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Productivity evaluation of jackfruit-papaya based multistoried agroforestry system in terrace ecosystem of Bangladesh

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ABSTRACT

The On-Farm (farmer's field) experiment was conducted in jackfruit orchard where the age of the trees ranged from 10-25 years with local and unknown varieties during the period from September 2011 to January 2014 in Narsingdi district which is an ideal location of central terrace ecosystem of Bangladesh to know the productivity and profitability of papaya under jackfruit based multistoried agroforestry system. The earlier established jackfruit orchard was transformed to multistoried agroforestry system. Jackfruit trees were considered as upperstoried crop; papaya was established as middlestoried crop; and seasonal vegetables were grown as lowerstoried crops. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. Each jackfruit tree was considered as a unit plot for a single replication. There were five treatments covering agroforestry (four orientations) and traditional farming (open field). At middlestorey light availability on papaya was 55.53%. Vegetative growth in terms of plant height, plant stem diameter and SPAD value and yield of papaya were higher in open condition (control). Among different orientations under jackfruit tree, growth and yield of papaya were better at south orientation and poor at north orientation in both the year. Soil moisture was higher in agroforestry system than control treatment but soil temperature was higher in control treatment than agroforestry system. The overall yield in multistoried agroforestry system was increased remarkably. The benefit cost ratio (BCR) for jackfruit-papaya based multistoried agroforestry system was 3.64 and 4.80 in 2012 and 2013, respectively. The land equivalent ration (LER) for jackfruit-papaya based multistoried agroforestry system was 1.76 and 1.78 in 2012 and 2013, respectively. Findings showed that farm productivity and profitability have been increased significantly that might have positive opportunity of employment and income generation and ultimately to the livelihood of the farmers living in terrace ecosystem.

Introduction

Bangladesh is one of the most densely populated countries in the world where 1203 persons are living per km^2 (World Bank, 2013). The per capita land area is decreasing at an alarming rate due to increasing population (Hossain and Bari, 1996). This availability of land has been declined from 0.19 ha in 1961 to 0.02 ha (World Bank, 2013). Increasing population and urbanization coupled with land degradation, soil salinization and global warming are causing food and nutritional insecurity in Bangladesh. On an average, the people of Bangladesh consume 166.1 g and 44.7 g of vegetables and fruits per capita per day against the minimum dietary requirement of 200 g and 100 g, respectively (NFPCSP and DDP, 2013). Although the production of vegetables and fruits have been increased in last couple of years, still now the production is not sufficient and there is a huge demand (BBS, 2013). On the contrary, farmers are not getting desired benefit due to high production cost for input and management practices. The low production level from the limited areas exerted pressure on nutritional security especially women and children in Bangladesh (FAO, 2003). To satisfy the demand of the country, the country imported 124.28 million US$ of fruit and 573.76 million US$

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of vegetables in 2013-14 financial years (Anon, 2015). Because of the increasing environmental hazards and demand for food, timber, fuel wood, fodder, fruits and poles etc. production of multiple products from the same land management unit is urgently needed. Multiple productions from homesteads and croplands are indispensable for a country like Bangladesh where the population growth rate is very high and faster than its agricultural growth rate. Since there is neither scope for expanding forest area nor sole grain crop area, the country has to develop combined production system integrating trees and crops which is now being popularly called agroforestry. A production model that offers higher production, ensures environmental and socioeconomic benefits and conserve plant diversity is being advocated (Harvey *et al.,* 2008; Ouinasavi and Sokpon 2008; Singh *et al.,* 2015). Well-planned intervention with new crops, local knowledge and enterprises, and scientific approaches are important in development of production system (Agbogidi and Adolor, 2013). Agroforestry, the integration of trees and food crops on the same area of land, is a promising way to increase production (Nair, 1990). It ensures various products, services and shelters that sustains food production, increases household income and improves the ecological condition. Moreover, perennial component of agroforestry system can be considered as carbon sink, create landscape small forest alike, compared to monoculture (Rasul and Thapa, 2006). Agroforestry system having multipurpose tree plantation helps to increase soil fertility, supplies fuelwood, creates employment and improves socioeconomic condition of the farmers (Alam, 2004). Various traditional and new agroforestry systems are practiced in different ecosystems of Bangladesh. Although agroforestry systems are prevailed throughout the country, specific agroforestry systems are found in specific ecosystems due to variations in topography, soil, water and climatic reasons as well as socioeconomic settings. Nowadays, several new agroforestry production systems based on both fruit and timber species are practiced by the farmers (Miah and Hussain, 2005). Fruit tree based systems are capable in providing higher economic return even under stressed growing conditions prevailing under the upland situations than the other annual crops (Bikash *et al.,* 2008). Many of the practices such as jackfruit based system in terrace, date palm and palmyra palm based system in southeast and mango based system in northeast region are well suited on the smallholdings of Bangladesh characterized by sub-optimal management and subsistence farming conditions. These traditional agroforestry systems have been contributing to the livelihood systems of the rural households of Bangladesh by providing diversified products (Abedin and Quddus 1990; Akter *et al.,* 1990). Terrace ecosystem consists of 8% landmass of Bangladesh, which is considered as one of the most potential areas for agroforestry, because farmers practice different types of agroforestry systems from time immemorial. Agroforestry systems in terrace ecosystem have already become an integral part of the rural livelihood systems for centuries and play key role in providing household food and energy securities, cash income, employment generation, investment opportunities and environmental protection. Among the different systems, jackfruit based agroforestry system is the most dominant one. (Khan, 2007) identified a large number of major and minor traditional and new agroforestry systems in terrace ecosystem of Bangladesh. Burmese grape based agroforestry systems are also found as economically viable practice in some areas of terrace ecosystem (Alam, 2004). These systems are being managed traditionally with low technical and technological knowledge's, which are responsible for low yields and benefits. Moreover, many sole jackfruit orchards are found widely, which are not well managed. These orchards usually featured with low capital inputs, poor yield due to using simple technology and integrating no cash crop. Therefore, it is imperative to suitable agroforestry model for augmenting the income and benefits of a farm. Considering the above facts, it is better to find out a high productive multistoried agroforestry system which will be a sustainable land use practice and high yielding multistoried model comprising food, fodder, fuel, timber and fruit trees and vegetables utilizing optimum natural resources (light, water, nutrient and vertical space) for homesteads/small land utilization. With the above view in mind the studies were, therefore, undertaken with the objective to examine the morphological behavior, yield and yield attributes of papaya in jackfruit based multistoried agroforestry system.

Materials and methods

The study was conducted at Abdullahpur farmer's field (On-Farm) belongs to the Belabo upazila under Narsingdi district during the period from September 2011 to January 2014. The geo position of the district is 23°46 to 24°14' north latitude and 90°35' to 90°60' east longitude (FAO/UNDP 1988). The climate of the locality is sub-tropical in nature. It is characterized by high temperature and heavy rainfall during kharif season (April to September) and a scanty rainfall during *rabi* season (October to March). The soil belongs to "Madhupur Tract" in agro-ecological zone (AEZ-28), (FAO, 1988) and has been classified as shallow Red-Brown Terrace soil, which is nearly equivalent to Ustocharepts suborder under the order Inceptisol of USDA Soil Taxonomy (Brammer, 1971; Shaheed, 1984). There were five treatments covering agroforestry (four orientations) and traditional farming (open field). Open (control): Non-agroforestry (Farmer's practice), AF-S: Agroforestry-south orientation, AF-N: Agroforestry-north orientation, AF-E: Agroforestry-east orientation, AF-W: Agroforestry-west orientation. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each jackfruit tree was considered as a unit plot for a single replication. The earlier established Jackfruit orchard was transformed to multistoried agroforestry system. Jackfruit trees were considered as upperstoried crop; papaya was established as middlestoried crop; and seasonal vegetables were grown as lowerstoried crops**.** Papaya seedlings were transplanted two weeks after pit preparation. Pit size for papaya was 45 cm x 45 cm x 45 cm and row to row and plant to plant distances were 6 m and 2 m, respectively**.** The pits were prepared on January 24, 2012 for first year; and March 7, 2013 for second year. The recommended doses of fertilizers were applied @ 100 g pit^{-1} of P, 45 g pit^{-1} of S, 3.5 g pit^{-1} of B and 7.0 g pit^{-1} of Zn in the form of TSP, Gypsum, Boric acid and Zinc Sulphate were applied during pit preparation. Total amount of cowdung were applied in pit and mixed with soil using spade**.** N and K in the form of Urea and MP were applied as top dressing @ 50 g per pit in every month after new leaves were appeared till flowering. After flowering, the rate of urea and MP application was doubled till final harvest (BARC, 2012). No urea was applied in pit during transplanting. Thinning, gap filling and first weeding were done 20 days after transplanting. After thinning, one-seedling per-hill was retained. Gap filling was done to ensure uniform stand. Uprooting was done since there were possibilities of injuring the adjacent seedlings that were left behind. Hand weeding was done to keep the plots free from weed infestation. Weeding was done at 20, 40 and 60 days after sowing/transplanting (DAS/DAT). The plants were irrigated by watering-cane whenever required to supply sufficient soil moisture. To control damping off disease of papaya seedlings in the experimental field, affected seedlings were removed and chemical control was done by using Ridomil Gold (2%). Papaya was harvested from May 15 to November 15, 2012 and from April 02 to December 10, 2013, two or three times per month. The harvesting was done by hand picking and cutting with sharp knife. Fruit per plant, fruit yield per plant, fruit weight, length and diameter of the sample fruits were taken immediately after harvesting. Five representative plants were selected from each orientation for data collection of vegetative growth. Samples were collected at every month interval in both the years. Ten representative papayas were selected from each orientation for yield and yield attributes. SPAD value of papaya leaves were measured by SPAD 502 plus chlorophyll meter and light was measured above the canopy of papaya by sunfluxceptometer at one time per month and the collected data were averaged and expressed as $\mu mm^{-2}s^{-1}$ in agroforestry plots and in the respective control plots at 11:00-12:00. Soil moisture (%) and temperature (^oC) was measured by PMS-714 Soil Moisture Meter (model) and Temp 4/5/6 Thermistor Thermometer (model), respectively. Soil moisture and temperature was measured at 10 cm deep soil adjacent to main root of vegetable crops in agroforestry plots and in the respective sole crop plots at 9:00-10:00 and 10:00-11:00 AM respectively, once per month and the collected data were averaged. It was done 3 days after irrigation. Cost and benefit analysis was used to compare the benefits of the tested agroforestry system with the monoculture tree or annual crop systems. Benefit-cost ratio (BCR) and land equivalent ratio (LER) are the two measurements of productivities which are normally used in agroforestry. Benefit-cost ratio is the ratio of gross return with total cost of production. It was calculated by using the following formula (Islam et al., 2004), BCR=Gross return (Tk. ha^{-1} $year^{-1}$)/Total cost of production (Tk. ha^{-1} $year^{-1}$). The term land equivalent ratio (LER) is derived from its indication of relative land requirements for intercrops versus monocultures. LER helps finding the relative performance of a component of a crop combination compared to sole stands of that species (Mead and Willey, 1980). In simple Agroforestry situations, LER can be expressed as: LER=Ci/Cs + Ti/Ts,

Where: Ci=crop yield under agroforestry, Cs=crop yield under sole cropping, Ti=tree yield under agroforestry, and Ts=tree yield under sole cropping. Data were statistically analyzed using the "Analysis of Variance" (ANOVA) technique with the help of computer package "Statistix 10.0" to examine the significant variation of the results due to different treatments. The mean differences were adjusted by Least Significant Different (LSD) at 5% level of significance (Gomez and Gomez, 1984).

Results and Discussion

Plant environment

The monthly agro-meteorological data during the study period (2011-2013) have been presented in the Fig. 1 and 2. It was observed that there was a distinct dry season from November to March and a wet season from April to October in the study period. More than 90% rainfall occurred from April to October in both the years. The monthly distribution of rainfall showed that the maximum rainfall was occurred in July 2012 (334.56 mm) and May 2013 (421.03 mm). Plant growth was not affected adversely though this was a prolong dry season and low ground water table (fluctuating from 19.45 m to 21.10 m in 2012 and 20.65 m to 22.54 m in 2013) due to moderate rooting systems of trees. During the wet season (April to October), both trees and crops received sufficient soil moisture, therefore, the growth and development of plants were higher than the dry season. Drainage facility was well developed to protect the plant from the heavy rainfall. The mean maximum air temperature in 2011-12 (34.3 ^{0}C) was relatively higher than 2012-13 (33.83 ^{0}C). The maximum temperature varied between 22.5 ^{0}C and 34.3 ^{0}C in 2011-12, while it varied between 23.67 ^{0}C and 33.83 ^{0}C in 2012-13. In both the years, soil moisture was inadequate for certain time due to high temperature and evaporation. Therefore, to protect plants from the shortage of soil moisture, irrigation was applied based on soil moisture level and visual observation. On the other hand, the mean minimum temperature varied from 11.7 ^{0}C to 27.1 ^{0}C and 9.74 ^{0}C to 27.38^{0}C in 2011-12 and 2012-13, respectively.

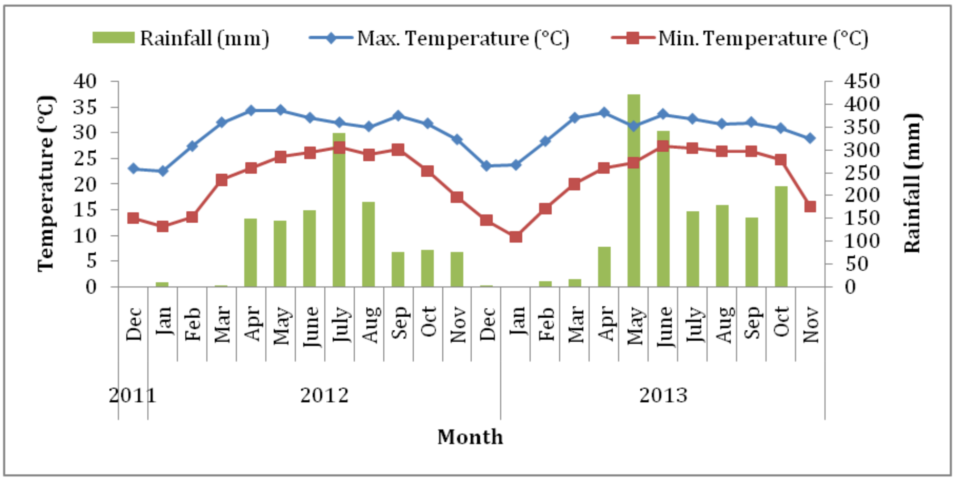

Figure 1: Monthly average rainfall and temperature at study site, during 2011 - 2013

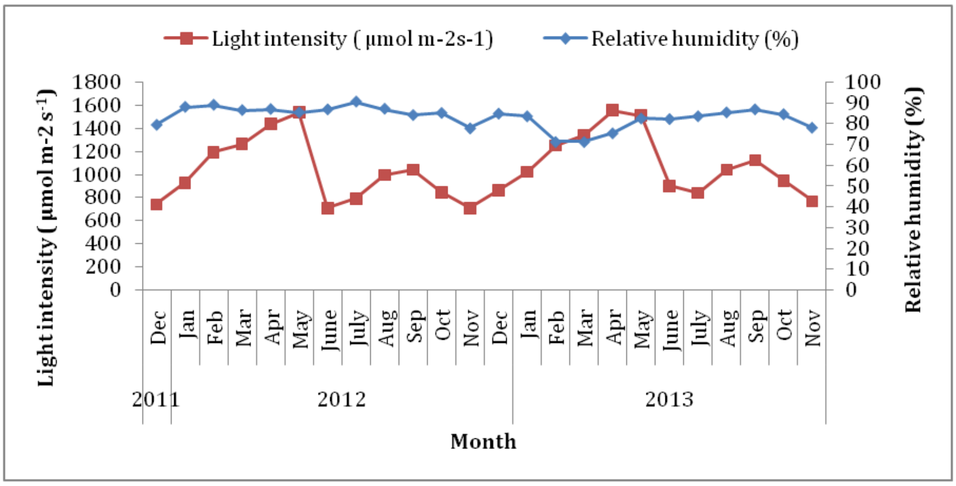

Figure 2: Monthly average light intensity (µmol $m^{-2}s^{-1}$) and relative humidity (RH).

In the agroforestry systems, Photosynthetically Active Radiation (PAR) is the most limiting factor. The light intensity (Fig. 2) in the open field varied between 706 µmolm^{-2} s^{-1} and 1553 µmolm^{-2}s^{-1} in the study period during 2011-2013. The maximum PAR was measured in April 2013 (1553 µmolm^{-2}s^{-1}) and minimum PAR was measured in November 2012 (706 µmolm^{-2}s^{-1}). Due to evergreen nature of jackfruit trees, understoried crops and plants received about 30 - 60% light intensity compared to open field. Therefore, crop environment was favourable for understoried crop production. To increase light availability in agroforestry treatments, all the fruit tree species were pruned each year according to their tolerant level. In general, pruning was done before *rabi* crop season. The highest relative humidity was recorded in July (90.4%) in 2011-12. On the other hand, the lowest relative humidity was recorded in March (71.22 %) in 2012-13 during the study period.

Soil moisture

The highest and lowest soil moisture was recorded in north orientation of agroforestry and in open field, respectively, in both the cropping years. Among the agroforestry plots, although the moisture level showed variation, but on an average, the higher soil moisture was recorded in north orientation followed by west, east and south orientations. Generally deep rooted fruit tree species which might have up taken more water from deeper soil layer and recycled them on the upper ground through litter fall. In addition, shade created by those tree species certainly reduced the evaporation, while irrigation was done at regular interval. All these phenomena might have increased the moisture status under those trees. The soil moisture was high in different orientation compared to open field due to shade condition which reduced the evaporation and preserved the soil moisture (Figure 3).

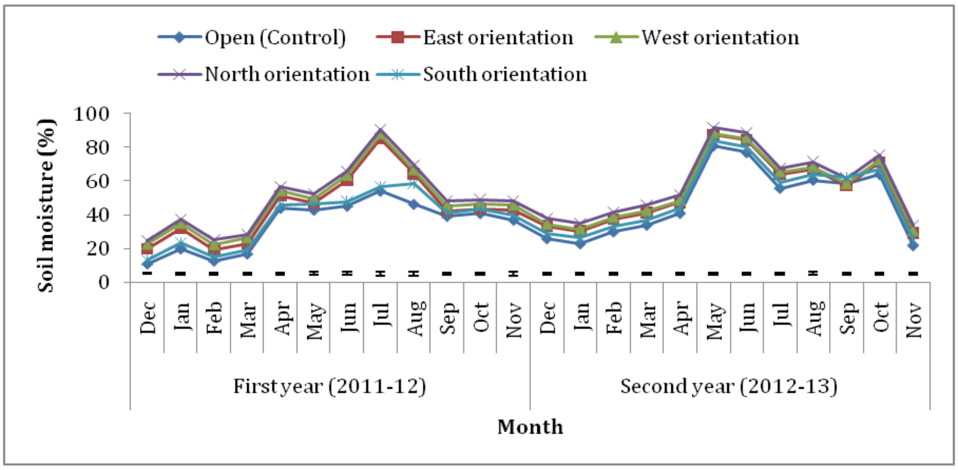

Figure 3: Soil moisture content at different orientations in multistoried agroforestry system and open plot. Vertical bars indicate the ± SE values.

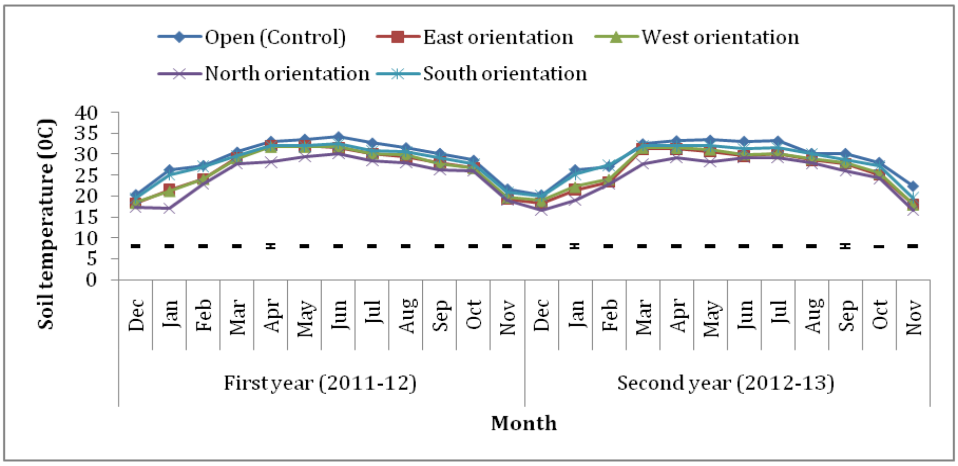

Figure 4: Soil temperature content at different orientations in multistoried agroforestry system and open plot. Vertical bars indicate the ± SE values.

Soil temperature

Result showed that soil temperature in open field was remarkably higher than that recorded beneath the trees regardless of orientations at all the measurement dates in both the years. Overall soil temperature was low during winter and post monsoon seasons, while it was high during summer (pre monsoon) and monsoon seasons (Figure. 4). Therefore, higher soil moisture and favorable soil temperature conservation were observed in agroforestry system. This might be due to shade cast by the crown of the Jackfruit trees. In open field, sunlight was easily absorbed by the ground that penetrated to the root system, thus increased soil temperature; but in agroforestry system, light was first absorbed by the tree canopy and diffused light was absorbed by the ground that might be reason of low soil temperature in agroforestry system.

Light availability

The highest light intensity was recorded in open (control) condition. Among the different orientations of agroforestry, the highest value was measured in May at south (925.0 µmol $m^{-2}s^{-1}$) and the lowest light was recorded in June at north (211.33 µmol $m^{-2}s^{-1}$) orientations of agroforestry which might be due to cloudy weather, respectively during 2012. On the other hand, the highest and lowest light was measured in April at south (934.0 µmol m^{-2} s^{-1}) and in November at north (230.0 µmol $m^{-2}s^{-1}$) orientations of agroforestry which might be due to foggy weather, respectively during 2013. In jackfruit-papaya system, the light interception was 55.53% (Fig. 5). Just beneath the jackfruit tree, light availability was reduced in north, south, east and west orientations, respectively, as compared to control (open) condition. However, this reduction of light at different orientations was due to dense crown cover of jackfruit tree, while the light availability was increased with the increase of distance from jackfruit tree base.

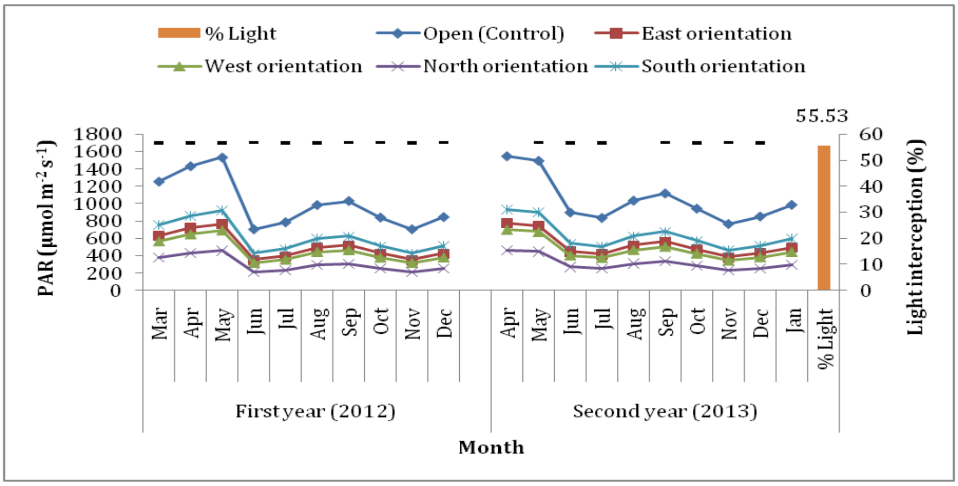

Figure 5: Light intensity on papaya plant at different orientations in multistoried agroforestry system and open plot. Vertical bars indicate ±SE values.

Plant height

The variation was distinct in growth of plant height of papaya among the different treatments over time, but the trend of variation was almost similar (Fig. 6). At all the measurement date during study significantly the tallest plant was recorded in control condition and the shortest plant was noted in north orientation of agroforestry system. In 2012, plant height was increased with time progressively and linearly. In 2013, growth of papaya plant in terms of height was very fast initially, but it became slower after sixth month of measurement and the height was shorter even than that of 2012. This variation might be due to the genetically factor of the varieties.

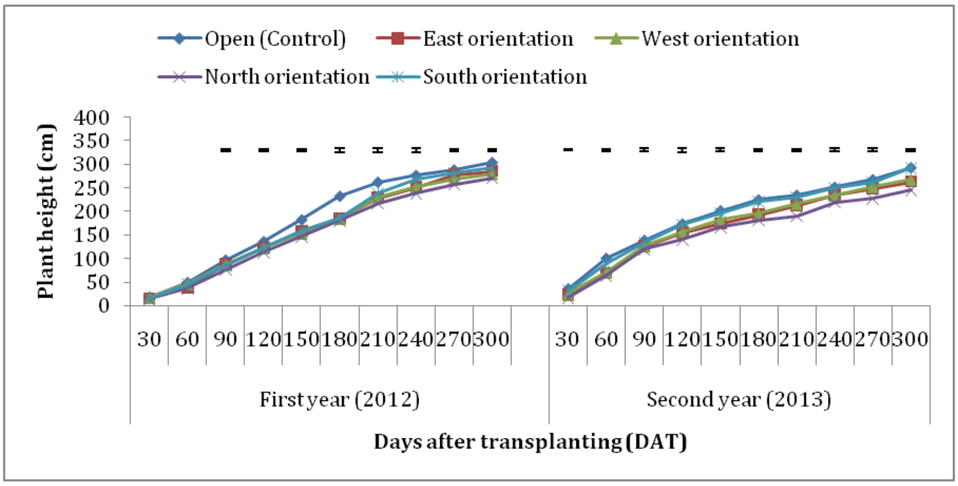

Figure 6: Plant height of papaya at different orientations in multistoried agroforestry system and open plot. Vertical bars indicate ±SE values.

Stem diameter

Stem diameter at collar region of papaya showed the similar trend of variation like plant height (Figure 7). In 2012, the stem diameter was very poor up to the first four months. But after that, the stem diameter increased very fast and the values in open condition were higher than that of agroforestry orientations. In 2013, the stem diameter was very fast initially and it did not increase steadily when it reached to reproductive stage. At the final measurement date, the highest stem diameter was found in open treatment and the lowest diameter was recorded in north orientation of agroforestry system in both the years. The diameter of papaya plants grown in non-agroforestry (control) system was relatively higher than that of agroforestry system. The higher diameter of papaya stem in open field was probably due to the benefits received by the tree species from the management practices (fertilizer, irrigation, weeding, and pest control) for associated crops.

SPAD value

Leaf SPAD value of papaya varied slightly and it showed almost similar trend of variation between open and agroforestry conditions in both the years. However, the leaf SPAD value in 2012 was slightly higher than that of 2013 (Fig. 8). At all the measurement date, the highest value was noted in control treatment, which was insignificantly followed by south, north and west orientations. The SPAD value was higher at open field than shade condition due to plant can produce more chlorophyll under full sunlight through photosynthesis.

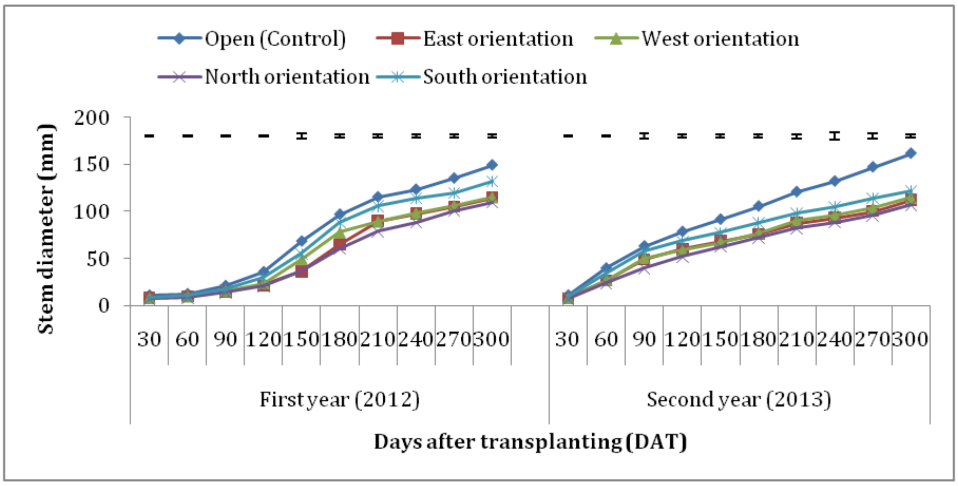

Figure 7: Stem diameter of papaya at different orientations in multistoried agroforestry system and open plot. Vertical bars indicate ±SE values.

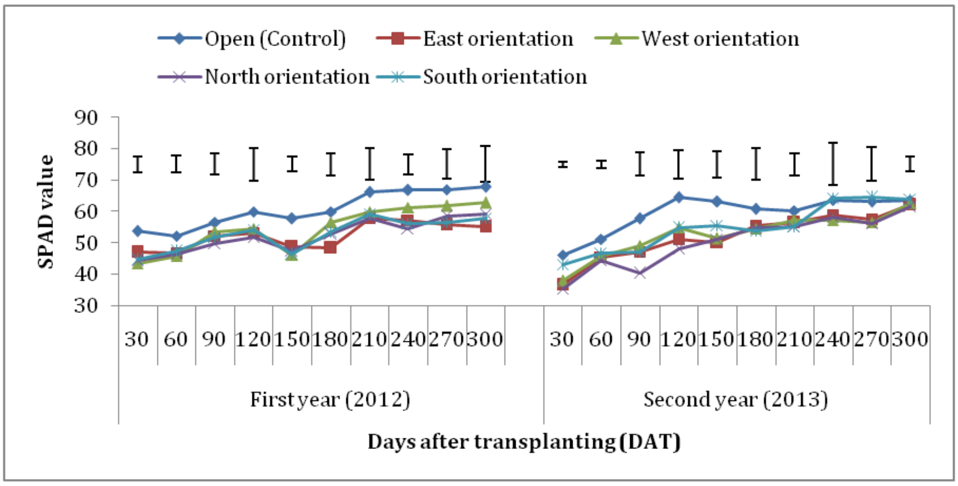

Figure 8: Leaf SPAD value of papaya at different orientations in multistoried agroforestry system and open plot. Vertical bars indicate ±SE values.

Fruit length

Fruit length of papaya varied between open field and agroforestry system (Table 1). In first year, the longest fruit (22.16 cm) was noted in control (open condition) treatment, which was statistically similar to south (20.23 cm) orientation. On the other hand, fruit length grown at east, west and north orientations in agroforestry system did not vary significantly, although the shortest fruit (16.96 cm) was recorded in north orientation in agroforestry system. In 2013, significantly the longest fruit (24.23 cm) was noted in control (open condition) treatment, which was also statistically similar to south (23.76 cm) orientation. Fruit length obtained at east (22.40 cm) and west (22.16 cm) orientations in agroforestry system did not vary significantly and the shortest fruit (18.30 cm) was recorded in north orientation in agroforestry system. Fruits grown under control plots enjoyed maximum light and more nutrients which might have increased the fruit length compared to fruits grown under tree species.

Fruit diameter

Fruit diameter of papaya varied remarkably at open field and agroforestry systems in 2012. In the first year, the highest fruit diameter (42.16 mm) was noted in control (open condition). The second highest fruit diameter (38.06 mm) was noted at south orientation of agroforestry system, which was also significant from other treatments. Although fruit diameter (29.56 mm) was recorded in north orientation, but it did not vary distinctly with east orientation in agroforestry system. In second year of experimentation (2013), significantly the highest (44.70 mm) and the lowest (30.43 mm) fruit diameter were noted in control (open condition) and north orientation, respectively. The second highest fruit diameter (42.10 mm) was noted at south orientation of agroforestry system, which was also significant from other treatments. Fruit diameters at east (35.13 mm) and west (35.53 mm) were statistically similar (Table 1). The lower fruit diameter under tree species might be due to relatively higher shade with lower mobilization of reserve assimilates to reproductive organs.

Individual fruit weight

The significant variation was recorded in individual fruit weight of papaya as influenced by open field and agroforestry system (Table 1). In 2012, the maximum fruit weight (0.98 kg) was noted in control (open condition) and in south (0.98 kg) orientation. Fruit weights obtain at east (0.83 kg) and west (0.84 kg) orientations in agroforestry system did not vary significantly. The minimum fruit weight (0.77 kg) was recorded at north orientation in agroforestry system. Again in 2013, the highest fruit weight (1.314 kg) was noted in control (open condition) which was statistically similar to south (1.302) orientation of agroforestry system. The lowest fruit weight (0.74 kg) was recorded in north orientation, but it did not vary significantly between east (1.192 kg) and west (1.194 kg) orientations. Light availability was high in open field compared to agroforestry system which made the differences.

Number of fruit per plant

Fruit per plant of papaya was significantly varied in open field and agroforestry system (Table 1). The highest number of fruits per plant (55.33) was noted in control (open condition), which was statistically similar to south (54.33) orientation of agroforestry. Fruit per plant produced at east (48.00) and west (48.33) orientations in agroforestry system did not vary significantly. The lowest number of fruits (42.33) was recorded at north orientation in agroforestry system. In second year of experimentation (2013), the maximum number of fruits per plant (65.66) was recorded in control (open condition), which was statistically similar to south orientation (65.00). Fruit per plant grown at east (61.66) and west (62.00) orientations was insignificant. Number of fruits per plant showed different trend of variation and better performance was noted in 2013 (BU papaya 1) than 2012 (Shahi papaya). This variation might be due to genotypic characteristics of the variety. Shade cast by tree canopy decreased the reproductive growth of plant and that might have accounted lower number of fruit per plant under agroforestry systems.

Fruit yield per plant

Fruit yield per plant showed similar trend like number of fruits per plant. A significant variation was found in fruit yield per plant in papaya (Table 1). In 2012, the maximum yield (54.68 kg) per plant was noted in control treatment, which was statistically similar to south orientation (53.50 kg). Significantly the lowest yield (32.75 kg) per plant was recorded in north orientations. No significant variation was found between east (40.01 kg) and west (40.79 kg) orientations. Similar trend of variation was noted in 2013, where the highest yield (86.32 kg) per plant was noted in control treatment and the lowest (37.24 kg) yield per plant was recorded in north orientation. Diffused light under agroforestry systems promoted the development of vegetative structures, while intense light favors the development of flowers, fruits and seeds (Weaver and Clements, 1973). This could be the reasons also for the aforementioned variations.

Table 1: Yield and yield contributing characters of papaya at different orientations in multistoried agroforestry system and open plot during 2012-2013

Treatment	Fruit length (cm)		Fruit diameter (mm)		Individual fruit weight (kg)		Fruit plant^{-1}		Yield (kg plant^{-1})	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Open (Control)	22.16a	24.23a	42.16a	44.70a	0.98a	1.314a	55.33a	65.66a	54.68a	86.32a
East orientation	18.23b	22.40b	32.43cd	35.13c	0.83b	1.192b	48.00b	61.66c	40.01c	73.50b
West orientation	18.13b	22.16b	33.36c	35.53c	0.84b	1.194b	48.33b	62.00bc	40.79c	74.05b
North orientation	16.96b	18.30c	29.56d	30.43d	0.77c	0.745c	42.33c	50.00d	32.75d	37.24c
South orientation	20.23ab	23.76a	38.06b	42.10b	0.98a	1.302a	54.33a	65.00ab	53.50a	84.63a
CV (%)	9.16	2.00	4.56	1.23	0.82	0.58	3.47	2.62	3.71	2.22
LSD	3.3014	0.8364	3.0144	0.8679	0.0144	0.0126	3.2430	3.0067	3.1012	2.9796

Table 2: Total cost and return from jackfruit based agroforestry system and control during 2012 and 2013

System	Total cost (Tk ha^{-1})		Total return (Tk ha^{-1})		Net return (Tk ha^{-1})	
	2012	2013	2012	2013	2012	2013
Jackfruit-Papaya	109379	111763	398580	537360	289200	425596
Sole Papaya	108879	111263	364800	504000	255920	392736

Economic performance

The performances of jackfruit-papaya based agroforestry systems in terms of economic performance was estimated and are presented in Tables 2 and 3. Papaya was grown in both the years as sole crop and under jackfruit trees. Between the agroforestry and sole systems, the highest net return from agroforestry system was observed because of good return from papaya yield which was achieved because of less interaction effect for growth resources especially shade effect. On the other hand, the adverse weather conditions viz: high temperature resulting high evapo-transpiration, low soil moisture might be the cause of less net return from sole plot. So, the study revealed that, the agroforestry systems are economically profitable over sole system.

Table 3: Benefit-cost ratio (BCR) and land equivalent ration (LER) of agroforestry systems and sole cropping during 2012 and 2013

System	Benefit-cost ratio (BCR)		Land equivalent ratio (LER)	
	2012	2013	2012	2013
Jackfruit-Papaya	3.64	4.80	1.76	1.78
Sole Papaya	3.35	4.52	1	1

To know the economic performance and land use in jackfruit based multistoried agroforestry system over sole cropping, benefit cost ratio (BCR) and land equivalent ratio (LER) have been calculated and presented in Table 3. Between two years, BCR was higher in 2013 as compared to 2012 in all aspects and systems. The highest and lowest BCR were calculated in multistoried agroforestry and sole cropping, respectively in both the years (Table 3). The result revealed that multistoried agroforestry system was economically profitable than the sole cropping. Likewise, Land Equivalent Ratio (LER) helps in judging the relative performance of a component of a crop combination compared to sole stands of that species. The term Land Equivalent Ratio is derived from its indication of relative land requirements for intercrops versus monocultures (Mead and Willey, 1980; Vandermeer, 1989). The highest LER was in jackfruit - papaya based system than that of sole system. It indicates that 1.76 and 1.78 times higher land would be required to get similar productions from sole cropping as compared to agroforestry system during 2012 and 2013, respectively. The data indicated that it would require more than two times land for sole cropping to get the yield obtained from multistoried agroforestry system (Table 3).

Conclusion

Performance of papaya in terms of fruit length, fruit diameter, fruit weight, fruit per plant and yield per plant were measured in both the years. Between agroforestry (different orientations) and open condition, variation on fruit length of papaya was recorded, where the longest fruit (22.16 cm and 24.23 cm in 2012 and 2013, respectively) and shortest fruit (16.96 cm and 18.30 cm in 2012 and 2013, respectively) were recorded in open condition and at north orientation. Fruit diameter varied significantly, where the highest fruit diameter (42.16 mm and 44.70 mm in 2012 and 2013, respectively) was noted in control (open condition). Among different orientations, the highest (38.06 mm and 42.10 mm in 2012 and 2013, respectively) and lowest (29.56 mm and 30.43 mm in 2012 and 2013, respectively) fruit diameter of papaya were measured at south and north orientations, respectively. Individual fruit weight and number of fruits per plant also varied significantly in open condition and agroforestry system. The highest (0.98 kg and 1.314 kg in 2012 and 2013, respectively) and lowest (0.77 kg and 0.74 kg in 2012 and 2013, respectively) values of papaya fruit weight were measured at open (control) and north orientation. The maximum (55.33 and 65.66 in 2012 and 2013, respectively) and minimum (42.33 and 50.00 in 2012 and 2013, respectively) number of fruits were also noted at open (control) and north orientation, respectively. A significant variation was found in fruit yield per plant in papaya. The maximum yield (54.68 kg and 86.32 kg in 2012 and 2013, respectively) per plant was noted in control treatment. Among the orientations, the maximum (53.50 kg and 84.63 kg in 2012 and 2013, respectively) and minimum (32.75 kg and 37.24 kg in 2012 and 2013, respectively) yields per plant were recorded at south and north orientations, respectively. Net return and BCR from jackfruit-papaya based multistoried agroforestry system were higher than sole system in both the years. The LER of jackfruit-papaya based agroforestry system were 1.74 and 1.76 in 2012 and 2013, respectively. The highest plant height, plant stem diameter, SPAD value and light was recorded in open field which was statistically similar to south orientation of agroforestry system. Therefore, higher soil moisture and favorable soil temperature conservation were observed in agroforestry system.

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References

Abedin, M.Z. & Quddus M.A. (1990). Household fuel situation, homegarden and Agroforestry practice at six agro-ecological different locations of Bangladesh. In: Abedin MZ, Lai CK, Ali MO

(Eds.). Homestead plantation and agroforestry in Bangladesh. Proceedings of a National Workshop held on 17-19 July, 1988 in BARI, Gazipur, Bangladesh:19-53.

Agbogidi, O.M. & Adolor E.B. (2013). Home gardens in the maintenance of biological diversity. App Sci Rep 1:19-25.

Akter, M.S., M.Z. Abedin & Quddus M.A. (1990). Why farmer grow trees in agricultural fields; some results. Proc. Regional Symposium on Tree Plantation in the Humid/Sub-humid Tropics in Asia; held on May 5-9, 1998 in University Partanian, Malaysia, and tree in the Sahel. Agrof Today, 7(1):9-11.

Alam, M.S. (2004). Indigenous agroforestry knowledge: Agro-economic studies of latkan (*Baccaurea sapiada*) production at Narsingdi district. MS Thesis, Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh.

Anon (2015). Export Promotion Bureau, Bangladesh. Ministry of Commerce. TCB Bhavan, Kawran Bazar (2nd & 3rd floor) C/A, Dhaka-1215.

BARC (2012). Fertilizer recommendation guide. BARC, Farmgate, Dhaka.

BBS (2013). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics, Statistical Division, Ministry of Planning, Government of the People’s Republic of Bangladesh.

Bikash, D.S., Ranvir & Kumar S. (2008). Fruit based agro-forestry system for uplands. Horticulture and Agro-Forestry Research Programme. ICAR Research Complex for Eastern Region Ranchi, Jharkhand, India.

Brammer, H. (1971). Soil Resources. Soil Survey Project Bangladesh. AGL:SF/Pak. 6 technical Report 3.

FAO (2003). Current market situation for tropical fruits. Publication of the Committee on Commodity Problems, Intergovernmental Group on Bananas and on Tropical Fruits Meeting 11-15 December 2003.

FAO/UNDP (1988). Agro-ecological regions of Bangladesh. FAO/UNDP, Rome, Italy.

Gomez, K.A. & Gomez A.A. (1984). Statistical procedures for agricultural research. (2nd eds) John Wiley and Sons. Inc., New York. PP. 680.

Harvey, C.A., Komar, O., Chazdon, R., Ferguson, B.G., Finegan, B., Griffith, D.M., MartI´Nez-Ramos, M., Morales, H., Nigh, R., Soto-pinto L. & Wishnie, M.V.A.N.B.M. (2008). Integrating agricultural landscapes with biodiversity conservation in the mesoamerican hotspot. Conserv Biol 22:8-15.

Hossain, S.M.A. & Bari. M.N. (1996). Agroforestry farming System. In: Agroforestry in Bangladesh. PP. 22-29.

Islam, M. S., Sattar, Rahman M. M., Qayum M. A., Alam M. S. & Mustafi (eds) R. A. (2004). *Krishi Projukti Hatboi (Handbook on Agro-technology),* 3rd Ed. Bangladesh Agricultural Research Institute, Gazipur- 1701, Bangladesh. P. 560.

Khan, M.S.I. (2007). Agro-economic performance of traditional agroforestry systems in Madhupur Tract of Banglades. An MS Thesis, Dept. of Agroforestry and Environment, BSMRAU, Gazipur, Bangladesh.

Mead, R. & Willey, R.W. (1980). The concept of "Land Equivalent Ratio" and advantages in yields from intercropping. Exp. Agric, 16: 217-228.

Miah, M.G. & Hussain M.J. (2005). Homestead Agroforestry in Bangladesh; Potential Resources for the rural household. In. Book of Abstract, 1st world Congress of Agroforestry held on 27 June to 2 July, 2004, Orlando, Florida, USA.

Nair, P.K.R. (1990). An introduction to agroforestry. Kluwer Academic Publishers in corporation with International Centre for Research in Agroforestry.

NFPCSP & DDP. 2013. Desirable diet for Bangladesh: A desirable dietary intake has been proposed after the evaluation of previous work and current consumption patterns of the population.

Ouinsavi, C. & Sokpon N. (2008). Traditional agroforestry systems as tools for conservation of genetic resources of *Milicia excelsa* Welw. C.C. Berg Benin. Agrofor Syst., 74:17-26.

Rasul, G. & Thapa, G.B. (2006). Financial and economic suitability of agroforestry as an alternative to shifting cultivation: The case of the Chittagong Hill Tracts, Bangladesh. Agricultural Systems 91(1-2):29-50.

Shaheed, S.M. (1984). Soils of Bangladesh: General Soil Types. Soil Resources Development Resources Institute (SRDI), Farmgate, Dhaka, Bangladesh. PP. 3.

Singh, A.K., Ingita G. & Datta M. (2015). Upscaling of agroforestry homestead gardens for economic and livelihood security in mid-tropical plain zone of India. Agrofor Syst., DOI 10.1007/s10457-015-9886-7.

Vandermeer, J. (1989). Ecology of Intercroping. Cambridge University Press, Cambridge, UK.

Weaver, J.E. & Clements F.E. (1973). Plant Ecology. Tata Mc Gnaw-Hill, New Delhi.

World Bank (2013). Bangladesh Poverty Assesment: Assessing a Decade of Progress in Reducing Poverty, 2000-2010. Bangladesh Development Series Paper No. 31.