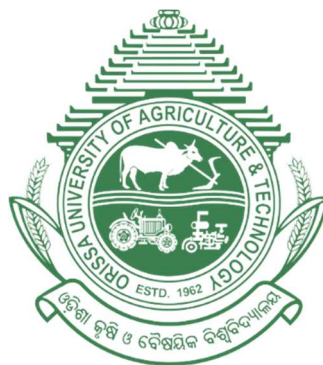


Integrated nutrient management of arrowroot in guava based agroforestry system

*A thesis submitted to the
Orissa University of Agriculture and Technology
in Partial fulfilment of the Requirements for the Degree of
Master of Science in Forestry
(Natural Resource Management)*

By
Archana Nayak
Adm. No. 05 NRM/15



**DEPARTMENT OF NATURAL RESOURCE MANAGEMENT
COLLEGE OF FORESTRY
ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR
2017**



**ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
DEPARTMENT OF NATURAL RESOURCE MANAGEMENT
COLLEGE OF FORESTRY
BHUBANESWAR-751003**

Mr. B.B. Behera
Jr. Scientist (Soil Science)
AICRP on Agroforestry, OUAT

Date:

CERTIFICATE – I

This is to certify that the thesis entitled “**Integrated nutrient management of arrowroot in guava based agroforestry system**” submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE IN FORESTRY (NATURAL RESOURCE MANAGEMENT)** to the Orissa University of Agriculture and Technology is a faithful record of *bona fide* and original research work carried out by **ARCHANA NAYAK** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.

(B. B. Behera)
CHAIRMAN
ADVISORY COMMITTEE

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Bhubaneswar

Date :

(Archana Nayak)
Adm. No. 05 NRM/15

ABSTRACT

A study was conducted at the experimental site of All India Co-ordinated Research Project on Agroforestry, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India, during July 2016 to June 2017 to evaluate fruit based agrihorticultural systems. The experiment was laid out in a Randomised Block Design (RBD) with three replications. The experiment was consisted of 10 treatment combinations. Arrowroot was grown as intercrop which is raised during kharif season. The maximum chlorophyll content was obtained in STD (100%) + FYM + biofertilizer followed by STD (100 %) + FYM and STD (75 %) + FYM + biofertilizer. The chlorophyll content was highest in September irrespective of the treatments. The maximum mean moisture content was found in STD (100 %) + FYM + biofertilizer i.e. 10.99 % at 0-15 cm depth and 12.20 % at 15-30 cm depth. The soil moisture content also found to increase from July to August. The maximum pH value was recorded in STD (100 %) + FYM (4.95) followed by STD (75 %) + FYM (4.94). The value of organic carbon content was higher in STD (100 %) + FYM (7.8 g kg⁻¹) and STD (100 %) + FYM + biofertilizer (7.8 g kg⁻¹) followed by STD (75 %) + FYM (7.5 g kg⁻¹). The maximum available nitrogen content and phosphorous content of 262.8 kg ha⁻¹ and 75.2 kg ha⁻¹ were found under STD (100 %) + FYM + biofertilizer followed by STD (100 %) + FYM i.e. 257.9 kg ha⁻¹ and 75.2 kg ha⁻¹ respectively but the maximum available potassium content of 253.8 kg ha⁻¹ was found under STD (100 %) + FYM followed by STD (100 %) + FYM + biofertilizer (241.8 kg ha⁻¹). The maximum guava tree height (5.95 m) and increment in tree height (0.78 m), basal diameter (19.64 cm) and increment in basal diameter (1.26 cm) were found under STD (100 %) + FYM + biofertilizer. The maximum plant height of arrowroot (123.3 cm), number of leaves (69.1) and rhizome weight (98 g culm⁻¹) was found under STD (100 %) + FYM + biofertilizer. The maximum guava yield (2788 kg ha⁻¹) and arrowroot yield (6534 kg ha⁻¹) was also recorded under STD (100 %) + FYM + biofertilizer followed by STD (100 %) + FYM (2692 kg ha⁻¹ and 6340 kg ha⁻¹) respectively. The maximum gross return (Rs 120228 ha⁻¹), net return (Rs 66330 ha⁻¹) and B:C ratio (2.23) were found under STD (100 %) + FYM + biofertilizer followed by STD (100 %) + FYM (Rs 6460 ha⁻¹, Rs 62862 ha⁻¹ and 2.17), respectively.

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ABBREVIATIONS USED

%	:	Percentage
ha	:	Hectare
q	:	Quintal
m	:	Metre
cm	:	Centimetre
mm	:	Millimetre
ml	:	Millilitre
kg	:	Kilogram
g	:	Gram
°C	:	Degree centigrade
t	:	Tonne
i.e.,	:	That is
CD	:	Critical differences
SEm	:	Standard error mean
Fig.	:	Figure
GBH	:	Girth at Breast height
DBH	:	Diameter at Breast Height
BCR	:	Benefit-cost ratio
<i>et al.</i> ,	:	Another

INTRODUCTION

Agroforestry is a land use management system in which trees or shrubs are grown around or among crops or pastureland. It combines shrubs and trees in agricultural and forestry ecosystems to create more diverse, productive, profitable, healthy, ecologically sound, and sustainable land-use systems. In the broadest sense, it encompasses a wide range of production systems, from forest to crop monoculture. In terms of composition, structure, management practices, and production functions, wide variations exist among these systems. Bene *et al.*, 1977 defines as a suitable land management system that increases total production, combines agricultural crops, tree crops, forest plants and/ or animals simultaneously or sequentially and applies management practices compatible with cultural patterns of the local population. There must be significant ecological and economic interactions between the woody and non-woody components in an agroforestry system (Lundgren and Raintree, 1982). It is recognized as a land-use option in which trees provide both products and environmental services. In agroforestry systems, the trees grown on different farmlands in the same locality when aggregated can bring about improved wooded situation thereby enhancing environmental protection (Otegbeye, 2002).

The fruit based agroforestry system can be defined as a planting system comprising combinations of plants with various morpho-phenological features to maximize the natural resource use efficiency and enhanced total factor productivity. The system comprise of a combination of perennial and annual plant species as different components in the same piece of land arranged in a geometry that facilitates maximum utilization of space in four dimensions (length, width, height and depth) leading to maximum economic productivity of the system. The fruit based agroforestry system is a self-sustainable system where solar energy can be harvested at different heights, soil resources can be efficiently used and cropping intensity is increased. The system consists of three main components viz. main crop, filler crop and inters crops which occupy three different tiers in space of the production system.

Fruit trees are planted and retained by the farmers as associate crops in the different places on agricultural fields of this region. The presence of trees also create hindrance during agricultural operation and on the agricultural productivity but their other benefits bound farmers to grow them in the suitable places. The status of natural

regeneration of tree crop is very poor in the existing systems due to the deliberate removal of seedlings from the field during cultural and other operations. The selection of intercrops depends mainly on edapho-climatic conditions of the area, farmer's need/traditions and resource availability.

Nutrient management is the science and art directed to link soil, crop, weather and hydrologic factors with cultural, irrigation and soil and water conservation practices to achieve the goals of optimizing nutrient use efficiency, yields, crop quality and economic returns, while reducing off-site transport of nutrients that may impact the environment. Nutrient management is the skillful task of matching a specific field soil, climate and crop management conditions to rate, source, timing and place (commonly known as the 4R nutrient stewardship) of nutrient application.

Some important factors that need to be considered when managing nutrients include (a) the application of nutrients considering the achievable optimum yields and, in some cases, crop quality; (b) the management, application and timing of nutrients using a budget based on all sources and sinks active at the site; and (c) the management of soil, water and crop to minimize the off-site transport of nutrients from nutrient leaching out of the root zone, surface runoff and volatilization (or other gas exchanges).

Guava (*Psidium guajava* L.), is one of most exquisite, valuable and popular fruits grown in tropical, sub-tropical and some parts of arid regions of India, which belongs to the family Myrtaceae. It is the fifth most important fruit in area after mango, citrus, banana and apple with covering an area of 0.22 million hectare. Fifth most important fruit in production after banana, mango, citrus and papaya with total production of 2.572 million tonnes (NHB, 2010). Conventional (chemical based) farming is nonsustainable because of many problems such as loss of soil health and productivity from excessive erosion and low farm income from high production costs etc. In view of these, there is an increasing awareness about alternate agriculture system known as integrated plant nutrient management. The basic concept of integrated nutrient management (INM) is the adjustment of plant nutrient supply with proper combination of chemical fertilizers, organic manure and biofertilizers suitable to the system of land use and ecological, social and economic conditions. Vermicompost is an ecofriendly natural fertilizer prepared from biodegradable organic wastes, rich in micro and macronutrients, vital plant promoting substances, humus forming substances, N-fixers and humus forming microorganism. *Azospirillum* is alternate source for nitrogen enrichment in non-leguminous crops, which fixed the atmospheric nitrogen and PSB has

highly efficient phosphate solubilizing microorganism (PSM) that grow and secrete organic acids, which dissolve this unavailable phosphate into soluble form and make it available to the plants. Malwa is an important region in Madhya Pradesh, where guava is widely grown. However, these guava orchards are declining in their productivity. There is an urgent need for an alternative nutritional package to attain long term sustainability for fruit production as well as for maintaining soil health and productivity under INM system. Keeping the above facts in view, an experiment was conducted to find out the INM doses for sustainable production. Adak *et al.* (2014) experimented on guava cultivation in subtropical region of India which is mainly confined to marginal lands under rainfed conditions resulting in low productivity and poor fruit quality.

Arrowroot (*Maranta arundinacea* L.) is an under-exploited tuber crop, the rhizomes of which are valued as food stuff and a source of starch. The rhizome contains 25-30% starch (CSIR, 1962). Arrowroot starch is used for the preparation of bakery products especially biscuits, as a base for face powder, in the preparation of specialized glues and in the manufacture of carbonless paper for computer printouts (CTCRI, 1996). The starch possesses demulcent and anti-diarrhoeal properties and is used in the treatment of intestinal disorders which adds medicinal value to the crop. The crop comes up well under shaded conditions and no serious pests and diseases are noted in the crop. Cultivation of this crop is cost effective. It is a hardy crop. Extraction of starch can be done even in households by adopting a simple procedure. It serves as a raw material for cottage industry by unemployed women and rural youth. It is in this context that the potential of this under-exploited crop should be evaluated. Realizing the need for organic production of arrowroot, an investigation was undertaken to derive an organic nutrient management schedule for sustained yield of arrowroot intercropped in guava.

Keeping in view the above facts, a study on “Integrated nutrient management of arrowroot in guava based agroforestry system” was undertaken with the following objectives:

- To evaluate the effect of arrowroot on growth of guava tree.
- To evaluate the effect of guava tree on the performance of arrowroot.
- To study the soil physico-chemical properties of guava based agroforestry system.
- To compare the economics of guava based agroforestry system.



REVIEW OF LITERATURE

A successful cultivation of any crop envisages sufficient knowledge about the nutritional requirements of the plant. The response and requirement of various nutrients differ widely on the agro-climatic conditions and management practices. Plants absorb a large number of elements from the soil and atmosphere. Some of these elements are directly involved in the nutrition of the plant and deficiency of them makes it impossible for the plant to complete its life cycle. These elements are known as essential elements for plant life (Arnon, 1950).

A good deal of research work has been done in India and abroad to evaluate the response of guava to application of integrated nutrient management. Further, the information on these aspects under agro climatic conditions of Malwa region is very meager. The up to date literature available on these aspects have been reviewed in this chapter under the following heads:

2.1 Effect of NPK

Mitra and Bose (1985) reported that the highest yield of 42.8 kg/tree was obtained with N:P:K at 260:160:260 g/tree, and N:P:K at 260:320:260 g/tree gave the highest individual fruit weight (174.4 g). K increased TSS, and N at high rates decreased TSS, whereas P had no marked effect on the 3-year-old guava tree.

Wagh and Mahajan (1987) studied the guava trees received N at 0-900 g, P₂O₅ at 0, 300 g and K₂O at 0, 300 g/tree, and the effects on fruit chemical compositions were assessed. Fruit quality was best when the trees received N: P₂O₅: K₂O at 600:300:300 g/tree.

Koen *et al.* (1990) reported that the highest yield was obtained with annual application rates of calcium ammonium nitrate at 800 g/tree, super phosphate at 300 g/tree and KCl at 400 g/tree. Fruit size was little affected by N and K application rates, but higher P rates had an adverse effect in 10-year-old guava cv. Fan Retief.

Ghosh (1991) reported that increasing N, P or K rates each increased yields. N application at 225 g/tree gave 84.6% higher yields than N application at 100 g/tree

respectively. Fruit TSS and total sugars contents were increased by increases in N and K application rates, but were not influenced by changes in P rate in three-year-old guava cv. Lucknow-49 trees.

Sharma and Sharma (1992) reported that the highest number of leaves/shoot (10.01), terminal shoot length (14.76 cm), fruit set (62.0%), fruit retention (30.50%) and fruit yield (28.36 kg/tree) were obtained with 3% N, 1% P and 1% K treatment combination. All treatments resulted in increased growth and yield when compared with the control in 5-year-old guava trees.

Natale *et al.* (1995) applied N, P₂O₅ and K₂O to one-year-old guava trees cv. Rica and Paluma. Each was applied at 0-300 g/tree in the first year of the trial and at double and triples of these rates in the second and third years, respectively. Brix values were analysed after each harvest. None of the treatments had any effect on Brix values, which ranged between 8.0 and 10.8 for Rica fruits and 8.4 and 9.65 for Paluma fruits in both the years.

Ke-Lih Shang *et al.* (1997) reported that the fruit yield and weight increased with increasing rates of N, P and K, except when N was applied at a rate higher than 200 g/plant. Fruit yield, weight and quality were best when the trees received N:P₂O₅:K₂O at 200:100:400 g/tree in four-year-old guava.

Kotur *et al.* (1997) reported that the highest fruit yield was obtained at 583 g N/plant, 271 g P/plant and 399 g K/plant, and at leaf concentrations of 1.89% N, 0.16% P and 2.34% K. The leaf nutrient composition associated with maximum fruit yield was 1.8-2.0% N, 0.12-0.16% P, 1.46-2.08% K, 1.13-1.69 % S in guava cv. Allahabad Safeda.

Zang and Lei (2000) reported that fertilizer requirement for high production of guava in India, when NPK is applied in the ratio 1:0.46:0.68 (0.583 kg N, 0.271 kg P and 0.399 kg K).

Uma Shankar *et al.* (2002) reported that the highest fruit yield during winter season was obtained with 450 g N + 300 g P₂O₅ + 450 g K₂O when applied in two equal doses before flowering and after fruit set. During the winter seasons, the highest total soluble solid 15.60 OBrix, ascorbic acid 269.33-285.15 mg/100 g, reducing sugar 7.56-7.60% and total sugar 10.10-10.31% contents were obtained with the application of N + P₂O₅ + K₂O at 450+300+450 g per plant in guava cv. Sardar.

Al-Qurashi (2005) studied the effect of foliar spraying of N:P:K at 18:18:18, 10:44:10 and 10:10:35 ppm on the growth and nutrition of guava was investigated. All foliar fertilizers increased the growth parameters compared to the control. The growth parameters increased more with N:P:K at 18:18:18 ppm than the others.

Khattak *et al.* (2005) reported that 4 kg NPK mixture (10:20:20) per tree gave the maximum plant height (19.26 cm), plant spread (19.22), fruit per tree (369) and yield (33.2 kg/tree) and the lowest fruit drop (52.6) in guava cv. Karela.

Kundu *et al.* (2007) reported that treatments with higher concentrations of urea were found very effective in increasing the number of fruits, yield, individual fruit weight and the size of fruit in guava cv. L-49. The response of calcium phosphate and muriate of potash was higher when combined with higher doses of urea. The maximum yield (48.09 kg/plant) was recorded by combined spraying of 3% urea and 2% each of calcium phosphate and muriate of potash, while spraying with 3% urea in combination with calcium phosphate (2%) and muriate of potash (1%) showed the maximum individual fruit weight (157.1 g). The quality of fruits showed marked improvement by spraying with higher doses of muriate of potash alone or in combination with urea and calcium phosphate. Combined spraying of urea (1%) calcium phosphate (2%) and muriate of potash (2%) and urea (3%) along with calcium phosphate (1%) and muriate of potash (2%) showed maximum TSS (12.03 0Brix) and ascorbic acid (252.4 mg/ 100 g pulp), respectively.

Kumar *et al.* (2008) studied the treatments with higher nitrogen level attained maximum yield and fruiting compared to treatments with lower nitrogen levels, in combination with phosphorus and potassium. Maximum yield of 22.66, 26.35 kg/plant and fruit set of 34.73%, 35.65% were recorded with 150 g N, 50 g P₂O₅ and 75 g K₂O/plant/year in the winter season in both years respectively, while treatment combinations with high potassium level recorded higher ascorbic acid and sugar content in the fruit.

Kumar *et al.* (2009) studied yield and quality of guava cv. Allahabad Safeda. The maximum plant height was recorded under 900 g nitrogen/tree, but it was at par with 600 g nitrogen/tree. Maximum stem diameter, canopy spread, fruit yield and TSS were recorded under 900 g potassium/tree/year, which was at par with 600 g

potassium/tree. Vegetative growth, fruit yield and quality were drastically reduced in control plots due to non-application of fertilizers. It was concluded that 600 g N, 300 g P and 600 g K per plant per year is the most appropriate and sustainable dose for getting good growth and yield.

Cardoso *et al.* (2011) studied the influence of mineral fertilization on productivity of guava Paluma and found that major physical and economic productivity (12.90 t/ha/crop) was obtained with 540-90-360 g/plant/year of N, P₂O₅ and K₂O, respectively. And also nitrogen fertilization had a positive effect on fruit production.

Binepal *et al.* (2013) analysed on seven year old guava tree cv. L-49 with two levels of nitrogen *i.e.*, 600 g N (100% N) and 450 g N (75% N), two levels of phosphorus *i.e.*, 400 g P₂O₅ (100% P₂O₅) and 300 g P₂O₅ (75% P₂O₅) and a common dose of potassium *i.e.*, 300 g K₂O and 30 g each of *Azospirillum* and PSB inoculation and 10 kg Vermicompost and found that the application of 100% N + 100% P₂O₅+*Azospirillum* + PSB + 10 kg vermicompost (T9) significantly influence the morpho-physical, reproductive and quality parameters of guava. Maximum increase in plant height (0.65 m), canopy spread N-S direction (0.92 m) and E-W direction (1.00 m), maximum fruit length (7.52 cm) and fruit diameter (7.91 cm) at harvest, fruit volume (217.41 ml), maximum fruit setting (79.56%), minimum fruit drop (20.41%), maximum fruit retention (79.59%), average fruit weight (220.37 g), number of fruits per tree (384), TSS (11.67 °Brix), total sugar (8.06%), reducing sugar (4.17%), non-reducing sugar (3.89%), pectin (0.81%), ascorbic acid (207.90 mg/100 g pulp) and lowest acidity (0.20%) were obtained with treatment T9.

Meena *et al.* (2013) studied the effect of integrated nutrients management after rejuvenating more than 25 years old guava orchard planted at 6 mx6 m apart under semiarid conditions of eastern Rajasthan and found that almost all treatments with combined application of organic and inorganic sources of nutrients had significantly increased the fruits yield of guava, soil dehydrogenase activity, NPK content of leaf, fruit and soil over control (recommended dose of NPK *i.e.* 500:200:500 g/ plant).

Shukla *et al.* (2014) assessed the influence of different organic fertilisers – vermicompost, mulching, *Azotobacter*, phosphate solubilising microbes (PSM) and *Trichoderma harzianum* added each year to mineral fertilisers containing NPK and to farmyard manure (FYM) on leaf nutrient status, tree growth, fruit yield and quality of guava grown in low fertile soil.

Verma *et al.* (2016) observed that the INM treatment 75 percent dose of NPK + 10 t FYM ha⁻¹ + *Azotobacter* /*Azospirillum* improved the uptake of NPK by plants and that of available N and P status of the soil. While 100 percent NPK or 50 percent NPK + 10 t FYM ha⁻¹ + *Azotobacter* /*Azospirillum* proved most beneficial for available potassium status of soil.

2.2 Effect of biofertilizers:

Ram and Rajput (2000) studied the effect of organic manures and biofertilizers on the yield the fruit quality of guava cv. Allahabad Safeda and found that treatment with *Azotobacter* recorded the highest weight of individual fruit, fruit diameter and fruit length for 2 years.

Devadas and Kuriakose (2005) studied the influence of various organic manures and biofertilizers on pineapple var. Mauritius and found that treatments applied with 250g poultry manure, *azospirillum* and phosphobacteria at 650 mg each along with N, P₂O₅, K₂O at 8: 4: 8g per plant, recorded higher values in terms of growth of plants, juice percentage and quality parameters of fruits. Soil fertility parameters such as available P and K of the experimental plots increased after one year. Organic carbon of soil also increased significantly, when compared to the control plots.

Dey *et al.* (2005) studied the effect of biofertilizers on physico-chemical characteristics of guava fruit cv. L-49 and found that phosphorus solubilizers significantly influenced physical and chemical parameters of guava. Highest fruit weight (154.5 g), fruit length (4.27 cm) and fruit diameter (4.68 cm) were obtained with the application of Phosphobacterin. Application of VAM gave highest TSS (10.10Brix), TSS: acid ratio (15.78) and Vitamin C content (151.8 mg/100 g).

Ram *et al.* (2007) studied integrated application of different fertilizers, organic manures and biofertilizers on 7 year old trees of Sardar guava and found

maximum increases in plant height (0.45 m) and spread (0.34 m, E-W & 0.57 m, N-S) with the dose of 250 g N, 100 g P₂O₅, 250 g K₂O, 10 kg FYM and 250 g *Azotobacter*. Number of fruits (1200/tree), yield (150.25 kg/tree) and fruit quality parameters such as TSS (13.50Brix) and reducing sugars (3.50%) were also higher with same treatments.

Ram and Pathak (2007) studied on 3-yrs-old plant of guava cv. Allahabad Safeda and found maximum number of fruits and yield (92 and 13.69 kg/tree and 283 and 40.11 kg/tree) were consistently recorded for 2 years from the trees, applied with 20 kg FYM inoculated with *Azotobacter* in comparison to 21.37 kg/tree fruit with recommended doses of fertilizer application. Fruit quality parameters, particularly TSS (16.20°Brix), were improved with application of 10 kg FYM along with celrich.

Ram *et al.* (2007) studied on 3 yrs-old plant of guava cv. Allahabad Safeda and found maximum fruit number and yield (92 and 13.69 kg/tree and 283 and 40.11 kg/tree) were recorded consistently for 2 years in the trees, applied with 20 kg FYM and inoculated with *Azotobacter*. Fruit quality parameters TSS (14.13°Brix) and vitamin C (242.40 mg 100/g fruit) were improved with application of 20 kg FYM + BD-500.

Singh *et al.* (2007) studied influence of organic and inorganic sources on guava and recorded maximum fruit set (59.66%), fruit retention (58.63%) and yield (43.24 kg/plant or 24 t/ha) in vermicompost @ 10 kg + 50 per cent recommended dose of NPK + PSB @ 20 g per plant treatment as compared to control.

Baksh *et al.* (2008) studied the effect of integrated nutrient management on 15-year-old plant of guava cv. Sardar and found the maximum increment in growth parameters (plant height, spread and trunk girth), improvement in yield and yield attributing characters (fruit set, retention, and individual fruit weight) and quality of fruits, *i.e.* total soluble solids, ascorbic acid, reducing and non-reducing sugars, were recorded with 100% NPK + 250 g phosphate solubilizing bacteria (PSB) + 250 g *Azotobacter* which was at par with 75% NPK + 250 g PSB + 250 g *Azotobacter*.

Singh *et al.* (2008) studied the effects of various organic manures, inorganic fertilizers and *Azotobacter* on guava cv. 'Sardar' and found that the maximum increase in shoot length (41.76%) was observed in vermicompost at 10 kg + 50% recommended dose of NPK + *Azotobacter* at 20 g per plant, followed by 100% recommended dose of NPK treatment (41.72%). Maximum increase in shoot diameter

(35.63%), minimum days taken to initiation of flowering (25.85), maximum number of flowers per shoot (8.30/shoot), maximum fruit set (60.06%), highest fruit retention (59.83%) and maximum yield (44.25 kg/plant or 49.16 tones/ha) was recorded in vermicompost at 10 kg + 50% recommended dose of NPK+ *Azotobacter* at 20 g per plant, followed by neem cake at 5 kg + 50% recommended dose of NPK + *Azotobacter* at 20 g per plant treatment (35.29%).

Dutta *et al.* (2009) studied that the effect of biofertilizers along with inorganic fertilizers on growth and productivity of guava cv. L-49 reported that different treatments of biofertilizers and inorganic fertilizer significantly increased the plant height and spread. *Azospirillum* + VAM inoculation along with 100% N + 100% P₂O₅ showed maximum plant height and spread while control recorded minimum. Inoculation of *Azospirillum* and VAM along with inorganic fertilizers also proved effective in increasing the total soluble solid, total sugar and ascorbic acid content of fruits while acid content declined through the inoculation of biofertilizers. The treatment maximized the biochemical constituents of fruits over control and inorganic fertilizer alone.

Sharma *et al.* (2009) observed on 15-year old guava trees cv. Sardar that the highest total soluble solids (12.330Brix), total sugars (7.76%), ascorbic acid (217.41 mg/100g of pulp), pectin (0.66%) of guava fruits and available soil nitrogen 258.80 kg/ha were found maximum when cent per cent nitrogen was applied through poultry manure augmented with *Azotobacter* and *Azospirillum*.

Shukla *et al.* (2009) studied the effect of combinations of organic manures (FYM @ 25 and 50 kg, vermicompost @ 5 kg and organic mulch 10 cm thick per plant), inorganic fertilizers (full dose of recommended NPK, 50% dose of recommended NPK), biofertilizers (*Azospirillum*, *Azotobacter*, *Pseudomonas fluorescence*, *Aspergillus niger* etc.) and foliar spray of micronutrients on eight year old guava trees cv. Sardar under high density planting and reported that the application of 50 per cent dose of recommended NPK + 50 kg FYM + 250 g *Azotobacter* significantly increased the canopy volume (201.42 m³), fruit weight (153.30 g), TSS (14 °Brix), ascorbic acid (198.30 mg/100 g pulp), reducing sugar (4.77%), total sugars (8.10%), leaf nitrogen (1.40%), phosphorus (0.46%), potassium (1.17%) contents and significantly higher fruit yield/plant (28.95 kg) with higher B: C ratio (2.53:1). Nitrogen, phosphorus and potassium content of the leaf were positively correlated with fruit yield.

Thangaselvabai *et al.* (2009) studied on banana nutrition and found that split application of inorganic fertilizers along with organic manures increases the leaf nutrient status, uptake and distribution of nutrients and ultimately it results in better growth and yield. And a fertilizer dose consisting of 20t FYM, 5 kg *Azospirillum* and Phosphobacteria/ha, 250g neem cake/ plant (basal dose at the time of planting) + 200:35:330 g NPK/plant (three split doses during 3rd, 5th and 7th month after planting) along with foliar application of 0.5% ZnSO₄, 0.2% FeSO₄, 0.2% CuSO₄ and Borax 0.1% (at 3rd, 5th and 7th month after planting) is recommended to get higher yield and quality fruits in banana.

Yadav *et al.* (2009) found on strawberry crop that the majority of plant growth parameters, like number of crowns, number of runners, length of runners, number of plantlets and fruit characteristics like number of flowers, number of berries, fruit yield and net monetary return were recorded maximum in *Azotobacter* inoculated treatments with 50% N substitution by vermicompost and remaining 50% through inorganic fertilizer in two equal splits at establishment and before flowering stage. However, plant growth characters like height, spread and leaf area recorded maximum in inorganic fertilized plots.

Dutta *et al.* (2010) studied with organic manures and biofertilizers with or without chemical fertilizer combinations on litchi cv. Bombai and found that the treatment consisting of 50 kg/tree FYM + 150 g *Azotobacter* + 100 g VAM + 500 g N : 250 g P₂O₅ : 500 g K₂O/tree/year through fertilizer showed maximum yield (98.72 kg/plant) and also have a significant improvement in terms of TSS, total sugars, ascorbic acid, TSS : acid ratio, fruit weight, fruit size, maximum leaf N and K content with maximum (8.3×10^6 cfu/g soil) microbial population in rhizosphere soil of litchi orchard. Treatment with only organic manure and biofertilizers also resulted in improvement in fruit quality and maximum (22.45 mg/100 g peel) anthocyanin content over other treatments.

Dwivedi *et al.* (2010) studied on 4 year old guava trees cv. Red Fleshed and found that the application of biofertilizer was more effective than organic manures in enhancing fruit growth parameters in guava. Average maximum fruit yield was 19.03 kg / tree with 250 g *Azotobacter* + 20 kg FYM. Vermicompost (20 kg/tree) had significantly higher yield over control. Highest fruit weight 299.2 g, fruit length 7.19

cm and fruit breadth 7.41 cm were obtained with the application of Phosphobacterin (50 ml/tree), which was, however at par with that obtained with VAM (10 kg/tree). Highest TSS 17.9 0B Vitamin C 189.57 mg/ 100 g was obtained with the application of VAM. Acidity was not influenced by the application of biofertilizer and acidity was highest (0.54%) under FYM treatment. When biofertilizers were grouped together, P-solubilizers were found to have more beneficial influence on fruit physicochemical characteristics of guava cv. Red Fleshed as compared to N-fixers.

Fawzi *et al.* (2010) studied the effect of organic farmyard manure (FYM) 50 kg/tree, Nile compost (COM) 45kg/tree, biofertilizers (Bio) as combination between (phosphorene and nitrobeine), 20 g/tree and sprays of magnesium sulphate 1.5% single or combination on 12- year- old trees of Le –Conte pear and found that, the application of different aforementioned treatments increased significantly vegetative growth (shoot length and leaf area), leaf minerals content (N, P, K and Mg), pigments content (Ch1. A & B), yield as well as physical and chemical properties of the fruits compared to untreated trees. From the economic point of view, the best results with regard to nutritional status of the trees, yield and fruit quality were obtained when "Le- Conte" Pear trees treated with (COM) 45 kg/tree + (Bio) 20 g/tree + (MgSO₄)1.5% .

Kumar (2010) studied the effect of integrated plant nutrient management for three years on Litchi and found that the treatment having *Azotobactor* (250 g/tree) with half of the recommended dose of chemical fertilizer and 50 kg of FYM proved to be the most dynamic substrate to record maximum fruit yield (96.66 kg/tree) categorizing maximum percentage of quality fruits under superior grade i.e. extra class (42.75%), better canopy spread, fruit weight and bearing (fruits/panicle) of heavier fruits though found at par with control i.e. the treatment having only chemical fertilizer which recorded fruit yield of 94.50 kg/tree categorizing less percentage of quality fruits under superior grade i.e. extra class (32.10%). Physicochemical characteristics in different treatments showed higher values in substrate having biofertilizer in particular. The effect of treatments on available N, P and K status of the soil was found profoundly influenced at the end of experimentation and was appreciably higher particularly in case of treatments having biofertilizers when compared to the initial status.

Mitra *et al.* (2010) studied the effect of different organic (neem cake, farm-yard-manure, vermicompost) and inorganic fertilizers as well as biofertilizers (*Azotobacter* and *Azospirillum*) on yield and fruit quality of guava cv. 'Sardar' and reported maximum fruit set of 71.4% and yield of 3.49 t/ha by the application of 50 g N, 40 g P₂O₅ and 50 g K₂O/plant/year of age along with 5 kg neem cake/tree/year during the rainy season. During the winter season the application of 50 g N, 40 g P₂O₅ and 50 g K₂O/plant/ year of age along with 10 kg of farm-yard-manure and 20 kg of *Azotobacter*/tree/year recorded the maximum of 45.5% fruit set. Fruit quality (total soluble solids, total sugar, acidity ascorbic acid and pectin content of fruit) in both rainy and winter seasons were found superior in fruit from the plants receiving 50 g N, 40 g P₂O₅ and 50 g K₂O /plant/year of age along with 5 kg of neem cake/tree/year.

Rubee *et al.* (2011) studied the effect of bio-fertilizer and organic manures on yield and quality of 4-year old guava cv. Red Fleshed and concluded that the application of bio-fertilizer was more effective than organic manures in enhancing fruit growth parameters in guava and found average maximum fruit yield with 250 g *Azotobacter* + 20 kg farmyard manure (FYM) was 19.03 kg per tree. Vermicompost (20 kg per tree) had significantly higher yield over control. Highest fruit weight (299.2 g), fruit length (7.19 cm) and fruit breadth (7.41 cm), were obtained with the application of phosphobacterin (50 ml per tree), which was, however at par with that obtained with vesicular arbuscular mycorrhizae (VAM) (10 kg per tree). Highest TSS (17.90Brix), as well as vitamin C (189.57 mg/100 g) was obtained with the application of VAM. Acidity was not influenced by the application of bio-fertilizer. However, acidity was highest (0.54%) under FYM treatment.

Yadav *et al.* (2011) studied the integrated nutrient management on mango cv. Amrapali under high density orcharding and found the maximum panicle length (23.92 and 23.96 cm), number of flowers per panicle (1710.67 and 1756.00), fruit set per panicle (194.67 and 201.33) and sex ratio (0.690 and 0.691), maximum fruit length (9.88 and 10.08 cm), width (6.62 and 6.48 cm), weight (151.25 and 153.00 g), pulp weigh (97.06 and 97.08 g), stone weight (26.45 and 26.62 g), pulp:stone ratio (3.693 and 3.694), number of fruits per tree (163.33 and 184.67) and fruit yield (25.00 and 26.72 q/ha), maximum TSS (23.72 and 23.910Brix), TSS: acid ratio (191.60 and 197.76), ascorbic acid content (44.13 and 45.63 mg/100 g), carotenoids (18.91 and

18.63 mg/100 g), reducing sugars (8.35 and 8.39%), non reducing sugar (9.94 and 9.95%), total sugars (18.29 and 18.34%) and minimum acidity content (0.120 and 0.121%) were recorded with the application of T8 (recommended NPK + vermicompost + *Azotobacter* + PSB + Zn + Fe + paclobutrazol) followed by T12 (recommended NPK + biodynamic compost + *Azotobacter* + PSB + Zn + Fe + paclobutrazol). T8 is at par with T12.

Yadav *et al.* (2011) studied the effect of various organic, inorganic and biofertilizer combination on the growth and physico-chemical attributes of papaya and found that combination of 10 kg Vermicompost + 100% NPK + 25g *Azotobacter* enhanced the growth characters like plant height, girth, fruiting depth and physico-chemical characters like fruit length, width, ascorbic acid, total soluble solids, total sugar content compared to other treatments.

Ravikumar *et al.* (2013) studied that the effect of biofertilizers in combination with organic manures and inorganic fertilizers on dry matter production, tuber yield and quality, nutrient uptake and economics in coleus (*Coleus forskohlii* Briq.) (cv. K-8) and observed that the recommended dose of FYM @ 15 t ha⁻¹ and NPK @ 40:60:50 kg ha⁻¹ along with 10 kg ha⁻¹ each of *Azotobacter crucocum*, *Bacillus megaterium* (phosphorus solubilising bacteria) and *Glomus fasciculatum* (vesicular arbuscular mycorrhiza) produced significantly higher dry weight of leaves (70.21 g), stem (138.38 g), tuber (39.39 g), total dry weight (247.98 g) per plant, leaf dry matter (15.00%), stem dry matter (16.97%), tuber dry matter (14.02%), forskolin content (0.76%), uptake of N (115.83 kg ha⁻¹), P (49.59 kg ha⁻¹) and K (151.55 kg ha⁻¹), net returns (Rs. 39065 ha⁻¹) and B:C ratio (1.95).

Sahu *et al.* (2014) reviewed the recent scientific investigations carried out in various parts of India on biofertilizer use in guava cultivation in terms of its effect on plant growth characters, yield, fruit quality parameters, fruit physical attributes, soil properties and benefit-cost ratio of cultivation. The different treatments of different levels of biofertilizers have got significant influence on growth, yield, quality and economics of guava production.

Rajeswari and Shakila (2015) studied the effect of integrated nutrient management practices on yield characters of Ambrette (*Abelmoschus moschatus*

Medic.) with recommended dose of fertilizers (120 : 30 : 40 kg NPK ha⁻¹) along with combination of FYM (25 t ha⁻¹), neem cake (1 t ha⁻¹) and biofertilizers (azospirillum and phosphobacteria each @ 2 kg ha⁻¹) and found that the treatment combination of 50% RDF + 50% FYM + 50% biofertilizers (azospirillum and phosphobacteria) recorded maximum values for yield characters in ambrette.

2.3 Effect of manures

Chaudhury *et al.* (1975) studied the effect of influence of inorganic and organic manures alone and in combination on guava, cv. Allahabad Safeda, and reported higher doses of inorganic NPK and FYM gave the best growth, yields and fruit quality.

Villasurda and Baluyat (1990) studied effect of organic and inorganic fertilizers on guava and found that stem diameter (but not plant height) was significantly affected by fertilizer application, being greatest with urea (105 g/plant) or (NH₄)₂SO₄ (226 g) in combination with cattle manure (2375 g). Flowering was advanced by 45 days (compared with the control) following application of urea (105 g) + poultry manure (1589 g). Fruit number/tree was highest (23) with (NH₄)₂SO₄ at 451 g/plant. N and K uptakes were greatest following the application of combined organic and inorganic fertilizers.

Pereira and Mitra (1999) studied the effect on organic along with inorganic nutrition on guava and found that treatment N, P, K at the rate of 75 g, 100 g, 75 g/plant respectively in 2 splits + 1.5 kg neem cake/plant produced the highest yield (13.7 kg/plant and 38.0 q/ha) and average fruit weight (96.39 g) and the total sugar content of fruits (6.4%). The total soluble solids (10.1 °Brix), vitamin C (130.0 mg/100 g) contents and TSS/acid ratio (29.3) were higher in fruits from the plants receiving only FYM at 30 kg/plant. While neem cake at 3 kg/plant produced the highest number of fruits/plant.

Corrales *et al.* (2000) studied the effect of poultry manure and mineral fertilizer on guava and found that applications of manure and mineral fertilizer resulted in more vigorous plants, good yields and better quality fruits. Treatment with manure resulted in improved nutrient content of plants and of soil organic matter and pH. Application of mineral fertilizers could be reduced by 33-66% with manure. It is concluded that application of a combination of manure with mineral fertilizer was economically viable.

Ram and Rajput (2000) studied the effect of organic manures and Biofertilizer on the yield the fruit quality of guava cv. Allahabad Safeda and found that the highest number of fruits per plant, reducing sugars and yield per plant (25.08 and 37.56 kg, for 1997 and 1998, respectively) was observed upon treatment with neem cake. Treatment with farmyard manure recorded the highest acidity and TSS, while treatment with *S. aculeata* recorded the highest ascorbic acid content.

Hartemink (2003) investigated the effects of organic and inorganic nutrients on sweet potato tuber yield in the humid lowlands of Papua New Guinea and found that sweet potato yield was lowest after *Gliricidia* fallow, but no yield differences were found after piper and imperata fallow.

Maity *et al.* (2006) studied the effect of different sources of nutrients on guava cv. L-49. and found that the number of fruits, yield and most of the physical and quality parameter like fruit weight, fruit size, pulp weight, total sugar and ascorbic acid content were significantly higher in 50% neem cake + 50% RDF treatment. The plant treated with 50% mahua cake + 50% RDF showed higher TSS (11.00Brix), reducing sugar (4.22%) and TSS/acid ratio (33.85). Among the organic sources, the use of mahua cake @ 10.4 kg and neem cake @ 5.0 kg resulted in better yield. However, better quality fruits were harvested from FYM treated plants.

Manjunatha *et al.* (2006) reported that the effect of vermicompost application with varied levels of recommended dose of fertilizer on 'Kalipatti' sapota (*Manilkara zapota*) and soil properties found that highest fruit yield was recorded under 100% recommended dose of fertilizer + vermicompost application (18.4 kg fruit/plant) that however remained on a par with 75% recommended dose of fertilizer + vermicompost and 100% recommended dose of fertilizer alone. Reduction in recommended dose of fertilizer beyond 75% resulted in significantly lower yields. The total soluble sugars remained significantly higher in all treatments involving vermicompost application. Application of vermicompost alone, however, resulted in significantly lower yield (46.7% reduction over recommended dose of fertilizer + vermicompost application). Reduction in recommended dose of fertilizer levels resulted in lesser number of fruits (309, 294, 240 and 203 fruits/plant under 100, 75, 50 and 25% recommended dose of fertilizer application respectively). The fruit weight significantly reduced when the crop was fertilized fully inorganically (100% recommended dose of fertilizer) and

also when less inorganic fertilizer was applied in conjunction with vermicompost (25% recommended dose of fertilizer + vermicompost). Soil organic carbon increased but bulk density decreased due to vermicompost application.

Patil *et al.* (2006) studied the effect of integrated nutrient management on Thompson Seedless grapes and found significantly higher number of bunches per vine (45.58), highest berry weight (122.34 g), highest bunch yield (10.26 kg) in T5-Recommended dose of fertilizers wherein 50 percent nitrogen supplied through vermicompost. Also T5 recorded significantly higher yield per hectare (35.61t/ha) as compared to other treatments.

Athani *et al.* (2007) studied the influence of vermicompost on 5 years old guava cv. Sardar and found maximum polar diameter (7.55 cm), fruit weight (221.0 g), fruit volume (218.50 ml) and pulp thickness (2.33 cm) and its weight (143.0 g) and TSS (10.830Brix), ascorbic acid (208.60 mg/100 g) and total sugars (8.62%) in the plants which received 75 per cent recommended dose of fertilizers (RDF) + 10 kg vermicompost followed by the plants, received vermiculture @ 50 worms/plant and 100 per cent RDF *in situ*. The treatment of 100 per cent RDF per plant recorded maximum reducing sugar (5.10%) followed by the treatments *in situ* vermiculture @ 50 worms and 75 per cent RDF + 10 kg vermicompost. The plants receiving 50 worms per plant recorded maximum yield (29.10 kg/plant and 8.10 t/ha) followed by 75 per cent RDF + 10 kg vermicompost and 100 per cent RDF/plant.

Athani *et al.* (2009) studied the effect of organic and inorganic fertilizers on 6-yrs-old guava cv. Sardar and found that application of 75 per cent RDF + 10 kg vermicompost/plant was significantly superior in leaf area (78.55 cm²), fruit polar diameter (7.57 cm), fruit weight (222.33 g), its fruit volume (218.67), pulp thickness (2.31 cm) and pulp weight (143.67 g). Maximum contents of nitrogen (1.64%), phosphorus (0.327%) and potassium (1.30%), Chlorophyll „a“ and total chlorophyll were higher (1.298 & 1.698 mg/g) in the plants supplied with 75 per cent RDF + 10 kg vermicompost while chlorophyll „b“ was more (0.407 mg/g) in *in-situ* application of vermiculture (at 50 worms/plant). Highest yield (33.11 kg/plant and 9.19 t/ha) was noticed in the Plants supplied with 75 per cent RDF + 10 kg vermicompost followed by plants supplied with 100 per cent RDF and *in situ* vermiculture application (50 worms/plant). *In situ* vermiculture application and 100 per cent recommended dose of

fertilizers were statistically at par with 75 per cent RDF + 10 kg vermicompost for fruit characters, leaf nutrient and chlorophyll contents and yield.

Khan and Hameedunnisa (2007) found out the effect of components of integrated nutrient management as individual and in combinations on the soil available nutrient status on young acid lime and found application of individual higher rate of farmyard manure (FYM) at 50 kg/plant and simultaneous use of iron pyrites at 200 g along with FYM at 25 kg + press mud at 2 kg/plant were superior treatments and significantly increased the available nutrient status of N, P, K and S in both years over the control.

Naik and Hari Babu (2007) studied the response of guava cv. L-49 (Sardar) to different organic manures and revealed that the vermicompost was superior to other organic sources and closely followed by poultry manure and leaf litter in improving vegetative growth, flowering, fruiting, yield and fruit attributes and fruit quality along with improvement in soil fertility and leaf nutrient status of the guava plant. The treatments with vermicompost resulted in maximum number of shoots/plant, more number of leaves/shoot and highest yield. The fruit yield was better with chemical fertilizers and good with poultry manures. TSS was highest with animal manures and least in control. Acidity was highest under FYM treatment closely followed by vermin-compost. Ascorbic acid content was highest in pig manure treatment, whereas total sugars and reducing sugars were maximal with goat manure.

Chakraborty *et al.* (2008) investigated the effect of organic manure and mulching on the growth, yield and quality of guava. Integration of organic manures with mulching showed good effect on crop. Combination of 15 kg compost + 6 kg soyabean mulch/tree/year was the best among all other treatments as it recorded the highest yield (76.82 kg/tree).

Katiyar *et al.* (2008) studied on 10-year-old guava trees and found N at 400 g, farmyard manure at 60 kg and Zn at 20 g per plant individually caused significant improvement on fruits set, size and weight of fruit, TSS, total sugar, ascorbic acid and yield per plant. These attributes improved further in association of either Zn or farmyard manure treatment. The combination of 400 g N + 60 kg farmyard manure + 20 g Zn improved the quality of fruit revealing significant improvement in the weight of individual fruit and yield per plant which increased by 28.6% compared to 400 g N applied alone.

Athani *et al.* (2009) studied the effect of organic and inorganic fertilizers on six years old guava cv. Sardar and reported that application of 75 per cent recommended dose of fertilizer (RDF) + 10 kg vermicompost per plant showed significant superiority in terms of leaf area (78.6 cm²), polar diameter (7.6 cm), weight of fruit (222.3 g), volume of fruit (218.7 ml), thickness of pulp (2.3 cm), weight of pulp (143.7 g), contents of nitrogen (1.6%), phosphorus (0.33%) and potassium (1.3%) and contents of chlorophyll 'a' (1.29 mg/g) and total chlorophyll (1.70 mg/g). Highest yield (33.1 kg/plant and 9.19 t/ha) has obtained in the plants supplied with 75 per cent RDF + 10 kg vermicompost per plant followed by plants supplied with 100 per cent RDF and *in-situ* vermiculturing @ 50 worms per plant.

Bashir *et al.* (2009) studied the effect of manure and fertilizers on 10-12 years old guava cv. Larkana Surahi and found that maximum yield per plant (63.78 kg), single fruit weight (193.52 g), pulp weight (190.04 g), fruit size (length x diameter = 9.74 x 7.63 cm), number of seeds (200.80/fruit) and TSS (11.35%) were obtained by guava plants applied with 40 kg FYM + 1 kg each of N-P₂O₅-K₂O per plant. Minimum values for these parameters were recorded in control where no manure or fertilizer was applied.

Kirad *et al.* (2009) studied the response of Integrated Nutrient Management on strawberry and found that the yield of strawberry was statistically at par with 75% recommended fertilizers rate + 25% vermicompost + rhizosphere bacteria culture in comparison to other treatments. Quality parameters of strawberry were increased with decreasing level of chemical fertilizers. Maximum plant spread (32.37 cm) and fruits per plant (8.77), fruit yield per hectare (8.07 t), shelf life (3.95 days) were recorded with 75% recommended fertilizers rate + 25% vermicompost + rhizosphere bacteria culture treatment, while maximum plant height (20.35 cm) and acidity (0.83%) were associated 75% recommended fertilizers rate + 25% vermicompost.

Dhaval and Naik (2010) studied the effect of pre-harvest treatment of organic manures and inorganic fertilizers on sapota cv. Kalipatti and found that 5 kg vermicompost + 400 + 60 + 300 g NPK/tree was found to be superior in respect of extending post-harvest shelf-life as well as other physico-chemical parameters, *viz.*, volume, peel weight, pulp weight, colour acceptance, TSS, reducing sugar, non

reducing sugar, acidity and vitamin-C content, while maximum firmness of fruits was found under 25 kg FYM + 400 + 60 + 300 g NPK/tree. Organoleptic test in respect of colour and texture was more acceptable under 5 kg vermicompost + 400 + 60 + 300 kg NPK/tree while flavour and taste was superior under 25 kg FYM alone/tree.

Jeyabaskaran and Mustaffa (2010) studied in banana that application of fertilizers along with organic manures and bio-fertilizers increased the nutrient use efficiency and also soil physicochemical properties and found application of FYM and gypsum along with increased potassium enhanced the banana yield in saline sodic soil by improving soil fertility.

Kirad *et al.* (2010) studied the response of Integrated Nutrient Management on papaya cv. Surya and found that the yield of papaya was statistically at par with 75% recommended fertilizers rate + 25% vermicompost + rhizosphere bacteria culture in comparison to control (recommended fertilizers dose).

Pilania *et al.* (2010) studied the effect of integrated nutrient management in guava and reported that use of 50, 20, 50 g NPK + 5 kg vermicompost enriched with *Azotobacter* + *Aspergillus niger* resulted in maximum canopy volume (0.69 m³), leaf area (57.19 cm²), flowers/shoot (49.12), fruit set (45.79%), fruit retention (44.76%).

Ravishankar *et al.* (2010) studied the effects of organic farming on papaya cv. “Coorg Honey Dew” and found that organic matter content in soil was significantly influenced by different treatments with the highest values recorded under FYM 20 kg/plant and urban compost 13.5 kg/plant treatments. Soils under different organic modules had significantly higher microbial population (bacteria, fungi and actinomycetes) and activities of urease, phosphatase, dehydrogenase and cellulases as compared to that under recommended dose of fertilizers. Significant positive association between organic matter status, microbial populations and enzyme activities in soil was recorded. Application of FYM 20 kg/plant was the best organic module with regard to higher microbial populations and enzyme activities in soil.

Singh *et al.* (2010) studied the effect of vermicompost (VC) on „Chandler” strawberry and revealed that with the increase in dose of VC; there was increasing trend for plant growth, yield and quality parameters of strawberry. However, vermicompost application @ 10 t/ha increased plant spread (16.1%), leaf area

(31.4%) and dry matter (17.7%), and increased total fruit yield (29.1 %), higher TSS, ascorbic acid content and lower acidity over inorganic fertilizer. All these parameters were appeared to be dose dependent and best results were achieved @ 7.5 t/ha. Substitution of vermicompost drastically reduced the incidence of diseases, proportion fruits free from any physiological disorders indicating that application of vermicompost had significant role in producing healthy fruits and thereby increasing the marketable fruit yield with better quality parameters.

Thomas *et al.* (2010) recommended NPK dose for adult coconut palms that is 500 g N, 320 g P₂O₅ and 1200 g K₂O and 50 kg organic manure/palm/year. Vermicomposting is an effective method to recycle the biomass to produce vermicompost with 1.8% N, 0.21% P and 0.20% K. Mixed farming system with dairy, poultry and silk worm rearing contribute to sizable quantities of biomass to the tune of 14 tonnes of cow dung, 295 kg of poultry bedding materials and droppings, 12 kg of silk worm waste (all on dry weight basis) and 50000 liters of cowshed washings. This waste biomass on recycling will meet 74% N, entire quantity of P, and 82% of K requirement of both coconut and grass grown as intercrop in one hectare of the coconut garden.

Verma *et al.* (2010) studied soil moisture distribution, nutrient content and apple productivity under organic farming technology by using organic manures (Commercial organic manure and farm yard manure) during years 2004 and 2005 and revealed that the improvement in soil moisture availability, pH, organic carbon and nutrient status of soil were significant under organic manures. Growth parameters, fruit characteristics and yield were recorded maximum with application of commercial organic manure @ 20 kg tree during 2004-2005 and Farm yard manure @ 100 kg tree during both the years of experimentation. Soil moisture, pH, organic carbon and available N, P and K were recorded maximum under the application of commercial organic manure @ 20 kg tree treatment and Farm yard manure @ 100 kg tree.

Allolli *et al.* (2011) conducted a field experiment during 2009-10 and 2010-11 at Regional Horticulture Research and Extension Center (RHREC), Dharwad (Karnataka) to study the effect of organic manures in combination with inorganic fertilizers on the productivity and economic feasibility in sweet potato and found that, among organics, application of FYM @ 10 tones ha⁻¹+ 50:25:50 kg NPK ha⁻¹ recorded significantly higher tuber yield per plot and hectare (24.16 kg and 33.55 tones ha⁻¹, respectively), and was as per with FYM @ 20 tones ha⁻¹.

Baviskar *et al.* (2011) studied the effect of different combinations of organic, inorganic manures and biofertilizers on yield and quality of sapota. The fruit yield in terms of number of fruits harvested per plant, was recorded maximum in plants which were treated with (1125:750:375 g NPK + 15 kg vermicompost + 250 g *Azotobacter* + 250 g PSB/plant). Same treatment also showed the superior fruit quality traits evaluated in terms of fruit weight, fruit size, fruit volume, pulp and peel weight, total soluble solids and total sugar with lower acidity.

Dhomane *et al.* (2011) revealed that integration of organic manures and inorganic fertilizers was more effective in increasing growth and yield of guava trees than the inorganic fertilizers alone and found that 75% of nitrogen through urea along with 25% nitrogen through neem cake was found to be the best over all the treatments in respect of vegetative growth parameters like increasing tree height (39.7 cm), tree spread (38.00 cm E-W), stem girth (5.30 cm), shoot length (24.82 cm), reproductive growth parameters like maximum number of flowers (17.97) and fruits (11.8) per square meter, fruit set (65.57%) and yield parameters like weight of fruit (243.80 g), yield per tree (58.1 kg) and yield per hectare (23.26 tonnes).

Mishra *et al.* (2011) studied the effect of organic and inorganic sources of NPK and foliar spray of chemicals on plant growth, fruit yield and quality of *ber* cv. Gola and revealed that application of 22 kg vermicompost + 0.82 kg urea + 1.15 kg SSP + 0.41 kg MOP per tree (F5) and foliar spray of thiourea @ 0.5 per cent per tree (T2) and reduced the fruit drop. The ascorbic acid and iron content of fruits and NPK uptake by fruits were enhanced along with improvement in relative leaf water content (RLWC) and chlorophyll content in leaves under treatment F5 and T2. All these parameters were appeared to be dose and source dependent and best results were achieved with the combined application of 22 kg vermicompost + 0.82 kg urea + 1.15 kg SSP + 0.41 kg MOP per tree + foliar spray of thiourea @ 0.5 per cent under integrated nutrient management systems of *ber* orchard.

Susan John (2013) concluded that sweet potato is the most nutritious among the tropical tuber crops in terms of macro and micronutrients contained in both the tubers and the green leaves. The available literature on minor tuber crops indicates their positive response to manures and fertilizers are also discussed.

Patel *et al.* (2012) reported that the effect of organic manures in combination with essential nutrients on yield of turmeric (*Curcuma longa* L.) cv. KESAR and observed that application of RD of nitrogen through poultry manure in combination with RD of essential nutrients like phosphorus, potassium, zinc sulphate and ferrous sulphate significantly improved the yield of turmeric.

Akpaninyang *et al.* (2013) evaluated the response of two varieties of orange-fleshed sweet potatoes (Umuspo 1 and Umuspo 3) to different fertilizer combinations (Poultry manure, NPK and agrolyser) and found that weed dry matter was lower with the control or with application of 2.5t ha⁻¹ poultry manure + 200kg NPK than with application of poultry manure at 10t ha⁻¹.



MATERIALS AND METHODS

The present investigation entitled “Integrated nutrient management of arrowroot in guava based agroforestry systems.” was carried out at the experimental site of All India Co-ordinated Research Project on Agroforestry, Orissa University of Agriculture and Technology, Bhubaneswar during July 2016 to June 2017. The climatic and edaphic condition of the experiment site and materials and techniques employed in conducting the experiment are being described in this chapter.

3.1 Experimental site

3.1.1 Location

The experimental site is situated inside the Horticultural Research Station of O.U.A.T., Bhubaneswar which is located at 20 °15’ N longitude and 85 °52’ East latitude with an altitude of 25.9 meter above mean sea level. The experimental site is situated at a distance of 8 km from the university headquarters on the site of the Khandagiri-Chandaka road. The location map is presented in Fig. 3.1.

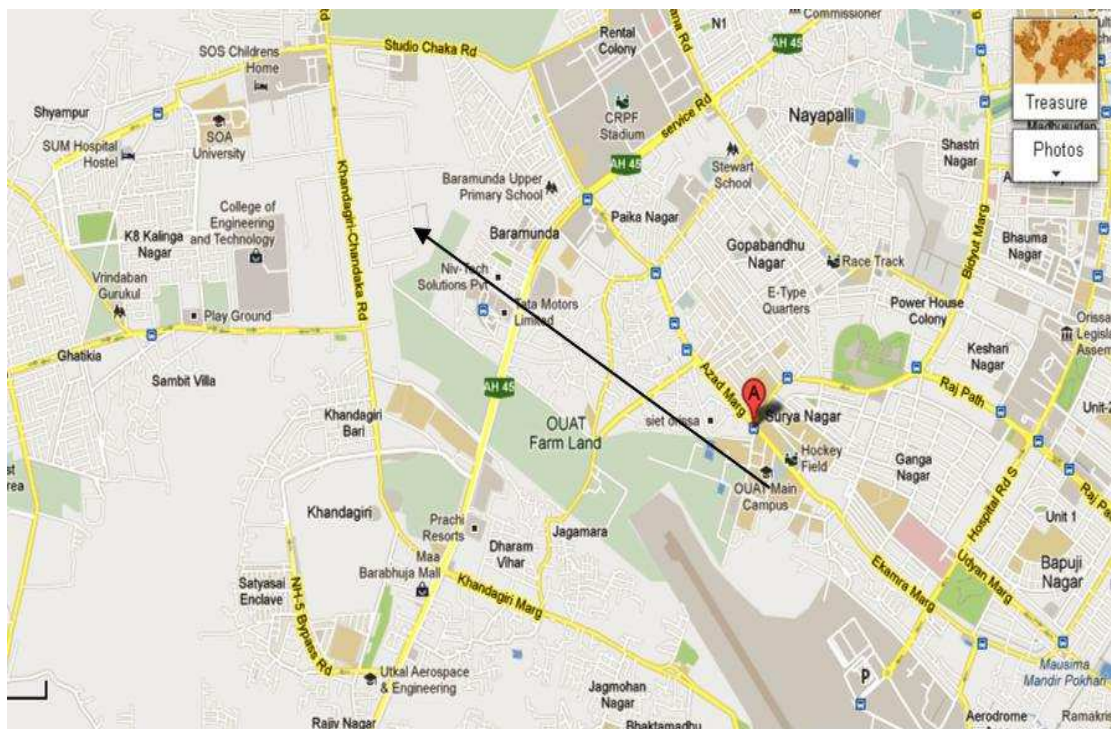


Fig.3.1 Location map of the experimental site

3.1.2 Climate and weather condition

The study area falls in the sub-tropical zone. It is about 64 km away from the Bay of Bengal in the east. It has a warm and moist climate characterised by humid summer and mild winter. In general, the climate of Bhubaneswar falls in the group of moist and hot climate.

The data on the weather condition during the investigation period with respect to maximum and minimum temperature, rainfall, relative humidity, sunshine duration and evaporation recorded at meteorological observatory of O.U.A.T., Bhubaneswar are presented in Table 3.1 and shown in Fig 3.2.

Table 3.1 Metrological data at Bhubaneswar from July 2016 to June 2017

Month/ Year	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	No.of rainy days	Bright sunshine hour	Evaporation (mm)
	Mean Max.	Mean Min.	Mean Max.	Mean Min.				
July, 16	32.2	25.8	91	78	222.2	17	5.2	3.4
Aug,16	31.7	25.5	93	79	247.8	21	4.2	3.1
Sept,16	31.4	25.3	93	79	238.0	24	3.3	3.3
Oct,16	32.1	22.6	89	37	132.8	12	6.1	3.4
Nov,16	31.0	17.4	91	46	20.3	3	7.3	3.0
Dec,16	30.1	15.1	86	38	0	0	7.0	3.5
Jan,17	29.7	14.5	90	38	0	0	6.5	3.6
Feb,17	33.8	19.1	94	38	0	0	7.9	3.7
Mar,17	34.7	22.8	91	43	45.4	5	7.1	4.8
April,17	36.9	26.3	88	49	29.2	1	7.6	7.5
May,17	38.8	27.2	82	46	43.1	3	8.3	8.7
June,17	35.3	26.5	87	60	122.0	15	3.6	5.5
Total/ Mean	33.1	22.3	89.5	49.4	1100.8	101	6.1	4.4

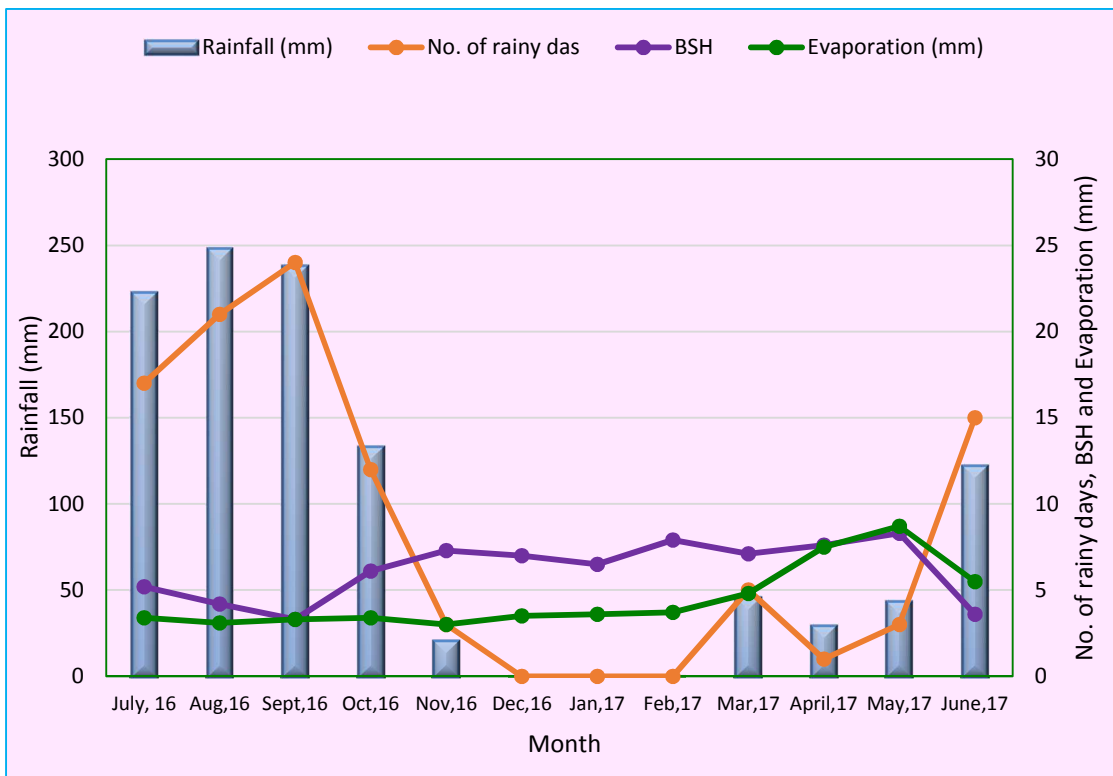
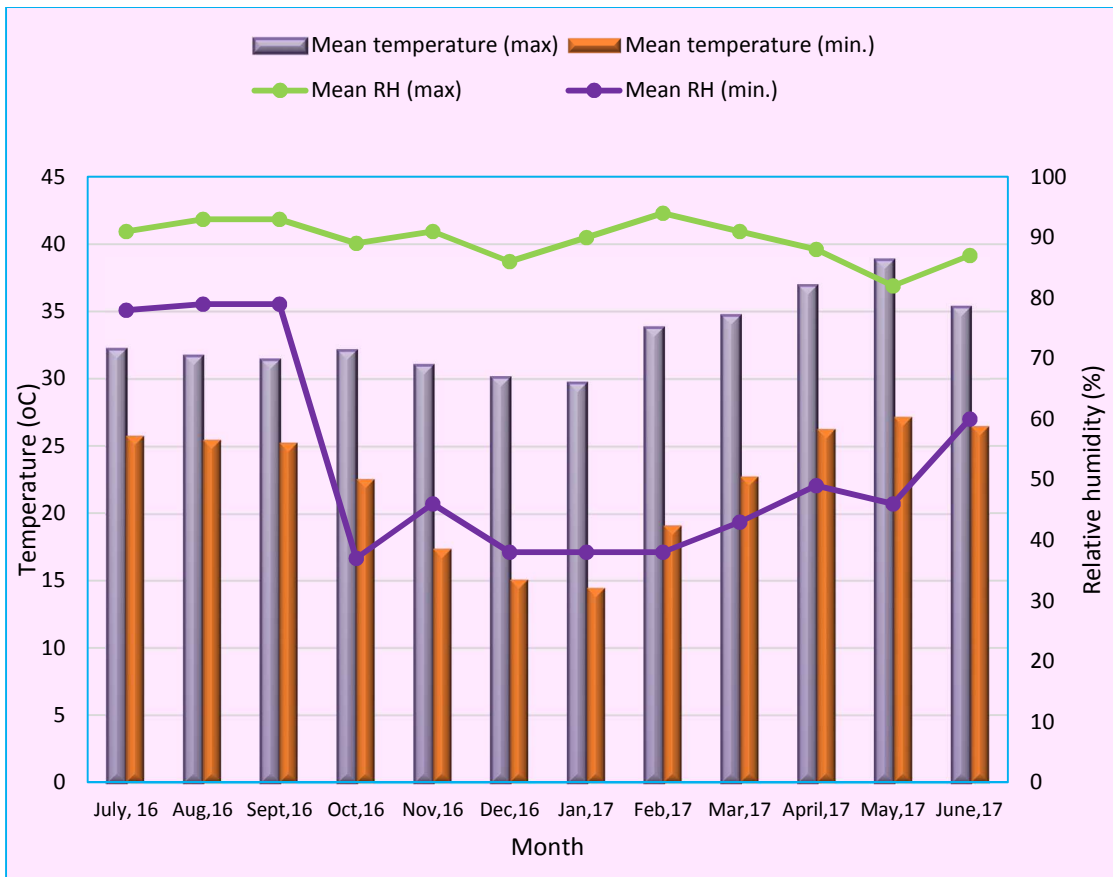


Fig. 3.2 Metrological data at Bhubaneswar from July 2016 to June 2017

The normal average rainfall of the station is 1493.7 mm with 113 rainy days in a year which is mostly received from the south-west monsoon. The monsoon sets on around mid June and recedes by mid-October. The rainfall received during the investigation period from July 2016 to June 2017 was 1100.8 mm in a 101 rainy days.

The mean maximum and minimum temperature during the experimentation ranged from 29.70C to 38.8 0C and 14.5 0C to 27.2 0C, respectively. The temperature begins to rise from the month of March and reaches its maximum in May. The mean minimum and maximum relative humidity in Bhubaneswar ranged between 49.4 to 89.5 per cent from July 2016 to June 2017. The maximum average bright sunshine hour (BSH) per day is 8.3 and minimum is 3.3 hours per days as average over 10 years. During investigation period July 2016 to June 2017 the crop received the max. BSH per day in May (8.3 hrs) while in min. BSH per day in Sept (3.3hrs).

The normal average rate of evaporation varies from 8.7 to 7.5 mm per day. The total evaporation from USWB Class-I open pan evaporimeter was 53.55 mm with a daily average of 4.4 mm during the investigation period.

3.1.3 Soil characteristics

The experimental field is fairly leveled and well drained. Soil is sandy loam texture. It is rich in oxides of iron and aluminium, but poor in di-basic cations and soluble salts. Soil samples were taken before conducting the experiment from a depth of 0-15 cm, taking all the possible precautions prescribed for soil sampling. The samples were brought to the laboratory, air dried and crushed to pass through 2.0 mm mesh sieve. The processed samples were subjected to appropriate mechanical and chemical analysis. The results thus obtained are presented in table 3.2.

Table 3.2 Mechanical composition of experimental site during 2016

Particulars	Percentage of composition on air dry basis	Method adopted
Sand	76.8	Bouyoucos Hydrometer Method (Piper, 1994)
Silt	12.6	
Clay	10.6	
Textural Class	Sandy Loam	Black <i>et al.</i> (1965)

Particulars	BD (g/cm ³)	Porosity (%)
Methods adopted	Cylinder method Black <i>et al.</i> (1965)	Cylinder method
Treatments		
T ₁ - Control (No Fertilizer)	1.55	41.52
T ₂ - STD* (50%)	1.55	41.5
T ₃ - STD (50%) + FYM**	1.54	41.9
T ₄ - STD(50%)+FYM + Biofertiliser***	1.54	41.9
T ₅ - STD (75%)	1.55	41.5
T ₆ - STD (75%) + FYM	1.54	41.9
T ₇ - STD (75%) + FYM + Biofertiliser	1.54	41.9
T ₈ - STD (100%)	1.55	41.5
T ₉ - STD (100%) + FYM	1.54	41.9
T ₁₀ - STD (100%)+ FYM + Biofertiliser	1.54	41.9

Particle density of soil (PD) =2.65 g cm⁻³

3.1.4 Cropping history

This experiment was started in 2015 and this is second year of agrihorticultural system. In the present study the intercrop was sown in respective plots where it was grown during 2015 in the existing fruit trees plantations.

3.2 Experimental details

3.2.1 Experimental design

The experiment was laid out in a Randomised Block Design (RBD) with three replications. The experiment was consisted of 10 treatment combinations.

3.2.2 Treatments

The details of different treatments are given in Table 3.3.

Table 3.3 Treatment details

Treatment	Details 2016-2017
T1	Control (No Fertilizer)
T2	STD* (50%)
T3	STD (50%) + FYM**
T4	STD(50%)+FYM + Biofertilizer***
T5	STD (75%)
T6	STD (75%) + FYM
T7	STD (75%) + FYM + Biofertilizer
T ₈	STD (100%)
T ₉	STD (100%) + FYM
T ₁₀	STD (100%)+ FYM + Biofertilizer

*STD (100%): Soil Test based dose

** FYM @5 t ha⁻¹

*** Biofertiliser: Azotobacter + Azospirillum + Phospho Solubilizing Bacteria (1:1:1) @ 4 kg each ha⁻¹ inoculated with lime and FYM @1:25 for 7 days at 30% moisture. (RDF= 50:50:50 kg ha⁻¹ N, P₂O₅, K₂O)

3.2.3 Details of field operations

3.2.3.1 Layout and leveling

The experimental plot was laid out into small plots of size 12m x 11m for different treatments as per the plan of layout. Each plot was leveled properly after breaking the clods and removing the weeds before sowing/planting. The layout is presented in Table 3.4 and Fig. 3.3.

Table 3.4 Layout of experimental field

Year of experimentation	2016-2017
Experimental design	Randomized block design
No. of treatment	10
No. of replication	3
Total number of plots	10 x 3 = 30
Plot size	12 m x 11 m = 132 m ²
Tree spacing	6.0 m x 5.5 m



Fig. 3.3 Layout plan of experimental field



3.2.3.2 Planting of intercrops

One intercrop i.e. arrowroot was raised during *kharif* season. The variety of arrowroot is Nayagarh local.

3.2.3.3 Planting of trees and inter crop

An earlier study on tree crop interactions indicated that arrowroot was the most suitable annual crop for the guava based agrihorticultural system from 5th to 9th year of tree plantation. Alhabad Safed is the variety of guava. As the yield recovery of arrowroot in the system was reduced to below 70% due to dense canopy of guava trees, a new experiment was carried out with different pruning practices of 15 year old guava trees during January 2013. Three tree species *Acacia mangium*, *Dalbergia sissoo* and *Gmelina arborea* which were planted at 6 m x 5.5 m spacing in 2001 in between two guava trees were broken due to super cyclone Phailin in October 2013 therefore cut down and this new experiment was started from 2015 after fruit trees were fully recovered and land is ready for new experimentation.

3.2.3.4 Package of practices followed for arrowroot

The detailed package of practices followed for arrowroot grown during growing seasons are presented in the table 3.5.

Table 3.5 Details of package of practices of Intercrops

Crop	Recommended Fertilizer dose	Spacing (cm)
Arrowroot	50:50:50	50 X 30

3.2.3.5 Plant protection

Recommended pesticides and fungicides were used for the fruit crop and inter crop during growing season.

3.2.4 Observations recorded

The observations were recorded on growth parameters of fruit crops which are described below.



Fig. 3.4 Analysis of soil samples using **KEL PLUS** Nitrogen analyser



Fig. 3.5 Experimental details

3.2.4.1 Basal diameter of fruit trees

Basal diameter over bark of trees was measured at a height of 1.37 m with the help of caliper in two directions (major axis and minor axis) and the average was computed and expressed in centimeter (cm).

$$\text{Basal dia} = \frac{d_1 + d_2}{2}$$

Where, d_1 - diameter of major axis

d_2 - diameter of minor axis

3.2.4.2 Height of fruit trees

Height of *guava* was measured vertically from ground level to tip the leading shoot with help of Ravi altimeter. Measuring tape was also used to measure 20 m distance from the tree. The top of the tree and base of the fruit tree from that point was seen through altimeter, measurements were taken in the 20 m scale of that instrument and then observer's eye height (1.67 m) was also added to the measured height.

3.2.4.3 Physico- chemical analysis of soil

For physico-chemical analysis, soil samples were collected from 0-15 cm depth of each plot before planting and after harvesting of annual crop. The samples were air dried under shade, finely ground and passed through a 2 mm mesh sieve and finally 250 gram of such soil were mixed thoroughly and composite samples were made for each treatment and filled in polythene bags with proper label for analysis of physico-chemical properties. The methods used were mentioned below:

- a) **Texture:** Mechanical analysis of the soil was done to find out the percentage of sand, silt and clay separately by means of Bouyoucus hydrometer method to determine the texture of soil (Piper, 1994).
- b) **Bulk density (BD):** Bulk density was determined by cylinder method with dividing the oven-dry soil sample by the total volume of the sample. The bulk density equation is as follows:

$$\text{Soil bulk density (g cm}^{-3}\text{)} = \frac{\text{Oven dry sample mass (g)}}{\text{Total volume of soil (cm}^3\text{)}}$$

- c) **Particle density (PD):** The PD of soil was taken as 2.65 g cm^{-3} . However, it was determined by dividing the oven dried sample by volume of solid. The equation as follows:

$$\text{Soil particle density (g cm}^{-3}\text{)} = \frac{\text{Oven dry sample mass (g)}}{\text{Volume of solid (cm}^3\text{)}}$$

- d) **Porosity:** The percentage porosity of soil was determined by the formula

$$\text{Porosity (\%)} = \left(1 - \frac{\text{BD}}{\text{PD}}\right) \times 100$$

- e) **pH:** Soil pH was determined in 1:2 soil and water suspension by using glass electrode pH meter (Jackson, 1967).
- f) **Organic carbon:** Organic carbon content of the soil sample was determined by Walkley and Black's rapid titration method (Piper, 1950).
- g) **Available nitrogen:** Available nitrogen was determined by the alkaline potassium permanganate method described by Subbiah and Asija (1956). Nitrogen released as ammonia during distillation of 20-gram soil with 100 ml 0.32% of KMnO_4 and 100 ml of 2.5% NaOH was received in 2% boric acid containing mixed indicator and ammonium borate complex was titrated against standard 0.02 N H_2SO_4 .
- h) **Available phosphorous:** It was determined by Bray's-I method with shaking 5-gram soil in 35 ml of extracting solution (0.03N NH_4F in 0.025N HCl) for 5 minutes. The filtrate was estimated by spectrophotometer for phosphorous after development of colour by SnCl_2 and measured at 660nm (Jackson, 1973).
- i) **Available potassium:** It was determined by neutral normal ammonium acetate method with equilibrating 5 gram of soil in 25ml neutral normal ammonium acetate (Jackson, 1973) and reading of extract was taken in flame photometer.

3.2.4.4 Soil moisture

Soil sample was collected in moisture box, one at 0-15 cm and another at 15-30 cm by gravimetric method. Fresh weight of soil sample will be taken immediately after collection of sample in moisture box and dry weight will be recorded at 105⁰ C after 24 hours in hot air oven. Then soil moisture content (%) calculated by,

$$\text{Soil moisture content (\%)} = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Dry weight}} \times 100$$

3.2.4.5 Crop yield

The yields of fruit tree, intercrop were recorded from time to time from each plot and the total yield was calculated at the end of each season and converted to yield per hectare.

3.2.4.6 Economics

Finally a detailed economics was worked out to compare the profitability of different treatments. The cost involved in production of different agroforestry systems was estimated and converted to per hectare value, then the return obtained from each treatment were evaluated and the net return (Rs ha⁻¹) was worked out by subtracting the cost of cultivation from the gross return obtained. The benefit: cost ratio was calculated by dividing the gross return by the cost of cultivation and presented to assess the profitability of different treatments.

3.2.4.7 Statistical analysis

For determining the significance between the treatment means and to draw valid conclusion, statistical analysis was made. Data obtained from various observations were subjected to statistical analysis by adopting appropriate method of “Analysis of Variance”. The significance of the treatment effect was judged with the help of ‘F’ test (Variance ratio). The difference of the treatments mean was tested using Least Significant Difference (L.S.D.) /Critical Difference (C.D.) at 5% level of probability (Gomez and Gomez, 1976).

When the treatment difference is greater than or equal to the critical difference it is significant other wise there is no significant difference between the treatment means.

If the variance ratio (F test) was found significant at 5% level of significance, the standard error of mean (SE_m±) and LSD were calculated for further comparison.

$$SE(m) = \sqrt{\frac{\text{Error sum of square}}{N}}$$

Where, n = number of observations

LSD/CD at 5% = S.Em. $\sqrt{2t}$ value at 5% error degree of freedom



RESULTS

The experimental results of the present investigation “**Integrated nutrient management of arrowroot in guava based agroforestry systems**” are presented in this chapter under following heads:

- 4.1 Growth factors in agrihorticultural system.
- 4.2 Soil fertility changes under guava based agrihorticultural system.
- 4.3 Growth of fruit trees and intercrops under agrihorticultural system.
- 4.4 Economics of the agrihorticultural system.

The relevant data pertaining to different attributes have been presented in Table 4.1 to Table 4.3.

4.1 Growth factors in agrihorticultural system

4.1.1 Chlorophyll content in guava+arrowroot agroforestry system

Among the treatment the chlorophyll content was observed maximum with STD (100%) + FYM + biofertilizer followed by STD (100%) + FYM and STD (75%) + FYM + biofertilizer during entire growth period. The chlorophyll content was observed minimum with control. The chlorophyll content was highest in September and decreased thereafter and minimum chlorophyll content was observed in November irrespective of the treatments.

Table 4.1 Chlorophyll content in guava+arrowroot agroforestry system

Treatments		August		September		October		November	
		SPAD	%	SPAD	%	SPAD	%	SPAD	%
T ₁	Control (No Fertilizer)	45.8	86.6	47.6	88.4	42.1	84.5	35.6	81.4
T ₂	STD (50%)	48.2	91.1	49.6	92.2	44.4	89.1	37.8	86.5
T ₃	STD (50%) + FYM	49.6	93.7	50.4	93.7	44.9	90.2	38.0	86.9
T ₄	STD (50%) + FYM + Biofertilizer	50.3	95.1	51.3	95.3	46.2	92.7	39.2	89.7
T ₅	STD (75%)	49.9	94.3	50.8	94.4	45.4	91.2	38.5	88.1
T ₆	STD (75%) + FYM	51.4	97.2	52.7	97.9	48.3	96.9	40.3	92.2
T ₇	STD (75%) + FYM + Biofertilizer	51.9	98.1	53.1	98.7	48.7	97.8	41.1	94.0
T ₈	STD (100%)	50.8	96.0	51.8	96.3	47.4	95.1	39.7	90.8
T ₉	STD (100%) + FYM	52.2	98.6	53.3	99.1	49.1	98.5	41.8	95.6
T ₁₀	STD (100%) + FYM + Biofertilizer	52.9	100	53.8	100	49.8	100	43.7	100

4.1.2 Soil moisture content

The soil moisture content at different depths in agrihorticultural systems as well as open control crops are presented in Table 4.2. In the present study mean moisture content was found highest with STD (100%) + FYM + biofertilizer i.e 10.99% at 0-15 cm depth and 12.20% at 15-30 cm depth and lowest moisture content was with control. The soil moisture content also found to increase from July to August and decline slowly from September onwards and minimum soil moisture content was recorded in November in all agrihorticultural systems. There was also higher moisture in lower depth compared to surface soil layer in all the systems during entire crop growth period.

Table 4.2 Soil moisture content (%) at different depth (cm) in agrihorticultural system

Treatments		July		Aug		Sep		Oct		Nov		Mean	
		0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
T ₁	Control (No Fertilizer)	10.11	11.47	11.09	12.14	10.77	11.51	7.04	8.14	5.68	6.77	8.94	10.00
T ₂	STD (50%)	10.19	11.65	11.17	12.28	10.87	11.88	7.14	8.53	5.83	6.92	9.04	10.25
T ₃	STD (50%) + FYM	10.22	11.88	11.25	12.41	10.91	12.03	7.32	9.13	6.18	7.05	9.18	10.5
T ₄	STD (50%) + FYM + Biofertiliser	10.51	12.05	11.40	12.74	11.15	12.31	8.78	9.91	6.89	7.82	9.75	10.96
T ₅	STD (75%)	10.38	11.87	11.32	12.58	11.08	12.19	7.75	9.75	6.61	7.65	9.43	10.80
T ₆	STD (75%) + FYM	11.03	12.53	11.66	13.01	11.42	12.73	9.17	10.26	7.15	8.19	10.09	11.34
T ₇	STD (75%) + FYM + Biofertiliser	11.15	12.79	11.91	13.29	11.52	12.85	9.58	10.94	7.31	8.42	10.29	11.65
T ₈	STD (100%)	10.65	12.41	11.54	12.88	11.24	12.52	9.03	10.15	7.08	8.06	9.90	11.20
T ₉	STD (100%) + FYM	11.68	13.18	12.25	13.45	12.09	13.25	9.75	11.04	7.58	8.65	10.67	11.91
T ₁₀	STD (100%) + FYM + Biofertiliser	11.94	13.33	12.88	13.77	12.23	13.51	10.22	11.48	7.61	8.94	10.99	12.20
Rainfall (mm)		222.2		247.8		238.0		132.8		20.3			

4.2 Soil fertility changes under guava based agrihorticultural system

The soil fertility status has improved in all the treatments compared to their initial values under agrihorticultural system (Table 4.3 and Fig.4.1).

4.2.1 pH

In guava based agrihorticultural system, the pH value ranged from 4.76 to 4.95. The maximum pH of 4.95 was found under STD(100%) + FYM treatment and the minimum pH of 4.76 was found under control treatment.

4.2.2 Organic carbon

In guava based agrihorticultural system, the organic carbon value ranged from 6.1 to 7.8 g kg⁻¹. The maximum organic carbon content of 7.8 g kg⁻¹ was found under STD (100%) + FYM and STD (100%) + FYM + biofertilizer followed by STD (75%) + FYM (7.5 g kg⁻¹). The minimum organic carbon content of 6.1 g kg⁻¹ was found under control condition.

4.2.3 Available nitrogen

In guava based agrihorticultural system, the available nitrogen content ranged from 188.1 kg ha⁻¹ to 262.8 kg ha⁻¹. The maximum available nitrogen of 262.8 kg ha⁻¹ was found under STD (100%) + FYM + biofertilizer followed by STD(100%) + FYM (257.9 kg ha⁻¹). The minimum available nitrogen content of 188.1 kg ha⁻¹ was found under control condition.

4.2.4 Available phosphorous

In guava based agrihorticultural system, the available phosphorous value ranged from 60.2 kg ha⁻¹ to 75.2 kg ha⁻¹. The maximum available phosphorous of 75.2 kg ha⁻¹ was found under STD (100%) + FYM + biofertilizer followed by STD(100%) + FYM (72.8 kg ha⁻¹). The minimum available nitrogen of 60.2 kg ha⁻¹ was found under control condition.

4.2.5 Available Potassium

In guava based agrihorticultural system, the available potassium content ranged from 120.5 kg ha⁻¹ to 253.8 kg ha⁻¹. The maximum available potassium content of 253.8 kg ha⁻¹ was found under STD (100%) + FYM followed by STD (100%) + FYM + biofertilizer the minimum available potassium of 120.5 kg ha⁻¹ was found under control condition.

Table 4.3 Soil fertility status in guava based agrihorticultural system

Treatments		pH (1:2)	OC (g kg ⁻¹)	Available N (Kg ha ⁻¹)	Available P (Kg ha ⁻¹)	Available K (Kg ha ⁻¹)
T ₁	Control (No Fertilizer)	4.76	6.1	188.1	60.2	120.5
T ₂	STD (50%)	4.83	6.6	223.5	63.9	155.6
T ₃	STD (50%) + FYM	4.93	7.1	230.8	65.1	189.2
T ₄	STD (50%) + FYM + BF	4.91	7.0	238.2	68.5	172.7
T ₅	STD (75%)	4.86	6.9	232.6	65.7	193.8
T ₆	STD (75%) + FYM	4.94	7.5	241.7	69.3	217.5
T ₇	STD (75%) + FYM + BF	4.93	7.2	250.3	71.8	203.1
T ₈	STD (100%)	4.93	7.3	246.1	70.1	225.7
T ₉	STD (100%) + FYM	4.95	7.8	257.9	72.8	253.3
T ₁₀	STD (100%) + FYM + BF	4.93	7.8	262.8	75.2	241.8
Initial soil status		4.53	5.8	179.1	62.3	106.3
SEM		0.011	0.082	1.384	0.703	3.357
CD (0.05)		0.030	0.236	3.974	2.018	9.641
CV %		0.59	3.19	1.62	2.85	4.72

4.3 Growth of fruit trees and intercrops under agrihorticultural system

The growth parameters viz. plant height, DBH of guava and plant height, no. of leaves and rhizome weight of arrowroot were recorded, analysed and presented below.

4.3.1 Plant height and basal diameter of guava trees

Data on height of guava trees during July, 2016 and January, 2017 were recorded, statistically analyzed and presented in Table 4.4. Among the different treatment combinations, the highest plant height was found in STD (100%) + FYM + biofertilizer (5.95m) during January, 2017. The increment in plant height was also found to be highest in case of STD (100%) + FYM + biofertilizer which was 0.78m followed by STD (100%) + FYM and STD (75%) + FYM + biofertilizer.

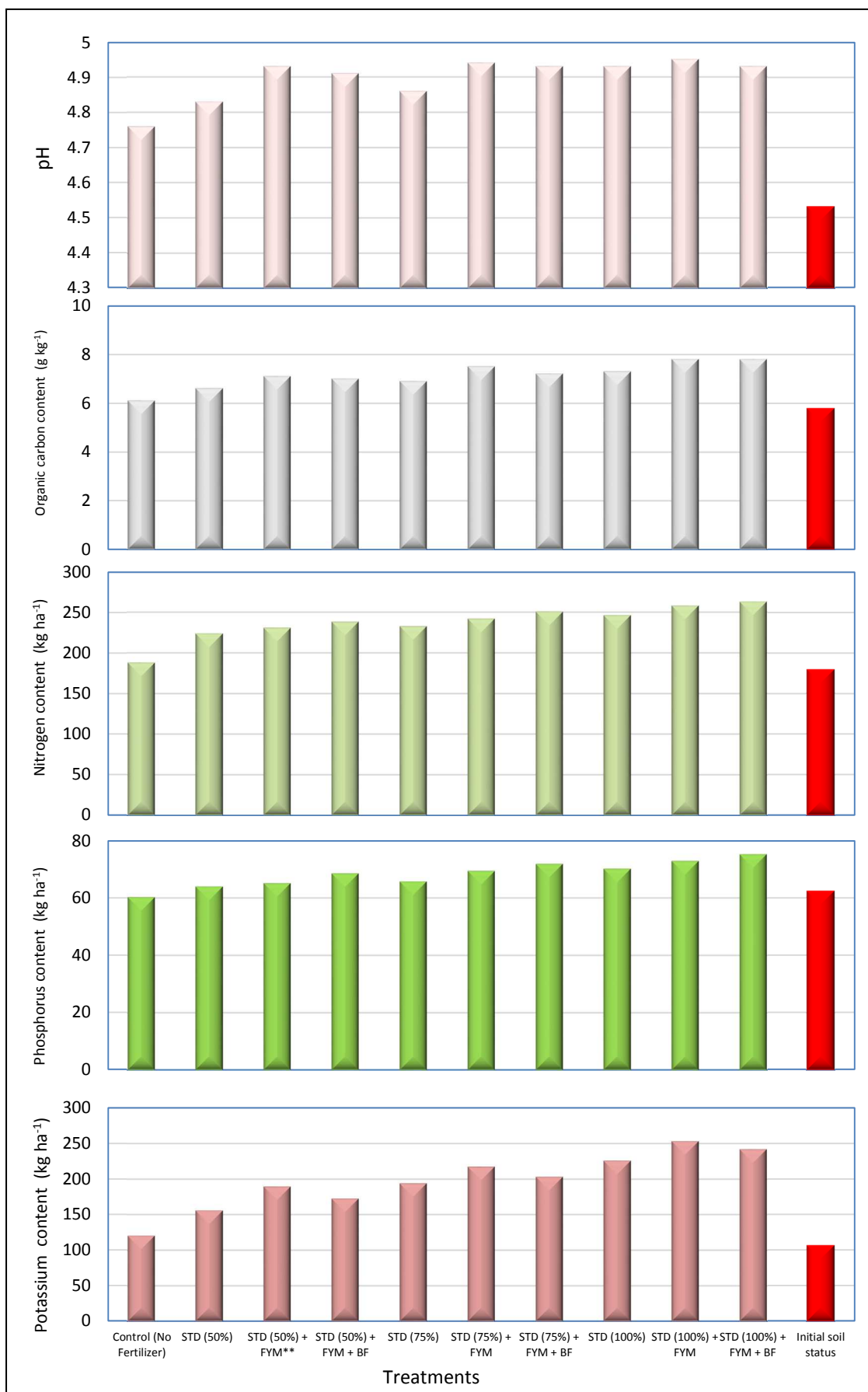


Fig. 4.1 Soil fertility status in guava based agrihorticultural system

Data on basal diameter of guava trees during July, 2016 and January, 2017 were recorded, statistically analyzed and presented in Table 4.4. Among the different treatment combinations, highest basal diameter was found in STD (100%) + FYM + biofertiliser condition (19.64 cm) during January, 2017. Along with the basal diameter, the increment in basal diameter was also found to be highest in case of STD (100%) + FYM + biofertiliser which was 1.26 cm followed by STD (100%) + FYM and STD (75%) + FYM + biofertilizer.

Table 4.4 Plant height and basal diameter of guava trees

Treatments		Plant Height (m)			Basal diameter (cm)		
		Initial (July, 2016)	Final (Jan., 2017)	Increment (m)	Initial (July, 2016)	Final (Jan., 2017)	Increment (cm)
T ₁	Control (No Fertilizer)	4.45	4.61	0.16	15.76	15.82	0.06
T ₂	STD* (50%)	4.53	4.72	0.19	16.38	16.52	0.14
T ₃	STD (50%) + FYM	4.71	5.03	0.32	16.46	16.7	0.24
T ₄	STD (50%) + FYM + Biofertilizer	4.81	5.26	0.45	17.02	17.64	0.62
T ₅	STD (75%)	4.73	5.08	0.35	16.52	16.86	0.34
T ₆	STD (75%) + FYM	5.00	5.58	0.58	18.24	19.3	1.06
T ₇	STD (75%) + FYM + Biofertilizer	5.03	5.66	0.63	18.28	19.42	1.14
T ₈	STD (100%)	4.95	5.46	0.51	17.26	17.96	0.70
T ₉	STD (100%) + FYM	5.08	5.82	0.74	18.34	19.54	1.20
T ₁₀	STD (100%) + FYM + Biofertilizer	5.17	5.95	0.78	18.38	19.64	1.26
SEM		0.045	0.043		0.076	0.084	
CD (0.05)		0.130	0.124		0.22	0.244	
CV%		2.58	2.25		2.46	2.62	

4.3.2 Plant height, no. of leaves and rhizome weight of arrowroot intercrop

The growth of arrowroot intercrop varied among different treatments under agrihorticultural systems in this study. The maximum plant height (123.3cm), no. of leaves (69.1) and rhizome weight (98 g) per culm was recorded with STD (100%) + FYM + biofertilizer followed by STD (100%) + FYM (Table 4.5).

Table 4.5 Plant height, no. of leaves and rhizome weight of arrowroot intercrop

Treatments		Height (cm)	No. of leaves	Rhizome wt. (g) per culm
T ₁	Control (No Fertilizer)	101.8	42.4	46.1
T ₂	STD (50%)	107.7	44.6	64.1
T ₃	STD (50%) + FYM	109.2	50.6	69.6
T ₄	STD (50%) + FYM + Biofertilizer	113.6	54.3	81.9
T ₅	STD (75%)	110.9	52.5	72.5
T ₆	STD (75%) + FYM	120.6	56.3	87.3
T ₇	STD (75%) + FYM + Biofertilizer	120.9	58.5	92.9
T ₈	STD (100%)	115.2	55.2	83.2
T ₉	STD (100%) + FYM	121.4	63.2	95.1
T ₁₀	STD (100%) + FYM + Biofertilizer	123.3	69.1	98.0
SEM		3.114	1.94	0.574
CD(0.05)		8.94	5.57	1.647
CV%		7.54	9.84	2.01

4.4 Yield and Economics of the agrihorticultural system

4.4.1 Guava yield

The guava fruit yield from guava based agrihorticultural system with STD(100%) + FYM + Biofertilizer recorded 2788 kg ha⁻¹, which was significantly higher than all other treatments. The highest yield of 2788 kg ha⁻¹ was found under STD(100%) + FYM + biofertilizer and the lowest yield of 1708 kg ha⁻¹ was found under control condition without application of any fertilizer (Table 4.6 and Fig.4.2).

4.4.2 Arrowroot yield

The arrowroot yield from guava based agrihorticultural system with STD(100%) + FYM + biofertilizer recorded 6534 kg ha⁻¹, which was significantly higher than all other treatments. The maximum yield of 6534 kg ha⁻¹ was found under STD(100%) + FYM + biofertilizer and the minimum yield of 3075 kg ha⁻¹ was obtained from control condition without application of any fertilizer (Table 4.6 and Fig. 4.7).



Fig. 4.2 Control plot (no fertilizer)



Fig. 4.3 Guava-arrowroot based agrihorticultural system STD (75 %) + FYM + BF



Fig. 4.4 Guava-arrowroot based agrihorticultural system STD (100 %) + FYM



Fig. 4.5 Guava-arrowroot based agrihorticultural system STD (100 %) + FYM + BF



Fig. 4.6. Harvesting of fresh arrowroot

4.4.3 Gross Return

In guava based agrihorticultural system, the maximum gross return of Rs 120228 ha⁻¹ was obtained from STD (100%) + FYM + biofertilizer. The minimum gross return of Rs 62520 ha⁻¹ was obtained from control condition.

4.4.4 Net Return

The net return from guava based agrihorticultural system with STD(100%) + FYM + biofertilizer recorded Rs 66330 ha⁻¹, which was significantly higher than all other treatments. The maximum gross return of Rs 66330 ha⁻¹ was obtained from STD(100%) + FYM + Biofertilizer and the minimum net return of Rs 17520 ha⁻¹ was obtained from control condition.

4.4.5 B:C Ratio

In guava based agrihorticultural system, the maximum B:C ratio of 2.23 was found in STD(100%) + FYM + Biofertilizer followed by STD(100%) + FYM value of 2.17 and the minimum B:C ratio of 1.39 was obtained from control condition without application of any fertilizer respectively.

Table 4.6 Economics of the guava+ arrowroot agrihorticultural system

Treatments		Guava yield (kg ha ⁻¹)	Arrowroot Yield (kg ha ⁻¹)	Gross return (Rs ha ⁻¹)	Net return (Rs ha ⁻¹)	B:C 01ratio
T ₁	Control (No Fertilizer)	1708	3075	62520	17520	1.39
T ₂	STD (50%)	2051	4274	82053	35253	1.75
T ₃	STD (50%) + FYM	2153	4638	87951	36151	1.70
T ₄	STD (50%) + FYM + BF	2249	5457	99219	47119	1.90
T ₅	STD (75%)	2169	4835	90555	42855	1.89
T ₆	STD (75%) + FYM	2367	5822	105369	52669	2.0
T ₇	STD (75%) + FYM + BF	2555	6196	112677	59677	2.13
T ₈	STD (100%)	2316	5548	101316	52718	2.08
T ₉	STD (100%) + FYM	2692	6340	116460	62862	2.17
T ₁₀	STD (100%) + FYM + BF	2788	6534	120228	66330	2.23
SE(m) ±		14.631	37.725		530.14	
CD(0.05)		42.019	108.34		1522.48	
CV%		1.76	1.98		3.11	

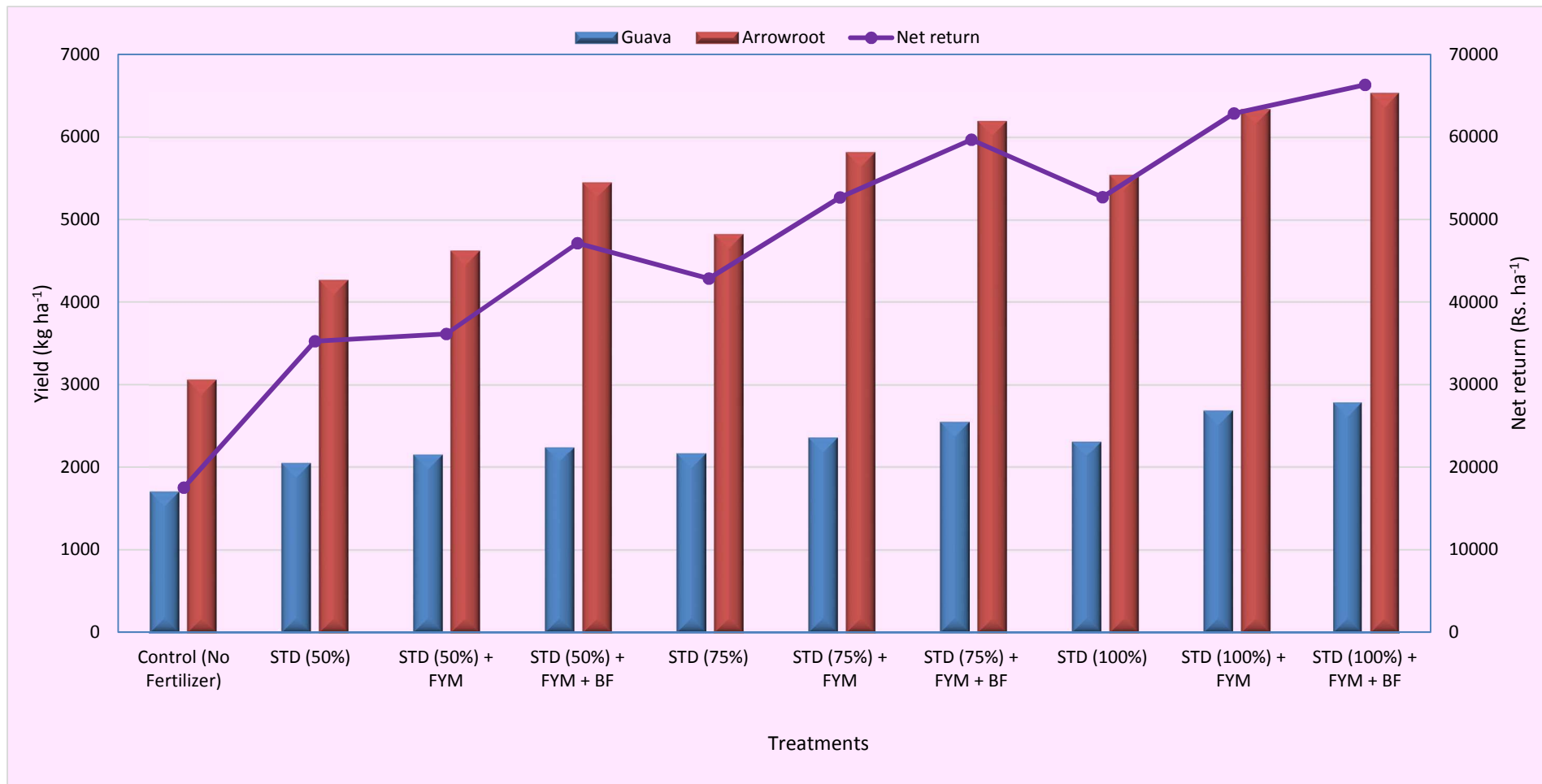


Fig. 4.7 Yield and economics of the guava+ arrowroot agrihorticultural system



DISCUSSION

The present investigation on “**Integrated nutrient management of arrowroot in guava based agroforestry system**” was carried out with objectives of (i) to evaluate the effect of arrowroot on growth of guava tree; (ii) to evaluate the effect of guava tree on the performance of arrowroot; (iii) to study the soil physico-chemical properties of guava based agroforestry system and (iv) to compare the economics of guava based agroforestry system. This chapter deals with possible results and reasons with various outcomes of present investigation. The details are discussed under the following headings.

5.1 Growth factors in agrihorticultural system

5.2 Soil fertility changes under guava based agrihorticultural system

5.3 Growth of fruit trees and intercrops under agrihorticultural system

5.4 Economics of the agrihorticultural system

5.1 Growth factors in agrihorticultural system

5.1.1 Chlorophyll content of arrowroot leaf

Among the treatments, the chlorophyll content of arrowroot leaf was observed maximum with STD (%) + FYM + biofertilizer followed by STD (100%) + FYM and STD (75%) + FYM + biofertilizer during the entire growth period. The chlorophyll content was higher in September and decreased thereafter and minimum chlorophyll content was observed in November irrespective of the treatments. During monsoon period the chlorophyll content was increasing due to moisture availability but after monsoon period it was decreasing due to loss of moisture content of the soil. The maximum content of chlorophyll a and total chlorophyll were higher (1.298 & 1.698 mg/g) in the plants supplied with 75% RDF + 10 kg vermicompost while chlorophyll b was more (0.407 mg/g) in insitu application of vermicompost (at 50 worms/plant) (Athani *et al.*, 2007).

5.1.2 Soil moisture content

In this study higher soil moisture content was observed with STD (100%) + FYM + biofertilizer followed by STD (100%) + FYM. The soil moisture content also

found to increase from July to August and decline slowly from September onwards and minimum soil moisture content was recorded in November in all agrihorticultural systems. There was also higher moisture in lower depth compared to surface soil layer in all the systems during entire crop growth period.

5.2 Soil fertility changes under guava based agrihorticultural system

5.2.1 pH and organic carbon

The pH value of soil differed slightly and ranged from 4.76 to 4.95. There was a little increase in soil pH under agrihorticultural system in comparison to initial status. This is due to addition of organic manures and crop residues from guava and arrowroot system.

There was increase in organic carbon content under agrihorticultural system in comparison to initial status. The value ranged from 6.1 to 7.8 g kg⁻¹. In this study, among the treatments, the combination of STD(100%) + FYM and STD(100%) + FYM + biofertilizer recorded highest organic carbon content. There was not much difference in organic carbon value among the agrihorticultural system but it increases from initial status might be due to addition of litter fall of trees, addition of crop residues from different treatments. This finding can be compared to the study done by, Verma *et al.* (2010) who have revealed that the improvement in soil moisture availability, pH, organic carbon and nutrient status of soil were significant under organic manures. Growth parameters, fruit characteristics and yield were recorded maximum with application of commercial organic manure @ 20 kg tree. Soil moisture, pH, organic carbon and available N, P and K were recorded maximum under the application of commercial organic manure @ 20 kg tree treatment and Farm yard manure @ 100 kg tree.

5.2.2 Available Nitrogen, Phosphorous and Potassium

The available micronutrient of the soil i.e. nitrogen, phosphorous and potassium content were found to be increased in the soil of agrihorticultural system in comparison to initial status.

The available nitrogen content ranged from 188.1 kg ha⁻¹ to 262.8 kg ha⁻¹. The maximum available nitrogen of 262.8 kg ha⁻¹ was found under STD(100%) + FYM +

biofertilizer followed by STD(100%) + FYM (257.9 kg ha⁻¹). The minimum available nitrogen content of 188.1 kg ha⁻¹ was found under control condition. This might be due to more addition of nitrogen from chemical as well as organic sources.

The value of available phosphorous value ranged from 60.2 kg ha⁻¹ to 75.2 kg ha⁻¹. The maximum available phosphorous of 75.2 kg ha⁻¹ was found under STD (100%) + FYM + biofertilizer followed by STD(100%) + FYM (72.8 kg ha⁻¹). The minimum available phosphorus of 60.2 kg ha⁻¹ was found under control condition. Koen *et al.* (1990) reported that the highest yield was obtained with annual application rates of calcium ammonium nitrate at 800 g/tree, super phosphate at 300 g/tree and KCl at 400 g/tree. Fruit size was little affected by N and K application rates, but higher P rates had an adverse effect in 10-year-old guava.

The available potassium content under agrihorticultural system ranged from 120.5 kg ha⁻¹ to 253.8 kg ha⁻¹. The maximum available potassium content of 253.8 kg ha⁻¹ was found under STD(100%) + FYM followed by STD(100%) + FYM + biofertilizer and the minimum available potassium of 120.5 kg ha⁻¹ was found under control condition.

5.3 Growth of fruit trees and intercrops under agrihorticultural system

5.3.1 Plant height and basal diameter of guava trees

Among the different treatment combinations, the highest plant height was found in STD (100%) + FYM + biofertilizer followed by STD (100%) + FYM. The increment in plant height was also found to be highest in case of STD (100%) + FYM + biofertilizer followed by STD (100%) + FYM and STD (75%) + FYM + biofertilizer. Khattak *et al.* (2005) reported that 4 kg NPK mixture (10:20:20) per tree gave the maximum plant height (19.26 cm), plant spread (19.22), fruit per tree (369) and yield (33.2 kg/tree) and the lowest fruit drop (52.6) in guava.

The highest basal diameter of guava trees was found in STD (100%) + FYM + biofertilizer condition followed by STD (100%) + FYM. The increment in basal diameter was also found to be highest in case of STD (100%) + FYM + biofertilizer followed by STD (100%) + FYM and STD (75%) + FYM + biofertilizer. Kumar *et al.* (2009) studied yield and quality of guava cv. Allahabad

Safeda in which the maximum plant height was recorded under 900 g nitrogen/tree, but it was at par with 600 g nitrogen/tree. The maximum stem diameter, canopy spread, fruit yield and TSS were recorded under 900 g potassium/tree/year, which was at par with 600 g potassium/tree.

5.3.2 Plant height, number of leaves and rhizome weight of arrowroot intercrop

The growth of arrowroot intercrop varied among different treatments under agrihorticultural systems in this study. The maximum plant height, number of leaves and rhizome weight per culm was recorded with STD (100%) + FYM + biofertilizer followed by STD (100%) + FYM. Sharma and Sharma (1992) reported that the highest number of leaves/shoot (10.01), terminal shoot length (14.76 cm), fruit set (62.0%), fruit retention (30.50%) and fruit yield (28.36 kg/tree) were obtained with 3% N, 1% P and 1% K treatment combination. All treatments resulted in increased growth and yield when compared with the control in 5-year-old guava trees.

5.4 Yield and Economics of the agrihorticultural system

Guava yield was comparatively less than arrowroot yield. Among the agrihorticultural system, the highest guava and arrowroot yield was found under STD(100%) + FYM + biofertilizer. The soil being poor in nutrient status the performance of STD(100%) + FYM + biofertilizer was relatively better compared to other treatments. Economics of all the agrihorticultural system and control treatment without fertilizer were differed due to their variation in production. Among the guava + arrowroot agrihorticultural system, STD(100%) + FYM + biofertilizer produced the highest net return of Rs 66330 ha⁻¹ with BCR of 2.23. STD(100%) + FYM was the next best treatment, which recorded net return of Rs 62862 ha⁻¹ with BCR of 2.17.

Ke-Lih Shang *et al.* (1997) reported that the fruit yield and weight increased with increasing rates of N, P and K, except when N was applied at a rate higher than 200 g/plant. Fruit yield, weight and quality were best when the trees received N:P₂O₅:K₂O at 200:100:400 g/tree in four-year-old guava. Wagh and Mahajan (1987) studied the guava trees received N at 0-900 g, P₂O₅ at 0, 300 g and K₂O at 0, 300 g/tree, and the effects on fruit chemical compositions were assessed. Fruit quality was best when the trees received N: P₂O₅: K₂O at 600:300:300 g/tree. Allolli *et al.* (2011) studied the

effect of organic manures in combination with inorganic fertilizers on the productivity and economic feasibility in sweet potato and found that, among organics, application of FYM @ 10 tones ha⁻¹+ 50:25:50 kg NPK ha⁻¹ recorded significantly higher tuber yield per plot and hectare (24.16 kg and 33.55 tones ha⁻¹, respectively), and was at par with FYM @ 20 tones ha⁻¹. Similarly, Kotur *et al.* (1997) reported that the highest fruit yield was obtained at 583 g N/plant, 271 g P/plant and 399 g K/plant, and at leaf concentrations of 1.89% N, 0.16% P and 2.34% K. The leaf nutrient composition associated with maximum fruit yield was 1.8-2.0% N, 0.12-0.16% P, 1.46-2.08% K, 1.13-1.69 in guava.



SUMMARY AND CONCLUSION

The present investigation entitled “**Integrated nutrient management of arrowroot in guava based agroforestry system**” was carried out at experimental site of All India Co-ordinated Research Project on Agroforestry, Orissa University of Agriculture and Technology, Bhubaneswar during July 2016 to June, 2017. The experiment was laid out as per Randomized Block Design (R.B.D.) consisting of ten treatments with three replications.

The observations were recorded on tree and crop growth chlorophyll content, of arrowroot leaf, physico-chemical parameters of soil e.g. bulk density, pH, organic carbon, available N, available P, available K and economics of agrihorticultural systems were worked out. Salient findings of the investigation are summarized below.

- In guava based agrihorticultural system STD (100%) + FYM had the maximum pH 4.95 and minimum pH was found in control condition (4.76).
- Status of organic carbon in guava based agrihorticultural system was highest 7.8 g kg⁻¹ in STD(100%) + FYM + Biofertilizer as well as with STD (100%) + FYM compared to lowest organic carbon in control (6.01 g kg⁻¹).
- In guava based agrihorticultural system, the highest values of available N and P were noticed with STD(100%) + FYM + biofertilizer i.e 262.8 kg ha⁻¹ and 75.2 kg ha⁻¹ where as the lowest was in control condition i.e 188.1 kg ha⁻¹ and 60.2 kg ha⁻¹ respectively.
- Available K content was maximum in STD (100%) + FYM (253.3 kg/ha) followed by STD(100%) + FYM + biofertilizer.
- In guava based agrihorticultural system, the chlorophyll content was observed maximum with STD(100%) + FYM + Biofertilizer followed by followed by STD (100%) + FYM and STD (75%) + FYM + biofertilizer and minimum in control.

- In guava based agrihorticultural system, the highest guava yield, arrowroot yield, gross return, net return and B:C ratio were found in STD(100%) + FYM + Biofertilizer i.e 2788 kg ha⁻¹, 6534 kg ha⁻¹, 120228 Rs ha⁻¹, 66330 Rs ha⁻¹ and 2.23 respectively.
- In guava based agrihorticultural system, the highest plant height and basal diameter of guava tree were found to be highest in case of STD (100%) + FYM + biofertilizer which was followed by STD (100%) + FYM and STD (75%) + FYM + biofertilizer.
- In guava based agrihorticultural system, the maximum plant height (123.3 cm), no. of leaves (69.1) and rhizome weight (98 g) per culm of arrowroot intercrop was recorded with STD (100%) + FYM + biofertilizer followed by STD (100 %) + FYM.

CONCLUSION

Integrated nutrient management studies in guava based agrihorticultural system resulted higher available N, P, K, pH and Organic carbon compared to their initial values.

At the end of cropping season, the pH and Organic carbon were ranged from 4.76 to 4.956.1 to 7.8 g kg⁻¹ respectively. The available N, P and K were ranged from 188.1 to 262.8 kg ha⁻¹, 60.2 to 75.2 kg ha⁻¹, 120.5 to 253.3 kg ha⁻¹, respectively at the end of cropping season.

In guava based agrihorticultural system, the performance of STD(100%) + FYM + biofertilizer in terms of chlorophyll content, soil moisture, available N, P, K, pH and Organic carbon has shown its superiority over all other treatments.

In guava based agrihorticultural system, the performance of STD (100%) + FYM + biofertiliser in terms of plant height and basal diameter of guava tree and plant height, no. of leaves and rhizome weight per culm of arrowroot intercrop shown its superiority over all other treatments

The highest guava fruit 2788 kg ha⁻¹ and arrowroot yield 6534 kg ha⁻¹, net return Rs 66330 ha⁻¹ and BCR of 2.23 was recorded with STD(100%) + FYM + biofertilizer compared to lowest guava yield (1708 kg ha⁻¹) and arrowroot yield (3075 kg ha⁻¹), net return Rs 17520 ha⁻¹ and BCR 1.39 without application of any fertilizer.



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