

PERFORMANCE OF AROID UNDER JACKFRUIT-BASED AGROFORESTRY SYSTEM IN TERRACE ECOSYSTEM OF BANGLADESH

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Abstract

The terrace ecosystem is considered as hotspot of jackfruit tree (*Artocarpus heterophyllus* Lam) in Bangladesh having potential for understory cropping. However, most of the jackfruit orchards are often found utilized or underutilized. A field experiment was conducted under the jackfruit orchard to study the performance of aroids (*Colocasia esculenta* L.) from April to October, 2017 in Belabo upazila of Narsingdi district. Four distances (1, 2, 3 and 4 m) from the base of jackfruit tree were considered for aroid planting to evaluate its performance as agroforestry crop in comparison to sole aroid. Land use and economic performances of agroforestry and sole systems were also evaluated. The results indicated that the production of jackfruit increased by 62.73%, while the yield of aroid reduced by 33.48% in agroforestry systems as compared to the yields of sole (non-agroforestry) systems. In agroforestry system, the photosynthetically active radiation (PAR) was severely reduced by 85-77% on aroid crop that caused yield reduction. It was also observed that soil temperature was lower in agroforestry system as compared to sole cropping of aroid, while soil moisture showed inverse trend in sole jackfruit. Economic analysis in terms of benefit cost ratio (BCR) was 2.60 in agroforestry, while the BCR of sole aroid was only 1.83. The land equivalent ratio (LER) was 2.31 in agroforestry system. The present results indicate that aroid cultivation in jackfruit-based agroforestry system under terrace ecosystem can ensure overall higher production and improve economic return.

Keywords: Benefit cost ratio, land equivalent ratio, active radiation, sole crop, understory.

Introduction

Bangladesh has a population of about 163 million making it one of the most densely populated countries of the world and struggling hard to feed the increasing population (BBS, 2018). Bangladesh has increased national capacity for securing food access of large population (GoB, 2013). Though the grain food production increased, food and nutrition

security remain under challenge due to insufficient vegetable and fruit production against huge demand. The country has only 7.76 million ha of arable land and per capita arable land availability decreasing at an alarming rate, from 0.174 ha in 1961 to 0.048 ha in 2016 (World Bank, 2018). Furthermore, the soil fertility of arable land is decreasing day by day due to intensive cropping with

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improper management. Under these scenarios, it is necessary to develop alternate systems that could increase crop production and land use efficiency wherever possible. Because of increasing demand for food, fruits, timber, fodder, fuel wood, and poles, production of multiple products from the same land management unit are indispensable. So, combined production system integrating field crops with perennial trees, which is called agroforestry, may be a viable option to overcome the future challenges. Such systems would increase production per unit area and per unit time, and at the same time would maximize the utilization efficiency of natural resources (Bhuiyan *et al.*, 2012). Moreover, such cropping systems are highly productive and sustainable that provides the opportunity for year-round production. Worldwide, fruit tree-based agroforestry systems are highly popular among resource limited producers (Bellow, 2004) and 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). Jackfruit based agroforestry systems are widely found in terrace ecosystem of Bangladesh with various vegetable and spice crops. Though most of the jackfruit trees are not planted in a systematic manner, there is enough space to grow suitable understorey crops and reported to increase the overall production (Miah *et al.*, 2018).

Under jackfruit-based agroforestry system, aroid (*Colocasia esculenta* L) is a compatible crop due to its shade tolerant nature and is extensively grown in terrace ecosystem. Aroid is a popular vegetable, which is widely grown in Kharif season and contributes a considerable amount of total supply of vegetables during

lean period (August to October). Aroids are rich sources of carbohydrate and contains enough protein (Verma and Singh, 1996). Despite huge demand of aroids, its production is low in Bangladesh. Thus, there is a scope of cultivating aroid in jackfruit orchards to increase the system productivity and economic benefits, and augment the supply of aroids in domestic market. There is not enough information on the performance of aroid as a component of jackfruit-based agroforestry system. In this context, the present experiment was undertaken with the aim to evaluate the performance and economic return of aroid and micro-environmental changes in jackfruit-based agroforestry system in the terrace ecosystem of Bangladesh.

Materials and Methods

The experiment was conducted in the existing jackfruit orchards at Belabo upazila of Narsingdi district during April 2017 to October 2017. Geographically, the study site is located at 24°05' North latitude and 90°50' East longitude at an elevation of 9m above the sea level and characterized by a sub-tropical climate with mild-summer and winter, heavy rainfall during the months from April to September and scanty rainfall during the rest of the year. The soil of the experimental area is clay-loam in texture belonging to Madhupur Tract (AEZ-28) and classified as shallow red-brown under Inceptisol soil category according to USDA Soil Taxonomy (Brammer, 1971; Shaheed, 1984). The land topography is characterized by upland and closely associated narrow-valleys, popularly alluded to as *Chala* and *Baid*, respectively.

The soil of the study area is red-brown in color and strongly acidic in nature with low-organic matter content and poor fertility levels.

The field experiment was conducted in randomized complete block design (RCBD) with three replications. Each jackfruit tree was considered as unit plot for a single replication. Plot size of each replication were not similar due to various age, canopy size and shape of jackfruit trees. There were five treatments for aroid viz. 1-meter distance from tree base (1m), 2-meter distance from tree base (2m), 3-meter distance from tree base (3m), 4-meter distance from tree base (4m) and open field (non-agroforestry/control). There were two treatments for jackfruit tree, open field (non-agroforestry) and agroforestry. Heterogeneous jackfruit trees with the age between 26 and 30 years were selected for this study. The seed tubers of aroid (local var. *Gaitta*) were planted on 3rd April 2017 at a depth of 6-8 cm by maintaining the spacing at 50 cm × 30 cm. Rainfed aroid plots were fertilized with cowdung, Urea, TSP and MoP at the rates of 5000, 150, 100 and 120 kg ha⁻¹, respectively (FRG, 2012). The full doses of cowdung, TSP and MoP were applied at the time of final land preparation. Urea was applied in two equal splits at 60 and 90 days after planting (DAP) of aroid. Weeding was done twice at 30 and 45 DAP. Earthing up of aroid was done by taking up the soil from the space between the rows of aroid field at 60 and 90 DAP.

Aroid was harvested on 4th October when the leaves become pale yellow after 180 DAP. Data on plant height and leaves per plant were measured when it reached peak at 130 DAP; whereas, number of sucker per hill, cormel number per hill, corm weight

per plant, total cormel weight per hill and yield were recorded from the average of ten plants at harvesting. The yield performance of jackfruit tree in both the agroforestry and non-agroforestry systems were measured. Photosynthetically active radiation (PAR) above aroid in agroforestry and open field were measured by sunfluxceptometer in terms of $\mu\text{molm}^{-2}\text{s}^{-1}$. Soil moisture percentage was recorded by DSMM500 soil moisture meter and the soil temperature (°C) was measured by Temp 4/5/6 Thermistor Thermometer. All microclimatic data were taken at noon. Benefit cost ratio (BCR) and land equivalent ratio (LER) were calculated according to the procedure Mead and Willey (1980). The recorded data were statistically analyzed to find out the significance of the results by the “Analysis of Variance” (ANOVA) technique using computer package “Statistix 10”. The mean differences of treatments were compared by Least Significant Difference (LSD) at $P < 0.05$. Finally, relevant tables and figures were prepared according to the objectives of the study.

Results and Discussion

Performance of aroid

Plant height: The plant height of aroid varied significantly in agroforestry system in comparison to that of non-agroforestry system (Table 1). The tallest plant (116.23 cm) was found at 1m distance from jackfruit tree base in agroforestry system and the shortest (95.42 cm) was found in sole (open) aroid field. However, aroid plant height increased by 21.81, 19.34, 12.69 and 5.64%, respectively, at 1, 2, 3 and 4m distance from the tree base, when equated with sole aroid field. This result might be due to variations of light percentage

Table 1. Growth and yield contributing characters of aroid in jackfruit-based agroforestry- and sole aroid-system

| Treatments | Plant height (cm) | No. of leaves per plant | No. of suckers per hill | Individual corm wt. (g) | No. of cormels per hill | Total cormel weight per hill (g) |
|------------|------------------------|-------------------------|-------------------------|-------------------------|-------------------------|----------------------------------|
| 1m | 116.23 (± 1.55)a | 4.06 (± 0.03)b | 3.63 (± 0.14)c | 73.48 (± 2.12)d | 11.00 (± 0.62)d | 160.58 (± 3.57)c |
| 2m | 113.87 (± 1.69)a | 4.07 (± 0.04)b | 3.80 (± 0.17)c | 81.53 (± 2.19)c | 12.46 (± 0.70)cd | 167.15 (± 4.92)c |
| 3m | 107.53 (± 2.23)b | 4.10 (± 0.05)b | 4.03 (± 0.08)bc | 87.83 (± 1.79)b | 13.73 (± 0.61)c | 193.67 (± 9.04)b |
| 4m | 100.80 (± 1.30)c | 4.36 (± 0.12)ab | 4.33 (± 0.14)b | 90.53 (± 1.59)b | 15.78 (± 0.59)b | 205.80 (± 5.03)b |
| Sole Aroid | 95.42 (± 1.43)c | 4.58 (± 0.13)a | 5.56 (± 0.12)a | 99.76 (± 3.01)a | 19.40 (± 0.70)a | 282.01 (± 3.99)a |

Values are means (\pm standard errors) ($n = 3$). Different alphabetical letters within the same column indicate significant differences among the treatments according to a least significant difference (LSD) test ($p < 0.05$).

in different distances from tree base. Crops grown in low light levels usually exhibit apical dominance due to high auxin production in shaded condition (Hillman, 1984). Similar results have also been reported for aroid in agroforestry systems under reduced of light levels (Bhuiyan *et al.*, 2013).

Leaves per plant: Though agroforestry system had a little effect on the number of leaves per plant of aroid, it increased with increasing of planting distances from tree base (Table 1). Nevertheless, the number of leaves decreased by 11.35, 11.14, 10.48 and 4.80%, respectively, at 1, 2, 3 and 4m distance from the jackfruit tree base in comparison with that of non-agroforestry condition. This result might be due to lower production of photosynthate under low light conditions that might have reduced the number of leaves per plant in shaded condition. Similar results were reported in agroforestry system in the previous study for onion (*Allium cepa*) by Miah *et al.* (1999) and aroid (*Colocasia esculenta*) by Bhuiyan *et al.* (2013).

Number of suckers per hill: Significantly the highest number of sucker (5.56) was found in

open field condition and the lowest (3.63) at 1m distance from tree base in agroforestry system (Table 1). In comparison to non-agroforestry (open) field, the number of suckers per hill was significantly attenuated by 34.71, 31.65, 27.52 and 22.12%, respectively at 1, 2, 3 and 4m distances from the tree base. This might be due to shade effect under agroforestry system. Rahman *et al.* (2010) also reported that the number of branches per plant of tomato decreased gradually with the increase of shade levels.

Yield contributing characters of aroid: Yield contributing features of aroid also significantly reduced in agroforestry systems as compared to sole (open) aroid field (Table 1). However, distance regimes of 1, 2, 3 and 4m from jackfruit tree base caused notable reduction in corm weight (26.34, 18.27, 11.96 and 9.25%, respectively), number of cormel per hill (43.30, 35.77, 29.23 and 18.66%, respectively) and total cormel weight per hill (43.06, 40.73, 31.33 and 27.02%, respectively) relative to that of sole aroid field (Table 1). These findings might be due to increasing competition for available resources (light, water and nutrients) sharing between jackfruit tree and aroid plant with decreasing of planting distances towards tree base.

Yield of aroid: Significant difference was observed in the yield of aroid between agroforestry and open field (Fig. 1). Both the maximum cormel yield (16.92 ton ha⁻¹) and corm yield (5.98 ton ha⁻¹) were recorded in sole aroid field, while the minimum cormel (9.63 ton ha⁻¹) and corm (4.40 ton ha⁻¹) yield were recorded at 1m distance from tree base in agroforestry system. These findings may be due to the competition for available growth resources like light, water and nutrients between jackfruit trees and aroids (Fig. 1). Competition for available light was a major factor in reducing maize yields in plants

grown closest to the trees (Everson *et al.*, 2004) as the shade of the tree induces stress conditions to the understory crop (Dufour *et al.*, 2013). Competition for nutrients and water are another negative influence of trees on the yield of associated crops (Ong *et al.*, 2002). From two different previous studies on ber and aroid based agroforestry system and *Colocasia esculenta* under 6 years old aonla (*Emblia officinalis*) tree recorded that the yield reduction of 28.3% and 20.5%, respectively, (Wadud, 1999; Das *et al.*, 2011).

Performance of jackfruit

Although the present study was conducted in unmethodically established jackfruit orchard, it was evident that agroforestry system had a positive influence on the yield performance of jackfruit (Table 2). Proper management practices of agroforestry system notably increased the number of fruits per tree (113.75%), fruit length (3.78%) and yield per tree (62.73%). However, the single fruit weight reduced by 13.54% and fruit diameter by 17.62%, as compared with that of the non-agroforestry jackfruit trees (Table 2). Though the fruit size and weight vary with genetic variability, on average the individual fruit

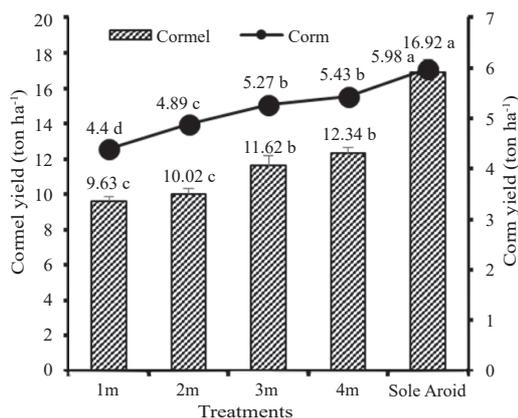


Fig. 1. Yield of aroid in jackfruit-based agroforestry system and sole aroid field.

Table 2. Yield and yield contributing characters of jackfruit in agroforestry and non-agroforestry system

| Parameters | Systems | | Variation (%) |
|---------------------------------------|----------------|------------------|---------------|
| | Agroforestry | Non-agroforestry | |
| Number of fruits per tree* | 20.67(±6.23) | 9.66(±.88) | +113.75 |
| Single fruit weight of jackfruit (kg) | 9.70(±3.55) | 11.22(±1.43) | -13.54 |
| Fruit length (cm) | 42.20(±2.65) | 40.67(±3.38) | +3.78 |
| Fruit diameter (cm) | 30.33(±3.63) | 36.82(±6.88) | -17.62 |
| Yield (kg tree ⁻¹) * | 173.25(±37.57) | 106.46(±9.34) | +62.73 |

Values are means (± standard errors) ($n = 3$). * Significant at the 0.05 level of probability.

weight was lower in agroforestry, which may be due to profuse bearing of fruits. Moreover, the yield increment of jackfruit in agroforestry system might be due to external application of manures and fertilizers to the crop component as well as decomposition of crop residues that would have been taken up by the tree. Similar observation was also reported by Miah *et al.* (2018) where eggplant and papaya were evaluated in jackfruit orchard.

Economic and land use performance

The economic and land use analyses revealed that higher benefits were obtained in agroforestry system in comparison to sole cropping system (Table 3). The highest net return (BDT 241860/ha) and BCR (2.60) was estimated in jackfruit-aroid agroforestry system as against their respective sole cropping systems (Table 3). The LER of jackfruit-aroid agroforestry system was 2.31, indicating that 2.31 times higher land would be required to produce similar amount of production in sole cropping as compared to agroforestry system (Table 3). This result might be due to excellent yield from jackfruit without additional management practices and satisfactory yield of aroid in agroforestry system. The higher economic benefits from jackfruit-based agroforestry system have also

been reported in other studies such as eggplant (Miah *et al.*, 2018; Rahman *et al.*, 2018) and pineapple (Hasan *et al.*, 2008).

Microclimatic modification in the agroforestry system

This study demonstrated that during the whole experimental period, on an average, the photosynthetically active radiation (PAR), soil temperature and moisture significantly varied in jackfruit-based agroforestry as compared to open field (Fig. 2). In comparison to open field, agroforestry resulted in the reduction of PAR by 85.54, 84.02, 80.11 and 77.85%, and soil temperature by 8.09, 8.03, 6.77 and 5.28% at 1, 2, 3 and 4m distances from tree base, respectively (Fig. 2). While it impressively raised the soil moisture content by 9.64, 23.81, 24.90 and 13%, respectively at the distances of 1, 2, 3 and 4m from the jackfruit tree base (Fig. 2). Though, light transmission was greatly influenced by canopy volume and ordination, PAR availability significantly decreased with reducing distance towards the tree base. To find out the relationship between PAR and crop yield, regression analysis was carried out. Polynomial relationships of aroid yields with PAR represented strong association as evident by $R^2 = 0.96$ (Fig. 3). The R^2 value indicates that 96% of contribution to the yield of aroid

Table 3. Economic and land use performances of jackfruit based agroforestry system in compared to sole cropping system

| Systems | Total Cost (a) (BDT/ha)* | Return (BDT/ha) | | Gross income (b+c) | Net return (b+c-a) | BCR | LER |
|----------------|-----------------------------|-----------------|-----------|-----------------------|-----------------------|------|------|
| | | Jackfruit (b) | Aroid (c) | | | | |
| Agroforestry | 150930 | 173200 | 219590 | 392790 | 241860 (135360)# | 2.60 | 2.31 |
| Sole aroid | 173430 | - | 317540 | 317540 | 144110 | 1.83 | - |
| Sole jackfruit | - | 106500 | - | 106500 | 106500 | - | - |

* 1\$= 83 BDT. #Additional income over sole jackfruit orcharding.

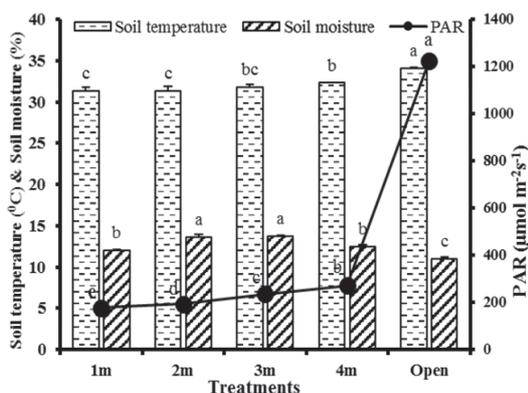


Fig. 2. PAR, Soil temperature and moisture percentage in agroforestry system as well as sole cropping system at different distant regimes amid the experimental period. (Vertical bars indicate standard error and different alphabetical letters indicate significant differences among various treatments).

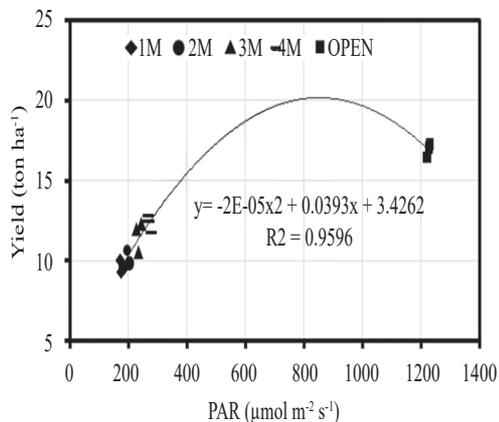


Fig. 3. Relationship between Photosynthetically Active Radiation (PAR) and the yield of aroid in jackfruit-based agroforestry system.

can be explained by the above polynomial regression equation. The regression line showed that if the aroid plants received 820 μmol m⁻² s⁻¹ PAR level, yield could be reached to 20-ton ha⁻¹, and beyond this PAR level, the yield would be decreased by 0.00002-ton ha⁻¹

with respect to per unit increment of PAR (Fig. 3). It was evident that the yield of aroid was greatly reduced by severe reduction of light grown under jackfruit tree. The results of the present study corroborated by the results of Rivest *et al.* (2009). The lower temperature in agroforestry might be due to shade casting by the canopy of the jackfruit trees. Overall higher moisture content in agroforestry may be attributed to the lower rate of evaporation of water from the soil surface and due to continuous shedding of litter from jackfruit trees which increased water retention capacity. Several studies in agroforestry systems in different region of the world have shown that soil temperature was substantially lower and soil moisture content was higher than open field (Rahman *et al.*, 2018; Lin *et al.*, 2015; Singh *et al.*, 2012).

Conclusions

Considering the present findings, it may be concluded that aroid cultivation under jackfruit orchard may be effective in improving system productivity and profitability. Jackfruit yield was increased dramatically by 62.73%, whereas the aroid yield was reduced by 33.48% in agroforestry systems. Though the yield of aroid was reduced in agroforestry due to heavy shade provided by jackfruit tree, it can be successfully cultivated in jackfruit orchards to generate substantial additional income and ensure better microclimate. Hence, cultivation of aroid under jackfruit-based agroforestry system might be encouraged.

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