Bangladesh J. Agric. and Environ. 14 (1): 29-42, June 2018

PERFORMANCE OF MUNGBEAN AS LOWERSTORIED CROP IN AONLA BASED MULTISTORIED AGROFORESTRY SYSTEM IN TERRACE ECOSYSTEM OF BANGLADESH

M G G Mortuza

M G G Mortuza, M G Miah[1]
M M U Miah[1] and M Z I Khan[2]

Project Director, Expansion of Cotton Cultivation Project
Cotton Development Board, Khamarbari, Dhaka, Bangladesh.

Abstract

The study was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University experimental farm from March 2009 to June 2009 and from March 2010 to June 2010 to know the morphological behavior, yield and yield contributing characters of mungbean varieties under multistoried agroforestry system in the terrace ecosystem of Bangladesh. Mungbean varieties were used as lowerstoried crop. Three mungbean varieties i.e., BU Mung 2 (V_1), BARI Mung 5 (V_2), and BARI Mung 6 (V_3) were tested following Randomized Complete Block Design (RCBD) with three replications. Three different combinations were T_1 = Aonla only, T_2 = Aonla + Middlestoried tree species (Carambola and Lemon), and T_3 = Open Field (control). Yield and yield contributing characters of mungbean varieties i.e., number of pod plant^{-1}, seed pod^{-1}, thousand seed weight and grain yield were found to be highest in T_3V_3 combination (BARI Mung 6 in open field), which was followed by T_3V_1, T_2V_3 and T_1V_3. Relationship between yield of mungbean varieties and light intensity (µmol m^{-2}s^{-1}) revealed that grain yields of mungbean varieties were increased with increasing light intensity (µmol m^{-2}s^{-1}). Among the varieties, BARI Mung 6 showed better performances in all treatment combinations in terms of benefit cost ratio (BCR), harvest index (HI) and land equivalent ratio (LER).

Key words: Organic, Inorganic, Indian Spinach, Yield.

Introduction

Most of the arable land in Bangladesh is intensively used for food production, because the country is running shortage of food grains. About 80% of arable lands are used for cereal crop production, which consequently reduce the area of other cash crops. In the terrace ecosystem of Bangladesh, medicinal plants like aonla are grown as natural vegetation. Aonla (*Phyllanthus emblica*) belongs to the family Euphorbiaceae, is one of the important medicinal plants in Bangladesh. It is indigenous to tropical South-east Asia and is under cultivation since ancient times (Firminger 1947). The fruit is highly nutritious and is the richest source of vitamin C. It is also the richest source of pectin. Medicinally, it acts as coolant, refrigerant, diuretic and laxative. Carambola (*Averrhoa carambola* L.) is an important fruit in the tropical and sub-tropical areas of the world. It is also a rich source of reducing sugars, ascorbic acid and minerals as K, Ca, Mg, and P (Haick 1952). Lemon is also a vitamin C rich crop which is adaptable to wide range of soils, environment and cultural arrangements over 100 nations (Ghosh *et al.* 2001). Carambola as a dwarf species is found to grow under some large trees in the homesteads of the country. Lemon is normally grown as a lowerstoried species in the dense homestead vegetation of Bangladesh. So, these two species have enough potentiality to grow as middlestoried component of multistoried agroforestry systems.

In both area and production, mungbean (*Vigna radiata*) is one of the important pulse crops in Bangladesh. Among the pulse crops, mungbean has importance in

[1]Professor, Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh
[2]Senior Executive Officer, Bangladesh Fertilizer Association, Purana Paltan, Dhaka, Bangladesh.

intensive crop production of the country for its short growing period (Ahmed *et al.* 1978). Not only that, mungbean has good potential to improve soil health by N_2 fixation and added organic matter to the soil. It can easily be fitted in the lowerstoried cropping pattern of agroforestry system as it has shade tolerant capacity (Sundari 2009).

The existing land use systems with separate allocation to agriculture and forest are insufficient to meet the demands for food, fuel, fodder, timber and other minor products in the 21st century. One should follow effective and compatible cultivation approaches where medicinal plants, fruits, fiber crop and pulse can be grown combined in the limited land. In this regard, the multistoried agroforestry system may be the best substitute cultivation approach. By practicing this cultivation system, one can efficiently amplify the production of medicinal plants, fruits, and fibre crop simultaneously from the same piece of land.

Multistoried production system is a complex phenomenon that combines all farming components layer by layer and provides food, fodder, fuel, timber and medicine to the millions of households. Most of the households in the country are acting as multistoried agroforestry unit. About 70 percent fruit, 40 percent vegetable, 70 percent timber and 90 percent firewood and bamboo production of the country comes from the homesteads (Miah and Hussain 2010).

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 medicinal plant (aonla), fruit trees (carambola, lemon), and pulse crop (mungbean) utilizing optimum natural resources (light, water, nutrient and vertical space) for homesteads / small land utilization. Therefore, this experiment has been undertaken to examine the morphological behavior, yield and yield attributes of mungbean in aonla based multistoried agroforestry system.

Materials and Methods

The experiment was conducted in the research field of the department of agroforestry and environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) from March 2009 to June 2009 and from March 2010 to June 2010. The university is located in Gazipur district; 50 km away from the capital city Dhaka of Bangladesh. The study area belongs to the agro-ecological zone 28 i.e. the Madhupur tract which lies between 24°09' N latitude and 90°26' E longitude with a mean elevation of 8.5 m above sea level (FAO/UNDP 1988).

The climate of the area is sub-tropical, characterized by a heavy rainfall during the period from July to September and scanty rainfall during the period of October to March. The pre-monsoon or hot season with scanty rainfall was observed from March to June. The soil of the experimental field was terrace soil, which is nearly equivalent to Ustocharepts suborder under the order Inceptisol of USDA Soil Taxonomy and belongs to the locally termed Salna Series of Shallow Red-Brown Terrace Soil (Brammer 1971; Shaheed 1984). The soil at the study site is silty clay loam in texture being acidic (pH 5.79) in nature, poor in fertility status, and impeded internal drainage.

The aonla orchard was established in 2000 maintaining 8 m x 8 m distance at the research farm of the Department of Agroforestry and Environment, which was used for the experimentation. Aonla trees were planted in North-South direction. There were six rows of aonla trees and each row had eleven trees. The aonla trees of the extreme northern side were considered as open field (control). Lemon and carambola were planted on November 2008 in between the aonla trees and open field condition to examine their performance. One year old seedlings of carambola and lemon were collected from Horticulture Research Centre of the Bangladesh Agricultural Research Institute (BARI), Gazipur. The aonla orchard was divided into four parts. To develop multistoried nature, carambola plant was planted just in the middle of two aonla trees and lemon plant was planted just in the middle in between aonla and carambola plant as lemon and carambola formed middlestorey standing in the same line of aonla in South-Western part. South-Eastern three rows of aonla were free from middlestoried trees (no carambola and lemon). In North-Western side only carambola plants were planted just in the middle of the two aonla trees. Only lemon plants were planted North western part of the orchard. The variety of aonla was local race, carambola was BARI Kamranga-1 and lemon was seedless BARI lebu. Three mungbean varieties (BU Mung 2, BARI Mung 5 and BARI Mung 6) were tested in the alley of the aonla trees.

The research was done for the sustainable and productive aonla based multistoried agroforestry

practices. With these aims in mind an aonla orchard was developed with middlestoried tree species namely, carambola (*Averrhoa carambola*) and lemon plant (*Citrus limon*). Three cotton (*Gossypium hirsutum*) varieties were tested in two successive seasons in aonla orchard. At aonla based multistoried agroforestry system, aonla was used as the upperstoried tree species and carambola and lemon were used as middlestoried; cotton was the lowerstoried crop.

The experiment was laid out following two factors Randomized Complete Block Design (RCBD) with three replications. The plot size for each treatment was 6 m X 7 m. Adjacent plots were separated by 1 m distance and neighboring blocks were separated by aonla and middle storied trees. Open field was adjacent to the south of aonla orchard. The experiment consisted of two factors, which were Factor A: Tree combinations T_1 = Aonla only, T_2 = Aonla + Middle storied tree species (Carambola and Lemon) and T_3 = Open Field (control); factor B: mungbean varieties are used for the study- Variety 1- BU Mung 2, Variety 2 - BARI Mung 5 and Variety 3 - BARI Mung 6.

The recommended doses of fertilizer for mungbean varieties were used in the experiments. All chemical fertilizers were applied @ 21 kg ha^{-1} of N, 20 kg ha^{-1} of P, 30 kg ha^{-1} of K, and 7.20 kg ha^{-1} of S in the form of urea, TSP, MP and Gypsum, respectively. All fertilizers were applied as basal dose at the time of final land preparation. Weeding was done at 15 and 30 days after sowing to keep the crop weed free. Thinning was done twice, once just after emergence and another 15 DAS just after first weeding. Finally 10 cm plant to plant distance was maintained. The excess rain water was drained out through side canal of the plot. For yield components of mungbean, ten plants of each variety were selected randomly from each replication at early stage of crop. The harvesting of mungbean pods was started 55 DAS and ended 75 DAS.

Yield of mungbean varieties was determined from the summation of all picking period and then converted to kg ha^{-1}. Length of individual pod, seed per pod and thousand seed weight were also recorded from the ten randomly selected plants of each plot. Light was measured by Sunflex Ceptometer (LP-80 AccuPAR) on each replication. It was done to determine the extent of shading by the aonla tree species and expressed as µmm^{-2}s^{-1}. Light intensities were measured above the canopy of mungbean crop in agroforestry plots and in the respective sole crop plots at 9:00-10:00 AM, 12:00-1:00 PM, and 3:00- 4:00 PM using LP-80 AccuPAR Ceptometer at 3 times per month and the collected data were averaged and expressed as µmm^{-2}s^{-1}.

Harvest index (HI) and land equivalent ratio (LER) are the two measurements of productivities which are normally used in agroforestry. So the productivity evaluations of the experimental systems are done by HI and LER.

Harvest index denoted ratio of economic yield to biological yield and was calculated with the following formula (Gardner *et al.* 1985):

Harvest index (%) = Grain yield/Biological yield x 100

For harvest index calculations, only above-ground dry matter was considered. Below ground dry matter production is very important too, because of its role in maintenance of soil organic matter. The mass of dry matter is no indication of economic value of the product.

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.

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.

The performances of the mungbean crop on various morphological and physiological parameters were analyzed using statistical program of MSTAT–C to find out the statistical significance of the treatment effects. The means for all the treatments and analysis of variance for all the characters were calculated. The mean differences among the treatments were evaluated by Duncan's Multiple Range Test (DMRT) at 1% and 5% levels of significance (Gomez and Gomez 1984).

Results and Discussion

Plant Environment

The monthly agro-meteorological data during the study period (2009-2010 and 2010-2011) have been presented in the Fig. 1 and 2. In Fig. 1, it was observed that there was a distinct dry season from November to April and a wet season from May 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 occurred in August 2009 (590.34 mm) and June 2010 (369.53 mm). Plant growth was not affected adversely though this was a prolong dry season and low ground water table (fluctuating from 14.6 m to 17.47 m in 2009 and 16.84 m to 19.32 m in 2010) due to moderate rooting systems of aonla trees. During the wet season (May 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.

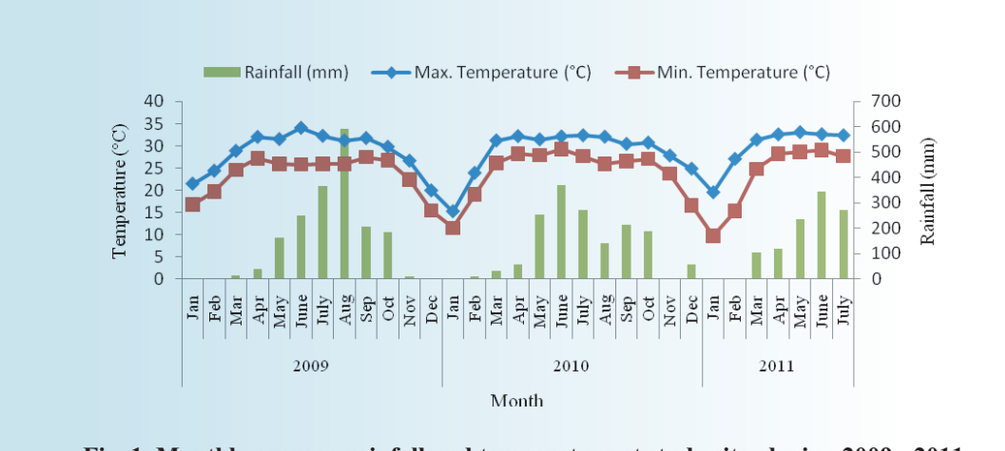

Fig. 1. Monthly average rainfall and temperature at study site, during 2009 - 2011.

The mean maximum air temperature was the highest in June 2009 (34.00°C) and July 2010 (32.32°C) and the lowest mean maximum temperature was in December 2009 (15.45°C) and January 2010 (11.58°C). The average maximum and minimum temperatures were 29.04°C and 24.23°C, respectively. The mean maximum temperature varied between 15.20°C and 34.00°C during the study period. On the other hand, the mean minimum temperature varied between 11.58°C and 27.90 °C.

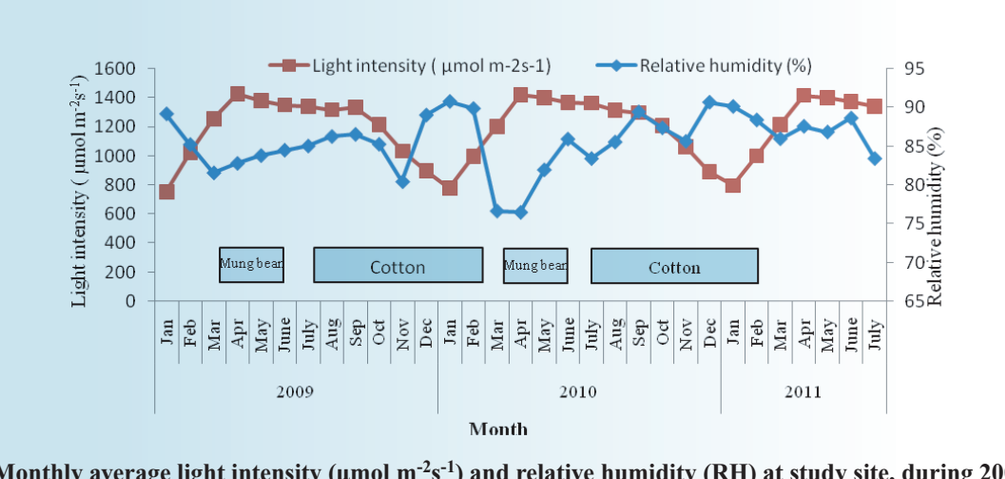

Fig. 2. Monthly average light intensity (µmol m^{-2}s^{-1}) and relative humidity (RH) at study site, during 2009 - 2011.

In the agroforestry systems, Photosynthetically Active Radiation (PAR) is the most limiting factor. The light intensity in the open field varied between 753 µmolm^{-2}s^{-1} and 1427 µmm^{-2}s^{-1} in the study period during 2009-2011. The maximum PAR was measured in April 2009 (1427 µmm^{-2}s^{-1}) and minimum PAR was measured in January 2009 (752 µmm^{-2}s^{-1}). Due to deciduous nature of aonla trees, understoried crops and plants received about 80 - 90% light intensity compared to open field. Therefore, crop environment was favourable for understoried crop

production. From the Fig. 2, it was found that when light intensity was higher, in contrary relative humidity was lower. The highest relative humidity was recorded in January (90.80%) in 2010. On the other hand, the lowest relative humidity was recorded in March (76.70%) and April (76.53%) in 2010 during the study period.

Availability of Photosynthetically Active Radiation (PAR)

Availability of light is the most important factor for the understoried crops in aonla based agroforestry systems. Different plants received different light levels as well. The monthly mean percentage of light incident in the aonla based agroforestry systems during 2009 and 2010 at mungbean cropping season has been presented in Fig. 3 and 4.

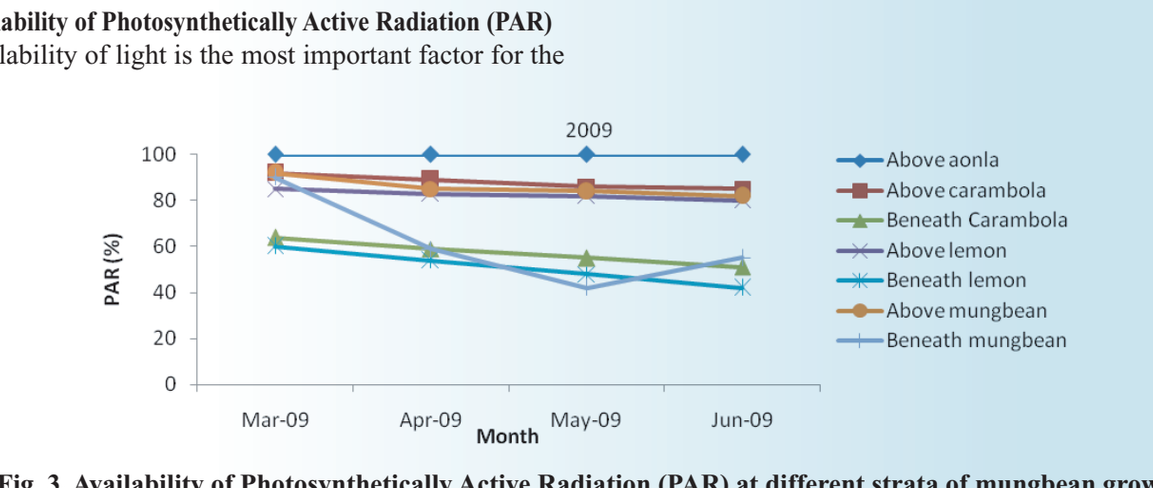

Fig. 3. Availability of Photosynthetically Active Radiation (PAR) at different strata of mungbean growing season in aonla based multistoried agroforestry system during 2009.

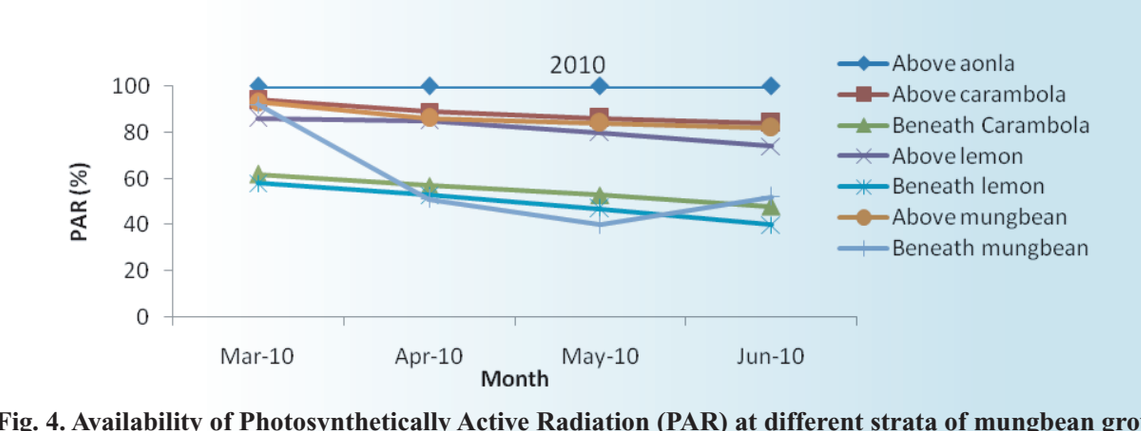

Fig. 4. Availability of Photosynthetically Active Radiation (PAR) at different strata of mungbean growing season in aonla based multistoried agroforestry system during 2010.

Upper-storied plant aonla received 100 percent PAR, but incident light was gradually decreased on carambola, lemon and mungbean. Light reduction on above mungbean crop was 7-8% in March and it was gradually reduced up to 18-20% in May in the both growing seasons. On the other hand, light reduction beneath the mungbean crop was 8-10% in March and it was gradually reduced to about 52-60% in May in both the growing seasons. Among the trees and crops, the lowest light incident was received by lemon in the growing season of mungbean.

Soil Moisture in Agroforestry Systems

The soil moisture (%) was recorded at 20 days interval during mungbean cultivation (Fig. 5) i.e. moisture data was recorded at 20, 40 and 60 DAS, respectively. Irrespective of sampling dates, the maximum soil moisture was found in Aonla + Carambola-Lemon + Mungbean based agroforestry system which was identical to that of Aonla + Mungbean based agroforestry system. Significantly, the lowest amount of soil moisture was recorded in the open field on both cropping years at each sampling dates.

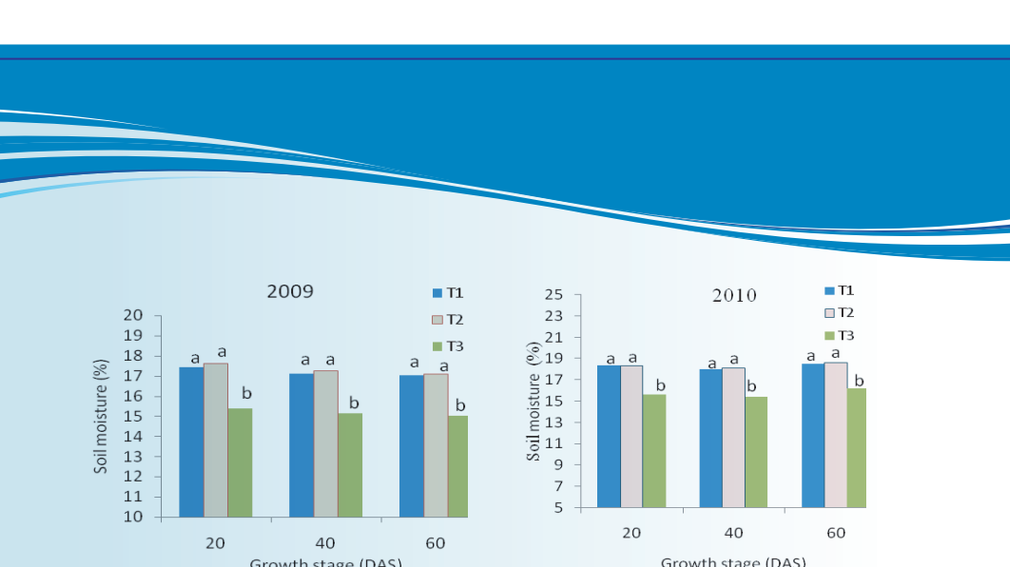

Fig. 5. Soil moisture at different growth stages of mungbean as influenced by aonla based multistoried agroforestry systems during 2009 and 2010 (T_1 = Aonla + Mungbean, T_2 = Aonla + Carambola- Lemon + Mungbean and T_3 = Open Field).

Soil Temperature in Agroforestry Systems

The soil temperature (°C) was recorded over the time (at 20 days interval) in mungbean field (Fig. 6). Irrespective of sampling dates, soil temperature increased with the increasing of day after measurement. Among the agroforestry systems and open field, significantly (p<0.01) the highest soil temperature was recorded in open field. The minimum soil temperature was recorded under Aonla + Carambola-Lemon + Mungbean agroforestry system which was insignificant for Aonla + Mungbean agroforestry system.

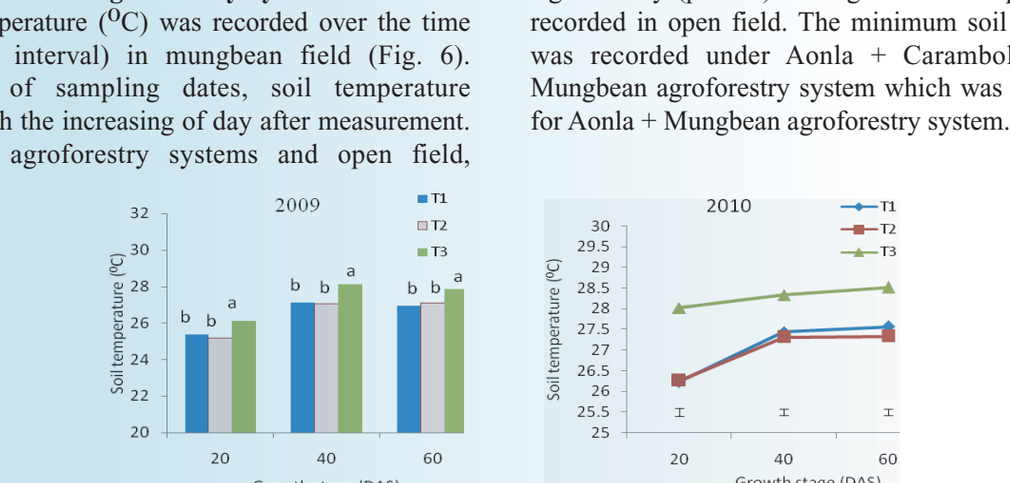

Fig. 6. Soil temperature at different growth stages of mungbean as influenced by aonla based multistoried agroforestry systems during 2009 and 2010 (T1= Aonla + Mungbean, T2 = Aonla + Carambola- Lemon + Mungbean and T3 = Open Field).

Plant height

Plant height of mungbean is an important morphological characteristic that was significantly influenced by different agroforestry systems and open field (Fig. 7). Among the agroforestry systems and open field, significantly the tallest plant was observed under Aonla + Carambola-Lemon + Mungbean based agroforestry system at all sampling dates in both the growing season which was followed by Aonla + Mungbean agroforestry system. Significantly the shortest plant was recorded under open field condition. Similar result was observed by Reza (2005), Bashir (2002) in mungbean and Miah (2001) in tomato.

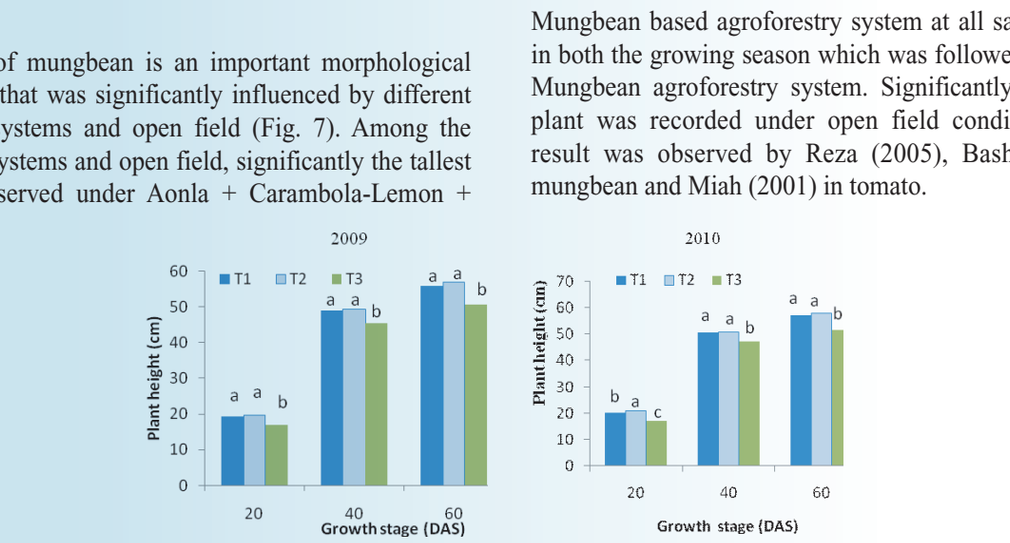

Fig. 7. Plant height of mungbean at different stages during 2009 and 2010 as influenced by aonla based agroforestry system (T_1 = Aonla + Mungbean, T_2 = Aonla + Carambola-Lemon + Mungbean and T_3 = Open Field).

Plant height of mungbean was significantly different due to the varietal characteristics (Fig. 8). In 2009, significantly the tallest plant (58.38 cm) was found in BARI Mung 6. Significantly the smallest plant (51.60 cm) was observed in BARI Mung 5 which was similar to that of BU Mung 2. In 2010, significantly the tallest plant (59.84 cm) was also found in BARI Mung 6 followed by BU Mung 2. Significantly the smallest plant (52.02 cm) was also observed in BARI Mung 5. The plant height of different mungbean varieties varied due to their genetic characteristics.

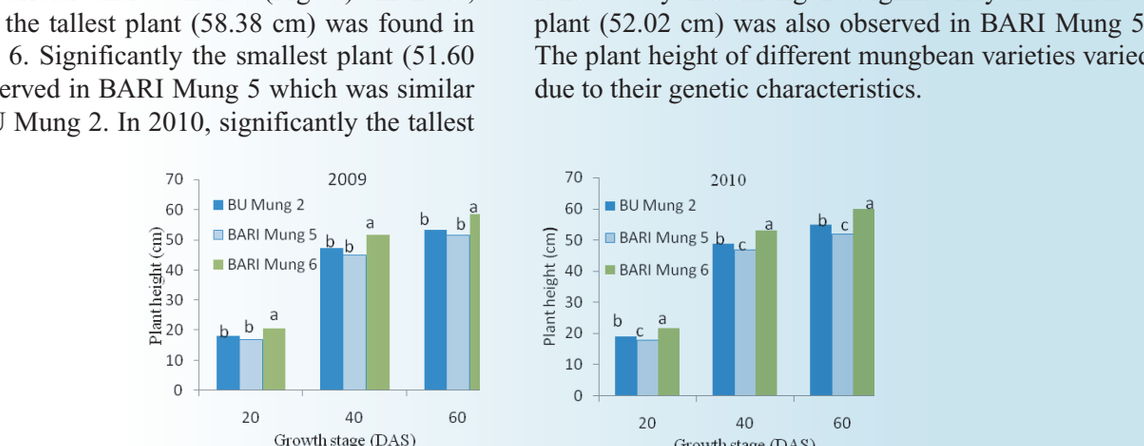

Fig. 8. Response of plant height of different mungbean varieties at different growth stages during 2009 and 2010 under aonla based agroforestry systems.

Duration of mungbean crop

The interaction effect of agroforestry systems and varieties of mungbean on crop duration was significant (Table 1). Significantly (p< 0.01) the longer duration was required in aonla based agroforestry systems while open field condition required shorter duration. Among the varieties, BARI Mung 5 needed maximum duration (75.00 days in 2009 and 2010) in aonla based agroforestry systems, while minimum duration (62.00 days and 61.33 days in 2009 and 2010 respectively) was recorded in BU Mung 2 at open field condition. The present study revealed that agroforestry systems prolonged duration in mungbean varieties.

Table 1. Interaction effect of agroforestry systems and varieties of mungbean on duration in aonla based multistoried agroforestry systems during 2009 and 2010.

Treatment combination	Duration of Mungbean	
	2009	2010
T_1V_1	73.33 a	72.67 a
T_1V_2	75.00 a	75.00 a
T_1V_3	69.00 bc	68.33 b
T_2V_1	72.00 ab	73.67 a
T_2V_2	73.67 a	73.33 a
T_2V_3	68.33 bc	68.67 b
T_3V_1	62.00 d	61.33 d
T_3V_2	65.33 cd	66.00 bc
T_3V_3	63.00 d	63.33 cd
LSD (0.01)	4.10	3.56
CV (%)	5.49	4.16

In a column, means followed by same letter (s) are not statistically different by DMRT.
T_1= Aonla + Mungbean, T_2 = Aonla + Carambola- Lemon + Mung bean and T_3 = Open Field,
V_1= BU Mung 2, V_2= BARI Mung 5 and V_3= BARI Mung 6.

Number of pods plant^{-1}

Number of pods plant^{-1} is one of the yield contributing characters of mungbean which was significantly influenced by the aonla based multistoried agroforestry systems and open field condition. Significantly the maximum number of pod plant^{-1} (8.71 and 8.77 in 2009 and 2010, respectively) was recorded in open field condition. The minimum number of pod (7.67 and 8.00 in 2009 and 2010, respectively) was recorded in Aonla + Carambola-Lemon + Mungbean (T_2) agroforestry system which was significantly followed by Aonla + Mungbean (T_1) agroforestry system.

Number of pod plant^{-1} of mungbean varieties was significantly influenced in aonla based multistoried agroforestry systems. Effect of influence pattern of pod plant^{-1} was almost similar in 2009 and 2010 cropping season. Significantly the highest number of pod plant^{-1} (8.78 and 9.40 in 2009 and 2010, respectively) was recorded in BARI Mung 6 in both the years. Significantly the lowest number of pod plant^{-1} (7.49 and 7.52 in 2009 and 2010, respectively) was found in BARI mung 5.

Interaction effect of agroforestry systems and varieties of mungbean on number of pod plant^{-1} showed that there was significant variation among the treatment combinations and influencing trend was almost similar in both the years (Table 2). The highest number of pod plant^{-1} was produced by BARI Mung 6 (9.40 and 9.67 in 2009 and 2010, respectively) in open field condition (T_3V_3) which was followed by T_2V_3 treatment combination in both years. Significantly the lowest number of pod plant^{-1} (7.13) was produced by T_2V_2 treatment combination in 2009 but T_1V_2 (7.23) treatment combination in 2010. The present study revealed that the number of pod plant^{-1} decreased with the increase of light intensities.

Table 2. Interaction effect of agroforestry systems and varieties on number of pod per plant in aonla based multistoried agroforestry system during 2009 and 2010.

Treatment Combination	Number of pod plant^{-1}			
	40 DAS		60 DAS	
	2009	2010	2009	2010
T_1V_1	4.73 c	4.60 d	7.40 d	7.33 e
T_1V_2	4.80 c	4.73 d	7.20 d	7.27 e
T_1V_3	6.00 b	5.87 bc	8.40 bc	9.20 b
T_2V_1	4.60 c	4.67 d	7.33 d	7.33 e
T_2V_2	4.53 c	4.53 d	7.13 d	7.33 e
T_2V_3	5.93 b	6.13 ab	8.53 b	9.33 ab
T_3V_1	5.87 b	6.00 bc	8.60 b	8.67 c
T_3V_2	5.77 b	5.47 c	8.13 c	7.97 d
T_3V_3	6.53 a	6.60 a	9.40 a	9.67 a
CV (%)	3.52	2.17	4.05	3.79

In a column, means followed by same letter (s) are not statistically different by DMRT.
T_1= Aonla + Mungbean, T_2 = Aonla + Carambola- Lemon + Mung bean and T_3 = Open Field,
V_1= BU Mung 2, V_2= BARI Mung 5 and V_3= BARI Mung 6.

Number of seed pod^{-1}

Number of seed pod^{-1} of mungbean was significantly influenced by the aonla based agroforestry systems and open field condition (Table 3). Significantly the highest number of seed pod^{-1} (9.43 and 9.48 in 2009 and 2010, respectively) was recorded in open field condition. Significantly the lowest number of seed pod^{-1} (8.78 and 8.72 in 2009 and 2010, respectively) was recorded in Aonla + Carambola-Lemon + Mungbean (T_2) agroforestry system which was statistically similar with Aonla + Mungbean (T_1) agroforestry system.

Number of seed pod^{-1} of mungbean varieties was significantly influenced due to varietal characteristics (Table 3). Influencing trend of number of seed pod^{-1} of mungbean was almost similar in 2009 and 2010 cropping seasons. Significantly the highest seed pod^{-1} (9.76 and 9.61 in 2009 and 2010, respectively) was recorded in BARI Mung 6 in both the years. Significantly the lowest seed pod^{-1} (8.50 and 8.52 in 2009 and 2010, respectively) was found in BARI Mung 5.

Number of seed per pod showed significant differences due to the interaction of agroforestry systems and varieties (Table 3). Significantly the highest number of seed pod^{-1} (10.13 and 10.17 in 2009 and 2010, respectively) was produced by BARI Mung 6 in open field condition (T_3V_3) which was followed by T_3V_1 treatment combination in both years. Significantly the lowest number of seed pod^{-1} (8.27 and 8.40 in 2009 and 2010, respectively) was produced by T_2V_2 treatment combination. The present study revealed that the lower number of seed pod^{-1} under aonla based agroforestry systems was probably due to poor photosynthetic capacity of plants. Similar variability in number of seed pod^{-1} of mungbean varieties was noted by Miah (2010), Reza (2005), Chowdhury *et al.* (1988), Ali and Shaikh (1987), Khanum *et al.* (1982) and Tickoo *et al.* (1988).

Table 3. Interaction effect of agroforestry systems and varieties on seed per pod of mungbean in aonla based multistoried agroforestry systems during 2009 and 2010.

Treatment combination	seed per pod	
	2009	2010
T_1V_1	8.50 de	8.47 d
T_1V_2	8.33 e	8.33 d
T_1V_3	9.67 b	9.40 bc
T_2V_1	8.60 de	8.50 d
T_2V_2	8.27 e	8.40 d
T_2V_3	9.47 b	9.27 bc
T_3V_1	9.27 bc	9.43 b
T_3V_2	8.90 cd	8.83 cd
T_3V_3	10.13 a	10.17 a
CV (%)	5.90	3.53

In a column, means followed by same letter (s) are not statistically different by DMRT.
T_1= Aonla + Mungbean, T_2 = Aonla + Carambola- Lemon + Mungbean and T_3 = Open Field,
V_1= BU Mung 2, V_2= BARI Mung 5 and V_3= BARI Mung 6.

Thousand seed weight of mungbean

Thousand seed weight of mungbean was significantly influenced by the aonla based agroforestry systems and open field condition (Fig. 9). Significantly the highest thousand seed weight (49.47 g and 49.49 g in 2009 and 2010, respectively) was recorded in open field condition. Significantly the lowest thousand seed weight (46.63 g and 46.48 g in 2009 and 2010, respectively) was recorded in Aonla + Carambola-Lemon + Mungbean (T_2) agroforestry system which was statistically similar with Aonla + Mungbean (T_1) agroforestry system.

Thousand seed weight of mungbean varieties was significantly influenced by varietal characteristics (Fig. 10). Influencing pattern of thousand seed weight of mungbean was almost similar in 2009 and 2010 cropping seasons. Significantly the highest thousand seed weight (49.87 g and 50.29 g in 2009 and 2010, respectively) was recorded in BARI Mung 6 in both the years. Significantly the lowest thousand seed weight (45.71 g and 45.59 in 2009 and 2010, respectively) was found in BARI Mung 5.

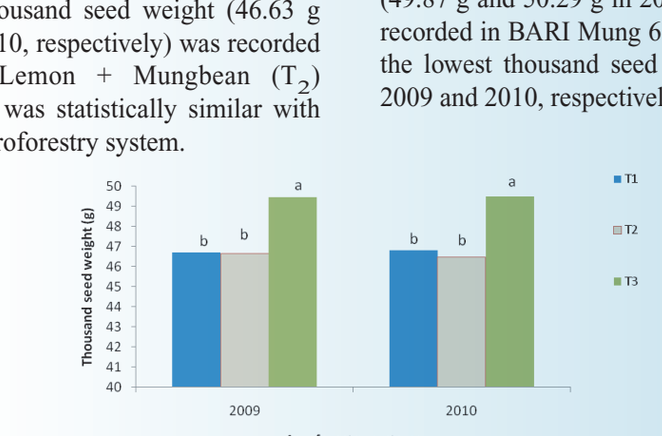

Fig. 9. Thousand seed weight of mungbean as influenced by aonla based multistoried agroforestry systems during 2009 and 2010 (T_1 = Aonla + Mungbean, T_2 = Aonla+ Carambola-Lemon + Mung bean and T_3= Open Field).

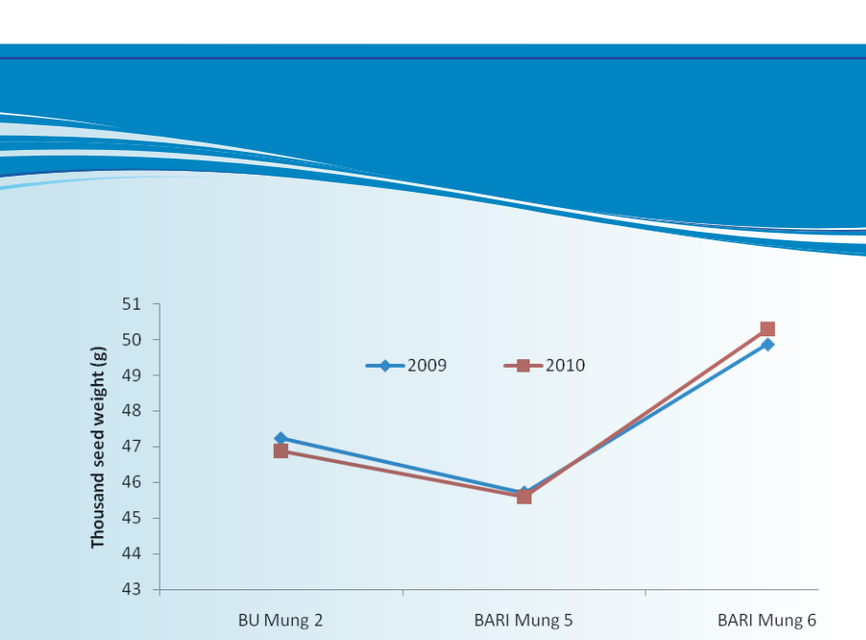

Fig. 10. Response of thousand seed weight of different mungbean varieties under aonla based multistoried agroforestry system during 2009 and 2010.

Yield performance of mungbean varieties

Yield of mungbean was significantly influenced by the aonla based agroforestry systems (Fig. 11). Significantly the highest yield (1371 and 1387 kg ha^{-1} in 2009 and 2010, respectively) was recorded in open field condition and the lowest yield (1058 and 1093 kg ha^{-1} in 2009 and 2010, respectively) was recorded in Aonla + Carambola-Lemon + Mungbean based agroforestry system.

There was a significant difference among the mungbean varieties influenced by the varietal characteristics (Fig. 12). Trend of influence on yield of mungbean was almost similar in 2009 and 2010 cropping seasons. Significantly the highest yield (1422 kg ha^{-1} and 1519 kg ha^{-1} in 2009 and 2010, respectively) was recorded in BARI Mung 6 which was followed by BU Mung 2. Significantly the lowest yield (973.30 and 975.90 kg ha^{-1} in 2009 and 2010, respectively) was found in BARI Mung 5. Two years average yield of mungbean produced by different varieties also showed the similar variation pattern.

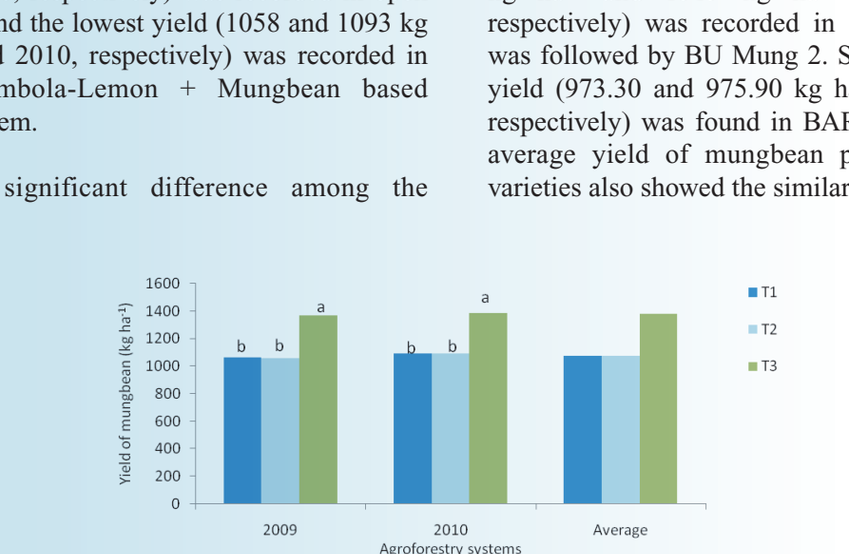

Fig. 11. Yield performance of mungbean as influenced by aonla based multistoried agroforestry systems during 2009 and 2010.

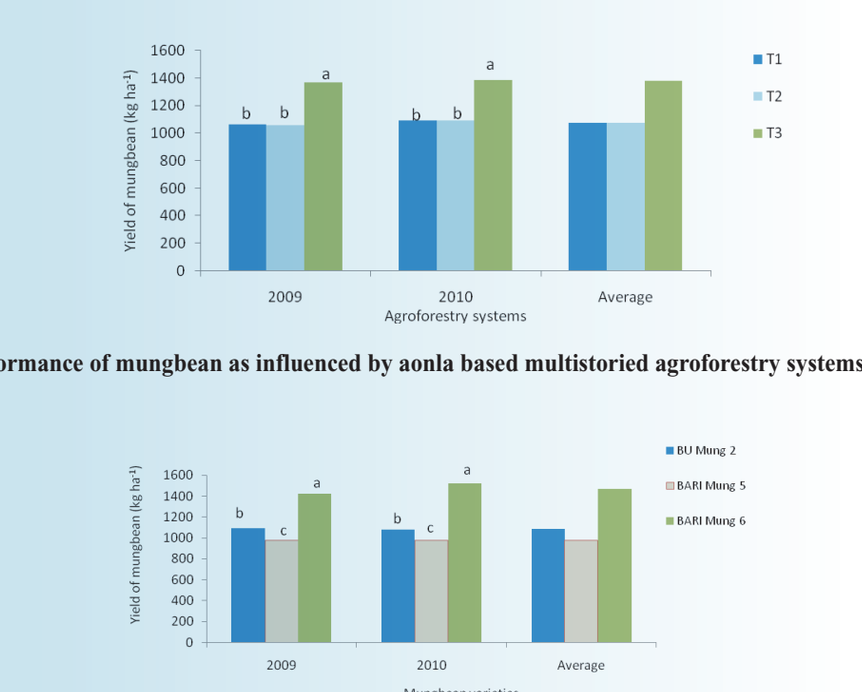

Fig. 12. Response on yield of different mungbean varieties under aonla based multistoried agroforestry system during 2009 and 2010.

Yield performance of mungbean was significantly (p<0.01) influenced by the interaction of different agroforestry systems and varieties of mungbean (Table 4). The trend of yield of mungbean was almost similar to the year 2009 and 2010 cropping years. Significantly the highest yield (1631 and 1742 kg ha^{-1} in 2009 and 2010, respectively) was produced by BARI Mung 6 in open field condition (T_3V_3) followed by T_3V_1 treatment combination in both years. BARI Mung 6 under aonla (T_1V_3 treatment combination) produced the statistically similar yield to that of BU Mung 2 (T_3V_1 treatment combination) in open field in both cropping seasons. In 2009, significantly the lowest yield (900.70 kg ha^{-1}) was produced by T_2V_2 treatment combination which was statistically similar to that of T_1V_2 treatment combination. In 2010, significantly the lowest yield (915.00 kg ha^{-1}) was produced by T_1V_2 treatment combination. From the present study higher yield performance was found in open field condition for V_3 and V_1 but V_2 produced comparatively lower yield in open field than V_3 under aonla T_2V_3 treatment combination. Lower seed yield of mungbean in shaded conditions was reported by Catedral and Lantican (1977), Abilay and Lantican (1982), and Miah (2010). The present study revealed that BARI Mung 6 produced highest yield and lowest yield was produced by BARI Mung 5.

Table 4. Interaction effect of agroforestry systems and varieties on yield per ha of mungbean in aonla based multistoried agroforestry systems during 2009 and 2010.

Treatment combination	Yield (kg ha^{-1})		
	2009	2010	Average
T_1V_1	970.0 d	957.0 d	963.50
T_1V_2	905.7 d	915.0 d	910.35
T_1V_3	1318 b	1406. b	1362.00
T_2V_1	955.0 d	943.3 d	949.15
T_2V_2	900.7 d	926.7 d	913.70
T_2V_3	1317 b	1409 b	1363.00
T_3V_1	1351 b	1333 b	1342.00
T_3V_2	1132 c	1086 c	1109.00
T_3V_3	1631 a	1742 a	1686.50
CV (%)	4.02	3.42	

In a column, means followed by same letter (s) are not statistically different by DMRT.
T_1= Aonla + Mungbean, T_2 = Aonla + Carambola- Lemon + Mungbean and T_3 = Open Field,
V_1= BU Mung 2, V_2= BARI Mung 5 and V_3= BARI Mung 6.

Productivity evaluation of mungbean in agroforestry system

Plant productivity, i.e., the amount of growth that can be attained by a plant within a given period of time, is a function of the net rate of photosynthesis, which is the difference between gross photosynthesis and respiration (Nair 1993). The productivity evaluation is commonly evaluated by the Harvest Index (HI) and Land Equivalent Ratio (LER).

Harvest index (HI)

Harvest index is used to denote the fraction of economically useful products of a plant in relation to its total productivity (Nair 1993). The highest HI was recorded in T_2V_3 combination (BARI Mung 6 under Aonla + Carambola-Lemon + Mungbean agroforestry system) and the values were 13.58 and 13.81% in 2009 and 2010, respectively followed by T_1V_3 in both the cropping years.

Table 5. Productivity evaluation through harvest index (HI) under aonla based multistried agroforestry systems during 2009 and 2010.

Treatment combination	Grain Yield (t ha^{-1})		Fresh weight (t ha^{-1})		Biological yield (t ha^{-1})		Harvest index (%)	
	2009	2010	2009	2010	2009	2010	2009	2010
T_1V_1	0.97	0.96	7.65	7.84	8.62	8.80	11.26	10.87
T_1V_2	0.91	0.92	7.50	7.44	8.41	8.35	10.77	10.95
T_1V_3	1.32	1.41	8.70	9.08	10.02	10.48	13.16	13.41
T_2V_1	0.96	0.94	7.45	7.88	8.41	8.82	11.36	10.69
T_2V_2	0.90	0.93	6.69	7.15	7.59	8.08	11.87	11.47
T_2V_3	1.32	1.41	8.38	8.80	9.70	10.21	13.58	13.81
T_3V_1	1.35	1.33	9.96	10.00	11.31	11.33	11.94	11.77
T_3V_2	1.13	1.09	9.18	9.22	10.31	10.31	10.98	10.54
T_3V_3	1.63	1.74	12.16	12.29	13.79	14.04	11.82	12.41

T_1= Aonla + Mungbean, T_2 = Aonla + Carambola- Lemon + Mungbean and T_3 = Open Field,
V_1= BU Mung 2, V_2= BARI Mung 5 and V_3= BARI Mung 6.

The lowest HI was found in BARI Mung 5 in Aonla + Mungbean based agroforestry system in 2009. On the other hand, the lowest HI was also found in BARI Mung 5 under open field condition in 2010. This study revealed that considering HI, BARI Mung 6 was the best variety irrespective of production systems even in open field.

Land equivalent ratio (LER)

It helps judging the relative performance of a component 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 (3.01 and 3.48 in 2009 and 2010, respectively) was found in T_2V_3 treatment combination in both cropping years. BARI Mung 6 performed the best in respect of LER. The lowest LER was found in BU Mung 2 under Aonla + Mungbean agroforestry system. This study revealed that BARI Mung 6 was the most suitable variety grown under aonla based agroforestry systems.

Table 6. Productivity evaluation through land equivalent ratio (LER) under aonla based multistried agroforestry systems during 2009 and 2010.

Treatment combination	Ci/Cs		Ti/Ts		LER	
	2009	2010	2009	2010	2009	2010
T_1V_1	0.72	0.72	1.23	1.24	1.94	1.96
T_1V_2	0.8	0.84	1.23	1.24	2.03	2.08
T_1V_3	0.81	0.81	1.23	1.24	2.04	2.05
T_2V_1	0.71	0.71	2.20	2.57	2.91	3.28
T_2V_2	0.8	0.85	2.20	2.57	3.00	3.42
T_2V_3	0.81	0.81	2.20	2.67	3.01	3.48
T_3V_1	-	-	-	-	-	-
T_3V_2	-	-	-	-	-	-
T_3V_3	-	-	-	-	-	-

T_1= Aonla + Mungbean, T_2 = Aonla + Carambola- Lemon + Mungbean and T_3 = Open Field,
V_1= BU Mung 2, V_2= BARI Mung 5 and V_3= BARI Mung 6.

Economic performance

Economic performance was evaluated by the benefit cost ratio (BCR). The highest BCR 4.81 (2009) and 5.08 (2010) was recorded in BARI Mung 6 at open field condition (T_3V_3) in both cropping years followed by T_3V_1 treatment combination. Between the agroforestry systems, BARI Mung 6 performed better in respect of BCR 3.88 (2009) and 4.11 (2010). The lowest BCR was recorded in BARI Mung 5 irrespective of treatment combinations. This study revealed that BARI Mung 6 was the most profitable variety grown under aonla based agroforestry systems over other two varieties i.e. BARI Mung 5 and BU Mung 2 grown in open field condition (BCR 3.34 and 3.17 in 2009 and 2010, respectively).

Table 7. Economic performance of mungbean under aonla based agroforestry system during 2009 and 2010.

Treatment combination	Gross return (Tk ha^{-1})			Cost of production (Tk ha^{-1})			BCR		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
T_1V_1	77600	76560	77080	27143	27728	27435.5	2.86	2.79	2.82
T_1V_2	72456	73200	72828	27143	27728	27435.5	2.67	2.67	2.67
T_1V_3	105440	112480	108960	27143	27728	27435.5	3.88	4.10	3.99
T_2V_1	76400	75464	75932	27143	27728	27435.5	2.81	2.75	2.78
T_2V_2	72056	74136	73096	27143	27728	27435.5	2.65	2.70	2.68
T_2V_3	105360	112720	109040	27143	27728	27435.5	3.88	4.11	4.00
T_3V_1	108080	106640	107360	27143	27728	27435.5	3.98	3.89	3.93
T_3V_2	90560	86880	88720	27143	27728	27435.5	3.34	3.17	3.25
T_3V_3	130480	139360	134920	27143	27728	27435.5	4.81	5.08	4.94

T_1= Aonla + Mungbean, T_2 = Aonla + Carambola- Lemon + Mungbean and T_3 = Open Field,
V_1= BU Mung 2, V_2= BARI Mung 5 and V_3= BARI Mung 6, Mungbean price : Tk 80/- per Kg.

Conclusion

Mungbean was grown as lower-storied crops in aonla based multistoried agroforestry systems. In this system, BARI Mung 6 was found suitable in aonla based multistoried agroforestry systems. Yield and yield contributing characters of mungbean varieties i.e., number of pod plant^{-1}, seed pod^{-1}, and grain yield were found to be highest in T_3V_3 combination (BARI Mung 6 in open field), which was followed by T_3V_1, T_2V_3 and T_1V_3. The highest HI (13.58 and 13.81 in 2009-2010 and 2010-2011, respectively) was recorded in BARI Mung 6 under Aonla + Carambola-Lemon + Mungbean agroforestry system (T_2V_3) in both cropping years. The highest LER (3.01 and 3.48 in 2009 and 2010, respectively) was found in T_2V_3 treatment combination in both cropping years. BARI Mung 6 performed better in respect of LER. The highest BCR (4.81 and 5.08 in 2009 and 2010, respectively) was recorded also in BARI Mung 6 at open field condition (T_3V_3) in the both cropping years followed by T_3V_1 treatment combination. Between the agroforestry systems, BARI Mung 6 performed better in respect of BCR (3.88 and 4.11 in 2009 and 2010, respectively).

References

Abilay R M and Lantican R M. 1982. Characters Associated with Yield Performance of grain legume crops under partial shade condition I. Mungbean (*Vigna radiata*). ***Philipp. J. Crop Sci., 1982, 7(2): 88-93.***

Bashir M M. 2002. Performance of Black gram and mungbean varieties under different light levels. An unpublished ***MS thesis BSMRAU***. Gazipur, Bangladesh.

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

Catedral I G and Lantican R M. 1977. Evaluation of legumes for intensive cropping systems. II Soybean (*Glycine max*). ***Philipp. J. Sci. 2: 67-71.***

Chowdhury M A, Khaleque M A and Rahman M M. 1988. Variability and correlation among some yield contributing characters in mungbean. ***Bangladesh J. Plant Breeding and Genetics 1 (1 & 2): 62-65***

FAO/UNDP. 1988. ***Agro-ecological regions of Bangladesh.*** FAO/UNDP, Rome, Italy. pp-570.

Firminger T A. 1947. ***Firminger's manual of gardening for India.*** Thacker Spink Co. Ltd., Calcutta.

Gardner F P, Pearce R B, and Mitchell R I. 1985. ***Physiology of crop lands.*** Iowa State Uni. Press. Iowa. p.66.

Ghosh S P, Mitra S K and Singh S. 2001. ***Fruit: Tropical and sub tropical, Volume I***, 3rd Edition, Naya Udyog, 206 Bidhan Sarani, Calcutta 700006.

Gomez K A and Gomez A A. 1984. ***Statistical procedures for Agricultural Res.*** 2nd Edn. Johnwiley and Sons, New York. P. 680.

Khanum M, Islam M Q, Mia M A K and Islam M A. 1982. Estimation A genotype and phenotypic variation, habitability and genetic advance of some important quantitative characters in Mungbean (*Vigna radiata*) In ***proc. Nat I. Workshop on pulses. (Aug. 18-19-1981) BARI, Joydebpur, Gazipur, Bangladesh. Pp. 26-31.***

Miah M G and Hussain M J. 2010. Homestead Agroforesrty: A Potential Resource in Bangladesh. Sociology, Organic Farming, Climate Change and Soil Science. ***Sustainable Agriculture Reviews, 2010, Volume 3, 437-463, DOI: 10.1007/978-90-481-3333-8_16***

Miah M M. 2001. Performance of five winter vegetables under different light conditions for Agroforestry system. An Unpublished ***M.S. thesis , BSMRAU***, Gazipur.

Miah M M U. 2010. Maximization of land use through Agroforestry Practices in Floodplain Ecosystem of Bangladesh. An unpublished ***PhD Dissertation of Hajee Mohammad Danesh Science and Technology University***, Dinajpur

Nair P K R. 1993. ***An Introduction to Agroforestry***. Kluwer Academic Publishers in cooperation with International Centre for Research in Agroforestry (ICRAF). P.315.

Reza T M B. 2005. Growth and yield of mungbean varieties as influenced by different light levels. An unpublish ***MS thesis, BSMRAU***. Gazipur. Bangladesh.

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

Sundari T. 2009. Morphological and Physiological Characteristics of Shading Tolerant and Sensitive Mungbean Genotypes. ***HAYATI Journal of Biosciences, December 2009, p 127-134***

Tickoo J L, Ahn C S, Chan H K and Shanmugasundaram S. 1988. Utilization of genetic variability from AVRDC mungbean germplasm. ***Proceedings of the second international symposium held at Bankok, Thailand, 16-20 Nov.1987. Pp 103-110.***