (Swain, 2016). Singh *et al*. (2016b) reported to have positive influence of intercropping on soil nutrient profile of aonla orchard. Swain (2014) found to have higher leaf nitrogen, phosphorus and potassium under vegetable-based intercropping in mango.

Economic analysis of the intercropping trial in banana manifested that intercropping with chilli + broccoli resulted in highest net return both in main and ratoon crop followed by intercropping with cowpea + french bean in main crop and brinjal + cabbage in ratoon crop. Highest benefit:cost (B:C) ratio was obtained in banana intercropped with chilli + broccoli followed by intercropping with ginger, whereas B:C ratio was lowest in intercropping with colocasia followed by mono cropping in main season. Kahn (2010) reported that pineapple intercropping with chilli is profitable. Singh *et al*. (2016b) found ginger as a suitable intercrop giving high benefit: cost ratio in aonla orchard. Kumar *et al.* (2010) suggested that intercropping contributed higher economic return that sole crop in litchi. Ratha and Swain (2006) found ginger, cowpea, french bean as potential intercrop in mango for better economic return than sole crop. Rathore *et al.* (2013) reported to have lower B:C ratio when mango intercropped with colocasia even that the sole crop.

In general, of both the experiments it was found that ratoon banana plants yield poorly than the main crop. Similar observation was found by Paul *et al.* (2008) and Pramanik *et al*. (2016).

Plate 1: View of Experimental-1 research plot

Plate 2: Banana in fruiting stage

Plate 3: Desuckering in banana

Plate 4: Measuring pseudostem of banana

Plate 5: Harvested banana bunch and hands

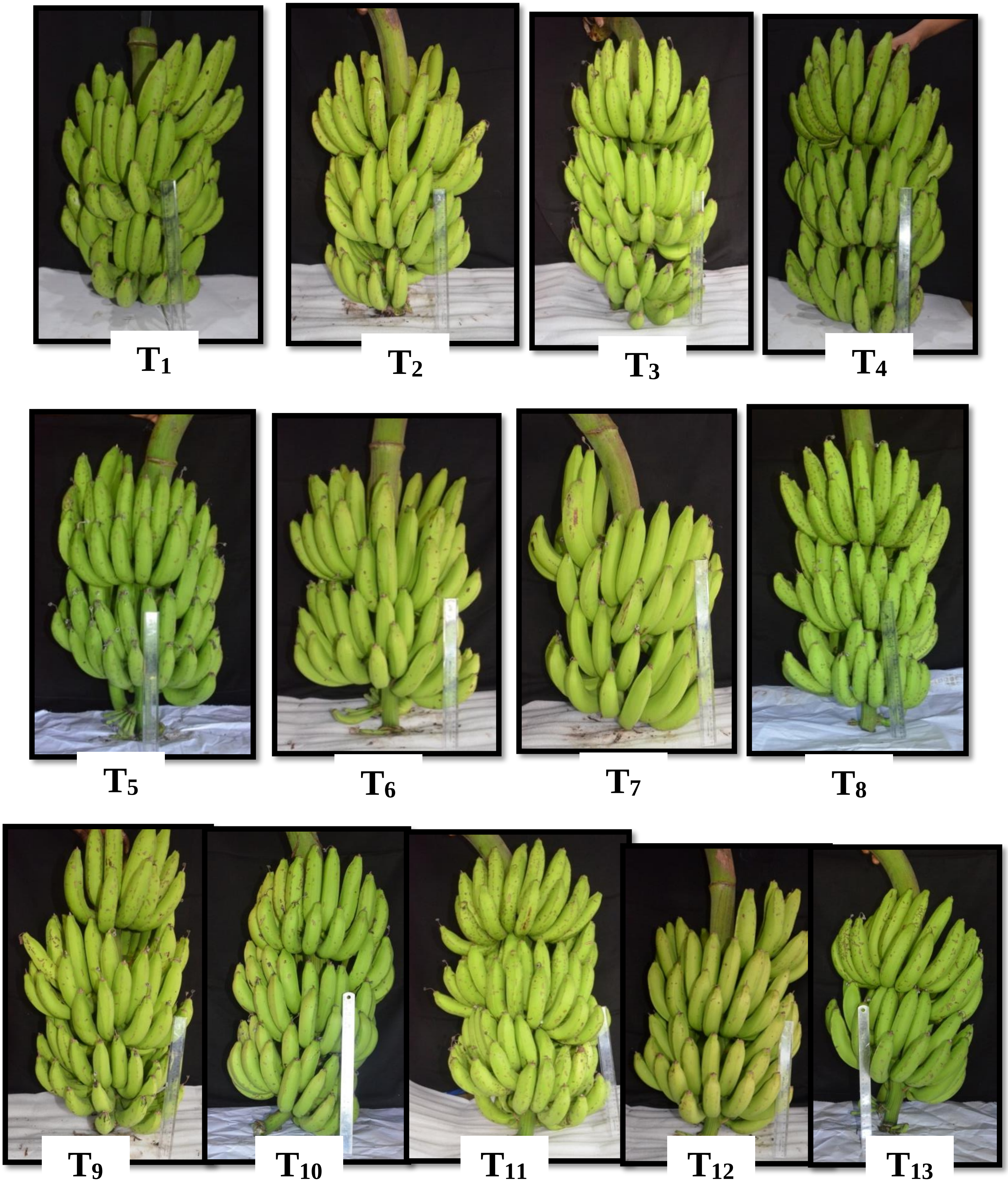


Plate 6: Harvested banana bunches of Experiment 1 (Main crop)

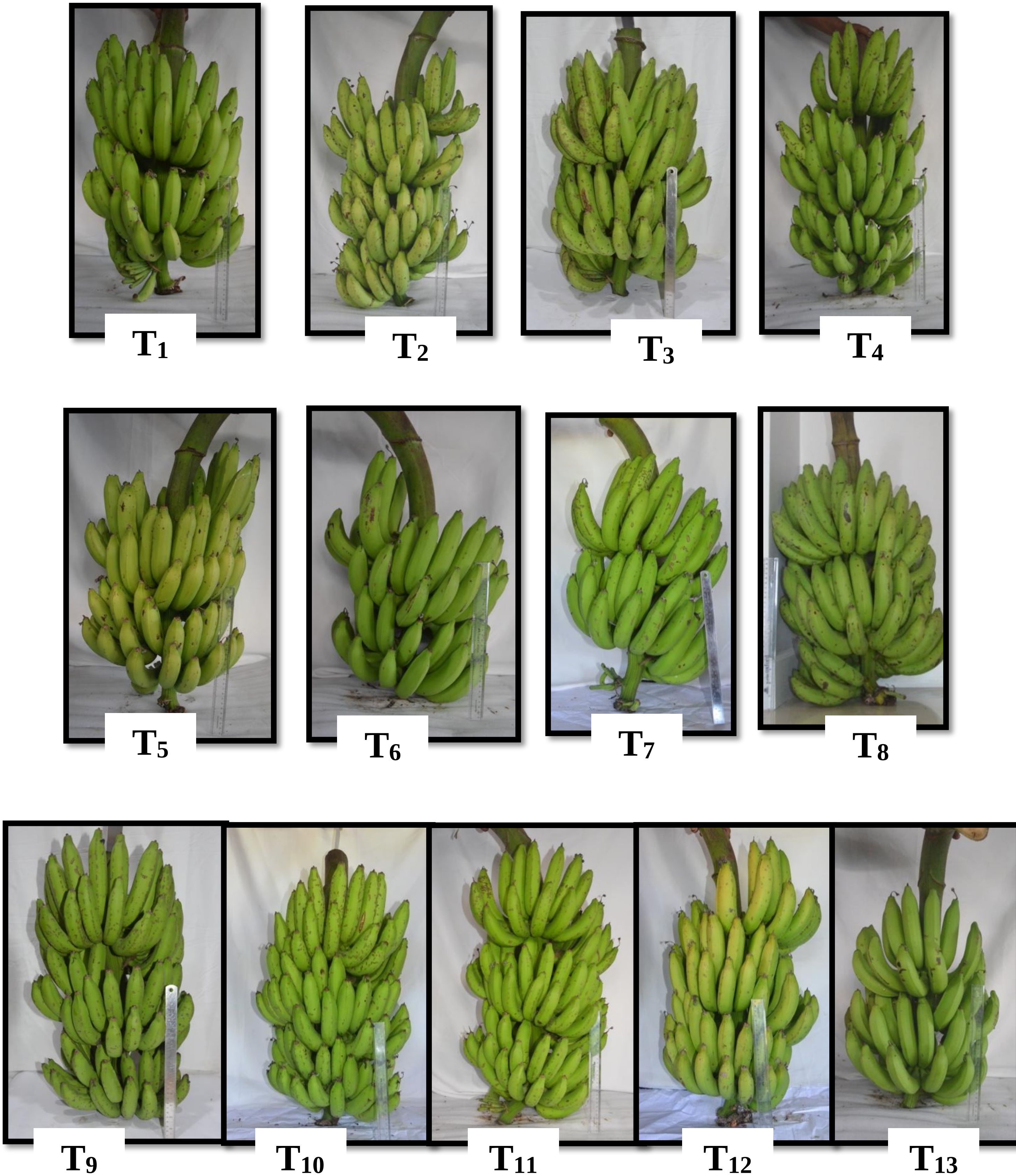


Plate 7: Harvested banana bunches of Experiment 1 (Ratoon crop)

T_1

T_2

T_3

T_4

T_5

T_6

T_7

T_8

T_9

T_{10}

T_{11}

T_{12}

T_{13}

Plate 8: Ripe hands of Experiment 1 (Main Crop)

T_1

T_2

T_3

T_4

T_5

T_6

T_7

T_8

T_9

T_{10}

T_{11}

T_{12}

T_{13}

Plate 9: Ripe hands of Experiment 1 (Ratoon Crop)

Plate 10: View of Experimental -2 research plot

T_1

T_2

T_3

T_4

T_5

T_6

T_7

Plate 11: Harvested banana bunches of Experiment 2 (Main crop)

T_1

T_2

T_3

T_4

T_5

T_6

T_7

Plate 12: Harvested banana bunches of Experiment 2 (Ratoon crop)

T_1 T_2

T_3 T_4 T_5

T_6 T_7

Plate 13: Ripe banana hands of Experiment 2 (Main crop)

T_1

T_2

T_3

T_4

T_5

T_6

T_7

Plate 14: Ripe banana hands of Experiment 2 (Ratoon crop)

Plate 15: Banana intercropped with ginger

Plate 16: Banana intercropped with turmeric

Plate 17: Banana intercropped with cowpea

Plate 18: Banana intercropped with French bean

Plate 19: Banana intercropped with brinjal

Plate 20: Banana intercropped with cabbage

Plate 21: Banana intercropped with chilli

Plate 22: Banana intercropped with broccoli

Plate 23: Banana intercropped with colocasia

Plate 24: Ripe bananas during peak season

CHAPTER 5

SUMMARY AND CONCLUSION

The investigation entitled 'Organic nutrient management and intercropping in banana orchard in Mizoram' was carried out during 2016-2018 at farmer's field situated at Kelsih, Aizawl district, Mizoram. The findings from the research trial under two experiments are summarized below.

Experiment 1: Organic Nutrient Management of Banana

- Highest pesudostem height (267.10 cm, 164.12 cm) and girth (73.96 cm, 71.28 cm) was recorded in main and ratoon plants treated with poultry manure (PM) along with *Azotobacter* (AZ), PSB and KSB @ 100gm/plant.
- Plants at control is having highest phyllocron days during three stages *viz.* small (9.84, 8.16 days), large (8.65, 8.02 days) and shooting (9.08, 8.52 days) stage in main crop as well as in ratoon plants.
- Plants at T_{11} (PM +AZ+PSB+ KSB) had highest number of functional leaves (34.15 and 32.34) in main and ratoon crops followed by T_{10} (32.67, 30.74) *i.e.* treatment with Neem Cake (NC) +AZ+PSB+ KSB.
- At harvesting, banana plants applied with PM+AZ+PSB+ KSB (T_{11}) had highest leaf area (11.02 m^2) and LAI (3.69) in main crop whereas, plants treated with NC+AZ+PSB+ KSB (T_{10}) had highest leaf area (10.18 m^2) and LAI (3.40) at ratoon crop.
- In case of main crop, plants treated with PM+AZ+PSB+ KSB (T_{11}) had shortest days for shooting (259.33, 254.67 days) and least crop duration

(346, 338 days) compared with control (330.67 and 430 days in main crop; 319.33 and 413 days in ratoon crop, respectively).

- Highest bunch weight was recorded in T_{11} (25.47 and 23.32 kg) for main and ratoon crop followed by T_{10} (22.37 and 20.08 kg) compared with control (9.08 and 6.28 kg).
- Number of hands per bunch was highest (7.89, 7.73) for main and ratoon crop in T_{11} (PM+AZ+PSB+ KSB) compared with control (5.33 and 4.64).
- Number of fingers per hand and finger weight for main (14.11; 221.93g) and ratoon crop (13.44; 209.47g) was highest in T_{11} (PM+AZ+PSB+KSB) followed by T_{10} *i.e.* NC+AZ+PSB+KSB (no. of fingers/hand: 13.33, 12.89 and finger weight: 216.20, 204.37 g).
- Yield was recorded highest for the plants treated with poultry manure along with biofertilizers *viz.* AZ+PSB+ KSB (28.30 t/ha in main crop and 25.91 t/ha in ratoon crop) whereas, yield was also high in T_{10} (NC +AZ+PSB+ KSB) (24.85t/ha, 22.31 t/ha) and T_9 (VC +AZ+PSB+ KSB) (24.33t/ha and 21.20 t/ha) compared with other treatments.
- In fruit physico-chemical qualities, PM +AZ+PSB+ KSB (T_{11}) treated plants had fruits with high pulp:peel ratio (2.61, 2.21) and TSS:acid ratio (122.62, 104.73) in main and ratoon crops. TSS content (25.75, 23.04 ºBrix) was also recorded high under this treatment.
- Plants treated with vermicompost along with biofertilizers combination (T_9) also had fruits with high TSS (24.83, 23.55 ºBrix), TSS: acid ratio (112.88, 107.05) and highest ascorbic acid content (9.48 and 8.76 mg/100g fruit weight) in main as well as in ratoon crops.

- Banana plants treated with neem cake along with biofertilizer (T_{10}) and poultry manure along with biofertilizer (T_{11}) had high soil (1296.81, 1345.78 kg/ha in main and 1267.87, 1321.38 kg/ha in ratoon) and leaf (2.21%, 2.24% in main and 2.16% and 2.19% in ratoon) nitrogen and potassium (T_{10}: 981.67 kg/ha in main crop and 978.45 kg/ha in ratoon crop in soil, 2.74% in main and 2.65% in ratoon crop in leaf and T_{11}: 986.78 kg/ha in main crop and 982.35 kg/ha in ratoon crop in soil, 2.83% in main crop and 2.81% in ratoon crop in leaf) with good soil C:N ratio (T_{10} 16.58, 15.72; T_{11}: 16.98, 15.93, main and ratoon crop, respectively).
- Banana plants at T_{11} (PM+AZ+PSB+ KSB) had high amount of Mn (53.06, 52.82 mg/kg) and Zn (5.86, 5.83 mg/kg) in soil of main and ratoon crop. Leaf Mn (667.12, 632.45 ppm), Cu (6.84, 7.42 ppm) and Zn (16.19, 15.07 ppm) content was also remained high under this treatment in main as well as in ratoon plants. Besides, it had secured the highest leaf C:N ratio (3.49 and 3.25) for both main and ratoon crop.
- Microbial analysis of the soil of experimental orchard revealed that banana plants treated with PM+AZ+PSB+KSB (T_{11}) had high AZ, PSB and KSB count in main (9.81, 7.81 and 7.51 X 10^6cfu g^{-1}) and ratoon crop (9.97, 7.84 and 7.53 X 10^6cfu g^{-1}).
- Poultry manure with biofertilizers (T_{11}) treated banana plants had highest benefit:cost ratio (3.89 in main, 6.79 in ratoon) compared with control (1.91 and 5.95 in main and ratoon).

Experiment 2: Intercropping in Banana

- Plant pseudostem height (262.43, 254.78 cm) and girth (74.83, 72.97 cm) at harvesting was found highest in T_6 (banana intercropped with chilli + broccoli) compared with other treatments in main as well as ratoon crop.
- Intercropping banana with chilli + broccoli (T_6) had maximum number of functional leaves (13.77, 12.52) at shooting compared with other treatments.
- Banana intercropped with cowpea and french bean (32.27, 30.55); brinjal + cabbage (33.18, 31.74) and chili + broccoli (34.67, 32.23) had high total leaf production than other treatments.
- Leaf area index (LAI) of banana was found highest in T_6 (main: 3.96, ratoon: 3.78) followed by T_5 (main: 3.96, ratoon: 3.78) whereas, it was found minimum in T_3 (main: 3.14, ratoon: 2.89) at shooting stage.
- Banana plants intercropped with colocasia had highest crop duration (390.55 days in main; 381.95 days in ratoon) and days for shooting (296.15 days in main, 289.37 in ratoon) compared with other treatments. Whereas crop duration was minimum (356.32 days) in T_6 in main crop and (344.17 days) in T_5 in ratoon crop.
- For the main crop, sucker production was recorded maximum (10.22) in T_6 (banana intercropped with chilli + broccoli) whereas it is maximum (6.19) in T_5 (banana intercropped with brinjal + cabbage) in ratoon crop.
- Bunch weight (23.15 kg in main, 19.45 kg in ratoon) and finger weight (214.58 g in main and 207.79 g in ratoon) was recorded highest in T_6 (banana intercropped with chilli + broccoli) compared with other treatments. Second hand weight (main: 2.97Kg, ratoon: 2.32 Kg) and number of finger

per hand (main crop: 13.57 and ratoon: 11.89) was also recorded maximum under this treatment.

- Plants at T_5 (banana intercropped with brinjal + cabbage) also had scored high second hand weight (2.53kg in main, 2.12 kg in ratoon) and finger weight (202.60 g in main and 189.10 g in ratoon).
- Highest yield was obtained in T_6 (25.72 t/ha in main & 21.61 t/ha in ratoon) followed by T_5 (22.38 t/ha in main and 19.16 t/ha in ratoon) compared with T_3 where it was recorded lowest (16.84t/ha in main and 13.46 t/ha in ratoon crop).
- Plants at T_5 and T_6 had high pulp: peel ratio (main: 2.32, 2.45 and ratoon: 2.27, 2.34), ascorbic acid content (main crop: 8.84, 8.78 and ratoon: 8.27, 8.34 mg/100g fruit), TSS:acid ratio (main crop: 109.45, 115.81 and ratoon crop: 101.91 and 109.00) and carbohydrate content (main crop: 23.47, 23.55 and ratoon crop: 22.21, 22.14 g/100g) compared with other treatments.
- Besides, fruits from the banana plants intercropped with chilli + broccoli (T_6) had highest total sugar (main crop: 21.32% and ratoon crop: 18.42%) and amylose content (main crop: 21.75% and ratoon crop: 20.42%).
- Banana plants intercropped with turmeric (T_2) and colocasia (T_3) had low soil nitrogen (main crop: 864.28, 816.56 and ratoon crop: 823.47, 792.38 kg/ha), soil potassium (main crop: 582.39, 562.48 and ratoon crop: 545.83, 528.76 kg/ha) along with low leaf nitrogen (main crop: 2.11%, 1.98% and ratoon crop: 1.78%, 1.71%) and leaf potassium (main crop: 2.24%, 2.14% and ratoon crop: 1.98%, 1.85%) compared with T_5 and T_6, where it was found significantly high.

- Banana plants intercropped with chilli + broccoli (T_6) had high soil C:N ratio (main crop: 17.49, ratoon crop: 16.11) and leaf carbohydrate: nitrogen ratio (main crop: 3.11 and ratoon crop: 3.09) compared with other treatments.
- Banana intercropped with chilli + broccoli (T_6) had highest benefit:cost ratio (6.08 in main , 7.21 in ratoon) followed by banana intercropped with ginger (5.66 in main , 6.60 in ratoon) compared with other treatments. Benefit: cost was minimum (2.79 in main and 3.57 in ratoon crop) in case of the banana plants intercropped with colocasia (T_3).
- Though, performance of banana intercropped with brinjal + cabbage (T_5) was also good however resulted with comparatively low benefit: cost ratio (main crop: 4.25 and ratoon crop: 5.44). However, benefit: cost ratio in case of control recorded quite high (6.52 in ratoon crop) as no intercrop and planting material cost was involved.

Conclusion:

For both the experiment, ratoon crops performance in term of agronomical and quality traits were lower than main crop, however, with higher B:C ratio.

Experiment 1: Organic Nutrient Management of Banana

- Organic manures added with biofertilizer provided better yield and fruit physico-chemical quality performance than solo application.
- Poultry manure when added with azotobacter, phosphate solubilizing bacteria and potash solubilizing bacteria had scored highest pseudo stem height; girth, maximum number of functional leaves along with highest bunch weight and yield of banana both in main crop and ratoon crop.

Besides, the treatment caused least crop duration, earlier shooting and shortest shooting to harvesting days. The fruits under this treatment had low fruit moisture with high pulp:peel ratio and TSS:acid ratio. Moreover, resulted in highest B:C ratio, thus, to be considered as the most promising organic nutrition management treatment among others.

- However, it was found that banana plants when provided with vermi compost along with AZ+PSB+KSB had good physico-chemical quality of fruits.
- Besides, banana plants manured with neem cake along with biofertilizers also had high yield of quality fruits but having lower B:C ratio due high input cost.

Experiment 2: Intercropping in Banana

- Banana plants intercropped with brinjal+cabbage (T_5) and chilli + broccoli (T_6) had better performance in terms of plant physiological characters and physcio-chemical characters of fruits along with yield.
- Banana plants intercropped with turmeric (T_2) and colocasia (T_3) had low soil and leaf nitrogen, phosphorus and potassium and consequently resulted in poor plant growth and agronomical records as well as fruit quality performance compared with other treatment.
- Intercropping banana plant with chilli+broccoli had resulted in highest pseudostem height, girth, total number of leaves, leaf area, bunch weight, finger weight, 2nd hand weight and yield. Besides, fruits of this treatment had highest pulp:peel ratio, TSS, TSS:acid ratio, amylose and carbohydrate content. This intercropping treatment caused presence of high soil and leaf

N, P and K which resulted in lowest phyllocron, days for shooting and crop duration with highest B:C ratio. Therefore, it may be concluded that chilli+broccoli was found as the best suited intercrops for banana cultivation in experimental location.

- Intercropped with brinjal + cabbage though had impacted good to the main crop banana, but resulted in comparatively, low B:C ratio, whereas, intercropping with ginger, though not given excellent performance impact to the main crop banana, however had high B:C ratio because of high return on investment from ginger.

Overall, from the present investigation entitled ‘organic nutrient management and intercropping in banana orchard in Mizoram’ it may be finally concluded that for organic cultivation of banana, poultry manure along with biofertilizers viz. Azotobacter, PSB and KSB is best suited treatment, whereas chilli + broccoli was the best performed intercrops at banana orchard in the experimental location.

BIBLIOGRAPHY

A.O.A.C. (2012). Official methods of Analysis. Association of Official Analytical Chemist. 12th Edition, Washington DC.

Aba, S.C., Baiyeri, P.K. and Tenkouano, A. (2011). Impact of Poultry Manure on Growth Behaviour, Black Sigatoka Disease Response and Yield Attributes of Two Plantain (*Musa spp*. AAB) Genotypes. *Tropicultura*, **29(1)**: 20-27.

Abbasi, M.K. and Yousra, M. (2012). Synergistic effects of biofertilizer with organic and chemical N sources in improving soil nutrient status and increasing growth and yield of wheat grown under greenhouse conditions. *Plant Biosyst*. - *Int. J. Deal. Asp. Plant Biol*., **146(1)**: 181–189.

Abd El-Aziz, A.B.K. (2002). Physiological studies on bio-fertilization of banana plants cv. Williams. *Ph.D. Thesis,* Fac. Agric. Minia University.

Abd El-Naby, S.K.M. (2000). Effect of banana compost as organic manure on growth, nutrient status, yield and fruit quality of Maghrabi banana. *Assiut J. Agric. Sci.*, **31(3)**: 101-114.

Ahmadi, E., Honnabyraiah, M.K., Alur, A.S., Adiga, J.D. and Rao, V. (2017). Impact of integrated nutrient management on yield and quality parameters of strawberry (*Fragaria* X *Ananasa* duch.) cv. “Sabrina” under polyhouse. *Int. J. Curr. Microbiol. App. Sci.*, **6(9)**: 3481-3487.

Ahmed, M.A., El-Sonbaty, M.R. and Soliman, S.S. (2009). Response of Maghrabi banana to different mixtures of organic fertilizers. *Green Farming,* **2(9)**: 577-583.

Aiyelaagbe, O.O.I. (2001). Productivity of an Intercropped Sweet Orange Orchard in Southwestern Nigeria. *Biol. Agri. Hort*., **18(4)**: 317-325.

Al Busaidi, K.T.S. (2012). Effects of Organic and Inorganic Fertilizers on Growth and Yield of Banana (*Musa* AAA cv. Malindi) in Oman. *Ph.D. Thesis* submitted to University of Kassel, Germany.

Alam, R., Faruq, O., Uddin, R., Zonayet and Syfullah, K. (2021). Intercropping of winte vegetables with banana in Khagrachari hill district of Bangladesh. *J. Global Agriculture and Ecology*, **11(3)**: 34-41.

Al-Hadethi, M. E.A. (2019). Response of hawthorn transplants to biofertilizers and poultry manure. *Iraqi J. Agril. Sci*., **50(2)**: 734-740.

Alvarez, C.E, Ortega, A., Fernandez, M. and Borges, A.A. (2001). Growth, yield and leaf nutrient content of organically grown banana plants in the Canary islands. *Fruits,* **56(1)**: 17-26.

Ani, J.U. and Baiyeri, P.K. (2008). Impact of poultry manure and harvest season on juice quality of yellow passion fruit (*Passiflora edulis* var. flavicarpa Deg.) in the sub-humid zone of Nigeria. *Fruits,* **63**: 239-247.

Ashokan, P.K., Wahid, P.A. and Sreedharan, C. (1988). Relative uptake of ^{32}P by cassava, banana, elephant foot yam and groundnut in intercropping systems. *Plant and Soil,* **109**: 23-30.

Asten, P.J.A., Wairegi, L.W.I, Mukasa, D. and Uringi, N.O. (2011). Agronomic and economic benefits of coffee – banana intercropping in Uganda's small holder farming system. *Agricultural Systems*, **104**: 326-334.

Athani, S.I. and Hulamani, N.C. (2000). Effect of vermicompost on fruit yield and quality of banana cv. Rajapuri (*Musa* AAB). *Karnataka J. Agril. Sci*., **13(4)**: 942-946.

Athani, S.I., Hulamanai, N.C. and Shirol, A.M. (1999). Effect of vermicompost on maturity and yield of banana cv. Rajapuri (*Musa* AAB). *South Indian Hort.*, **47**: 4-7.

Athani, S.I., Ustad, A.I., Prabhuraj, H.S., Swamy, G.S.K., Patil, P.B. and Kotikal, Y.K. (2007). Influence of vermicompost on growth, fruit yield and quality of guava cv. Sardar. *Acta Hort.*, **735**: 381-385.

Attia, M., Ahmed, M.A. and El-Sonaty, M.R. (2009). Use of biotechnologies to increase growth, productivity and fruit quality of Maghrabi banana under different rates of phosphorus. *World J. Agric. Sci.,* **5(2)**: 211-220.

Avilan, R.L., Garcia, M.L. and Sue, E. (1983). Intercropping system for Avocado (*Persea* spp.) in the central region of Venezuela. *Agronomia Trop*., **33**: 326-334.

Bakshi, M., Wali, V.K., Sharma, A. and Raina, V. (2018). Economic Evaluation of Kinnow Mandarin Cultivation Using Inorganic and Organic Nutrient Sources Along with Biofertilizers. *Int. J. Curr. Microbiol. Appl. Sci*., **7(8)**: 130-138.

Bakshi, P., Bhushan, A. and Kour, K. (2019). Intercropping in fruit orchards: a way forward for doubling the farmer's income. *Int. J. Agri. Sci*., **11**: 9274-9276.

Balakrishna, H.T., Swamy, G.S.K., Sabarad, A.I., Patil, C.P. and Athani, S.I. (2005). Response of *Glomus fasciculatum*, Vermiculture and *Trichoderma harzianum* for yield and yield attributes on banana ratoon crop. *Karnataka J. Hort.,* **1(4)**: 63-70.

Barker, A.V. (1975). Organic vrs. inorganic nutrition of horticultural crops and quality. *Hort. Sci.,* **10**: 73-75.

Barve, J.V. (1992). Vermiculture in grape cultivation. In: *Congress on traditional science and technology-keynote papers. Indian Inst. Technol.*, Bombay, Extended Abstracts. p.10-13.

Berad, S.M. (1993). Effect of different intercrops on growth, yield and economics of bottle gourd cv. *Varad* under south Gujarat conditions. A thesis submitted to Gujarat University, Navsari.

Bhalerao, V.P., Patil, N.M., Badgukar, C.D. and Patil, D.R. (2009). Studies on integrated nutrient management for tissue cultured 'Grand Naine' banana. *Indian J. Agric. Res*., **43**: 107-112.

Bharadwaj, V. and Omanwar, P.K. (1994). Long term effects of continuous rotational cropping and fertilization on crop yields and soil properties- II. Effects on EC, pH, organic matter and available nutrients of soil. *J. Indian Soc. Soil Sci.,* **42**: 387-392.

Bhowmik, S.R. and Pan, J.C. (1992). Shelf-life of matured green tomatoes stored in controlled atmosphere and high humidity. *J. Food Sci*., **4**: 948-953.

Bhuma, M. (2001). Studies on the impact of humic acid on sustenance of soil fertility and productivity of green gram (VBNGG-2). *M.Sc. (Agri.) Thesis,* Tamil Nadu Agric. Univ., Coimbatore.

Bhuva, H.P., Katrodia, J.S., Patel, G.L. and Chundawat, B.S. (1988). Response of intercropping on economics and effects on main crop of mango under South Gujarat condition. *Acta Hort.*, **231**: 316-320.

Bindiya, Y., Srihari, D. and Babu, J.D. (2012). Effect of organic manures and biofertilizers on growth, yield and nutrient uptake in gherkin (*Cucumis anguria* L.). *J. Res. ANGRAU*, **40(1)**: 26-29.

Black, C.A. (1965). Methods of Soil Analysis: Part I, Physical and Mineralogical Properties. American Society of Agronomy, Madison, Wisconsin.

Blair, M.W., Wu, X., Bhandari, D., Zhang, X. and Hao, J. (2016). Role of Legumes for and as Horticultural Crops in Sustainable Agriculture. In: Nandwani, D. (ed.) Organic Farming for Sustainable Agriculture, **9**: 185-211.

Chapman, H. D. and Pratt, P. F. (1961). Methods of Analysis for Soils, Plants and Waters. University of California, Agricultural Science, Berkeley. p. 309.

Chezhiyan, N., Balasubramani, P., Harris, C.V and Ananthan, M. (1999). Effect of inorganic and biofertilizers on growth and yield of hill banana var. Virupakshi. *South Indian Hort.,* **47**: 161-166.

Choudhary, S.K., Jat, M.K., Sharma, S.R. and Singh, P. (2011). Effect of INM on soil nutrient and yield in groundnut field of semi-arid area of Rajasthan. *Legume Res*., **34(4)**: 283-287.

Chundawat, B.S., Joshi, H.H. and Patel, N.L. (1984). Studies on intercropping in Basrai banana. *South Indian Hort.*, **32(1)**: 23-25.

Das, A. K. and Maharana, T. (1995). Profitable intercrops in banana. *Orissa J. Hort*., **23(1)**: 127-128.

Devadas, V.S. and Kuriakose, K.P. (2005). Evaluation of different organic manures on yield and quality of pineapple var. Mauritius. *Acta Hort*., **666**: 185-189.

Devi, H. L. and Mitra, S.K. (2012). Effect of different organic and biofertilizer sources on guava (*Psidium guajava* L.) 'Sardar'. Proc. 3rd IS on guava and other Myrtaceae, *Acta Hort.*, **959**: 201-208

Devi, H. L. and Mitra, S.K. (2018). Organic nutrient management system for cultivation of pineapple (*Ananas comosus* L.) cv. Kew. *Innovative Farming*, **3(4)**: 181-184.

Devi, H.L., Poi, S.C. and Mitra, S.K. (2014). Organic Nutrient Management Protocol for Cultivation of 'Bombai' Litchi. *Acta Hort*., **1029**: 215-224.

Dheware, R.M., Nalage, N.A., Sawant, B.N., Haldavanekar, P.C. , Raut, R.A., Munj, A.Y. and Sawant, S.N. (2020). Effect of different organic sources and biofertilizers on yield and quality production in mango cv. Alphonso. *J. Pharmacog. Phtyochem*., **9(2)**: 97-99.

Dickman, S.R. and Bray, R.H. (1940). Colorimetric determination of phosphate. *Ind Eng Chem Anal.,* **12**: 665–668.

Donald, C.M. (1962). In search of yield. *Assist. Inst Agric. Sci.,* **28:** 171-178.

Dwivedi, V. (2013). Effect of integrated nutrient management on yield, quality and economics of guava. *Annals of plant and soil research,* **15(2)**: 149-151.

Elangovan, M., Suthanthirapandian, I.R. and Sayed, S. (1980). Intercropping of onion in chilli. *South Indian Hort.,* **30(1)**: 48-50.

El-Moniem, E.A. and Radwan, A.A. (2003). Response of Williams banana plants to biofertilization in relation to growth productivity and fruit quality. *Arad Universities J. Agric. Sci.,* **11(2)**: 751-763.

Eman, A, El-Monium, Abd., Abd-Allah, A.S.E. and Ahmed, M.A. (2008). The combined effect of some organic manures, mineral N fertilizers and Algal cells extract on yield and fruit quality of Williams banana plants. *American-Eurasian J. Agric. And Envtl. Sci.,* **4(4)**: 417-426.

Ewulo, B.S., Ojeniyi, S.O. and Akanni, D.A. (2008). Effect of poultry manure on selected soil physical and chemical properties, growth, yield and nutrient status of tomato. *African J. Agril. Res*., **3**: 612-616.

FAO (2006). FAO-Statistics 2006, Food and Agriculture Organization of United Nations, Rome, Italy. (http://www.faostat.fao.org. visited on 29th March 2016).

FAO (2009). FAO-Statistics 2009, Food and Agriculture Organization, Rome (http://www.faostat.fao.org. visited on 29th March 2016).

Fawzy, Z.F., El-Bassiony, A.M. and Saleh, S.A. (2007). Effect of chemical fertilizer, poultry manure and biofertilizer on growth, yield and chemical contents of tomato plants. *J. Agric. Sci. Mansoura Univ*., **32(8)**: 6583-6594.

Florence, T., Janos, T., Adam, C. and Tamas, N.P. (2021). Usage of fermented chicken manure as a biofertilizer in apple orchard. *Nat. Res. Sustain. Dev*., **11(2)**: 193-204.

Gaikwad, R.T., Bhalerao, V.P., Pujari, C.V. and Patil, N.M. (2009). Effect of fertilizars on nutrient uptake and yield attributes of banana. *Asian J. Soil Science,* **4(2)**: 271-274.

Ganapathi, T. and Dharmatti, P.R. (2018). Effect of integrated nutrient modules on growth, yield and quality parameters of banana cv. Grand Naine. *Intl.J. Curr. Microbiol. App. Sci.,* **7(1)**:1974-1984.

Geetha, K. and Nair, R.R. (2000). Integrated plant nutrition system (IPNS) for banana. *Ann. Agril. Res.,* **21(4)**: 499-503.

Ghosh, D.K., and Hore, J.K. (2011). Economics of a coconut – based intercropping system as influenced by spacing and seed rhizome of ginger. *Indian Journal of Horticulture*, **12**: 449-452.

Ghosh, S.N. (2001). Intercropping in guava orchard in watershed area. *Hort. J.,* **14(3)**: 36-40.

Gill, M.S., Khehra, S. and Gupta, N. (2018). Impact of intercropping on yield, fruit quality and economics of young Kinnow mandarin plants. *J. Appl. Nat. Sci*., **10(3)**: 954-957.

Girija Devi, L. Gladis, R and Joseph, B. (2011). Performance studies of various crops in coconut based cropping system compared to sole cropping. *Journal of Progressive Agriculture,* **2(1)**: 47-50.

Gogoi, D., Kotoky, U. and Hazarika, S. (2004). Effect of biofertilizers on productivity and soil characteristics in banana. *Indian J. Hort.,* **61**: 354-356.

Gomes, J.A., Nobrega, A.C., Salgado, J.S. and Da-Rocha, A.C. (1988). Utilization of organic matter in banana cultivar Prata in the state of Espirito Santo. *Comunicado Tecnico Empresa Capixaba de pesquisa Agropecuaria*, EMCAPA., **49**. p.4.

Gomez, K.A. and A.A. Gomez, (1983). Statistical procedures for agricultural research (2 ed.). John wiley and sons, NewYork, pp.20-29.

Gottreich, M., Bradu, D. and Haleway, Y. (1964). A simple method for determining average fruit weight. *Ktavim*., **14**: 161-162.

Gupta, C.R. (1999). Intercropping in cashew orchard under rainfed condition – a model for Bastar plateau zone of Madhya Pradesh. *The Cashew,* **13(2)**: 18-22.

Hammam, M.S. (2003). Effect of biofertilization on growth and fruiting of Cavendish and Williams banana. *Egyptian J. Hort.,* **30(1/2)**: 67-81.

Hazarika, B.N. and Ansari, S. (2008). Effect of integrated nutrient management on quality of banana cv. Jahaji (AAA). *Indian Agriculturist*, **52(3/4)**: 175-178.

Hazarika, B.N. and Ansari, S. (2010). Effect of integrated nutrient management on growth and yield of banana cv. Jahaji. *Indian J. Hort*., **67(2)**: 270-273.

Hazarika, T.K., Malsawmkimi and Ngurthankhumi, R. (2022). Phenological attributes, fruit set, fruit drop, yield and quality of Khasi mandarin Orange as influenced by application of organic amendments and biodynamic preparations. *Biol. Agric. Hortic*. https://doi.org/10.1080/01448765.2022.2060758.

Hazarika, T.K., Nautiyal, B.P. and Bhattacharya, R.K. (2011). Effect of INM on productivity and soil characteristics of tissue culture banana cv. Grand Naine in Mizoram, India. *Progressive Horticulture*, **43(1)**: 30-35.

Hema, R., Bhagavan, B.V.K. and Sudhavani, V. and Umakrishna, K. (2016). Effect of Organic Manures and Bio-fertilizers on Yield and Fruit Quality of Banana cv. Grand Naine (AAA). *Int. J. Bioresources Stress Mgmt*., **7(4)**: 832-836.

Hipparagi, K. and Chinnapa, B. (2008). Production potential and economics of banana based cropping systems, *Indian J. Agric. Res.*, **42(2)**: 116-119.

Hipparagi, K., Narayana, J. and Venkatesha, J. (2010). Effect of organic, inorganic and biofertilizer manuring on growth and yield of ratoon crop of banana cv. Dwarf Cavendish. *J. Asian Hort.*, **6(2)**: 38-40.

Hodge, J.E. and Hofreiter, B.T. (1962). Carbohydrate chemistry.17 (Eds. R.L. Wistler and J.N. Bemiller) Academic Press, New York (Quoted by Thimmaiah, S.K. 1999) In: Standard methods of biochemical analysis, Kalyani publishers, New Delhi, pp. 54-55.

Hussain, F.S., Reddy, L. and Ramudu, V. (2017). Studies on integrated nutrient management (INM) practices on soil characteristics and yield in tissue culture banana cv. Grand Naine (AAA). *Int. J. Curr. Microbiol. App. Sci.*, **6(12)**: 2557-2564.

Hussain, Z., Ilyas, M., Luqman and Khan, I.J. (2016). Influence of sowing orientation and intercropping of chili on tomato yield and its weed. *Pak. J. Weed Sci. Res*., **22(3)**: 395-406.

Isuwan, A. (2014). Agronomic Traits and Fruit Quality of Pineapple with Different Levels of Chicken Manure Application. *Silpakorn Univ. Sci. Tech. J*., **8(1)**: 67-73.

Jackson, M.L. (1973). *Soil Chemical Analysis.* Pretence Hall of India Pvt. Ltd., New Delhi, pp. 1-498.

Jain, P.K. and Raut, R.L. (2004). Influence of intercrops on yield attributes and land equivalent ratio of mango (*Mangifera indica*). *In: First Indian Horticulture Congress (Abst.),* 6-9 November, 2004, Pusa, New Delhi, pp. 171-172.

Jaipaul, Sharma, S., Dixit, A.K. and Sharma, A.K. (2011a). Growth and yield of capsicum (*Capsicum annum*) and garden pea (*Pisum sativum*) as influenced by organic manures and biofertilizers. *Indian J. Agril. Sci*., **81(7)**: 637-642.

Jaipual, Sharma, S. and Sharma, A.K. (2011b). Effect of organic fertilizers on growth, yield and quality of potato under rainfed conditions of central Himalayan region of Uttarakhand. *Potato J*., **38(2)**: 176-181.

Jata, S.K. (2009). Intercropping elephant foot yam in orchard crops. *Odisha Review,* **10**: 82-84.

Jayakumar, M., Ponnusawmy, K. and Amanullah, M.M. (2008). Influence of intercropping and sources of nitrogen on yield attributes, yield and economics of cotton. *Res. J. Agric. & Biol. Sci.,* **4(2)**: 149-153.

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

Jeyabaskaran, K.J., Pandey, S.D., Mustaffa, M.M. and Sathiamoorty, S. (2001). Effect of different organic manures with graded levels of inorganic fertilizers on Poovan banana. *South Indian Hort.*, **49**: 105-109.

Jeyabaskaran, K.J., Pandey, S.D., Mustaffa, M.M. and Sathiamoorty, S. (2010). Integrated nutrient management in banana. *Indian Journal of Fertilizers*, **6**: 24-31.

Joshi, P.S. (2000). Role of municipality in food security. In: *Proc. Int. Conf. and Workshop: Foos Security of Urban and Peri-Urban System in Developing Countries, Vienna*, 15-18th November, 2000. pp. 25-28.

Kadam, P. (2004). Influence of use of bio-fertilizers on benefit:cost ratio of banana cultivation cv. Rajapuri. *M.Sc. (Hort.) Thesis,* Univ. Agril. Sci., Dharwad.

Kale, R.D., Mallesh, B.C., Bano, K. and Bhagyaraj, D.J. (1992). Influence of vermicompost application on available micronutrients and selected microbial population in a paddy field soil. *Bio and Biochem.,* **29(12)**: 1317-1320.

Kanamadi, V.C., Shirol, A.M., Thammaiah, N. and Swamy, G.S.K. (2010). Effect of integrated nutrient management on growth and yield of banana cv. Rajapuri. *J. Asian Hort.,* **6(2)**: 38-40.

Kanamadi, V.C., Shirol, R.K.B.A.M., Thammaiah, N. and Athani, S.I. (2004). Influence of organic and inorganic fertilizers on growth and yield characters of banana cv. Rajapuri. *Karnataka J. Hort.*, **1(1)**: 81-85.

Karlidag, H. and Yildirim, E. (2009). Strawberry Intercropping with Vegetables for Proper Utilization of Space and Resources. *J. Sustainable Agri*., **33(1)**: 107-116.

Khalil, M.I., Hossain, M.B. and Schmidhalter, U. (2005). Carbon and nitrogen mineralization in different upland soils of the subtropics treated with organic materials. *Soil Biol. Biochem*., **37**: 1507-1518.

Koko, L.K., Snoeck, D., Lekadou, T.T. and Assiri, A.A. (2013). Cacao-fruit tree intercropping effects on cocoa yield, plant vigour and light interception in Côte d'Ivoire. *Agroforest Syst.*, **87**: 1043-1052.

Krishnakumar, V., Dhanpal, R. and Thomas, G.V. (2013). Integrated nutrient management for elephant foot yam intercropped in coconut garden. *Journal of Root Crops,* **39(2)**: 263-264.

Kulapati, H., Narayana and Venakatesha, J. (2009). Effect of integrated nutrient management on growth and yield of banana cv. Dwarf Cavendish (AAA). *Asian J. Hort.,* **5(40)**: 127-130.

Kumar, A. and Pillai, S.J. (1989). Economics of coconut based cropping system. *South Indian Hort.*, **37(2)**: 94-96.

Kumar, A., Pandey, S.D., Patel, R.K., Rai, R.R., Srivastava, K. and Nath, V. (2014). Studies of feasibility of intercropping under litchi based cropping system. *The Ecoscan*, **5**: 101-109.

Kuttimani, R., Velayudham, K. and Somasundaram, E. (2013). Growth and yield parameters and nutrient uptake of bananas influenced by integrated nutrient management practices. *Int. J. Recent Scientific Res.*, **4(5)**: 680-686.

Lahav, E. and Turner, D.W. (1983). Banana nutrition. *Int. Potash Institution Bulletin*, **7**: 33.

Lenka, J. and Lenka, P.C. (2014). Effect of integrated nutrient management on growth and yield of banana (*Musa* spp.) variety Grand Naine. *Journal of Crop and Weed*, **10(1)**: 182-185.

Lenka, P.C., Samal, S., Mohapatra, K.C., Boswal, M.K. (2005). Intercropping in cashew orchard under Orissa condition. *The Cashew*, **XIX(4)**: 20-23.

Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. (1951). Protein measurement with the Folin phenol reagent. *J Biol Chem*., **193(1)**: 265-275.

Mahadevaswamy, M. and Martin, G.J. (2003). Economics of wide row sugarcane intercropped with aggregatum onion under garden land conditions. *Madras Agric. J.*, **90**: 426-430.

Mahammad Amanulla, M., Sekar, S. and Muthukrishnan, P. (2010). Prospects and potential of poultry manure. *Asian J. Plant. Sci.*, **9**: 172-182.

Mahanta, H.D., Patil, S.J., Bhalerao, P.P., Gaikwad, S.S. and Kotadia, H.R. (2012). Economics and land equivalent ratio of different intercrops in banana (*Musa paradisiaca* L.) cv. Grand Naine under drip irrigation. *Asian J. Hort.*, **7(2)**: 330-332.

Maji, S. and Das, B.C. (2013a). Intercropping in young guava orchard. *Annals of Hort*., **6(1)**: 93-98.

Maji, S. and Das, B.C. (2013b). Effect of Intercropping on flowering and fruiting of guava cv. L49. *Annals of Hort*., **6(1)**: 76-81.

Mamatha, K., Naidu, M.M., Nagalakshmi, R. and Bhagavan, B.V.K. (2021). Studies on the Response of Different Commercial Banana Cultivars of Andhra Pradesh to Organic Production. *Chem. Sci. Rev. Lett*., **10**: 308-313.

McCready, R.M., Guggolz, J., Silviera, V. and Owens, H.S. (1950). Determination of starch and amylase in vegetables. *Anal Chem*., **22**: 1156-1158.

McIntyre, B., Gold, C., Kashaija, I., Ssali, H., Night, G. and Bwamiki, D. (2001). Effects of legume intercrops on soil-borne pests, biomass, nutrients and soil water in banana. *Biol. Fertil. Soils*, **34**: 342-348.

Meenakshi, K.J., Fazullah Khan, A.K. and Appadurai, R. (1974). Studies on the intercropping of short duration vegetables with maize. *Madras Agric. J.* **61(8)**: 389-401.

Meghwal, M.L., Jyothi, M.L., Pushpalatha, P.B. and Bhaskar, J. (2021). Yield and Fruit Quality of Banana *Musa* (AAB) Nendran as Influenced by Nutrient Sources. *Int. J. Bio-res. Stress Mgmt*., **12(2)**: 131-136.

Mensah, D.B., Dorcas, Q.M., Kwame, B.R. and Kodjo, D.S. (2012). Comparative study on the field performance of FHIA-01 (hybrid dessert banana) propagated from tissue culture and conventional sucker in Ghana. *J. Plant Develop*., **19**: 41-46.

Mishra, P.J. and Swain, S.C. (2001). A note on evaluation of different agri-horti systems in watersheds for Eastern Ghats High land zone of Orissa, *Orissa J. Hort*., **29(1)**: 1112-1114.

Mitra, S.K., Gurung, M.R. and Pathak, P.K. (2012). Organic nutrient management in high density guava orchard. *Acta Hort*., **933**: 233-238.

Mohapatra, A., Dash, D.K., Tripathy, P. and Sethi, K. (2016). Impact of Organic Inputs on Quality of Cashew Apple (*Anacardium occidentale* L.). *Adv. Life Sc*., **5(7)**: 2663-2667.

Mollah, M.R.A., Rahman, S.M.L., Khalequzzaman, K.M., Rahim, M.A. and Akther, M.A. (2007). Performance of intercropping groundnut with garlic and onion. *Int. J. Sustain. Crop Prod.,* **2(5)**: 31-33.

Morsy, S.M., Drgham, E.A. and Mohamed, G.M. (2009). Effect of garlic onion and extracts on their intercropping on suppressing damping-off, powdery mildew disease and growth characteristics of cucumber. *Egypt. J. Phytopathol.*, **37(1)**: 35-46.

Murray, D.M. (1960). The effect of deficiencies of major nutrients on growth and leaf analysis of the banana. *Trop. Agric. Trin*., **37**: 97-106.

Mustaffa, M.M., Kumar, V., Tanuja Priya, B. and Dhanasekhar, D. (2004). Influence of organic manure on growth and yield of banana. *International Congress on Musa:* Harnessing research to improve livelihoods, Penang, Malaysia. **214**: 65-66.

Nachegowda, V., Kumar, S. K. and Prasad, G.C.R. (2004). Effect of organic and inorganic fertilizers on growth, yield and quality of tissue cultured banana cv. Robusta. *Proc. of national seminar on banana industry – present scenario and future strategies*, held at BCKV, FTC, Kalyani, Est Bengal, 11-13th June, 2004. pp.11-13.

Nair, P.K.R., Nelliat, C.V. and Varma, R. (1974). Intercropping for enhanced profits from coconut plantations. *Indian Fmg.*, **24(4)**: 11-12.

Naresh, B. and Anamika, S. (2002). Effect of integrated nutrient management on production of banana and soil. *Global Conf. on banana and plantain,* 28-31st October, Bangalore. p. 126.

Naresh, B. and Sharma, A. (2005). Effect of integrated nutrient management on productivity of 'Jahajee' banana and soil properties under Nagaland foot hills condition. *Orissa J. Hort.*, **33(2)**: 31-35.

Nayak, M.R., Behera, L.K., Mishra, P.J. and Bhola, N. (2014). Economics and yield performance of some short duration fruit and medicinal crops under agri-silviculture system in rainfed uplands of Odisha. *Journal of Applied and Natural Science*, **6(1)**: 274-278.

Nayar, T.V.R and Suja, G. (1996). Intercropping dioscorea with banana var. Nendran (*Musa* AAB). *J. Root Crops*, **22**: 115-120.

Nazrul, M.I., Rahman, M.A. and Quayyum, M.A. (2007). Performance of intercropping banana with vegetables, *SAARC Journal of Agriculture*, **5(1)**: 53-57.

Ndukwe, O.O., Muoneke, C.O. and Baiyeri, K.P. (2011). Effect of the time of poultry manure application and cultivar on the growth, yield and fruit quality of plantains (*Musa* spp. AAB). *Tropical Subtropical Agroecosystems*, **14**: 261-270.

Nedunchezhiyan, M.; Misra, R. S. and Shivlinga Swamy, T. M. (2002). Elephant foot yam as an intercrop in banana and papaya. *The Orissa J. Hort*., **30(1)**: 80-82.

Netsere, A. and Kufa, T. (2015). Intercropping of Arabica coffee with turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) at Tepi, *Journal of Biology*, **5(7)**: 65-68.

Nybe, E.V., Abraham, C.Y. and Suma, A. (1991). Weed management in banana cv. Nendran with cowpea as an intercrop. Agricultural Research Journal of Kerala, **29**: 53-56.

Ouma, G. (2009). Intercropping and its application to banana production in east Africa. *J. Pl. Breeding & Crop Sci.*, **1(2)**: 13-15.

Ouma, G. and Jeruto, P. (2010). Sustainable horticultural crop production through intercropping: The case of fruits and vegetable crops: A review. *Agriculture and Biology Journal of North America*, **1**: 1098-1105.

Oustani, M., Halilat, M.T. and Chenchouni, H. (2015). Effect of poultry manure on the yield and nutriments uptake of potato under saline conditions of arid regions. *Emir. J. Food Agric.*, **27(1)**: 106-120.

Pandey, V., Kumar, D. and Naik, G. (2004). Intercropping of some fruit and vegetable crops in young mango orchards in coastal Orissa. *In: First Indian Horticulture Congress (Abst.)*, 6-9 November, 2005, Pusa, New Delhi, p. 172.

Pandit, S.N., Singh, C., Ray, R.N., Jha, K.K. and Jain, B.P. 1992. Fertilizer scheduling for dwarf banana in Bihar. *J. Res. Bihar Agric. Univ.*, **4**: 25-29

Panelo, B.C. and Diza, M.T. (2017). Growth and Yield Performance of Banana (*Musa acuminata* L.) as Affected by Different Farm Manures. *Asia Pacific J. Multidisciplinary Res.*, **5(2)**: 199-203.

Parida, G.N., Ray, D.P., nath, N. and Dora, D.K. (1994). Effect of graded levels of NPK on growth of Robusta banana. *Indian Agric.*, **38(1)**: 43-50.

Parvathareddy, P., Nagesh, M., Rao, M.S. and Devappa, V. (1997). Integrated management of the burrowing nematode *Radopholus similis*, using endomycorrhiza, *Glomus mosseae* and oil cakes. *Pest Management in Horticulture Ecosystems*, **3(10)**: 25-29.

Patil, S.J., Patel, R.B., Hiray, S.A., Solia, B.M. and Patel, N.B. (2015). Effect of intercropping on growth and yield of banana (*Musa paradisiaca*) cv. Grand Naine under drip irrigation. *Curr. Hort.*, **3(2)**: 50-53.

Patil, V.K. and Shinde, B.N. (2013). Studies on integrated nutrient management on growth and yield of banana cv. Ardhapuri (*Musa* AAA). *J. Hort. Forestry.*, **5(9)**: 130-138.

Patrik, B.R. (1992). Performance of biofertilizers from food wastes. *Congress on Traditional Sciences and technology of India*, India Institute of Technology, Bombay, **14**: 10-26.

Pattar, S.S., Nadagowda, V.B., Salakikop, S.r., Kannur, V.S. and Gaddi, A. V. (1998). Effect of organic manures and fertilizer levels on nutrient uptake, soil nutrient status and yield of groundnut. *J. Oilseed Res.*, **16(1)**: 123-127.

Pattnaik, A.K., Lenka, P.C., Mohapatra, K.C. and Mohapatra, R.N. (2007). Intercropping in cashew plantation with vegetable crops. *National Seminar on Research, Development and Marketing of Cashew*, 20-21, November, 2007. p. 61.

Paul, J.C., Mishra, J.N. and Pradhan, P.L. (2008). Response of banana to drip irrigation and mulching in coastal Orissa. *J. Agril. Engg*., **45(4)**: 44-49.

Piper, C. S. (1966). Soil and Plant Analysis, IVth Edn. 135-200 Univ. of Adeleide, Australia.

Prabhakar, B.S. and Shukla, V. (1990). Crop land use efficiency in sequential intercropping systems with vegetables. *Indian J. Hort.,* **47(4)**: 427-430.

Prabhuram, R. and Sathiamoorthy, S. (1993). Effect of organic manures on duration of cropping in banana. *South Indian Hort.,* **41(6)**: 370-371.

Pramanik, S., Lai, S.,Ray, R. and Patra, S.K. (2016). Effect of Drip Fertigation on Yield, Water Use Efficiency, and Nutrients Availability in Banana in West Bengal, India. *Communications in Soil Science and Plant Analysis*, **47**: 1691-1700.

Purakayastha, T.T. and Bhatnagar, R.K. (1997). Vermicompost – a promising source of plant nutrients. *Indian Farming*, **40**: 34-37.

Radford, P.J. (1967). Growth analysis formulae, their use and misuse. *Crop Sci.,* **7**: 171-175.

Radha, T., Pushkaran, K. and John, P.J. (1991). Effect of intercropping in pineapple. *Indian Hort.,* **39(4)**: 179-183.

Rahman, M.Z., Rahman, M.H., Haqu, M.E., Kabir, M.H. and Naher, S.L. (2006). Banana based intercropping system in northern part of Bangladesh. *J. Agron.,* **5(2)**: 228-231.

Raju, B. (1996). Micropropagation and nutritional studies of tissue cultured banana var. Grand naine, *Ph.D. (Hort.) Thesis*, Univ. of Agril. Sci., Bangalore.

Rajput, A., Memon, M., Memon, K.S., Tunio, S., Sial, T.A. and Khan, M.A. (2017). Nutrient composition of banana fruit as affected by farm manure, composted pressmud and mineral fertilizers. *Pak. J. Bot.,* **49(1)**: 101-108.

Randhawa, G.S. and Sharma, C.B. (1972). Possibilities of intercropping in banana. *Proceeding* of Symposium held at HAU, Hisar. pp. 326-327.

Randhawa, M.A., Lodhi, T.E., Khan, M.A., Chaudhary, M.S. and Saleem, M.I. (1999). Interactive relationship between growth and yield characters of autumn sugarcane and associated cultures. *Intl. J. Agri. & Biol.,* **1(4)**: 345-346.

Ranganna (1986). Handbook for analysis and quality control for fruit and vegetable products (Second edition). Tata MacGraw-Hill Publishing Company Ltd., New Delhi. pp. 9-10.

Rani, M., Kaur, G., Kaur, K. and Arora, N.K. (2021). Effect of organic manures and biofertilizers on growth, fruit quality and leaf nutrient status of guava. *Agric. Res. J*., **58(5)**: 835-839.

Rao, M.M. and Edmunds, J.E. (1984). A review of banana/ plantain cropping system. *Fruits,* **39(2)**: 79-88.

Ratha, S. and Swain, S.C. (2006). Performance of Intercrops in Mango orchard in Eastern Ghat High Land Zone of Orissa. *Indian J. Dryland Agric. Res. Dev*., **21(1)**: 12-15.

Rathore, A.C., Saroj, P.L., Lal, H., Sharma, N.K., Jayaprakash, J., Chaturvedi, O.P., Raizada, A., Tomar, J.M.S. and Dogra, P. (2013). Performance of mango based agri-horticultural models under rainfed situation of Western Himalaya, India. *Agroforest Syst*., **87**: 1389-1404.

Ray, A.K., Borah, A.S., Maheswarappa, H.P. and Acharya, G.C. (2007). Economics of intercropping vegetables and flowering crops in pre-bearing arecanut garden under Assam conditions. *J. Plantn. Crops,* **35(2)**: 84-87.

Ray, P.K. and Yadav, J.P. (1996). Effect of combined use of organic manures and chemical fertilizers on growth and productivity o banana. *Ann. Agric. Res.*, **17(4)**: 366-369.

Reddy, K.C.K., Reddy, P.V.K., Raghuteja, P.V. and Sekhar, V. (2021). Integrated nutrient management on quality and yield of strawberry fruits (*Fragaria* x *ananassa* Duch.) cv. Camarosa under shade net condition. *Int. J. Agril. Sci*., **17**: 74-78.

Reganold, J.P., Andrews, P.K., Reeve, J.R., Carpenter-Boggs, L., Schadt, C.W., Alldredge, J.R., Ross, C.F., Davies, N.M. and Zhou, J. (2010). Fruit and Soil Quality of Organic and Conventional Strawberry Agroecosystems. *Plos One*, **5(10)**: https://doi.org/10.1371/journal.pone.0012346.

Rivera-Cruz, M. del C., Trujillo Narcía, A., Córdova Ballona, G., Kohler, J., Caravaca, F. and Roldán, A. (2008). Poultry manure and banana waste are effective biofertilizer carriers for promoting plant growth and soil sustainability in banana crops. *Soil Biol. Biochem*., **40**: 3092–3095.

Rodge, B.M. and Yadlod, S.S. (2009). Studies of intercropping in vegetables. *Intl. J. Agril. Sci.,* **5(2)**: 357-358.

Rokhzadi, A., Asgharzadeh, A., Darwish, F., Naur Mohammadi, G. and Majidi, E. (2008). Influence of plant growth-promoting rhizobacteria on dry matter accumulation and yield of chickpea (*Cicer arietinum* L.) under field conditions. *Am-Euras J. Agric. Envt. Sci.*, **3(2)**: 253-257.

Roussos, P.A. and Gasparatos, D. (2009). Apple tree growth and overall fruit quality under organic and conventionalorchard management. *Scientia Hort*., **123**: 247-252.

Sabarad, A.I. (2002). Influence of VAM, Vermiculture and *Trichoderma harzianum* on banana. *M.Sc. (Hort.) Thesis* submitted to Univ. Agric. Sci., Dharwad.

Sabarad, A.I., Swamy, G.S.K., Patil, C.P., Patil, P.B. and Athani, S.I. (2004). Influence of VAM, vermicompost and *Trichoderma harzianum* on growth of banana cv. Rajapuri (*Musa* AAB). *Karnataka Agric. Sci.,* **17(3)**: 515-518.

Sairam, C.V. and Gopalasundaram, P. (1997). Capital requirement for adoption of coconut based intercropping systems in Kerala. *Indian coconut Journal,* **27(10)**: 2-4.

Saravanan, P., Ilavarasan, N., Karthikeyan, A. and Padmanaban, B. (2020). Management of Root Knot Nematode Meloidogyne incognita in Banana (cv. Robusta) through Biocontrol Agents and Neem Cake. *Indian J. Agric. Res*., **55**: 231–234.

Sarkar, S.K., Bauri, F.K., Misra, D.K. and Bandyopadhyay, B. (2007). Role of soil microbes in banana production by artificial inoculation. *Journal of Mycopathological Research,* **45(2)**: 285-287.

Sarker, P.K., Rahman, M.M. and Das, B.C. (2007). Effect of intercropping of mustard with onion and garlic on aphid population and yield. *J. Bio-Sci.,* **15**: 35-40.

Selvabai, T.T., Kannan, J., Manonmani, K. and Sujata, J.J. (2007). Split application of nitrogen and biofertilizar *Azospirillum on* growth, yield and quality of banana. *J. Ecobiology,* **21(4)**: 349-353.

Sharma, A., Wali, V.K., Bakshi, P. and Jamwal, M. (2011). Effect of organic manures and biofertilizers on leaf and fruit nutrient status in guava (*Psidium guajava* L.) cv. Sardar. *J. Hort. Sci*., **6(2)**: 169-171.

Sharma, A., Wali, V.K., Bakshi, P., Sharma, V., Sharma, V., Bakshi, M. and Rani, S. (2016). Impact of poultry manure on fruit quality attributes and nutrient status of guava (*Psidium guajava*) cv. L 49 plant. *Indian J. Agril. Sci*., **86(4)**: 533-540.

Sharma, D.P. (1999). Effect of intercropping and cultural practices on yield and economics of newly planted mango. *Adv. Pl. Sci.,* **12(2)**: 337-340.

Sharma, R. Prasad, Mohan, N.K. and Medhi, G. (1996). Economic feasibility of growing some root and tuber crops under intercropping system in coconut garden. *Hort. J.,* **9(2)**: 167-170.

Shirgure, P.S. (2012). Effect of different intercropping systems on soil moisture conservation, fruit yield and quality of Nagpur mandarin (*Citrus reticulata*) in Central Indian. *Sci. J. Agri*., **1**: 168-176.

Simmonds, N.W. (1953). The development of banana fruit. *J. Exp. Bot.* **4**: 87-105.

Singh, A.K. (2010). Probable Agricultural Biodiversity Heritage Sites in India: VI. The Northeastern Hills of Nagaland, Manipur, Mizoram and Tripura. *Asian Agri-Hist*., **14(3)**: 217-243.

Singh, A.K., Daniel, S. and Kishore, P. (2021). Response of organic manures on vegetative growth and yield parameters of banana (*Musa* spp.) cultivar G-nine and Cavendish dwarf under popular based Agro-forestry system. *The Pharma Innovation J*., **10(6)**: 858-861.

Singh, A.K., Singh, S. and Rao, V.V. (2012). Influence of organic and inorganic nutrient sources on soil properties and quality of aonla in semiarid ecosystem. *Indian J. Hort.*, **69(1)**: 50-54.

Singh, B., Singh, V., Singh, R.P. and Srivastava, B.K. (1998). Economic prospects of vegetable intercropping in young Eucalypts plantation. *Annals of Agricultural Research*, **19**: 470-474.

Singh, J., Arya, C.K., Bhatnagar, P., Jain, S.K. and Pande, S.B.S. (2012). Intercropping in orchard is a better option. *Indian Horticulture*, ICAR, New Delhi, Jan-Feb., 2012. pp. 5–7.

Singh, J., Kashyap, R. and Sharma, D.P. (1996). Effect of cultural practices and intercropping on growth and economic yield of mango orchard cv. Langra, *Indian J. Hort.*, **53(4)**: 290-294.

Singh, J., Singh, S. and Hoda, M.N. (2001). A note on intercropping in young orchard of mango cv. Langra. *Orissa, J. Hort.*, **29(10)**: 96-98.

Singh, R.S. and Nath, V. (1995). Performance of pea varieties as intercrops in ber orchard in semi arid region, *Indian J. Hort.*, **52(2)**: 137-140.

Singh, S., Gajja, B.L., Omprakash and Singh, S. (1988). Economics of intercropping in coconut plantations with tuber crops in south Andaman, *Andaman Sci. Assoc.*, **4(1)**: 79-80.

Singh, S.K. and Saravanana, S. (2012). Effect of bio-fertilizers and micronutrients on yield and quality of strawberry (*Fragaria* x *ananasa* Duch.) cv. Chandler. *Asian J. Hort.*, **7(2)**: 533-536.

Singh, S.K., Sharma, M. and Singh, P.K. (2016a). Combined approach of intercropping and INM to improve availability ofsoil and leaf nutrients in fruit trees. *J. Chem. Pharma. Sci.*, **9(2)**: 823-829.

Singh, S.K., Sharma, M. and Singh, P.K. (2016b). Intercropping- An approach to reduce fruit drop and improve fruit quality in guava. *J. Chem. Pharma. Sci*., **9(4)**: 3182-3187.

Singh, S.P. and Dahiya, S.S. (1982). Grow papaya for health and wealth, *Farmer and parliament,* **17**: 15-18.

Singh, V.K., Singh, A., Soni, M.K., Singh, K. and Singh, A. (2015). Increasing Profitability of Mango (*Mangifera indica* L.) Orchard through Intercropping. *Acta Hort*., **1066**: 151-157.

Singh, Y., Prakash, S., Prakash, O. and Singh S. (2017). Effect of integrated nutrient management to reduce the cost of cultivation of Amrapalli mango (*Mangifera indicia* L.) by minimizing the indiscriminate use of chemical fertilizers under high density planting. *Int. J. Pure App. Biosci.,* **5(5)**: 287-293.

Sit, A.K. and Roybarman, J. (2012). Performance of different turmeric cultivaars under coconut plantation for sub Himalayan Teria region of West Bengal. *Int. J. Agric. Sci.*, **8(1)**: 59-61.

Smith, B. L. (1998). Microorganisms in soil benefit growth and yield of bananas. *Neltropika Bull.* No. 299. pp. 22-25.

Song, B.Z., Wu, H.Y., Kong, Y., Zhang, J., Du, Y.L., Hu, J.H. and Yao, Y.C. (2010). Effects of intercropping with aromatic plants on the diversity and structure of an arthropod community in a pear orchard. *BioControl,* **55**: 741-751.

Soni, S., Kanawjia, A., Chaurasiya, R., Chauhan, P.S., Kumar, R. and Dubey, S. (2018). Effect of organic manure and biofertilizers on growth, yield, and quality of strawberry (*Fragaria* x *ananasa* Duch) cv. Sweet Charlie. *J. Pharmacog. Phytochem*., **SP2**: 128-132.

Srivastava, A. K., Huchche, A. D., Ram, L. and Singh, S. (2007). Yield prediction in intercropped versus monocropped citrus orchards. *Scientia Hort.*, **114(1)**: 67-70.

Srivastava, A. K., Singh, S. and Marathe, R. A. (2002). Organic citrus: soil fertility and plant nutrition. *Journal of Sustainable Agriculture,* **19(3)**: 5-29.

Stofella, P.J., Pelosi, R. and William, B.J. (1986). Potential of citrus-cowpea intercropping in South Florida. *Proc. Interamerican Soc. For Trop. Hort.*, **30**: 165-170.

Subbaiah, K.K., Ramachandra, B.S.N.M. and Kolandaiswamy, S. (1980). Intercropping in banana. *Madras Agric. J*., **67**: 712-715.

Subhramanyam, K.V. (1987). Intercrop papaya, it improves economy. *Indian Fmg.*, **32(3)**: 9-13.

Subramanian, A.R., Kumar, V., Ravichamy, P. and Balan, K.C.S. (2019). The effect of organic and inorganic sources of nutrients on fruit quality including shelf life of banana cv. Grand Naine. *International J. Chem. Sci*., **SP6**: 728-731.

Suhasini, S.P., Hipparagi, K., Biradar, I.B., Patil, S.N., Suma, R. and Awati, M. (2018). Effect of integrated nutrient management on growth parameters of banana cv. Rajapuri. *Int. J. Pure App. Biosci*., **6(1)**: 1328-1334.

Suja, G., Sundaresan, S., John, K.S., Sreekumar, J., Misra, R.S. (2012). Higher yield, profit and soil quality from organic farming of elephant foot yam. *Agron. Sustain. Dev*., **32**: 755-764.

Suresh, C.P. ans Hasan, M.A. (2001). Studies on the response of Dwarf Cavendish banana (*Musa* AAA) to biofertilizer inoculation. *Horticultural J.*, **14(1)**: 35-41.

Swadija, O.K., Padmanabhan, V.B. and Vijayaraghavakumar (2013). Growth and yield of arrowroot intercropped in coconut garden as influenced by organic management. *J. of Root Crops*, **39(1)**: 67-72.

Swain, S. C. and Patro, L. (2006). Intercropping in guava orchard: A holistic farming system approach for sustainable development of environment and society. In Proceedings of the National Conference on Biodiversity Conservation for Sustainable Society (Mishra, K. and Palita, S. K. eds.), Nayagarh, Nayagarh College, Orissa. pp. 78–83.

Swain, S.C. (2014). Performance and profitability study of different mango based intercroppingsystems in Easternghat high land zone of Odisha. *J. Crop and Weed*, **10(2)**: 170-178.

Swain, S.C. (2016). Influence of intercropping systems on soil health, productivity and quality of guava (*Psidium guajava* L.) in Eastern India. *J. Plant Nutri*., **39(14)**: 2037-2046.

Swain, S.C. and Patro, L. (2007). Horticulture based cropping system – A strategy for sustainable development in rainfed upland. In: *Environmental Hazards* (Eds; L. Patro and S.N. Tripathy), Sonali Publication, New Delhi. pp. 44-69.

Swaminathan, C. (1999). Early growth performance of mango and cashew co-planted with four nitrogen fixers in a tropical Alfisol. *Journal of Sustainable Forestry*, **8(2)**: 15-26.

Swamy, G.S.K., Sabarad, A.I., Balakrishna, H.T., Patil, C.P. and Patil, P.B. (2005). Influence of AM fungi, vermiculture and *Trichoderma harzianum* on growth and yield of plant and ratoon crop of banana cv. Rajapuri (*Musa* AAB). *Karnataka J. Hort.*, **1(3)**: 57-62.

Syed, Z. (2009). Integrated nutrient management studies in banana cv. Ardhapuri. *The Asian J. of Hort.*, **4(1)**: 126-130.

Talwar, D., Singh, K. and Singh, J. (2017). Effect of biofertilizers on soil microbial count, nutrient availability and uptake under November sown onion. *J. Applied Nat. Sci*., **9(1)**: 55-59.

Thangaselvabai, T., Suresh, S., Prem Joshua, J. and Sudha, K.R. (2009). Banana nutrition – a review. *Agric. Rev.*, **30(1)**: 24-31.

Tirkey, T., Agarwal, S. and Pandey, S.D. (2003). Effect of organicmanures on growth, maturity and yield of banana cv. Dwarf Cavendish. *South Indian Horticulture,* **50**: 19-24.

Tiwari, D.K., Hasan, M.A. and Chattopadhyay, P.K. (1998). Studies on the effect of inoculation and *Azotobacter* and *Azospirillum* on growth, yield and quality of banana cv. Giant Cavendish. *Indian J. Agric.*, **42(4)**: 235-240.

Turemis, N. (2002). The effects of different organic deposits on yield and quality of strawberry cultivar Dorit (216). *Acta Hort*., **567**: 507-510.

Ushakumari, K., Prabhukumari, P. and Padmaja, P. (1997). Efficiency of vermicompost on yield and quality of banana (AB) cv. Njalipoovan. *South Indian Hort.,* **49**: 158-160.

Venugopal, V. and Sheela, K.R. (2009). Crop intensification in Nendran banana based cropping systems for higher yield and profitability. *Agric. Res. New Series,* **30**: 36-38.

Vincent, J. M. (1970). A manual for the practical study of the root-nodule bacteria. IBP handbook 15 Blackwell Scientific Publications, Oxford, p.164.

Walkley, A. and Black, I.A. (1934). An estimation of the Degtjareff method for determination soil organic matter and a proposed modification on thecromic acid titration method. *Soil Sci.,* **34**: 29-38.

Willer, H. and Kilcher, L. (2009). The world of organic agriculture – Statistics and emerging trends 2009. FIBL-IFOAM Report, IFOAM, Bonn, pp. 25-58.

Williams, J.E. (1946). The physiology of plant growth with special reference to the concept of net assimilation rate. *Ann. Bot*., **60**: 61-72.

Yadav, S.K., Khokhar, U.U. and Yadav, R.P. (2010). Integrated nutrient management for strawberry cultivation. *Indian J. of Hort.,* **67**: 445-449.

Yadukumar, N. (2007). Development of sustainable cashew based cropping systems – Inter and mixed cropping with cashew. National Seminar on Research, Development and marketing of cashew, 20-21st Nov., 2007, Goa, *Souvenir and Extended Summaries*. p. 62.

Yamano, T. (2008). Dairy-banana integration and organic fertilizer use in Uganda. *GRIPS Policy Information Center Discussion Paper*, **8**: 1-25.

<u>**BRIEF BIO-DATA OF THE CANDIDATE**</u>

NAME	:	ABIGAIL ZOTHANSIAMI
FATHER'S NAME	:	LALTHANTLUANGA
DATE OF BIRTH	:	15th April, 1981
ADDRESS	:	**Home:** T-5, Tuikhuahtlang, Aizawl, Mizoram – 796001 **Work:** Dept. of Horticulture, Aromatic and Medicinal Plants, School of Earth Sciences & Natural Resource Management, Mizoram University, Aizawl, Mizoram – 796004
Educational Qualification	:	**B.Sc. (Horticulture)** – College of Horticulture & Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. **M.Sc. (Horticulture in Fruit Science)** – College of Horticulture, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

PARTICULARS OF THE CANDIDATE

NAME OF THE CANDIDATE	**:**	**ABIGAIL ZOTHANSIAMI**
DEGREE	**:**	**DOCTOR OF PHILOSOPHY**
DEPARTMENT	**:**	**DEPARTMENT OF HORTICULTURE, AROMATIC & MEDICINAL PLANTS**
TITLE OF THE THESIS	**:**	**ORGANIC NUTRIENT MANAGEMENT AND INTERCROPPING IN BANANA ORCHARD IN MIZORAM**
DATE OF ADMISSION	**:**	**10.08.2015**
BOS	**:**	**05.04.2016**
SCHOOL BOARD	**:**	**13.04.2016**
MZU REGISTRATION NO.	**:**	**1705279 of 2018**
PH.D. REGISTRATION NO. & DATE	**:**	**MZU/Ph.D./ 1134 of 13.04.2016**
EXTENTION (IF ANY)	**:**	**No. 16-2/MZU (ACAD)/20/431-33**

HEAD

Dept. of Hort., Aromatic & Medicinal Plants