PERFORMANCE OF PINEAPPLE AND ITS QUALITY AS AFFECTED BY MULTISTORIED AGROFORESTRY PRODUCTION SYSTEM

A Thesis

By

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Examination Roll No. JD 32/02
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NOVEMBER, 2003

DEDICATED
TO THE DEPARTED SOUL
OF MY BELOVED PARENTS

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Abstract

An experiment was conducted at the Germplasm centre, Fruit Tree Improvement Project, Bangladesh Agricultural University (FTIP-BAU-DH), Mymensingh, during the period of May 28, 2002 to August 30, 2003 to determine the production and quality of pineapple (var. Giant Kew) as affected by different multistoried agroforestry systems. Different multilayered agroforestry production systems under study were; sissoo + guava + pineapple, sissoo + lemon + pineapple, mango + guava + pineapple, coconut + guava + pineapple, coconut + lemon + pineapple and a control pineapple plot. Different multistoried agroforestry systems under this study had showed significant influence on yield, yield attributing and quality parameters of pineapple. Considering the effect of shade on yield without crown (27.08 t/ha) different multistoried tree combinations showed statistically similar trend, but when total yield compared with control plot, it showed significant difference. The highest fruit set (82.23%), individual fruit weight (0.96 Kg), fruit size (42.28 cm), L/B ratio (1.31), pulp of fruit (0.46 kg), pulp-peel ratio (2.35) and edible portion (70-05%) were obtained when pineapple grown under sissoo + lemon based agroforestry system where light intensity was 22.99% i.e., under partial shade. An increase in peel of fruit (0.22 kg), length / breadth ratio (1.26), total yield with crown (38.44 t/ha), moisture content (81.05%), total titratable acidity (0.59%) and decrease in total sugar (9.53%), edible portion (65.51%) pulp-peel ratio (1.96) were observed, when pineapple grown under mango + guava based agroforestry system with 13. 45% noon time light intensity i.e., in full shady place. Under control condition (86.30% light intensity) fruit size (35.38 cm), fruit weight (0.77kg), pulp of fruit (0.36 kg), total yield with (32.19 t/ha) and without crown (23.44 t/ha), length of fruit (24.38 cm), edible portion (64.86%) were decreased with increase of light intensity and increase in TSS / acidity ratio (38.79) and p^H (5.16).

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CHAPTER I

INTRODUCTION

INTRODUCTION

The forestry situation in Bangladesh reveals a dismal picture. Bangladesh has about 1.6 million hectares i.e., 13.60% (BBS, 2000) of forest land but the effective tree covered area is estimated at around 5.4%. This remaining forest is also shrinking gradually due to encroachment for human habitation and agricultural expansion. This has made the country as a whole ecologically critical. Such a precarious tree cover situation is exerting serious repercussions in the biodiversity of the region. Moreover, due to widening the gap between demand and supply of fuel wood (310 m and 125 m cft) and timber (115 m and 44 m cft) respectively people used to burn cow dung and agricultural residues as domestic cooking resulting the reduction in soil fertility which are the traditional sources of farm manure. A country needs 25% of forest land of its total area for ecological stability and sustainability. So, the effective area of forest (5.4%) in Bangladesh is neither in a position to fulfill the requirements of the peoples demand for fuel and timber nor to stabilize the climatic condition. Moreover, the country is loosing 8,000 ha of forest land per year.

On the other hand, in Bangladesh the need to maintain balance between population and food nutrition can hardly be emphasized. The country has only 8.16 million hectares of arable land to feed more than 140 million people. The population has doubled in the last 30 years and 806 persons per square kilometer at present. As a result, per capita land availability had declined from 0.19 ha in 1961 to 0.10 ha in 1992 (Haque, 1992) which put heavy pressure on land for human habitation and crop production. This increased pressure on crop land has increased total crop production but has decreased per capita consumption. The country has 9.2 million hectares of cultivable land. Various field crops are grown in the major parts of the cultivated land while fruits and vegetables are grown only in 0.24 and 0.14 million hectares respectively of the total cultivable land (Abedin *et al.*, 1990). Much emphasis was not given in fruit production although it is an important source of nutrition. The Bangladeshis consume only 35 g/day/capita which is far behind the requirements of 85 g. Moreover, most of the people of our country can not afford to buy even average requirements of fruits due to its unavailability and high price. So, the consequence of this event is, therefore, widespread malnutrition throughout the country.

Giving importance on the production and protection, it is urgently necessary to think about a joint production system that can be needed for population-food-nutrition balance, fulfill the demand of fuelwood and timber, and finally conserve the biodiversity. Multistoried production systems may fulfill this balance. Multistoried production system combines several (2-5) vertical strata with high species diversity with pineapple, aroids, turmeric, zinger and some other vegetables such as papaya, banana, guava, lemon along with multipurpose high yielding fruit and timber yielding trees. In Bangladesh, the multistoried production systems have wider implications and potentials, because in the system per unit production is several times higher than agriculture and forestry alone. In fact, it is a highly productive and sustainable system with continuous production round the year. Moreover, this system is one kind of insurance of the farmers against the risk of total crop failure in case of monocropping system.

Pineapple is one of the delicious tropical fruits which are juicy with aromatic flavour. *Ananas* is its generic name but it is also called pineapple due to its conical shape of fruit which is similar to the cone (inflorescence) of pine tree. Pineapple is originated in South America. The Hawaii islands are the best place for its growth in terms of weather and soil conditions. However, it can grow well in tropic and relatively moist areas of Australia, Southern and Northern America and Southeast of Asia. It is an important popular fruit of Bangladesh due to its taste and flavour but its cultivation is confined to limited areas such as Madhupur, Chittagong Hill Tracts and Sylhet. Pineapple occupied an area of about 14657 hectares of land and produced 1, 48,350.00 tones of pineapple per year (BBS, 2000). The yield of pineapple is 9.88 t/ha in Bangladesh which is low as compared to India (15 t/ha) and Hawaii (40 t/ha). The quality of pineapple is not tested duly. Moreover, the production is not properly distributed evenly in the country. Under multistoried tree garden, pineapple is a compatible fruit crop due to its shade tolerant nature and easily grown habit in all homesteads or in any tree garden. Farmers can easily grow this popular fruit and can meet up their nutrient requirements and can earn some additional cash income after their house consumption. On the other hand, during non-bearing season of pineapple, farmers can harvest other component crops like guava, lemon, mango, coconut which are other marketable products. Moreover, an owner can easily meet up their fuelwood, timber and fodder demand from multistoried agroforestry production system. In fact, multistoried agroforestry systems offer several advantages such as soil conservation, nutrient cycling and efficiency, microclimate amelioration, labour efficiency and continuous production. Farmers of Bangladesh used to practice this production system by planting trees in homestead, in and around crop field or by managing naturally grown trees, but not popularize this term, agroforestry with its management practices, productivity and sustainability.

The Fruit Tree Improvement Project, Bangladesh Agricultural University, Mymensingh (FTIP-BAU-DH), recently has trialed pineapple production under different multistoried tree combinations and has found a significant yield as compared to monocropping or other agricultural production system or sole pineapple plantations (Rahim and Haider, 2002). But no trial has been set up for quality assessment and suitable tree-crop combination.

In this view, the present investigation was undertaken is to meet the following objectives:

i) To determine the effect of trees (Sissoo, mango, coconut, guava, lemon) on the yield and quality of pineapple grown under different tree combinations; and

ii) To evaluate the performance of different multistoried cropping systems.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Literature pertinent to the investigation to this study, especially those related to the effect of yield and quality of pineapple is very meager. In Bangladesh, there have not been many studies regarding yield and quality of pineapple with their shade and light effect growing in multistoried cropping system. Some of the relevant informations available in the theses, books, journals, reports and other forms of publications have been presented in this chapter which might contribute to the justification of present study.

2.1 Changes in yield and quality of pineapple

To determine the effect of planting materials on flowering in pineapple var. Giant Kew, Teaotia and Pandey (1966) conducted an experiment in Uttar Pradesh, India, using suckers, crowns and stumps of Giant Kew variety as planting material. They found that there was no difference between slips and suckers for flowering but slips were found more vigorous in growth than suckers. They also observed that slips produced maximum (42.5%) flower during first year followed by suckers (38.75%), whereas suckers gave higher number of flowers in the second year.

Ahmed and Matin (1974) obtained the highest yield in an experiment conducted at Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, by planting crowns of Giant Kew variety of pineapple. They suggested the use of crowns as planting materials.

Chadha *et al.* (1974) investigated the effect of the type and size of Kew pineapple on the yield. They conducted the investigation at Indian Institute of

Horticultural Research, Bangalore, India, and used crown, slips and suckers graded in 5 different sizes as planting materials. The highest yield (71 t/ha) was obtained from the largest suckers (1250 g), however, when yield and quality were considered together, slips having 300-450 g weights yielded 68.39 t/ha were found the best planting material.

In another experiment, Tay and Wee (1976) observed that the highest yield (44.77 t/ha) and quality fruits were obtained from planting larger length of crowns (40 cm) followed by smaller ones (24 cm).

Nandy *et al.* (1982) in a study on standardization of planting materials of pineapple on yield and quality were observed in India. They found that slips are followed by those raised from side suckers gave the best results with regard to yield and quality.

Uddin and Hossain (1988) conducted an experiment to study the effects of different types of planting materials on the growth and yield of pineapple cv. Giant Kew. It was conducted at Fruit Research Station, Jaintapur, Sylhet during December, 1981 to August, 1984. They used three types of planting materials such as crown, slip and stem sucker. They reported that overall performance of crown was superior to slip and stem sucker in respect of fruiting and yield. Fruits produced from crowns were heavier (1.34 kg) as compared to those produced on plants from stem sucker (0.91 kg) and slips (0.79 kg). Plants from crown flowered 77% during first season whereas 24 and 7% plants flowered from stem sucker and slips respectively.

Chadha *et al.* (1970) conducted an experiment in October 1970 taking uniform suckers of Kew pineapple planted in various densities viz., D_1

(43036 plants/ha), D_2 (47849 plants/ha), D_3 (53796 plants/ha), D_4 (57383 plants/ha), D_5 (61480 plants/ha) and D_6 (63758 plants/ha) for evaluation of fruit size and yield. They concluded that the fruit size with or without crown and fruit length and breadth were all the largest in D_2 followed by D_4 except fruit breadth. Differences within treatments were significant in respect of fruit size with and without crown; D_2 yields the largest fruits (2.012 and 1.811 kg respectively). They also observed the highest yield in D_6.

Chan *et al.* (1997) conducted an experiment at MARDI, Malaysia, on the soil treatments (drought, peat and mineral) with six promising hybrids developed from hybridization programme with 2 control varieties. They found that the yields were 50% higher in peat soil than mineral soil. However, fruit quality especially total soluble solid content was lower. A20-3 and D4-37 had high stable yields found in all environments, while A25-34 had moderate yields but high and stable TSS, which makes it suitable as table fruit.

Santana *et al.* (2001) conducted an experiment to determine the effect of row on qualitative and quantitative production of pineapple cv. Smooth Cayenne. They observed that pineapple production was the highest with 20 cm between plant spacing. Average fruit weight, dimensions and quality (sugar, acidity, juice content and sugar/acidity ratio) were not significantly influenced by plant density. Increasing plant density increases yield by 8.27 t/ha while reducing the average fruit weight by 102 g.

A 9 years durable areca nut, pepper, pineapple, banana, turmeric kasturi based High Density Multispecies Cropping System (HDMSCS) was conducted by Ray and Reddy (2001) to observe the net economic return after applying full, two third and one third doses of fertilizer. The major share was derived from the main crop of areca nut (48%) followed by the component crop pepper (43%) while other crops contributed the remaining 8-9%. The pineapple cultivation was found to be uneconomical as a component crop in the areca nut based HDMSCS model.

2.2 Changes in physical characteristics of pineapple

2.2.1 Edible portion of fruit

Rahman *et al.* (1979) observed in an experiment that pineapple fruit (cv. Giant Kew) had 66.68% edible portion.

In an experiment to find out edible and non-edible wastage of some fruits of Bangladesh, Ahmed and Rahman (1974) carried out a work at Dhaka during 1969 and 1970. They found that pineapple fruits contained 67.7% edible portion of their whole weight.

Samson (1986) reported that fresh pineapple contains 60% edible portion. Uddin and Hossain (1988) got 57.88% edible portion in pineapple fruits.

Reinhardt *et al.* (2002) studied principle characteristics and behavior of cv. Perola and cv. Smooth Cayenne. They found that the Perola contained less fibrous flesh and edible central core, lower acidity and higher total soluble solid: titratable acidity ratio than smooth cayenne.

2.2.2 Moisture content in fruit pulp

In an experiment, Rahman *et al.* (1979) found that 83.53% moisture in fresh pineapple fruits. They also mentioned that the moisture content of pineapple decreased slightly with storage time. According to their investigation, the fruits showed a slight increase in moisture towards the end of the storage period.

According to Purseglove (1985) pineapple fruit contained approximately 65% moisture. Salunkhe and Desai (1984) reported 81.02 - 86.2% moisture in pineapple fruits. Samson (1986) stated that fresh pineapple fruits contained 80% to 85% moisture.

2.3 Changes in qualitative characteristics of pineapple

2.3.1 P^H

According to Gowramma *et al.* (1981) pineapple juice has a p^H value of 3.8. Lopez-Lago *et al.* (1997) studied the physico-chemical characteristics of pineapple fruits harvested from Costa Rica and Ivory Coast and observed that the fruits from these two places had P^H of 3.5 and 3.4 respectively. Botrel *et al.* (1993) in an experiment observed that ripe pineapple fruits held at 5^0C had a higher p^H than that at 25^0C.

Singleton and Gortner (1965) found that the P^H of the fruit pulp of developing pineapple (cv. Smooth Cayenne) showed almost a straight-line fall from the early reading (above p^H 5.5) to near p^H 3.3 a week or two before final ripening.

2.3.2 Total soluble solids (TSS)

A chemical analysis was conducted in India with pineapple (cv. Giant Kew) by Morton (1987). He found that the highest quality of pineapple contains 13.8 - 17% total soluble solids at harvest time. Gowramma (1981) obtained 13% TSS in pineapple juice, while Dull (1971) recorded 10.8 to 17.5% TSS in ripe pineapple fruit juice.

In another experiment Sen (1996) found 12.85 and 13.7% TSS in three pineapple cultivars namely, MARDI Hybrid and Singapore Spinach.

Botrel *et al.* (1993) harvested pineapple fruits (cv. Smooth Cayenne) in 6 weight grades (600-899, 900-1099, 1100-1299, 1300-1499, 1500-1799, and 1800- 2300 g). They observed that the largest fruits (1500-1799 and 1800-2300 g) had the highest content of TSS.

Gortner (1965) studied the chemical changes in developing pineapple fruits. He concluded that TSS content increased steadily to ripe fruit level of about 16%. The summer fruit showing higher TSS levels than winter.

2.3.3 Ascorbic acid content in fruit pulp

Samson (1986) reported that ascorbic acid content of pineapple varies from 8-30 mg/100 g edible portion. Morton (1987) also found that 27.2-165.2 mg ascorbic acid in each 100 g edible portion of pineapple fruits.

Freshly harvested pineapple contains 2.9- 165.2 mg of ascorbic acid per 100 g juice of fruits of different varieties. It has been found 6.1-10.2 mg in the juice of Giant Kew, 14.0-16.6 mg in Kew and 19.3-24.8 mg in a local Mauritius type (Hayes, 1966).

Kermasha *et al.* (1987) studied the changes in ascorbic acid content of pineapple fruits after 65 days (premature), 100 days (early mature) and 150 days (late mature) from flowering. The fruits were chemically analyzed and it was observed that the ascorbic acid content from 20.4 - 11.1 mg/ 100 g edible fruit during development.

Ascorbic acid in 11 exotic fruits including pineapple was estimated at two different stages of ripening; immediately after purchasing from local fresh fruit market and after a 1 week period of artificial ripening. Results showed that the fruit contained 20 to 90 mg ascorbic acid/100 g fruit pulp. Moreover, a remarkable loss in ascorbic acid content (30-40 mg/100 g fruit pulp) was observed after 1-week period of artificial ripening (Vinci *et al.*, 1995).

2.3.4 Total titratable acidity

Gowramma *et al.* (1981) reported that pineapple juice contain 0.8% acidity (as citric acid). Dull (1971) noticed 0.6 to 1.62 % total titratable acidity in pineapple. Total titratable acidity in pineapple juice was recorded by Purseglove (1985) to be as 0.6%.

Leverington (1970) reported that the average acidity based on factory fruit varies from 1.0% in winter to 0.5% in summer. According to the work of Singleton and Gortner (1985) which has been confirmed by American Food Preservation Research Laboratory, the acidity rises significantly as the fruit ripens, and about 10 days after a peak is reached, the fruit is at optimum ripeness based on consumer acceptability. The acidity falls away sharply after the peak.

Studies on physico-chemical changes in pineapple fruit (cv. Kew) during growth and development revealed that total titratable acidity (0.77%) increased with maturity (Chadha *et al.*, 1972).

2.3.5 Sugar content in fruit pulp

Purseglove (1985) mentioned that the edible portion of fresh pineapple contain 14% sugar. According to Dull (1971) ripe pineapple pulp contained 5.9-12.0% sucrose, 1.0-3.2% fructose and 0.6-2.3% glucose. Gowramma *et al.* (1981) reported 11% reducing sugar in pineapple fruit.

Kermasha *et al.* (1987) carried out an experiment to study the chemical composition of the Kew pineapple harvested after 65 days (premature), 100 days (early mature) and 150 days (late mature) from flowering and chemically analyzed them for sugars. They found 5.0% (premature), 2.4 %(early mature), and 1.2 %(late mature) sugar on fresh weight basis.

Developing pineapple fruits (cv. Smooth Cayenne) were chemically analyzed by Singleton and Gortner (1965) at weekly intervals, two lots in 1958 and four lots in 1963. They observed that during the first part of developmental period, the sucrose content was below 1% and thus more than 80% of the sugars were present as invert sugar. A marked build-up in sucrose was noticed during the last two months of fruit development and the reducing sugars remained fairly constant except for a small rise during the final week of ripening and thus, the proportion of invert sugars in the total sugar present dropped rapidly to about one-third of the total just before the final week of ripening.

Samson (1986) reported that pineapple fruit contained 12-15% sugars (of which two thirds were in the form of sucrose and the rest in glucose and fructose forms). Hayes (1966) quoted analyses of a number of varieties in different countries, showing the sugar content of pineapple fruit juice which varies from about 8-15%. Pineapple fruits (cv. Smooth Cayenne) were harvested after different periods of time in relation to the mode of fruit transportation to the export market (sea or air). Amankwa *et al.* (1995) reported that total sugars in fruit juice increased gradually with time.

2.3.6 TSS/acidity ratio

According to Leverington (1970), the palatability of fruits depends on TSS/acidity ratio. He observed that the existence of wide variation in TSS/acidity ratio between summer and winter fruits, the average being about 9 in winter and 28 in summer. The summer fruit is, therefore, much sweeter than the winter fruit, and is consequently much more attractive.

Chadha *et al.* (1972) observed that very young pineapple had a high TSS/acidity ratio and with advancement in maturity, TSS/ acidity ratio decreased. A steady increase in TSS/ acidity ratio was observed as fruit was attaining the full-ripe condition.

In an another experiment, Chadha *et al.* (1972) studied physico-chemical changes in pineapple fruit (cv. Kew) during growth and development and noticed that TSS/acidity ratio (21.2) in fruit decreased at the mature stage.

In a similar experiment, Singleton and Gortner (1965) observed that young fruit contain very low sugar content and, however, a still lower content of organic acids in these fruits led to a high TSS/ acidity ratio of the fruit shortly after flowering had ceased. The ratio fell very sharply and reached a minimum approximately two weeks before normal field ripeness. Only then the TSS/acidity ratio begins to rise, although but moderately.

2.4 Light as a factor of multistoried agroforestry production system

Solar radiation is very important resource in multistoried production system because it is the energy source for photosynthesis and transpiration, hence growth and development of plants. But excessive density as well as excessive exposure or drastic reduction of solar energy may depress economic yield.

In any agroforestry system, trees grown in close proximity to crop, often much more scope for useful management of light interception and distribution than do monoculture. Jackson (1987) stated that the potential benefits of combining field crops with trees are so obvious from consideration of waste of light resources experienced in orchard and tree-crop combination.

Trees in crop land bring about microclimatic changes under their canopies by reducing soil and air temperature, irradiance and wind speed. These changes will have direct influence on soil water evaporation and humidity which intern may significantly affect crop growth, depending on the climate in the SAT (Semi Arid Tropics). *Adansonia digitata* and *Acacia tortilis* trees reduced soil temperature under their crown by 6^0C at 5 and 10 cm depth, compared with open areas (Uddin, 1999).

Okigbo (1980) identified more efficient use of light resources by plants of different heights and canopy structures as one of the advantages to be gained by growing crops in mixed stands. Wassman (1990) observed an experiment of pineapple production in Queensland is situated at subtropical latitudes. He found that seasonal variations in sunlight and temperature are the main climatic factors affecting fruit quality, harvesting time and plant growth. Fruit quality is optimal during the summer and acidity is low, while these trends are reversed in winter.

Nair (1993) stated that multispecies tree gardens characterized by a large variety of multipurpose plants in various vegetation layers, which provides for effective utilization of environmental factors like water, nutrients and sunlight. He also stated that shade lowers ground surface temperature which may reduce the rate of loss of soil organic matter by oxidation.

Acording to Ong *et al*. (1991), shading by trees is responsible for poor yields of associated crops. Limiting light is obviously the most important factor that causes poor performance of under storey crops.

Reifsnyder (1987) stated that the major constraint of microclimate and growth in agroforestry practice is solar radiation. Interaction among the trees and solar geometry produces the particular solar climate of a tree/crop system. These interception of radiation of tree stands of various densities, effect of canopy structure, effect of shading, effect of latitude, and time of years on solar paths, shade from single crowns and spectral quality of sunlight under partial shade.

2.5 Effect of light intensity on pineapple production

Under systematic investigation of the study of multistoried/multilayered cropping system in Fruit Tree Improvement Project, at Bangladesh Agricultural University, Mymensingh (FTIP-BAU-DH), Rahim (2002) found that natural resources could be used properly in this system. Trees planted at different layers absorbed sunlight from different strata.

Collins (1960) stated that the amount of sunshine which falls on the growing plants is an important climatic factor in both plant growth and fruit quality. A very low percentage of possible sunshine, such as results of high percentage of cloudy days, retards growth and results in small fruits of poor quality, particularly lacking in sugars. On the other hand, too much sunshine may cause sun burning of nearly mature fruits of pineapple.

An experiment was conducted at Madhupur Tract under Gazipur District in Bangladesh to estimate the effect of light intensity on production of pineapple. In this experiment Hossain (1999) observed that the yield of pineapple would be maximized (64 t/ha) at a mean season light intensity of 610 $\mu mol/m^2/s$ or 55% of open light condition. Such a light condition occurs in jackfruit orchards with an estimated crown cover of $9803/m^2/ha$.

Angles and Mendoza (1988) conducted an experiment on intercropped with banana and pineapple cv. Smooth cayenne and papaya. They observed that intercropping increased papaya fruit size, number and yield/tree from 0.9 kg, 7.1 and 6.6 kg /tree respectively in pure stands to 1.7 kg, 22.1 and 3607 kg/tree respectively.

Sen (1990) observed that both sunshine and total shade are harmful for pineapple. Chadha *et al.* (1974) reported from Bangalore, India, that dense planted pineapple resulted in high yield without affecting the quality or size of fruits. They also stated that besides increased yield, high density planting of pineapple has other advantages. Overlapping of the basal leaves provides shade and reduces evaporation loss as well as weed growth. Aside from crowding of the plants under high plant density, the vigorous growing leaves tends to twist and grow upright which provide the fruits a natural covering to prevent sunscald and result in uniformly coloured and lustrous fruits.

Johnson (1935) mentioned that the optimum temperature range for pineapple production is 15.5^0 to 32.5^0 C. Very low temperature is harmful but mild cool weather in the cool season improves the quality. Both bright sunshine and total shade are harmful. Annual rainfall of 1500 mm is considered optimum for pineapple.

An observation to find out both adequate shade and high quality products from both trees and crops (cocoa, pineapple, pepper, zinger etc.) was carried out by Silva and Dias (1988). They found that high proportion of light which penetrates through the canopy of palms is considered most suitable for various crop combinations in agroforestry system. The highest yield obtained when the palms were spaced at 6m X 6m.

Khaleque and Gold (1993) observed the evolution of an indigenous agroforestry system currently practiced by the Garo Community in Bangladesh. They observed that the Garo agroforestry system incorporates crops (food crops with zinger, turmeric, pineapple) with tree species (primarily *Albizia chinensis*) for shade, weed growth suppression and ecological sustainability. While incorporating agricultural crops and pineapple for economic return. The present system was socially desirable and economically profitable.

Krauss (1949) reported that pineapple in a CAM plant the stomata of pineapple leaves are closed during the days, open in the late afternoon and remain fully open through night which helps rapid absorption of water.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

This study was conducted on the existing multistoried garden in Fruit Tree Improvement Project, Bangladesh Agricultural University (FTIP-BAU-DH), Mymensingh, during January- August, 2003. The location of the site (22.03^{0}N Latitude, 90.26^{0}E Longitude) is shown in the Figure 1.

The experiments were divided into two parts. Firstly, collection of some morphological data on fruit size, shape, weight, diameter, length etc. for yield estimation in the FTIP field laboratory and secondly, chemical analysis of pineapple pulp for quality assessment in the Biochemistry Laboratory of Bangladesh Agricultural University, Mymensingh.

3.1 Description of the study area

3.1.1 Climate

The experimental site is situated under tropical monsoon climate characterized by heavy rainfall during the months from April to September and then scanty rainfall during the rest period of the year. Informations regarding monthly maximum and minimum temperature, rainfall and relative humidity etc. recorded during the period of experiment collected from Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh, is presented in Appendix 1.

3.1.2 Soil

The experiment was laid out in a high land belonging to the AEZ Old Himalayan Flood Plain area (FAO, 1971). The soil texture was sandy loam with a p^H 6.8. The structure of the soil was fine and the organic mater content was 0.83%. This characteristic of the soil was previously tested in the Soil Science Department, BAU, Mymensingh and presented in Appendix II.

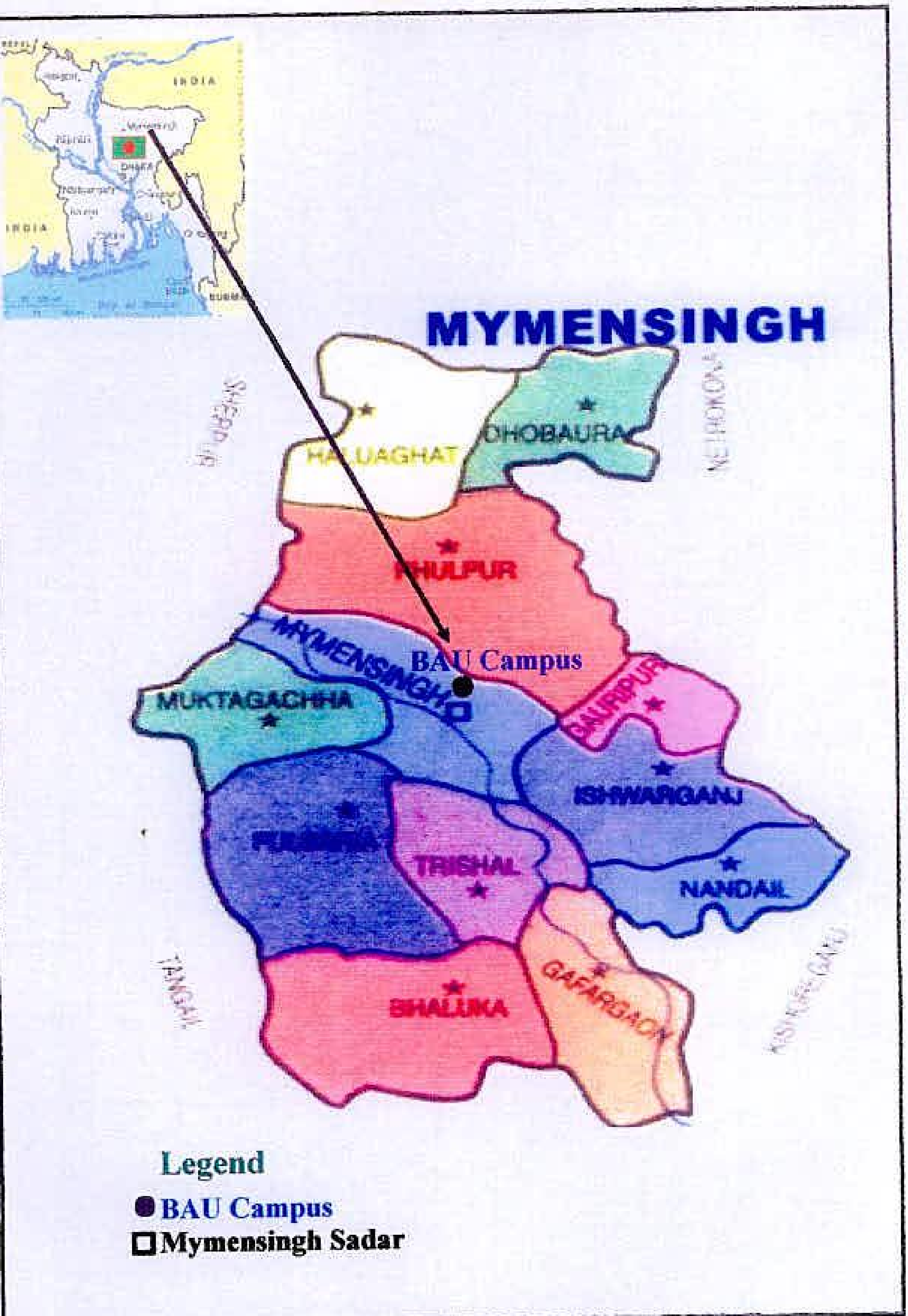

Fig 1. Map of the study area

3.2 Methodology of the study to determine the morphological data and chemical test of pineapple fruit

To estimate necessary data for analyzing production and quality of pineapple, five different multistoried (three layered) agroforestry production systems and a sole pineapple orchard were selected. This multistoried cropping system and sole orchard of pineapple were similar in terms of soil characteristics and management regimes (plant spacing, manuring and weed control etc). The variety was Giant Kew and planting time was May, 2002. No fertilizer, manure and irrigation were applied to the crop. Only weeding was done during March and decrowning and desuckring were done before weeding.

Five temporary plots were set up in each three agroforestry gardens, maintaining tree and row spacing 6 m × 8 m with plot distance of 4 m. This was done with a view that the light intensity would be different in different multistoried systems within an agroforestry garden. Within five plots, pineapple was planted by giving 8 m × 1.5 m spacing. One temporary plot of the same size was also set-up in sole pineapple orchard for compare the yield and quality with pineapple produced in multistoried production system. The sole pineapple and pineapple planted in the agroforestry gardens were replicated four times.

The morphological data of pineapple were measured by measuring tape, balance, knife etc. and the chemical test was done in laboratory using appropriate chemicals. The light intensity or the top of the pineapple grown under multistoried agroforestry production system and under open condition was measured with lux meter around noon time. Three readings were taken from each plot and values were averaged. The mean season light intensity in each experimental plots was derived by averaging the readings of the different sampling dates.

3.3 Design and lay out of the experiment

The experiment was laid out following a randomized complete block design with single factorial arrangement of multistoried production system and six different types of plots. Four replications were used in this study. So, in total 24 (6X4) plots were set up. Each plot size was 6 m × 8 m. Distance between two plots was 4 m. The treatments were randomly distributed within the blocks.

T_1R_1	T_1R_2	T_1R_3	T_1R_4
T_2R_1	T_2R_2	T_2R_3	T_2R_4
T_3R_1	T_3R_2	T_3R_3	T_3R_4
T_4R_1	T_4R_2	T_4R_3	T_4R_4
T_5R_1	T_5R_2	T_5R_3	T_5R_4
T_6R_1	T_6R_2	T_6R_3	T_6R_4

Fig 1. Field lay out of the experiment.

3.4 Treatments of the study

There were 6 (six) treatments (T_1 to T_6) in the study.

T_1 comprises the combination of Sissoo+ Guava+ Pineapple based agroforestry production system (Plate 1).

This was a three-layered canopy configuration production system. The ground layer covered by pineapple plant (var. Giant Kew) which was planted on 28 May, 2002. The spacing of pineapple was 40 cm × 60 cm. The second layer had guava plants which were five years old and was in full bearing condition. Spacing between plant and rows of guava was 6 m × 8 m. The upper layer was occupied by sissoo, a good multipurpose and deciduous tree. The sissoo was planted eight years ago and the spacing of plantation was also 6 m × 8 m.

T_2 comprises the combination of Sissoo + Lemon + Pineapple based multistoried agroforestry production system (Plate 2).

This three layered canopy configuration consists of sissoo, lemon and pineapple plant. The pineapple was in ground layer, lemon with in fruiting condition was in middle layer and sissoo occupied the third layer. The spacing between plant and between row and the age of sissoo, lemon and pineapple were the same as said in T_1.

T_3 comprises the combination of Mango + Guava + Pineapple based multistoried agroforestry production system (Plate 3).

In T_3 treatment, mango, guava and pineapple occupied the entire three vertical canopy layers. Here mango occupied the upper third layer and it was planted in 1980. The spacing of mango and guava in terms of between plants and between rows was 6 m × 8 m. The spacing of pineapple was the same as described earlier.

Plate 1. T_1- Sissoo + Guava + Pineapple based agroforestry system

Plate 2. T_2- Sissoo + Lemon + Pineapple based agroforestry system

Plate 3. T_3- Mango + Guava + Pineapple based agroforestry system

Plate 4. T_4- Coconut + Guava + Pineapple based agroforestry system

T_4 comprises the combination of Coconut + Guava + Pineapple based multistoried agroforestry production system (Plate 4).

Under this treatment, a three layered canopy configuration was dominated. The coconut plant was 25 years old and it stands the uppermost layer. The guava was in middle and pineapple was in lower layer. The spacing of coconut and guava was 6 m × 8 m and the spacing of pineapple was 40 cm × 60 cm.

T_5 comprises the combination of Coconut + Lemon + Pineapple based multistoried agroforestry production system (Plate 5).

The compatible admixtures of this production arrange coconut in the upper layer, lemon in the middle layer and pineapple in the lowermost layer. The spacing of coconut, lemon and pineapple was the same as T_4. .

T_6 comprises the control pineapple plot (Plate 6).

The pineapple var. Giant Kew was planted in full sunny place in May, 2001. The spacing between plants and between rows was 40 cm × 60 cm for comparison of light and shade effect with pineapple grown in T_1, T_2, T_3, T_4 and T_5.

3.5 Harvesting

Fruits were harvested during June to July, 2003 at ripening stage. The ripening stage was determining on the basis of orange-yellow colouring of lowermost eyelets and flattening in the center of eyes, when bracts become loose and turned brown in colour. Fruits were harvested by hand picking and carried out in the FTIP Field Laboratory and Biochemistry Laboratory of Bangladesh Agricultural University, Mymensingh, for collection of morphological data and quality analysis recording.

Plate 5. T_5- Coconut + Lemon + Pineapple based agroforestry system

Plate 6. T_6- Pineapple planted in open field (Control)

3.6 Collection and analysis of data

Twenty pineapple plants were selected randomly from each plot to record plant yield and yield attributing parameters. The yield parameters under study were:

Morphological parameters:

i) Per cent of fruit set (%)

ii) Fruit size and shape

iii) Individual fruit weight with and without crown

iv) Pulp to peel ratio

v) Fruit length with and without crown

vi) Fruit diameter

vii) Total yield

Quality parameters:

Four randomly selected pineapples from each plot were taken to estimate the following physico-chemical properties.

i) Vit-C content (%)

ii) Total soluble solids (TSS)

iii) Titratable acidity

vi) Total sugar

v) Reducing sugar

vi) Non- reducing sugar

vii) p^H

i) Fruit set (%)

Per cent of fruit set was recorded by counting, fruiting and non-fruiting pineapple plants by using the following formula:

$$\text{Per cent fruit set (\%)} = \frac{\text{Total pineapple plants - Non - fruiting pineapple plants}}{\text{Total pineapple plants}} \times 100$$

ii) Fruit size and shape

Fruit size and shape were determined by eye estimation in the plots and taking weight of sampled fruits. The size of the fruit was small (<500 g), medium (501 - 700 g) and large (>701 g). The shape of the pineapple was more or less same and it was cylindrical shape in with upper and lower ends slightly tapering.

iii) Weight of fruits

Each sampled fruit was weighted with and without crown by simple balance and recorded in kilogram (Kg).

iv) Length

Length of fruits with and without crown was measured from the base to the "D" leaf and to the apex by measuring tape.

v) Diameter of fruits

The diameter was measured at the middle of the fruit by slide calipers.

vi) Pulp to peel ratio of pineapple fruit

Peeling of each of individual fruits was done by sharp knife. Pulp and peel were separately weighted. Then the ratio was calculated by divided by pulp with peel.

vii) Total yield of fruit (t/ha)

Fruit yield was calculated by converting fruit weight of all twenty pineapple fruits with crown and without crown in tones per hectare.

3.7 Moisture content in fruit pulp

A thin layer of finely divided asbestos (Gooch grade) was placed into a flat bottom crucible. The crucible was dried at 110^0 C for 1 hour. The crucible was then covered, cooled and weighted. Twenty grams of thinly sliced fruit pulp were placed over the asbestos layer and the crucible was weighed very quickly. The crucible was then placed in an oven and the drying was done at 80^0C for 72 hours until a constant weight was attained. Again the crucible was weighed. The percentage of moisture of fruit was calculated by using the following formula:

$$\text{Per cent moisture of fruit pulp (\%)} = \frac{\text{Initial weight of fruit pulp - Final weight of fruit pulp}}{\text{Initial weight of fruit pulp}} \times 100$$

Four samples were taken from each plot and per cent of moisture was calculated by averaging them after oven dry.

3.8 Titratable acidity in fruit pulp

Ten grams pineapple fruit pulp were taken in a blender machine and homogenized with distilled water. The blended material was then filtered and transferred to a 250 ml volumetric flask and volume was made up to the mark with distilled water. Ten ml of pulp solution was taken in a conical flask and titrated with 0.1 N NaOH just below the end point using phenolphthalein indicator. The titration was done for three times.

Percentage of titratable acidity was calculated using the following formula:

$$\text{Total titratable acidity (\%)} = \frac{T \times N \times V1 \times E}{V2 \times W \times 1000} \times 100$$

Where,

T = Titre

N = Normality of NaOH

V_1 = Volume made up

E = Equivalent weight of acid

V_2 = Volume of sample taken for estimation, and

W = Weight of sample taken

Four samples were taken from each plot and per cent of titratible acidity was calculated by averaging them after oven dry.

3.9 p^H in fruit juice

One gram of fruit pulp was homogenized in 100 ml of distilled and ionized water. The p^H of fruit juice was recorded by using an electric p^H meter. The p^H meter was standardized with the help of a buffer solution.

3.10 Sugars in fruit pulp

Sugar content in fruit pulp was estimated following procedures described below:

3.10.1 Standardization of Fehling's solution

Fifty milliliters of both Fehling's solution A and Fehling's solution B were mixed together in a beaker. Ten milliliters of mixed solution were pipetted into a 250 ml conical flask and 25 ml distilled water was added to it. Standard sugar solution was taken in a burette. The conical flask containing mixed solution was heated on a hot plate. When the solution began to boil, three drops of methyleene blue indicator solution was added to it without removing the flask from the hot plate. Mixed solution was titrated by standard sugar solution. The end point was indicated by decolourization of the indicator. Fehling's factor was calculated by using the following formula:

$$\text{Fehling's factor (g of invert sugar)} = \frac{\text{Titer } 2.5}{1000}$$

3.10.2 Preparation of sample

Twenty grams of fresh fruit pulp were taken in a blender machine and homogenized with distilled water. Then the blended material was transferred to a 250 ml volumetric flask. The volume was made up to the mark with distilled water. The pulp solution was filtered. Hundred milliliter filtrate was taken in a 250 ml volumetric flask. Five milliliters of 45% neutral lead acetate solution were added to it and then shaken and waited for 10 minutes. Five milliliters of 25% potassium oxalate solution were further added to the flask and the volume was made up to the mark with distilled water and filtrate.

3.10.3 Titration of reducing sugar

Ten milliliters of mixed Fehling's solution were taken in a 250 ml conical flask and 50 ml distilled water was added to it. Purified pulp solution (filtrate) was taken in a burette. Conical flask containing the mixed Fehling's solution was heated on a hot plate. Methylene blue indicator (3 – 5 drops) was added to the flask when boiling started and titrated with solution taken in the burette. The end point was indicated by decolourization of indicator. This was repeated 3 times and reducing sugar was calculated according to the following formula:

$$\text{Reducing sugar (\%)} = \frac{F \times D \times 100}{T \times W \times 1000}$$

Where,

F = Fehling's factor

D = Dilution

T = Titre, and

W = Weight of sample.

3.10.4 Estimation of total sugar

Fifty milliliters of purified solution (filtrate) were taken in a 250 ml conical flask. Five grams citric acid and 50 ml distilled water were added to it. The conical flask containing sugar solution was boiled for inversion of sucrose and finally cooled. Then the solution was transferred to a volumetric flask and neutralized by 1N NaOH using phenolphthalein indicator. The volume was made up to the mark with distilled water. Then the mixed Fehling;s solution was titrated using similar procedure followed as in case of reducing sugar (invert sugar) mentioned earlier. The percentage of total sugar was calculated by using the formula in case of reducing sugar.

3.10.5 Estimation of non-reducing sugar

Non-reducing sugar (%) = % of Total sugar - % Reducing sugar

3.11 Ascorbic acid content in fruit pulp

Ascorbic acid content in fruit pulp estimated by using 2, 6-Dichloropheno-Indolphenol Visual Method as described below:

3.11.1 Standardization of dye solution

Five milliliter standard ascorbic acid solution was taken in a conical flask and 5 ml metaphosphoric acid (HPO_3) was added to it and shaken. A micro burette was filled with dye solution. Then the mixed solution was titrated with dye using phenolphthalein indicator solution to a pink coloured that persisted at least 15 seconds. Dye factor was calculated using following formula:

$$\text{Dye factor} = \frac{0.5}{\text{Titre}}$$

3.11.2 Preparation of sample

Ten gram fresh fruit pulp was taken in a blender machine and homogenized with 3% Metaphosphoric acid, and then blended material was filtered. The filtrate was transferred to a 100 ml volumetric flask and the volume was made up to the mark with 3% meta-phosphoric acid.

3.11.3 Titration of prepared solution

Ten milliliters of metaphosphoric acid extracted sample were taken in an aliquot and titrated with standard dye solution using phenolphthalein indicator to a pink coloured end point that persisted at least 15 seconds. The titration was replicated three times for each fruit.

Ascorbic acid content was calculated by using the following formula:

Ascorbic acid content (mg per 100 g fruit pulp) = $\frac{T \times D \times V1}{V2 \times W} \times 100$

Where,

T = Titer

D = Dye factor

V_1 = Volume made up

V_2 = Volume of extract taken for estimation, and

W = Weight of sample taken for estimation.

3.12 Total soluble solids content in fruit pulp

The total soluble solids (TSS) content in fruit pulp was determined by using an Abbe refractometer by placing a drop of fruit juice on its prism. The percentage of TSS was obtained from direct reading of the refractometer.

3.13 TSS/acidity ratio in fruit pulp

The TSS / acidity ratio of fruit pulp was calculated using the following formula:

$$\text{TSS/acidity ratio of fruit pulp} = \frac{\%\ \text{TSS content of fruit pulp}}{\%\ \text{Acidity in fruit pulp}}$$

3.14 Estimation of the degree of shading on pineapple plants under different multistoried tree combinations

To generate necessary data for estimating light intensity underneath different tree combinations were selected. Light intensity in different layers from six plots was measured in June and July, 2003 at around noon time during data collection period. The light intensity for each layer and for each replication were measured by averaging three different data collected from three different places from each replication. The average light intensity for six different plots was measured to calculate the per cent light intensity under the treatments was computed as follows:

$$\text{Light intensity (\%)} = \frac{I_i}{I_0} \times 100$$

Here,

I_0 = Photosynthetically Active Radiation (PAR), one meter above the ground level

I_i = PAR, under the agroforestry garden, one meter above the ground level.

The crown diameter for each tree in the plots was measured along North-South and East-West axis using a measuring tape. The crown areas of each tree were calculated from the measured crown diameter using the following of an ellipse which is given below:

$$CC = \pi/4 \left(\frac{D_1 + D_2}{2}\right)^2$$

CC = Crown area (cover) of the tree (m^2)

D_1 = Crown diameter along North-South axis (m)

D_2 = Crown diameter along East-West axis (m).

The total crown cover of a plot was calculated by adding the crown areas of all trees in the plot. The crown cover per hectare was derived from the calculated crown cover of the respective plots.

3.15 Statistical analysis

The collected data were statistically analyzed by MSTAT Statistical Package Programme. The means were compared by DMRT (Duncan's Multiple Range Test).

CHAPTER IV

RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSION

Under multistoried agroforestry production system, the results on the effect of different tree combinations on production and quality of pineapple var. Giant Kew have been presented in this chapter. Some of the qualitative and production oriented data have been presented and expressed in tables and others in figures, photographs, graphs for ease of discussion, comparison and understanding. The analytical results are presented and discussed in this chapter under following headings.

4.1 Effect of multistoried agroforestry production systems on fruit weight and fruit size of pineapple

4.1.1 Fruit set (%)

The per cent of fruit set was calculated on the basis of plants fruited at the time of harvesting season. The plants in various treatments significantly differed in respect of fruit set. The highest number of fruit set (82.33%) was found in T_2 followed closely by T_3 and T_6. T_1 has the lowest fruit set (81.42%) in respect of harvested fruit (Table 1). It was observed from the Table 2 that the highest yield (27.08 t/ha) was also recorded from T_2 treatment as it was the highest fruit set.

4.1.2 Weight of individual pineapple fruit with crown

The weight of pineapple fruit with crown was highly influenced by different multistoried tree combinations (Table 1). Considering fruits with crown the individual fruit weight due to different tree combinations was significantly higher in T_2 (0.96 kg) followed by T_3 (0.92 kg). The lowest fruit weight with crown (0.77 kg) was observed when pineapple was grown in T_6 treatment (control).

Table 1. Effect of multistoried tree combinations on fruit weight and fruit size of pineapple

Treatment combinations	Fruit set (%)	Weight of individual fruit (kg)		Fruit size in length (cm)		Diameter (Breadth) of fruit (cm)	L/B ratio
		With crown	Without crown	With crown	Without crown		
T_1	81.42c	0.87c	0.63abc	39.98b	11.30abc	9.15bc	1.24a
T_2	82.33a	0.96a	0.65ab	42.28a	12.25a	9.33b	1.31a
T_3	82.24ab	0.92b	0.65ab	40.03b	11.85ab	9.40ab	1.26a
T_4	81.58bc	0.85d	0.59bc	39.30b	11.13abc	9.18bc	1.20a
T_5	81.58bc	0.84e	0.67a	36.85c	10.93bc	9.63a	1.14a
T_6	82.24ab	0.77f	0.56c	35.38d	10.53c	8.95c	1.38a
CV (%)	0.51	0.77	7.41	1.74	6.38	1.89	13.40

Means in a column having same letter(s) do not differ significantly at 5% level of estimation by DMRT

T_1 = Sissoo + Guava + Pineapple T_4 = Coconut + Guava + Pineapple

T_2 = Sissoo + Lemon + Pineapple T_5 = Coconut + Lemon + Pineapple

T_3 = Mango + Guava + Pineapple T_6 = Control plot (open)

4.1.3 Weight of individual pineapple fruit without crown

Pineapple planted under different multistoried agroforestry production systems significantly influenced by different treatment combinations in respect of individual fruit weight without crown (Table 1). The highest fruit weight (0.67 kg) was observed when pineapple was grown in treatment T_2 followed by T_3 (0.65 kg) and T_4 (0.59 kg). Weight of individual fruit significantly reduced when pineapple was grown in full sunny place (T_6 control). The lowest fruit weight without crown (0.56 kg) was recorded in T_6 (control). The cause of smaller fruit weight without crown (0.56 kg) might be due to the sudden increase of light intensity. Such a trend truely represents the biological realities about the fruit yielding behaviour of pineapple as Sen (1990) said that bright sunshine is harmful for pineapple.

4.1.4 Length of individual pineapple fruit with and without crown

Different treatment combinations had high significant effect on length of pineapple fruit with or without crown. The greater fruit length with (42.28 cm) and without crown (12.25 cm) was observed in pineapple produced in treatment T_2 (Table 1).

The fruit length with crown was statistically similar in other treatments but significantly different. T_6 produced the smallest fruit (35.38 cm) with crown. In case of fruit length without crown T_3 (11.85 cm) was the second highest followed by T_1 (11.30 cm) and T_4 (11.13 cm). T_6 produced the smallest pineapple fruit without crown.

4.1.5 Breadth of the pineapple fruit

There was significant difference in this character in various treatments (Table 1). While pineapple plants in T_5 produced the highest diameter of fruit (9.63 cm) followed by T_3 (9.40 cm), T_6 produced the lowest one (8.95 cm). This difference was significant. T_1 (9.15 cm) and T_4 (9.18 cm) were statistically similar as the fruit breadth concerned.

4.1.6 Length/ breadth ratio of pineapple fruit

Length/breadth ratio of pineapple produced in shade or sunny place in different multistoried tree combinations had no significant effect. The highest length/ breadth ratio (1.38) was observed in pineapple produced in full sun light (T_6, control) whereas, it was minimum (1.14) in T_5 (Table 2). The reason for this insignificant effect may be due to pineapple produced in control plot had least diameter and length, and pineapple produced in moderate shade had the highest length and diameter resulting more or less same ratio. Length/ breadth ratio of pineapple produced in T_2 (1.31), T_3 (1.26) and T_4 (1.20) was statistically similar.

4.2 Effect of multistoried cropping systems on fruit quality and yield of pineapple

4.2.1 Pulp and peel of pineapple fruit

Pulp, the edible portion, of pineapple fruit differed significantly in different multistoried production systems as compared to open (control) place (Table 2). The highest pulp weight (0.46 kg) was recorded in T_2 followed by T_5, T_1 and T_3 treatments while the lowest (0.36 kg) was in T_6. There was no significant difference among the treatments. The peel of pineapple was not significantly affected by multistoried production system. So, it may be said that different multistoried production systems have no significant effect on pulp of fruit as well as peel, but other parameters were affected significantly as compared to pineapple production in control plot (T_6).

4.2.2 Pulp-peel ratio of pineapple fruit

The pulp to peel ratio of pineapple fruit significantly influenced by the effect of different treatment combinations (Table 2). The T_2 treatment produced fruit with higher pulp-peel ratio (2.35) followed by T_1 (2.31) while T_6 produced the smallest pulp peel ratio (1.82). The other treatments i.e., T_3, T_4 and T_5 were statistically similar. The fact of this insignificant result is that pineapple produced in sunny place contains slightly thin peel compared to the pineapple produced in shade with moderately thick one.

4.2.3 Fruit/crown ratio (weight basis)

All the treatments had highly significant effect on the ratio of fruit weight with/without crown. The maximum value of fruit/crown ratio was observed in T_6 (0.45), while T_1 (0.36) was the minimum (Table 2). The values of fruit/crown ratio observed in T_5 (0.43), T_2 (0.42) and T_3 (0.42) were statistically similar but significantly different from T_4 (0.39) and T_1 (0.36). The reason for highest fruit/crown ratio (0.45) may be due to scorch sun light which had hampered the growth and development of weight and length of pineapple fruit and crown. Similarly, shade condition increases the weight and length of pineapple fruit and crown.

Table 2. Effect of multistoried tree combinations on fruit quality and yield of pineapple

Treatment Combinations	Pulp of fruit (kg)	Peel of fruit (kg)	Pulp-peel ratio	Fruit and crown ratio (wt. basis)	Yield (t/ha)	
					Without crown	With crown
T_1	0.42ab	0.19a	2.31a	0.36d	26.35a	36.08b
T_2	0.46a	0.19a	2.35a	0.42b	27.08a	39.17a
T_3	0.44ab	0.22a	1.96b	0.42b	26.67a	38.44a
T_4	0.40bc	0.19a	2.10ab	0.39c	25.52a	35.42bc
T_5	0.45ab	0.22a	1.98b	0.43b	25.21a	34.90c
T_6	0.36c	0.20a	1.82b	0.45a	23.44b	32.19d
CV (%)	8.33	12.19	9.61	4.03	4.41	1.46

Means in a column having same letter(s) do not differ significantly at 5% level of estimation by DMRT

T_1 = Sissoo + Guava + Pineapple

T_2 = Sissoo + Lemon + Pineapple

T_3 = Mango + Guava + Pineapple

T_4 = Coconut + Guava + Pineapple

T_5 = Coconut + Lemon + Pineapple

T_6 = Control plot (open)

4.2.4 Yield of pineapple fruit (t/ha) with and without crown

Significant differences in the estimated yield per hectare were noticed in different treatment combinations (Table 2). T_6 gave significantly inferior yields (23.44 t/ha) in respect of without crown. This is because of individual fruit weight without crown was the lowest (0.56 kg). T_2 (27.08 t/ha) was significantly superior to all other treatment combinations followed by T_3 (26.35 t/ha), T_4 (25.52 t/ha) and T_5 (25.21 t/ha).

In respect of total yield with crown, it was evident from the Table 2 that the highest yield (39.10 t/ha) was obtained from the treatment T_2 and it was highly significant and superior to all other treatments followed by T_3 (38.44 t/ha). On the contrary, the lowest fruit yield with crown (32.19 t/ha) was recorded from the treatment T_6 (control). The cause of the highest and the lowest yield may be due to shade effect increased the crown length and fruit size and light intensity decrease the crown length and fruit size.

Considering with and without crown the highest fruit yield was obtained from treatment T_2 (Sissoo+ Lemon + Pineapple) combination.

4.3 Effect of multistoried tree combinations on physical conditions of pineapple fruit

4.3.1 Length of fruit crown

It was observed from Table 3 that different tree combinations had high significant effect on length of crown. The highest crown length (30.15 cm) was observed in T_1 followed by T_2 (29.01 cm), while it was least in T_6 (24.38 cm). The lowest length of crown observed in T_6 resulted the lowest total yields with crown (32.19 t/ha). So, shade is responsible for higher crown length.

4.3.2 Edible portion of pineapple fruit

Per cent of edible portion of pineapple fruit pulp was highly significant as observed in different multistoried cropping systems (Table 3). The highest per cent of edible portion of pineapple fruit (70.05%) was observed in T_2 followed by T_1 (69.74%). Edible portion was the lowest (64.86%) in T_6. While fresh fruit weight was obtained the highest (0.67 kg) edible portion was lowest in the same treatment. The lowest fresh fruit weight (0.56 kg) of pineapple as observed in T_6 (Table 1) is responsible for the lowest % of edible portion.

4.3.3 Moisture content in pineapple fruit pulp

Per cent moisture content in pineapple fruit pulp under different multistoried agroforestry cropping system was analyzed and presented in Table 3. It was found from the analysis of variance that moisture content significantly influenced by different treatments. The moisture decreased as the light intensity increased. The highest moisture content (81.05%) was observed when pineapple was produced in T_3. The lowest moisture content (77.65%) was observed in pineapple produced in T_6 (Control). The decreased in moisture in control plot (T_6) could be due to full light intensity in ripening season.

4.4 Effect of multistoried tree combinations on biological quality of pineapple fruit

4.4.1 P^H of pineapple fruit juice

The different treatments had significant effect on p^H of pineapple fruit pulp (Table 4). The highest p^H (5.16) was observed in T_6 followed by T_5 (5.06) and T_4 (5.05). The lowest p^H (4.65) was recorded in treatment T_3. The T_1, T_2 and T_3 were statistically similar but significantly different from T_4, T_5 and T_6. It may be concluded from the result that low and high p^H values could be due to shade and light effect and p^H of fruit juice was reverse to that of titratable acidity (Table 4). Similar trend was also recorded by Sigleton and Gortner (1965) and Botrel *et al.* (1993).

Table 3. Effect of multistoried tree combinations on physical conditions of pineapple fruit

Treatment Combinations	Length of crown (cm)	Edible portion (%)	Moisture (%)
T_1	30.15a	69.74a	78.23b
T_2	29.06b	70.05a	78.87b
T_3	28.30bc	65.51cd	81.05a
T_4	27.93c	67.71b	78.52b
T_5	25.73d	66.49c	77.92b
T_6	24.38e	64.86d	77.65b
CV (%)	1.60	1.07	1.77

Means in a column having same letter(s) do not differ significantly at 5% level of estimation by DMRT

T_1 = Sissoo + Guava + Pineapple
T_2 = Sissoo + Lemon + Pineapple
T_3 = Mango + Guava + Pineapple
T_4 = Coconut + Guava + Pineapple
T_5 = Coconut + Lemon + Pineapple
T_6 = Control plot (open)

4.4.2 Total titratable acidity

The quality of pineapple depends on per cent of acidity present in fruit juice. The total titratable acidity influenced significantly by the different treatments. The highest titratable acidity was observed in T_3 (0.59 %) followed by T_1 (0.58 %). The lowest titratable acidity (0.53%) was found in T_6 (control). Estimated titratable acidity found in T_2, T_4 and T_5 was statistically similar. A continuous increase in total titratable acidity was obtained with the increase of shade level.

4.4.3 Sugars in pineapple fruit pulp

4.4.3.1 Reducing sugar content in fruit pulp

Highly significant differences were observed in respect of reducing sugar content in pineapple fruit. There was slow increase in reducing sugar content due to shade but it was decreased in full sunny condition (Table 4). The highest reducing sugar content (6.69%) was observed in T_4 while it was 6.36% in T_5. Reducing sugar content in T_6 (6.21%) and T_2 (6.20%) was statistically similar. The lowest reducing sugar content (5.73%) was noted in T_3. So, it may be concluded that moderate shade (T_4 & T_5) is optimum for higher reducing sugar content.

4.4.3.2 Non-reducing sugar content in pineapple fruit pulp

The highest non-reducing sugar content (5.48%) was observed in T_4 in full ripe pineapple fruits (Table 4). Non-reducing sugar content thereafter decreased as the shade increase followed by decrease of reducing sugar. The lowest non-reducing sugar content (3.80%) was observed in T_3 followed by T_5 (3.99%) and T_6 (4.00%). The non-reducing sugar content was statistically similar in T_1 (4.77%) and T_2 (4.53%).

Table 4. Effect of multistoried tree combinations on biological quality of pineapple fruit

Treatment combinations	pH of fruit juice	Total titratable acidity (%)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)	TSS/ acidity ratio
T_1	4.74d	0.58a	6.04bc	4.77ab	10.81b	32.39c
T_2	4.74b	0.58ab	6.20b	4.54ab	10.74b	36.12ab
T_3	4.65b	0.59a	5.73c	3.80b	9.53c	33.98bc
T_4	5.05a	0.54ab	6.69a	5.48a	12.17a	38.40a
T_5	5.06a	0.57ab	6.36ab	3.99b	10.35bc	37.68a
T_6	5.16a	0.53b	6.21b	4.00b	10.21bc	38.79a
CV (%)	3.87	4.14	4.29	15.50	5.79	4.87

Means in a column having same letter(s) do not differ significantly at 5% level of estimation by DMRT

T_1 = Sissoo + Guava + Pineapple

T_2 = Sissoo + Lemon + Pineapple

T_3 = Mango + Guava + Pineapple

T_4 = Coconut + Guava + Pineapple

T_5 = Coconut + Lemon + Pineapple

T_6 = Control plot (open)

4.4.3.3 Total sugar content in pineapple fruit pulp

Total sugar content in fruit pulp was found to vary significantly in different treatments. The highest total sugar content (12.17%) was observed in T_4 and the lowest one was in T_3 (9.53%). Total sugar content observed in T_1, T_2, T_5 and T_6 was statistically similar (Table 4). So, it was therefore, concluded that total sugar content is the highest when pineapple produced in moderate shade as in T_4, T_1 and T_5.

4.4.4 TSS/acidity ratio in pineapple fruit pulp

For most fruits, a higher TSS/acidity ratio is interpreted as better eating quality (Singleton and Gortner, 1965). According to Rahman *et al.* (1979) the increase in TSS/acidity ratio is associated with the development of taste and flavour in a number of fruits thus making them more palatable and they also considered the TSS/acidity ratio of fruits to be the yard stick of its acceptability.

The present study revealed the highly significant effect of different treatment combinations on TSS/acidity ratio of pineapple fruit. Quality of the fruit as judged by the best TSS/ acidity ratio was the best in T_6 (38.79) followed by T_4 (38.40). Statistically similar result was observed in T_5 (37.68) T_6 and T_4. The lowest TSS/acidity ratio was found in T_1 (32.39). So, it may be concluded from the study that TSS/acidity ratio increases as the shade increase. In case of full sunny place, the reason for increase in TSS/acidity ratio was due to lower acidity.

4.5 Vitamin C content in pineapple fruit pulp

Pineapple fruit produced in different multistoried tree combinations had highly significant effect on Vitamin C content in fruit pulp. It was observed from the experiment (Fig. 2) that the highest Vitamin C (9.42 mg/100 g fruit juice) was found in T_3. After that, Vitamin C content decreased with the increase of light intensity. The lowest Vitamin C content (5.70 mg) was observed in T_6 (control). The Vitamin C content found in T_2 (7.56 mg) and T_5 (7.40 mg) were statistically similar but significantly different from T_1 (8.27 mg). So, it may be concluded that Vitamin C content increased with the increase of shade level.

4.6 Total soluble solids content in pineapple fruit pulp (TSS)

TSS is one of the important qualitative factors for pineapple and also other fruits. High TSS indicates high sweetness. Morton (1987) observed that a pineapple contained 13.8 - 17% TSS, indicates its highest sweetness.

In the present study, the TSS content of fruit juice was found to have high significant effect by different multilayered tree combinations (Fig. 3). T_4 contained the highest TSS (21.23%) followed by T_5 (21.13%). The lowest TSS was observed in T_1 (18.86%). The trend of TSS content in different treatment indicates that TSS content decreases in full sunny and deep shady place (T_1 & T_3).

4.7 Effect of light intensity on yield of pineapple fruit

The light intensity affected the production of pineapple (ground layer) in different multistoried tree combinations (Fig 4). Light intensity intercepted by three layered multistoried production system of the present study was presented in Appendix III.

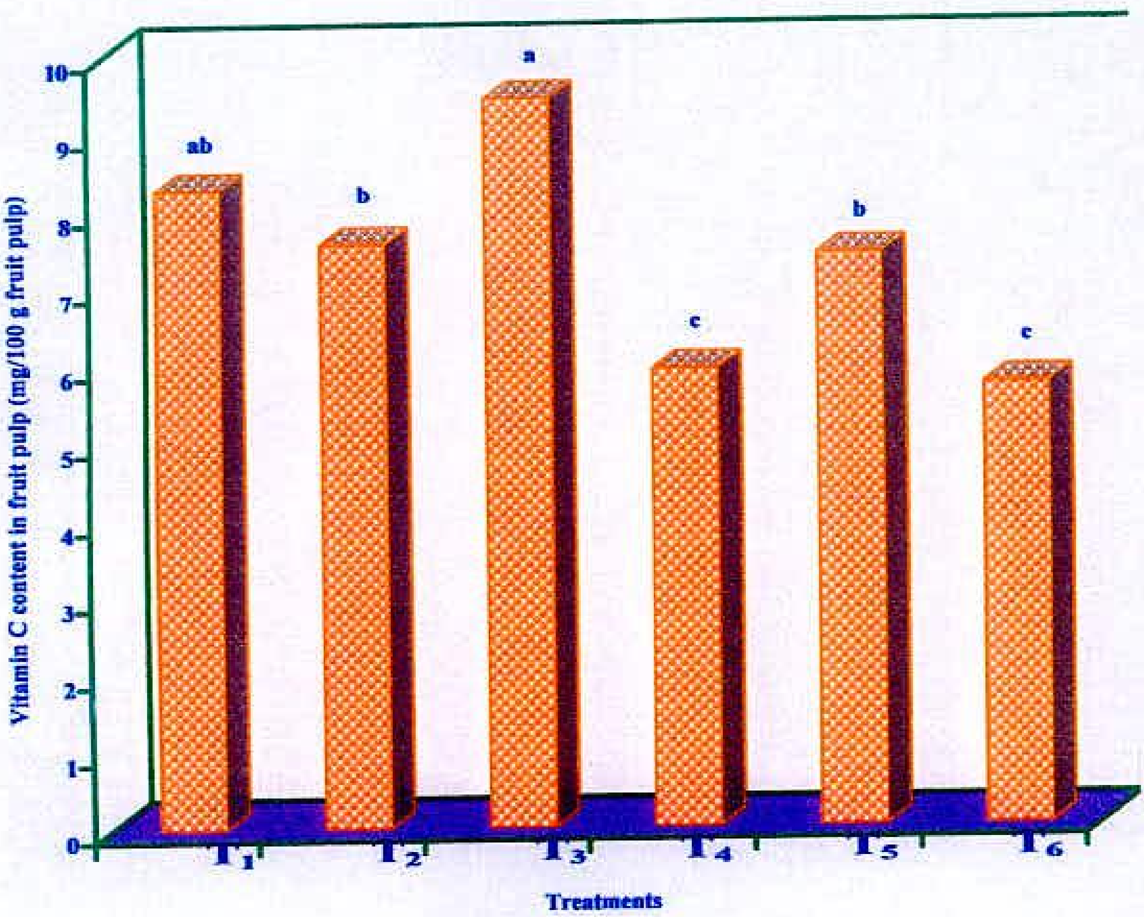

Fig 2. Effect of multistoried tree combinations on Vitamin C content in pineapple fruit pulp

T_1	=	Sissoo + Guava + Pineapple	T_4	=	Coconut + Guava + Pineapple
T_2	=	Sissoo + Lemon + Pineapple	T_5	=	Coconut + Lemon + Pineapple
T_3	=	Mango + Guava + Pineapple	T_6	=	Control plot (open)

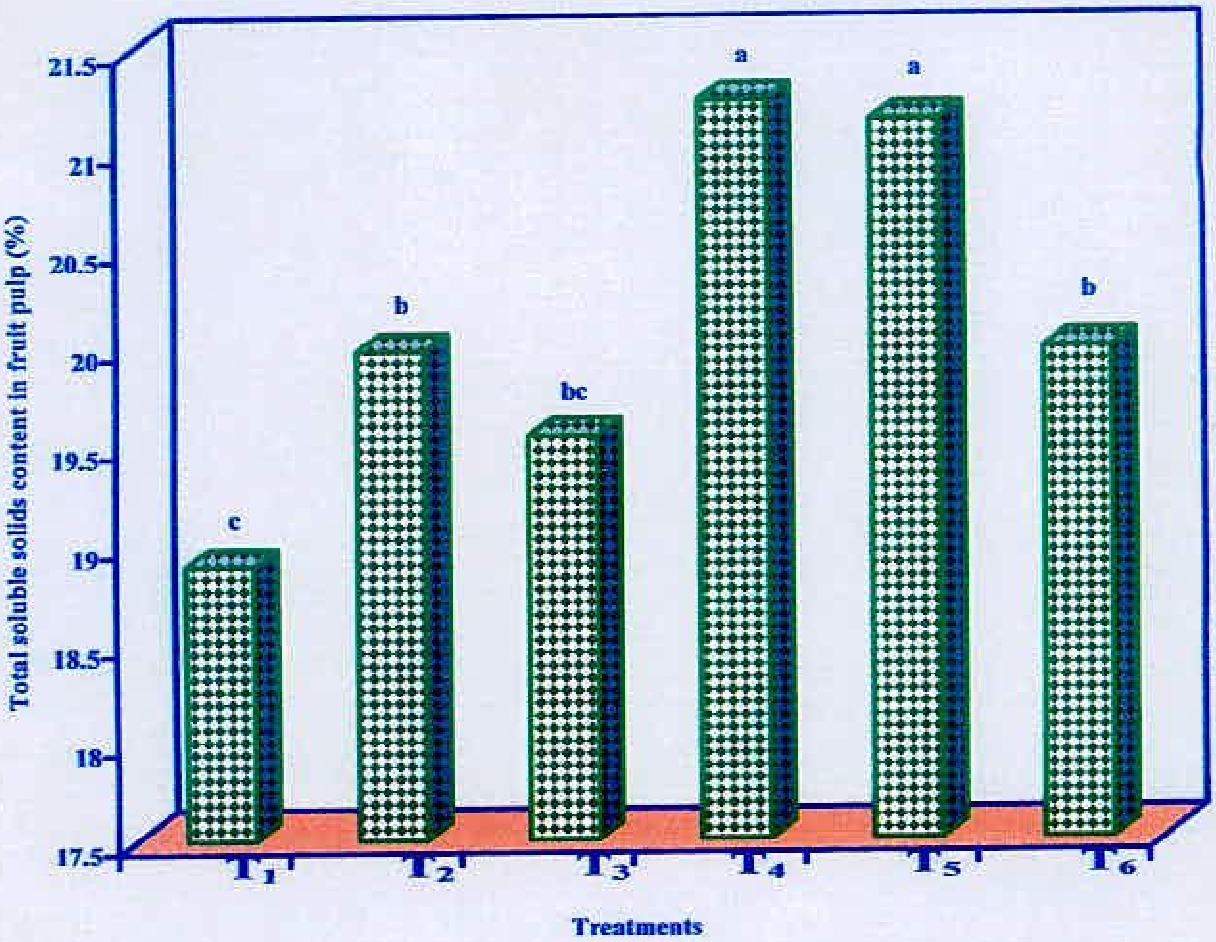

Fig 3. Effect of multistoried tree combinations on total soluble solids (TSS) content in pineapple fruit pulp

T_1	=	Sissoo + Guava + Pineapple
T_2	=	Sissoo + Lemon + Pineapple
T_3	=	Mango + Guava + Pineapple
T_4	=	Coconut + Guava + Pineapple
T_5	=	Coconut + Lemon + Pineapple
T_6	=	Control plot (open)

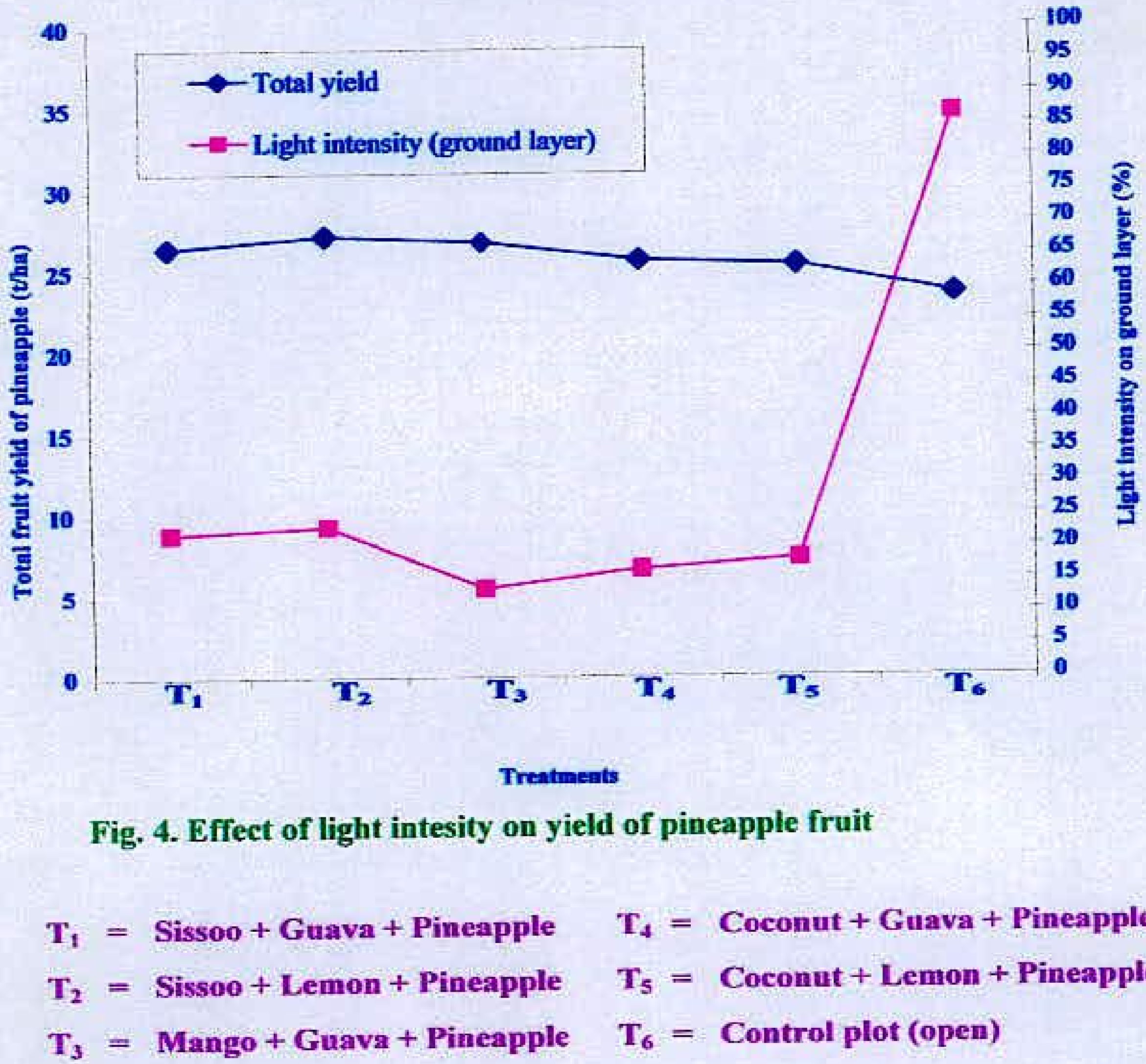

Fig. 4. Effect of light intesity on yield of pineapple fruit

T_1	=	Sissoo + Guava + Pineapple	T_4	=	Coconut + Guava + Pineapple
T_2	=	Sissoo + Lemon + Pineapple	T_5	=	Coconut + Lemon + Pineapple
T_3	=	Mango + Guava + Pineapple	T_6	=	Control plot (open)

The highest light intensity (86.33%) recorded in treatment T_6 (Control) resulted the lowest pineapple production (23.99 t/ha). In full sunny condition sun scald occur in the outside of the pineapple fruit resulted reduce the yield and other qualities (Plate 7). Light intensity recorded in T_2 treatment (22.99%) yielded the highest pineapple production (27.08 t/ha). Then yield decreased with the decrease of light intensity. The pineapple fruit grown under deep shady place ripes some days later as compared to other multilayered production system (Plate 8). No significant yield reduction was observed from 13.45 – 22.99% light intensity in different multistoried tree combinations. It is, therefore, concluded that the light intensity ranging from 13.45 – 22.99% observed in ground layer under multistoried agroforestry systems is suitable for pineapple production.

Plate 7. T_6- Sun scald of pineapple fruit in control (open) plot

Plate 8. T_3- Delayed ripening of pineapple fruit under deep shade

CHAPTER V

SUMMARY

SUMMARY

People of Bangladesh are facing huge shortage of fruit nutrition as compared to their daily requirements. Simultaneously, it is utmost necessary to supply fuel and timber as well as fodder for rapidly expanding population in rural as well as urban areas for cattle and household consumption. The farmers of Bangladesh traditionally grow pineapple in different areas under partial shade. Trees are planted in pineapple field neither thinking its economic return nor considering its appropriate canopy configurations rather than keeping production aspects of pineapple in mind. Recently, Fruit Tree Improvement Project, Bangladesh Agricultural University (FTIP-BAU-DH), Mymensingh, trialed and evaluated the pineapple production under multilayered production system and found a good result, but no experiment was set up to find out its qualitative characteristics suitable for table taste. However, the present investigation was carried out to find its qualitative parameters as well as production under different multistoried agroforestry systems.

In order to maximize the production and quality of pineapple, an investigation was carried out at FTIP, BAU, Mymensingh, during the period of December, 2002 to August, 2003. The experiment included five different multilayered canopy configurations and one sole pineapple orchard. The single factor experiment was laid out in randomized complete block design with four replications. Data were collected on yield; yield attributing and qualitative characters and they were analyzed for evaluation for the treatment effects.

Performance of pineapple production in terms of per cent fruit set was affected significantly by different multilayered tree combinations. The

highest fruit set (82.33%) was observed in T_2 while it was the lowest in T_1 (81.42%). In case of fruit weight with crown, the largest fruit was observed in T_2 (0.96 kg) but T_6 yielded the smallest fruit (0.77 kg). The severe light intensity decreased the individual fruit weight with crown in control plot (T_6). Fruit weight without crown was increased significantly as the light level decreased up to a certain limit.

Multilayered production systems had high significant effect on diameter of fruits. The highest fruit diameter was observed in T_5 (9.63 cm) when ground layer light intensity was 17.91%. The lowest diameter of fruit (8.67 cm) was recorded in T_6. Length breadth ratio of pineapple fruit was more or less statistically similar in all pineapple gardens. Significantly the highest pulp was recorded in T_2 (0.46 kg) while it was observed the lowest in T_6 (0.36 kg). Peel of the pineapple fruit in different treatments was statistically similar but significantly different as compared to pineapple produced in open place (T_6). The highest pulp-peel ratio was observed in T_2 (2.35) and it was the lowest in T_6 (1.82).

Significantly the lowest fruit/crown ratio in weight basis was observed in T_4 (0.39). The highest fruit crown ratio was observed in T_6 (0.45) i.e., increased light intensity decreased the crown weight resulting increased fruit/crown ratio.

Multilayered production system exhibited marked influence on fruit yield of pineapple with and without crown. The highest yield per hectare with and without crown was recorded when pineapple planted in T_2 (sissoo + lemon based agroforestry system) while it was the lowest in T_6 (open) treatment. When light intensity was taken into consideration, the yield of pineapple was statistically similar to 13.45%- 22.99% light intensity. Further increase in light intensity decreased the yield of pineapple.

Multilayered production system had high significant effect on length of crown in pineapple fruit. Significantly the longest length of crown was recorded in T_1 (30.15 cm) and the smallest one was observed in T_6 (24.38 cm). The edible portion of pineapple fruit was significantly affected by multilayered canopy configurations. The largest edible portion was recorded in T_2 (70.05%) while the smallest edible portion was recorded in T_6 (64.86%). Moisture content of fruit pulp was significantly affected by different multilayered production systems. Pineapple produced in T_3 contained the maximum moisture (81.05 %) while it was the lowest in T_6 (77.65%). Among other treatments moisture content was not significantly affected by multilayered production systems.

The other biological parameters like p^H were found the highest in T_6 (5.16) and titratable acidity was the lowest in T_6 (0.53). Vitamin C content in pineapple was significantly affected by multilayered production system. Vitamin C content was observed decreased trend as the light intensity increased. The highest Vitamin C content was recorded in T_3 (9.42 mg/100 gm fruit) as compared to the lowest amount observed in T_6 (5.70 mg/100 g fruit). The maximum TSS was recorded in T_4 (21.23%) and T_5 (21.13%) while it was the lowest in T_1 (18.86%).

Among different multilayered production systems, T_4 contained the highest reducing, non-reducing and total sugar while these parameters were the lowest in T_3. Sugar content was observed the highest under moderate shade, further increase or decrease of shade level decreased the sugar content. TSS/acidity ratio which is the indicator of good palatability, was recorded highest in T_6 (38.79) and the lowest in T_1 (32.39). Pineapple produced in full sun light contained high TSS/acidity ratio.

The light intensity observed in different multistoried production systems had no significant effect on pineapple yield. The yield of pineapple was statistically similar when the ranges of light intensity were 13.45 – 22.99% in multilayered tree garden. But in full sunny place (control) the light intensity was the highest (86.30%) and the yield of pineapple was the lowest. In full sunny place sun scaled occurs in the out side of pineapple fruit resulted reduce the yield and other qualities of pineapple fruit. Simultaneously, the pineapple fruit grown under deep shady place ripes some days later as compared to other multilayered production systems.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

CONCLUSION AND RECOMMENDATION

Considering the above mentioned results and discussion, it is, therefore, concluded that the performance of pineapple and its quality under different multilayered agroforestry production systems were different. Among the five different agroforestry gardens with three layered canopy configurations, the pineapple yield was not significantly different. But as compared to pineapple plantation in open condition, the yield was much higher. Under open condition (86.30% light intensity) the per cent of fruit set, individual fruit weight, per cent edible portion, crown length, Vitamin C content declines, whereas sugar content, TSS, individual fruit weight increase with decrease of light intensity. It is, therefore, necessary to grow pineapple fruit in partial shade and farmers may adopt it. The estimated yield of pineapple was statistically similar (25.21-26.67 t/ha) in different multistoried agroforestry production systems at a light intensity ranging from 13.45 - 22.99% on ground layer. Among the five multistoried canopy configurations sissoo + lemon + pineapple and coconut + lemon + pineapple were better than other multistoried agroforestry systems practiced in this study. Sissoo is multipurpose deciduous tree and it always helps to keep moist its ground layer under which pineapples are grown better. Coconut is other fruit yielding agroforestry species under which pineapple plantations receive light (PAR) round the clock which is appropriate for better yield and quality. Whereas, mango is a close canopy evergreen tree under which pineapple plantations may receive less light (PAR) as compared to its requirements resulting reduce yield and quality of this fruit.

However, the findings of the present study were achieved based on one season trial which may not be sufficient to asses the sustainability of the results. So, similar experiments should be repeated at least in another season so that results should be conclusive. But as the light or shade conditions were natural in this experiments, may, therefore, depicts strong recommendations to farmers level to grow qualitative pineapple with their economic yields under partial shade.

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APPENDICES

Appendix 1. Monthly date on maximum, minimum, average temperatures, relative humidity, rainfall, evaporation and soil temperature recorded during the study period.

Month	** Air Temperature((°C)			**Humidity (%)	*Rainfall (mm)	**Wind Speed (kmh)	*Sun Shine (hrs)	*Evaporation (mm)	** Soil Temperature (°C) at the Depth				
	Max.	Min.	Av.						05 cm	10 cm	20 cm	30 cm	50 cm
January	21.77	10.17	15.97	83.65	Trace	4.32	165.6	52.5	17.5	16.9	18.3	17.6	19.0
February	26.67	15.49	21.13	75.21	27.1	4.45	229.2	77.2	21.1	21.6	21.4	20.0	20.7
March	27.95	18.11	23.03	75.39	114.0	6.91	199.3	104.6	24.1	24.5	24.3	22.7	23.4
April	31.63	22.25	26.94	80.07	96.2	9.78	220.7	129.1	28.2	27.9	27.9	26.1	26.4
May	32.03	23.33	27.68	81.13	265.0	10.05	185.6	136.3	29.6	30.3	29.8	27.8	28.4
June	30.57	25.68	28.13	86.23	425.3	12.41	105.9	108.2	30.0	30.3	30.0	28.3	28.9
July	31.81	26.89	29.35	85.00	212.9	10.82	129.6	126.1	31.1	31.6	31.0	29.4	29.6
August	32.23	27.10	29.66	84.55	126.7	9.70	168.3	106.5	31.7	31.9	31.6	29.8	30.1

* = Monthly total ** = Monthly Average

Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh

Appendix II. Soil analysis data recorded from experimental plot

Sl. No.	Soil properties	Analytical data
1	p^H	6.8
2	Organic C	0.83%
3	Total N	0.075%
4	Available P	13 ppm
5	Available K	0.28 mg of k/100 g of soil
6	Sulpher	10 ppm
7	Zink	2 ppm
8	Sand	35.2%
9	Silt	60%
10	Clay	4.8%
11	Textural class	silty loam

Appendix III: Observed tree density, crown cover and noon time light intensity in different multistoried agroforestry systems

Vertical layers	Treatments	Plant density (trees/ha)	Crown area (m2/tree)	Crown cover (m2/ha)	Noon time light intensity (%)
Third layer	T_1	208	24.00	5000.00	60.39
	T_2	208	23.00	5010.00	57.04
	T_3	123	65.38	7847.90	27.31
	T_4	208	33.16	6909.38	58.61
	T_5	208	33.16	6909.38	59.16
	T_6	0	0	0	86.22
Second layer	T_1	208	5.10	1062.03	26.17
	T_2	208	5.31	1106.25	27.56
	T_3	208	5.10	1062.50	26.17
	T_4	208	5.10	1062.50	26.17
	T_5	208	5.31	1106.25	27.56
	T_6	0	0	0	85.76
Ground layer	T_1	416	29.10	6062.03	21.91
	T_2	416	28.31	6172.50	22.99
	T_3	331	68.68	8911.40	13.45
	T_4	416	38.26	7971.88	16.30
	T_5	416	38.47	8015.63	17.91
	T_6	0	0	0	86.30

Third layer: Shading of sissoo, mango and coconut

Second layer: Shading of guava and lemon

Ground layer: Sole pineapple orchard (control)

Appendix IV. Analysis of variance of the data on fruit weight and fruit size of pineapple as affected by multistoried tree combinations

Sources of variation	Degrees of freedom	Mean squares of shoot regeneration						
		Fruit Set (%)	Weight of individual fruit (kg)		Fruit size in length (cm)		Diameter of fruit (cm)	L/B ratio
			With crown	Without crown	With crown	Without crown		
Replication	3	0.085	0.001	0.005	0.236	1.275	0.108	0.044
Factor A (Multilayered)	5	3.382*	0.089**	0.035*	122.293**	7.887*	1.087*	0.143NS
Error	15	2.653	0.001	0.032	6.869	7.848	0.460	0.425
CV (%)		0.51	0.77	7.41	1.74	6.38	1.89	13.40

* = Significant at 5% level

** = Significant at 1% level

NS = Non Significant

Appendix V. Analysis of variance of the data on fruit quality, yield and light intensity of pineapple as affected by multistoried tree combinations

Sources of variation	Degrees of freedom	Mean squares of shoot regeneration						
		Pulp of fruit (kg)	Peel of fruit (kg)	Pulp-peel ratio	Fruit and crown ratio (wt basis)	Total yield (t/ha)		Light intensity on ground layer (%)
						With crown	Without crown	
Replication	3	0.063	0.184	0.162	0.001	2.745	14.003	1.793
Factor A (Multilayered)	5	0.028*	0.004NS	0.872*	0.018**	128.235**	34.646*	15566.873**
Error	15	0.018	0.009	0.603	0.004	4.161	19.358	5.281
CV (%)		8.33	12.19		9.61	1.46	4.42	1.99

* = Significant at 5% level

** = Significant at 1% level

Appendix VI. Analysis of variance of the data on physical conditions and biological quality of pineapple fruit as affected by multistoried tree combinations

Sources of variation	Degrees of freedom	Mean squares of shoot regeneration										
		Length of crown (cm)	Edible portion (%)	Moisture (%)	pH	Total titratable acidity (%)	Reducing sugar %)	Non-reducing sugar (%)	Total sugar (%)	TSS/acidity ratio	TSS (%)	Vitamin C (%)
Replication	3	0.169	4.360	2.457	0.203	0.002	0.609	3.589	1.940	12.884	6.971	2.766
Factor A (Multilayered)	5	92.552**	93.672**	29.054*	0.902**	0.011**	2.023**	8.042*	15.523**	132.591**	16.867**	39.853**
Error	15	2.924	7.804	29.337	0.539	0.008	1.063	7.071	5.697	46.664	6.209	10.094
CV (%)		1.60	1.07	1.77	3.87	4.14	4.29	15.50	5.79	4.87	3.20	11.13

* = Significant at 5% level

** = Significant at 1% level