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Agro-economic performance of eggplant as lowerstoried crop in jackfruit based multistoried agroforestry system in terrace ecosystem of Bangladesh

Mohammad Mahbub Islam[1]*, Arifur Rahman[2], Farzana Zarin Eivy[3], Md. Mahmudul Hasan[4], Md. Junaied Alam[5], Md. Imran Hossain[6], Muhammad Monoar Hossain Khan[7], Md. Anayet Husain Topeder[8], BadrunNahar[9], Md. Moklesur Rahman[8], Partha Sarathi Das[10], Md. Mosaraf Hossain[1]

[1]Research Associate, Land Zoning Project, Ministry of Land, Dhaka
[2]Quarantine Entomologist, Plant Quarantine Wing, Department of Agricultural Extension, Khamarbari, Dhaka
[3]Department of Agriculture, Bangabandhu Sheikh Mujibur Rahman Science and Technology University, Gopalgonj
[4]Deputy Director (Research and Training), Patuakhali Science and Technology University, Patuakhali
[5]Upazilla Agriculture Officer, Department of Agricultural Extension, Senbag, Noakhali
[6]MS Student, Sher-e-Bangla Agricultural University, Dhaka
[7]Deputy Director, Tambulkhana seed production farm, BADC, Faridpur
[8]Junior Monitoring and Reporting Specialist, Smallholder Agricultural Competitiveness Project, Department of Agricultural, Extension, Ministry of Agriculture
[9]Assistant Professor, Department of Mathematics, Government Tolaram College, Narayanganj
[10]Lecturer, Department of Fisheries, Bangamata Sheikh Fojilatunnesa Mujib Science and Technology University, Jamalpur

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***Corresponding Author**

Mohammad Mahbub Islam
mahbub229@gmail.com

ABSTRACT

An on-farm experiment was conducted at the farmer's field from September 2011 to January 2014 at Narsingdi district which is an ideal location of central terrace ecosystem of Bangladesh. The research was aimed to evaluate the agro-economic performance of eggplant grown under 10-25 years old jackfruit trees using five treatments covering agroforestry (four orientations) and traditional farming (open field) considered as control for crop cultivation. 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; lemon, sweet orange, mandarin and papaya were established as middlestoried crops; and eggplant were grown as lowerstoried crops. At lowerstorey light availability on eggplant was 30.81%. Vegetative growth in terms of plant height, plant stem diameter and SPAD value and yield of eggplant were higher in open condition (control). Among different orientations, yield of eggplant were better at south and poor at north orientation in both the years. Soil moisture was higher in agroforestry system than control treatment but soil temperature was higher in control treatment than agroforestry system. The benefit cost ratio (BCR) for jackfruit-eggplant based multistoried agroforestry system was 4.63 and 5.26, in 2012 and 2013, respectively. The land equivalent ration (LER) for jackfruit-eggplant based multistoried agroforestry system 1.80 and 1.83 in 2012 and 2013, respectively.

INTRODUCTION

Population of Bangladesh is increasing gradually with estimated population of 161,376,708 in 2018 (UNDES, 2019). The country has only a land area of 14.39 million hectares, but to the ever-growing population per capita land area is decreasing at an alarming rate of 0.02 ha/capita/year (World Bank, 2013; Hossain and Bari, 1996). Rising population pressure and urbanization coupled with land degradation, soil salinization and global warming are causing food and nutritional insecurity of Bangladesh. On an average, the people of Bangladesh consume 166.1 g and 44.7 g of vegetables and fruits/capita/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

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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$ 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. Through agroforestry, important forest products and desirable forest environment may be obtained almost everywhere in the country (Manandhar, 1986). Jackfruit (*Artocarpus heterophyllus* Lam K.) is a multipurpose tree with a great importance for its fruit, timber, fodder and fuel wood. It is the national fruit as it is consumed by all classes of rural Bangladeshi people as well as it is native to the country (Rashid et al., 1987). Jackfruit is the principal fruit tree in Madhupur tract. It was identified as an important cash-generating crop (Ahmed, 1999). Basher (1999) found that 50 per cent of all households at Kapasia upazila under Gazipur district had pineapple gardens adjoining their homesteads mostly under the jackfruit trees. In this system, farmers believe that the partial shade of the trees improves the physical environment for pineapple that ultimately enhances the yield and quality of the later. The jackfruit trees not only provide suitable ecology for the under storey crop but also produce other basic requirements of the growers such as food, fodder, fuel wood and timber. The average annual net returns of the traditional agrisilvicultural practices were found much higher than the agriculture (Abedin and Quddus, 1991). 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 develop 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 this study was, therefore, undertaken with the objective to examine the morphological behavior, yield and yield attributes of eggplant in jackfruit based multistoried agroforestry system.

MATERIALS AND METHODS

Location of the study area

The experiment was carried out at Abdullahpur farmer's field belongs to the Belabo upazila under Narsingdi district during the period from September 2011 to January 2014. The place is geographically located at 23°46 to 24°14' north latitude and 90°35' to 90°60' east longitude (FAO/UNDP, 1988).

Climate and weather

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).

Soil characteristics

The topography of the field was medium high land above flood level belongs to the Madhupur Tract in Agro-Ecological Zone 28 (FAO/IAEA, 1988). It is characterized by shallow Red-Brown Terrace soil, which is nearly equivalent to Ustocharepts suborder under the order Inceptisol of USDA Soil Taxonomy (Brammer, 1971; Shaheed, 1984) having pH 5.5 and soil texture was clay loam being acidic in nature, poor in fertility status, and impeded internal drainage.

Experimental design

The experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. Each jackfruit tree was considered as a unit plot for a single replication. Five treatments of this study are used covering agroforestry (four orientations) and traditional farming (open field) such as 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.

Establishment of multistoried agroforestry system

The earlier established Jackfruit orchard was transformed to multistoried agroforestry system. Jackfruit trees were considered as upperstoried crop; lemon, sweet orange, mandarin and papaya were established as middlestoried crops; and eggplant, ash gourd and bottle gourd were grown as lowerstoried crops. Thirty five days old seedlings of egg plant collected from local nursery which is locally called Singnath were transplanted at 75 cm x 75 cm spacing on May 17, 2012; and May 05, 2013, respectively.

Fertilizer application

The recommended doses of fertilizers were applied @ 5000 kg of cowdung, 115 kg N, 75 kg P and 78 kg K per hectare (Rashid et al., 2006). The entire quantity of cowdung, P and half of N and K fertilizers were applied as basal dose at the time of final land preparation (BARC, 2012). The remaining N and K were applied in two equal installments at the time of flowering and fruiting (Hossain et al., 2015).

Intercultural operation

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 transplanting (DAT). The plants were irrigated whenever required to supply sufficient soil moisture. Some seedlings of egg plant were attacked by virus. Affected plants were uprooted and burnt immediately. Malathion 57 EC was applied at the rate of 2 ml l^{-1} for virus vector control each 25 days interval. Dithene M 45 was also applied at the rate of 2g lit^{-1} for protection against fungal disease after one month of seedling transplanting. Vilumeflexi Poison bait and sex pheromone were also used to reduce the infestation of insects especially white fly and fruit borer had attacked on leaves and fruits, respectively. To control those insects, malathion 57 EC @ 2 ml /L water and cypermethrin 40 EC 1 ml /L water were applied twice per week and thrice for cropping life. Dursbern 20 EC @ 2 ml /L water and Asataf 75 SP @ 1g /L water were applied to control soil borne insects.

Fruit harvesting

The harvesting started at 70 days and ended at 180 days after transplanting during both the years experimentation and three or five 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.

Data collection

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 eggplants were selected from each orientation for yield and yield attributes**.** SPAD value of eggplant leaves were measured by SPAD 502 plus chlorophyll meter and light was measured above the canopy of plants 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 am-12:00 pm. Soil moisture (%) and temperature (^{o}C) were measured by PMS-714 Soil Moisture Meter (model) and Temp 4/5/6 Thermistor Thermometer (model), respectively. Soil moisture and temperature were 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.

Economic Performance

Cost and benefit analysis were done 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.

Statistical analysis

Data were analyzed statistically by ANOVA to examine whether treatment effects were significant. Mean differences were adjusted by Least Significant Different (LSD) at 5% level of significance (Gomez and Gomez, 1984). The software package "Statistix 10.0" was followed for statistical analysis.

RESULTS AND DISCUSSION

Plant Environment

The monthly agro-meteorological data during the study period (2011-2013) have been presented in Figure 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 it was maximum in July 2012 (334.56 mm) and May 2013 (421.03 mm). Plant growth was not affected adversely though there was a prolonged 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 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.

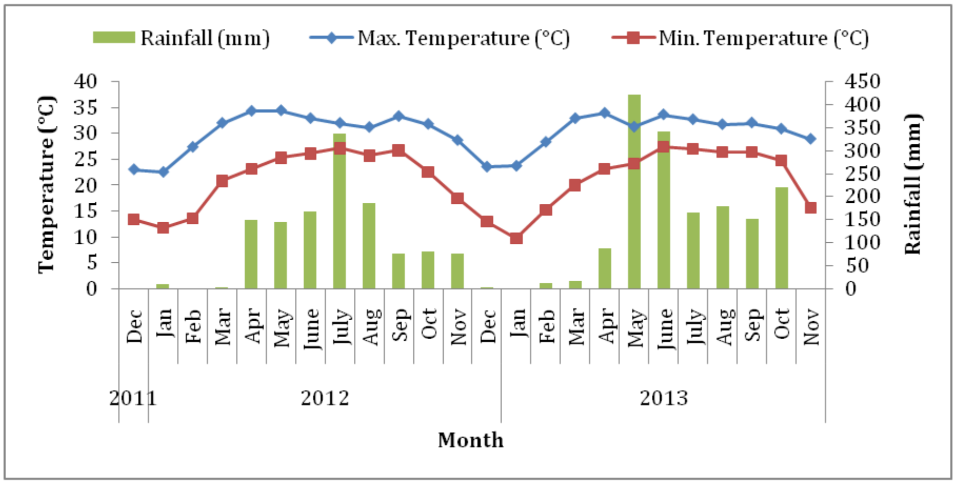

Figure 1: Monthly average rainfall and temperature at study site.

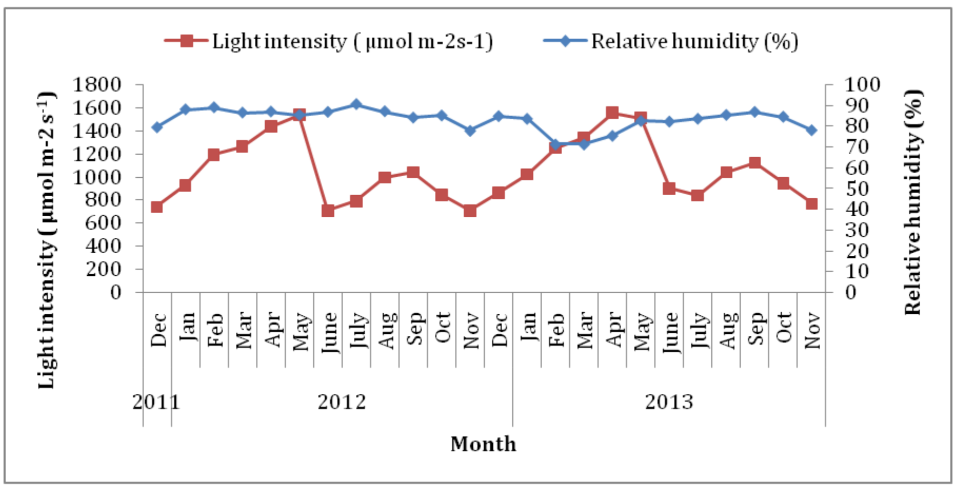

Figure 2: Monthly average light intensity (µmol $m^{-2}s^{-1}$) and relative humidity (RH).

In the agroforestry systems, Photosynthetically Active Radiation (PAR) is the most limiting factor. The light intensity (Figure 2) in the open field varied between 706 µmol $m^{-2}s^{-1}$ and 1553 µmol $m^{-2}s^{-1}$ in the study period during 2011-2013. The maximum PAR was measured in April 2013 (1553 µmol $m^{-2}s^{-1}$) and minimum in November 2012 (706 µmol $m^{-2}s^{-1}$). Due to evergreen nature of jackfruit trees, understoried crops and plants received about 30-60% light intensity compared to open field. Therefore, crop environment were favorable for understoried crop production. The highest and lowest relative humidity were recorded in July (90.4%) in 2011-12 and in March (71.22 %) in 2012-13 during the study period, respectively.

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 orientations compared to open field due to shade condition which reduced the evaporation and preserved the soil moisture (Figure 3).

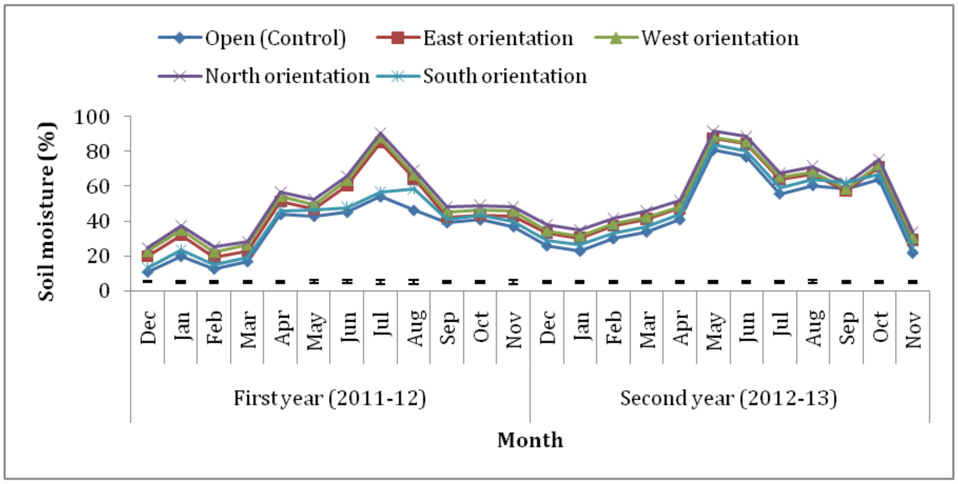

Figure 3: Soil moisture at different orientations in multistoried agroforestry system and open plot. Vertical bars indicate the ± SE values.

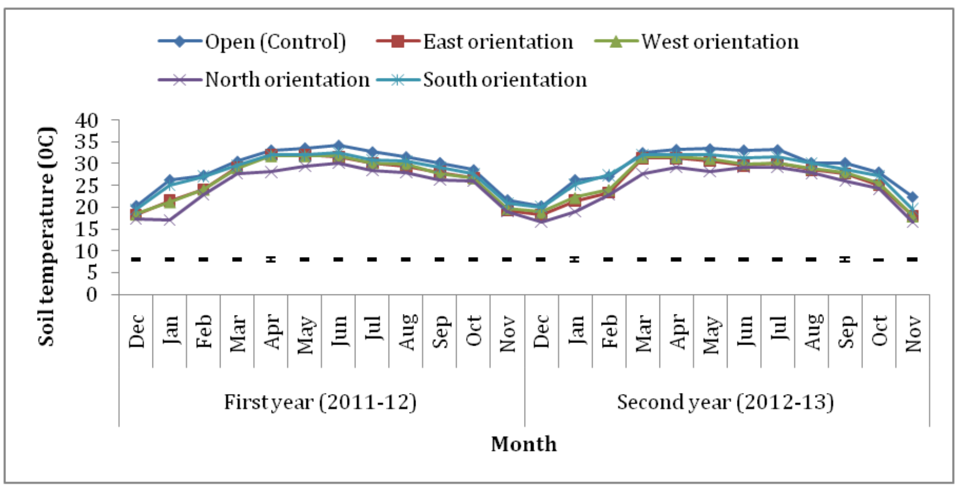

Figure 4: Soil temperature at different orientations in multistoried agroforestry system and open plot. Vertical bars indicate the ± SE values.

Soil temperature

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, favorable soil temperature conservation was 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 the reason of low soil temperature in agroforestry system.

Light availability

Light intensity of egg plant in terms of photosynthetically active radiation (PAR) was measured at every month interval during experimentation to know the light availability on associated crops in the studied jackfruit based multistoried agroforestry systems (Figure 5). However, the light availability at eggplant (lower storey crop) was reduced significantly and the light interception was 30.81% only. This might be due to higher light interception by top (jackfruit) and middlestorey (lemon, sweet orange, mandarin orange and papaya) plants. The average maximum light 850.1 µmol $m^{-2}s^{-1}$ in 2012 and 943.6 µmol $m^{-2}s^{-1}$ in 2013 were found at open (control) condition followed by different orientations of agroforestry system. Among the different orientations of agroforestry, the highest value was measured in September at south (629.7 µmol $m^{-2}s^{-1}$) and the lowest light was recorded in November at north (211.67 µmol m^{-2} s^{-1}) orientation of agroforestry, respectively in 2012. Similar trend was found in 2013. Just beneath the jackfruit tree, light availability was reduced in different orientations 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.

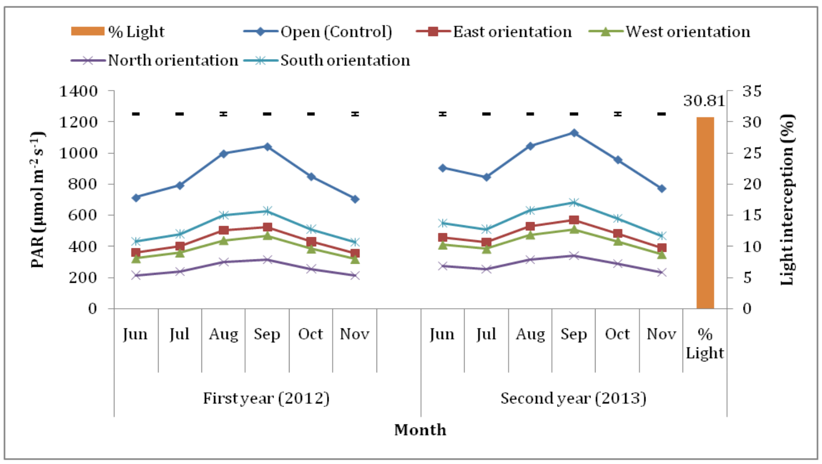

Figure 5: Light intensity on eggplant at different orientations in multistoried agroforestry system and open plot. Vertical bars indicate ±SE values.

Plant height

Usually, plant grown in low light levels was found to exhibit apical dominance than those grown in high light environment resulting in taller plants under shade (Hilman, 1984). In the study the height of eggplant was recorded every 30 days interval and the variation is presented in Table 1. At all the measurement date, the tallest plant was noted in north orientation, which was significantly different from control, east, west and south orientations. Plant height grown at open (control) and south orientation did not vary distinctly, although the shortest plant was recorded at south orientation in agroforestry system. Longer plant height under tree species might be due to diffused light of tree canopy as it promotes the development of vegetative structure (Weaver and Clements, 1973).

Stem diameter

Eggplant stem diameter at base (30 cm) was significantly varied among the agroforestry and non-agroforestry treatments (Table 2). In the study, significantly the highest and lowest stem diameter was noted in control treatment (open field) and north orientation of agroforestry, respectively in both the years. Among the agroforestry orientations, the highest value was observed in south orientation, which was statistically similar to west orientation and the lowest stem diameter was noted in north orientation of agroforestry. The diameter of eggplant grown in non-agroforestry (control) systems was relatively higher than that of agroforestry system. The higher diameter growth of egg plant species in open field was probably the benefits received by the crop species from the management practices (fertilizer, irrigation, weeding, and pest control).

SPAD value

The leaf SPAD (Soil Plant Analysis Development) value of eggplant did not vary significantly among the treatments at most of the measurement dates (Table 3). The highest and the lowest SPAD values were noted in control (open) condition and north orientation of agroforestry system, respectively. Among the agroforestry system, the highest SPAD value was recorded in south orientation. No significant difference was found in east, west and north orientation of agroforestry system. The SPAD value was higher at open field than shade condition due to plant can produce more chlorophyll under full sunlight through photosynthesis.

Fruit length

Fruit length of eggplant was remarkably varied in open field and agroforestry systems (Table 4). Significantly, the longest fruit (20.73 cm) was noted in control (open condition) in 2012 followed by south orientation. Fruit length, however, grown at east and west orientations in agroforestry system did not vary significantly. Significantly the shortest fruit (16.30 cm) was recorded in north orientation in agroforestry system. In 2013, similar trend of variation was found where significantly the longest and shortest fruits were noted in control condition and north orientation, respectively. Fruits grown under control plots exhibited maximum light and more nutrients which increased fruit length compared to that grown under tree species.

Fruit diameter

In 2012, significantly the highest (30.61 mm) and the lowest (26.16 mm) fruit diameters were recorded in control and at north orientation, respectively (Table 4). Fruit diameter in other orientations of agroforestry was statistically similar. In 2013, the maximum fruit diameter was noted in control (31.09 mm) treatment, which was statistically similar to south (30.45 mm) orientation. However, significantly the minimum fruit diameter was noted in north (27.06 mm) orientation of agroforestry system. Fruit diameter recorded in south, east and west orientations were statistically similar. 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

A significant variation was found in producing fruit weight of eggplant grown in open field and agroforestry practice (Table 4). In 2012, the highest weight per fruit (102.02 g) was noted at control condition, which was statistically similar to south (101.22g) orientation in agroforestry practice. Fruit weight grown in east and west orientations in agroforestry practice did not vary significantly, while significantly the lowest value (90.22 g) was noted at north orientation. Similar trend was found in second year (2013) experiment, where the highest (103.27 g) and significantly the lowest (91.20 g) values were noted in open field and in north orientation, respectively. Light availability was high in open field compared to agroforestry system which was reflected on fruit weight.

Table 1: Plant height of eggplant at different orientations in multistoried agroforestry system and open plot

Treatment	Plant height (cm)											
	2012						2013					
	30DAT	60DAT	90DAT	120DAT	150DAT	180DAT	30DAT	60DAT	90DAT	120DAT	150DAT	180DAT
Open (Control)	17.11c	32.06c	65.43c	118.81c	137.63e	145.47d	27.33cd	64.66c	82.69e	116.54e	149.12d	182.08d
East orientation	19.33bc	51.13ab	77.96b	142.67a	161.77b	183.23b	32.00b	81.10b	98.73c	132.53c	170.17b	196.30bc
West orientation	21.46b	46.40b	78.20b	132.17b	153.37c	173.13c	29.33bc	82.20b	105.10b	136.10b	173.27b	204.32b
North orientation	26.66a	56.50a	88.13a	147.63a	179.87a	192.27a	43.66a	97.63a	129.10a	157.97a	189.64a	218.48a
South orientation	16.17c	35.24c	60.16d	118.53c	145.30d	167.60c	26.33d	65.33c	92.73d	124.30d	161.62c	186.57cd
CV (%)	8.71	8.35	2.08	3.26	1.01	1.97	4.95	4.03	2.23	1.08	1.56	2.85
LSD	3.3045	6.9632	2.8939	8.1095	2.9688	6.3876	2.9571	5.9321	4.2717	2.7219	4.9472	10.601

Column having the same letter (s) are statistically identical and different letter (s) statistically different at 5% level of significance

Table 2: Stem diameter of eggplant at base (30 cm) over time at different orientations in multistoried agroforestry system and open plot

Treatment	Plant stem diameter (mm)											
	2012						2013					
	30DAT	60DAT	90DAT	120DAT	150DAT	180DAT	30DAT	60DAT	90DAT	120DAT	150DAT	180DAT
Open (Control)	4.67a	9.55a	13.86a	16.30a	17.01a	17.83a	6.75a	8.22b	12.91a	15.33a	16.73a	18.04a
East orientation	4.23ab	7.98bc	11.70b	12.66b	13.76c	14.90c	4.86c	6.11d	11.24d	14.75bc	15.75b	16.93b
West orientation	4.63a	8.43b	11.84b	12.83b	13.83c	14.56c	5.72b	8.21b	11.99b	14.36c	15.76b	17.69a
North orientation	3.92b	7.44c	9.98c	11.27c	12.76d	13.43d	4.80c	7.24c	11.49cd	13.45d	14.47c	16.33c
South orientation	4.25ab	8.55b	11.90b	13.00b	14.33b	15.73b	6.50a	9.95a	11.80bc	14.93ab	15.96b	17.80a
CV (%)	6.48	5.73	1.59	3.26	1.80	2.12	6.53	3.59	1.44	1.65	1.73	1.75
LSD	0.5298	0.9050	0.3561	0.8122	0.4874	0.6106	0.7042	0.5380	0.3219	0.4527	0.5127	0.5736

Column having the same letter (s) are statistically identical and different letter (s) statistically different at 5% level of significance

Table 3: Leaf SPAD value of eggplant at different orientations in multistoried agroforestry system and open plot

Treatment	Plant leaf SPAD value											
	2012						2013					
	30DAT	60DAT	90DAT	120DAT	150DAT	180DAT	30DAT	60DAT	90DAT	120DAT	150DAT	180DAT
Open (Control)	36.46a	38.90a	39.66a	44.80a	46.13a	47.93a	40.20a	40.23ab	42.33a	42.90a	46.16a	48.23a
East orientation	35.16b	36.10c	37.13c	41.96b	43.30cd	45.26b	37.60ab	39.26b	40.13b	41.46b	43.93b	45.33b
West orientation	35.30b	36.33bc	37.53bc	42.40b	43.73bc	44.90b	37.90ab	40.86a	41.93a	42.43a	43.56c	45.26b
North orientation	35.43b	36.06c	37.23c	41.63b	42.80d	43.70c	36.30b	36.76c	38.76c	40.10c	42.83d	43.96c
South orientation	35.33b	36.56b	38.06b	42.83b	44.16b	45.16b	39.80a	40.23ab	41.50a	42.53a	43.43c	45.56b
CV (%)	1.25	0.64	0.85	1.56	1.03	0.79	3.87	1.36	1.50	0.68	0.44	0.63
LSD	0.8375	0.4409	0.6072	1.2530	0.8501	0.6758	2.7956	1.0087	1.1579	0.5386	0.3622	0.5375

Column having the same letter (s) are statistically identical and different letter (s) statistically different at 5% level of significance

Table 4: Yield of eggplant at different orientations in multistoried agroforestry system and open plot

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)	20.73a	21.46a	30.61a	31.09a	102.02a	103.27a	9.58a	9.67a	977.66a	998.58a
East orientation	18.06c	19.32c	28.64b	29.36b	94.33b	95.45b	8.42b	8.37c	794.33b	799.20b
West orientation	18.13c	19.41c	28.75b	29.41b	94.82b	96.60b	8.41b	8.13d	798.05b	786.03c
North orientation	16.30d	18.99d	26.16c	27.06	90.22c	91.20c	7.40c	8.06e	667.94c	735.71d
South orientation	19.20b	21.02b	29.43b	30.45ab	101.22a	102.70a	9.52a	9.61b	963.64a	987.64a
CV (%)	1.26	0.83	1.74	2.04	1.87	0.74	3.21	0.26	3.57	0.81
LSD	0.4392	0.3150	0.9410	1.1296	3.3900	1.3587	0.5231	0.0436	56.48	13.124

Column having the same letter (s) are statistically identical and different letter (s) statistically different at 5% level of significance

Number of fruits per plant

Number of fruits per plant was higher in open condition than in agroforestry system in both the years. Number of fruits per plant was relatively higher in 2013 than 2012 for both open and agroforestry conditions. In 2012, the maximum number of fruits (9.58) per plant was noted in control treatment, which was statistically similar to south orientation (9.52) in agroforestry system. On the other hand, no significant variation in producing number of fruits per plant was noted between east and west orientations, while significantly the lowest number of fruit was recorded in north orientation. In 2013, significantly the highest and lowest numbers per plant were recorded in open and north orientation under agroforestry system, respectively. No significant variation was found among south, west and east orientations (Table 4). Shade cast by tree canopy decreased the reproductive growth of plant and that might have accounted for lower number of fruits per plant under agroforestry systems.

Fruit yield per plant

A significant variation was observed in producing fruit yield per plant between agroforestry (orientation) and non-agroforestry (open) systems in both the experimentation years (Table 4). In 2012, yield per plant (977.66 g) was significantly higher in open (control) field, which was statistically similar to south (963.64 g) orientation of agroforestry. However, significantly the lowest yields per plant were recorded in north (667.94 g) orientation under agroforestry system. There had no significant variation between east (794.33 g) and west (798.05 g) orientations. In 2013, the highest (998.58 g) and lowest (735.71 g) yields per plant were recorded in open and north orientation under agroforestry system, respectively. Yield reduction in agroforestry system was due to competition between tree and crop for light, water and nutrients. In this study, water and nutrient were not so much limited as these resources were applied for crop production. However, light was the most limiting factor for multistoried agroforestry system. Moreover, the canopy of jackfruit tree was dense and light availability was minimum at the vicinity of the tree base as cited in production environment section

Economic performance

The economic performance of Jackfruit-eggplant based agroforestry systems was estimated (Tables 5 & 6). The overall economic performance of Jackfruit-eggplant based agroforestry system was found to outperform over sole system. The average net return of Jackfruit-eggplant based agroforestry system was 32% and 37% higher than that of sole cropping during both the years. Between the agroforestry and sole systems, the highest net return from Jackfruit-eggplant based agroforestry system was because of good return from jackfruit and eggplant 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 5: Total cost and return from jackfruit based agroforestry and control system

System	Total cost (Tk ha^{-1})		Total return (Tk ha^{-1})		Net return (Tk ha^{-1})	
	2012	2013	2012	2013	2012	2013
Jackfruit-eggplant	87707	88772	406420	467640	318712	378867
Sole eggplant	87207	88272	347600	390500	260392	302227

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 6. Between two years, BCR was higher in Jackfruit-eggplant as compared to sole systems. 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 observed in jackfruit-eggplant plant system than that of sole cropping which was 1.80 in 2012 and 1.83 in 2013 respectively. It indicated that 1.80 and 1.83 times higher land would be required to get similar productions from sole cropping as compared to agroforestry system during 2012 and 2013, respectively.

Table 6: Benefit-cost ratio (BCR) and land equivalent ration (LER) of different agroforestry and control system

System	Benefit-cost ratio (BCR)		Land equivalent ratio (LER)	
	2012	2013	2012	2013
Jackfruit-eggplant	4.63	5.26	1.80	1.83
Sole eggplant	3.98	4.42	1	1

CONCLUSION

The highest plant height was at north orientation but the lowest value of plant height was recorded in control condition in both the years. The highest and lowest plant diameter and leaf SPAD values were recorded in control treatment and in north orientation, respectively. Light availability was found higher in control plots compared to agroforestry systems. Therefore, higher soil moisture and favorable soil temperature conservation were observed in agroforestry system. Significant variations were found in terms of fruit length, fruit diameter, individual fruit weight, fruits per plant and yield of fruits in producing at different treatments during study time. The longest fruit (20.73 cm and 21.46 cm in 2012 and 2013, respectively) was noted in control (open condition) and significantly the shortest fruit (16.30 cm and 18.99 cm in 2012 and 2013, respectively) was recorded at north orientation. However, the highest (30.61 mm and 31.09 mm in 2012 and 2013, respectively) and the lowest (26.16 mm and 27.06 mm in 2012 and 2013, respectively) fruit diameters were recorded in control and at north orientation, respectively. The highest weight of individual fruit (102.02 g and 103.27 g in 2012 and 2013, respectively) was noted at open (control) condition which was statistically similar to south orientation in agroforestry practice. Fruit weight grown at other orientations (east and west) of agroforestry practice did not vary significantly, although the lowest value (90.22 g and 91.20 g in 2012 and 2013, respectively) was noted at north orientation. The maximum number of fruits (9.58 and 9.67 in 2012 and 2013, respectively) per plant was also noted in control treatment which was statistically similar to south orientation and minimum (7.40 and 8.06 in 2012 and 2013, respectively) number of fruits per plant was recorded at north orientation of agroforestry. The maximum yield (977.66 g and 998.58 g in 2012 and 2013, respectively) per plant was noted in control treatment which was statistically similar to south orientation, and minimum (667.94 g and 735.71 g in 2012 and 2013, respectively) per plant was recorded at north orientation which was also similar to other orientations of agroforestry. Net return and BCR from jackfruit-eggplant based agroforestry system was higher than sole system in both the years. The LER of jackfruit-eggplant based agroforestry system were 1.80 and 1.83 in 2012 and 2013, respectively.

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