Productivity and Profitability Assessment of Lemon Based Agroforestry Systems in Bangladesh

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors contributed equally to the planning and design of the study. Authors ZFB and MAR performed the research work and statistical analysis. Authors ZAR, SRS and MZ wrote the protocol, managed the analyses of the study and wrote the manuscript. All authors read and approved the final manuscript.

ABSTRACT

A field experiment was conducted from May 2017 to February 2018 at the research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University to evaluate the performance and profitability of three seasonal (Broccoli, Cabbage and Okra) and two annual crops (ginger and turmeric) in lemon-based agroforestry systems. The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated thrice. For seasonal crops the treatments were sole field ($T_0$), 50 cm distance from tree base (DTB) with ginger ($T_1$), 50 cm DTB with turmeric ($T_2$), 100 cm DTB with ginger ($T_3$) and 100 cm DTB with turmeric ($T_4$). For annual crops (ginger and turmeric) the treatments were sole field ($T_0$) and four distance regimes (50, 100, 150 and 200 cm) from the lemon tree base in agroforestry systems. The results of the study revealed that the yield of seasonal crops decreased and the yield of annual crops and perennial trees increased in agroforestry than

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respective sole cropping systems. The yield performance of crops component was significantly decreased with the decreasing distance towards tree base in agroforestry systems. The economic analysis showed that the net return, benefit-cost ratio (BCR) and land equivalent ratio (LER) was higher in the lemon-based agroforestry system than sole cropping. Therefore, the cultivation of cabbage, broccoli, okra, ginger and turmeric under lemon-based agroforestry systems are economically profitable.

Keywords: Agroforestry; sole cropping system; lemon; benefit-cost ratio; land equivalent ratio.

1. INTRODUCTION

Bangladesh is a land deficient country with a population of 163 million; the availability of per capita arable land has been declined from 0.174 ha in 1961 to 0.048 ha only in 2018 [1,2]. The country is lying between the two contrasting settings in the Bay of Bengal to the south and the Himalayas to the north; it will be the one of worst sufferer country to climate changes due to its disaster prone and low elevation geography. Decreasing natural resources and increasing climatic vulnerability appeared as the great challenges to keep pace of food production in the background of increasing population [3]. Currently most of the land in the country suitable for cultivation is under cropping practices, having limited scope for expanding the cropland [4]. Since, there is very limited scope for expanding sole cropped area, the country has to develop combined production system integrating crops and tree which is now being called agroforestry system. Fruit trees-crops agroforestry systems can ensure year-round food and nutritional security and enhance incomes for small-scale farmers [5].

Recently there has been established many commercial lemon orchards in different agro-ecosystems of Bangladesh, which allows enough space for the cultivation of different crops in between the two line of lemon trees. During early establishment of lemon (Citrus limon L.) orchard, seasonal vegetable crops can be grown which can provide seasonal returns and even after profuse growth of lemon tree, partial shade tolerant crops can also be grown [6]. The performance of lemon orchard is hampered during winter and summer due to dearth of water. So, it will perform better by enjoying the resources that will be applied for vegetable crops. Though farmers are practicing lemon-based agroforestry system in small scale, yet these systems are modestly studied in Bangladesh. Cabbage (Brassica oleracea var. capitata), broccoli (Brassica oleracea var. italica) and Okra (Abelmoschus esculentus) are the most popular seasonal vegetables of Bangladesh. Turmeric (Curcuma longa) and ginger (Zingiber officinale) are two annual herbaceous plants and consuming as major spices in the Indian sub-continent. Ginger and turmeric being shade loving crops could be cultivated in agroforestry system [7]. The compatible combination is necessary to get the potential benefits of the agroforestry. Considering the above facts, it was aimed to utilize the lemon orchard for maximizing the system’s production. Therefore, the present study was conducted to evaluate the performance and economic return of different crops in lemon tree-based agroforestry systems.

2. MATERIAL AND METHODS

2.1 Experimental Location and Climatic Conditions

The field study was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) farm located at 24°09’ N latitude and 90°20’ E longitude in the upland of terrace topography during the period from May 2017 to February 2018. The soil is silty-clay loam in texture which belongs to Salna series of Shallow Red-Brown Terrace soil. The study area has subtropical climate characterized by three distinct seasons; the monsoon (May to October), the dry season (November to February) and the pre-monsoon (March to April).

2.2 History of the Lemon Orchard and Development of Agroforestry Systems

Well established 3 years old Lemon orchard was selected to develop agroforestry system in order to assess the productivity and profitability of the systems. The lemon variety "Colombo" was transplanted on 9 February, 2014 at a spacing of 4.0 m × 4.0 m. The land was prepared thoroughly by disking followed by harrowing and ladderling until a good tilth was obtained. During Kharif season, ginger (var. BARI Ada1) and
turmeric (var. BARI Hulud1) were planted at a spacing of 25 cm × 20 cm, on 23 May 2017; Okra seeds (hybrid var. Nayem) were sown at a spacing of 50 cm × 45 cm, on 29 June 2017. In winter, healthy 35-day-old seedlings of cabbage (var. ATLAS 70) and broccoli (var. Broccoli Green) were transplanted on 20 November, 2017 at a spacing of 60 cm × 50 cm. All seasonal and annual crops were fertilized according to the doses and methods of fertilizer recommendation guide, 2012 [8]. Plant protections along with all agronomic management practices were done regularly.

2.3 Experimental Design and Treatments

The experiment was conducted in a Randomized Complete Block design (RCBD) with three replications. This experiment comprised of five treatments for seasonal crops (Okra, Cabbage and Broccoli) viz. sole field (T₀), 50 cm distance from tree base with ginger (T₁), 50 cm distance from tree base with turmeric (T₂), 100 cm distance from tree base with ginger (T₃) and 100 cm distance from tree base with turmeric (T₄). There were also five treatments for annual crops (ginger and turmeric) viz. sole field (T₀) and four distance regimes like 50 (T₁), 100 (T₂), 150 (T₃), and 200 (T₄) cm from the base of the lemon tree in agroforestry systems. The performance of lemon tree was evaluated under three treatments e.g., sole plot, lemon with ginger and turmeric.

2.4 Data Collection and Statistical Analyses

Growth, yield and yield contributing characters were collected periodically from the experimental plots. All recorded data were processed, calculated and analyzed by using computer software such as MS-Excel and Statistix10. Necessary tests were done to compare the treatment means. One-way analysis of variance (ANOVA) was done and the mean differences were adjusted by Least Significant Difference (LSD) at 5% level of significance.

2.5 Cost-benefit and Land Use Analyses

Benefit-Cost analysis of crop production was done by calculating on-site and off-site costs and benefits of crops and fruit tree. The Benefit-Cost Ratio (BCR) was calculated by the following formula:

\[ BCR = \frac{\text{Gross return (BDT ha}^{-1}\text{year}^{-1})}{\text{Total cost of Production (BDT ha}^{-1}\text{year}^{-1})} \]

The comparative advantage of land use through agroforestry and traditional farming was calculated in the term Land Equivalent Ratio (LER) by the following formula:

\[ LER = \frac{X_i}{X_s} + \frac{Y_i}{Y_s}; \text{Where, } X \text{ and } Y \text{ are the yields of crop components in agroforestry (i) and sole cropping system's (s).} \]

3. RESULTS AND DISCUSSION

3.1 Performance of Broccoli

Growth and yield parameters of broccoli were found to be significant in lemon-based agroforestry system when compared to sole cropping system (Table 1). The maximum leaves number (19.67) of broccoli was found in sole field condition and the minimum (14.67) was noted in T₂ treatment. The highest leaf length and breadth (54.67 and 24.00 cm) was recorded in sole cropping system and significantly the lowest (46.00 and 19.33 cm) in T₁ treatment under agroforestry system. Both curd diameter and individual curd weight were the highest (15.33 cm and 0.48 kg) in sole cropping system, while significantly the lowest (9.67 cm and 0.38 kg) were observed at 50 cm distance from tree base (DTB) in ginger associated lemon-based agroforestry system. These results might be due to higher photosynthate production in full light conditions and lower competition of water and nutrients in sole cropping field which caused higher curd yield as compared to that of lemon-based agroforestry field. The present findings of the experiment corroborate to the findings of Santos et al. [9] who reported that the yield of broccoli reduced due to higher competition in intercropping system.

3.2 Performance of Cabbage

The growth and yield characteristics of cabbage were significantly influenced by the different treatments and it was observed that all studied parameters except outer number of leaves per plant were superior in sole cropped field (Table 2). Maximum number of outer leaves (21.13) was counted from 50 cm DTB in ginger associated lemon field and the minimum (17.33) was in sole cabbage field. The highest leaf length (30.50 cm), leaf breadth (27.10 cm), head diameter (22 cm) and head weight (1.58 kg) were recorded in sole (T₀) cropped field of cabbage. In contrast the lowest leaf length (25.67 cm), leaf breadth (23.30 cm), head
diameter (18.51 cm) and head weight (1.14 kg) were found at 50 cm DTB in ginger coupled lemon-based agroforestry system. Higher number of outer leaves with small size in agroforestry system than sole cropped field might be due to shade effect of lemon trees. In agroforestry systems inter competition for light, water and nutrients among the crop components were higher than sole cropping system, which resulted lower head weight of cabbage. Rahman et al. [10] has been reported similar effect of planting distances from tree base in cabbage production under agroforestry system. The present finding of the experiment is also supported by the finding of Miah et al. [11] who reported that the yield of cabbage was reduced under multipurpose trees in agroforestry systems.

### 3.3 Performance of Okra

Significant variation was observed in yield and yield contributing characters of okra as influenced by planting distances from tree base along with associated annual crops (Table 3). The highest number of fruits per plant (23.40), single fruit weight (17.34) and yield per plant (449.65 g) were recorded in sole cropped field. As compared to sole cropped okra, the yield reduction was noted by 19.26% in T1, 20.01% in T2, 8.69% in T3 and 12.72% in T4 under lemon-based agroforestry systems. The performance of okra significantly increased with increasing planting distances from tree base in agroforestry systems. These results might be due to increasing light percentage and decreasing competition for available growth resources (nutrients and water) among the components in agroforestry systems with increasing planting distances from tree base. Competition for light is an important factor in yields reduction of the plants grown closest to the trees [10,12] and the highest edible vegetables flower buds were formed under full sunlight situation [13]. The result of this experiment is in conformity with the result of Bhusara et al. [14] who reported that harvested lower okra yield in *Melia composite* based agroforestry than open field condition.

#### Table 1. Morphological characters of broccoli in lemon-based agroforestry and sole cropping system

| Treatments | Number of leaves plant \(^{-1}\) | Leaf length (cm) | Leaf breadth (cm) | Curd diameter (cm) | Curd weight (kg) |
|------------|-----------------------------------|------------------|-------------------|-------------------|-----------------|
| T1         | 16.00b                            | 46.00c           | 19.33b            | 9.67b             | 0.38b           |
| T2         | 14.67b                            | 51.33b           | 20.27b            | 13.17ab           | 0.39b           |
| T3         | 16.75ab                           | 48.83c           | 20.17b            | 10.17b            | 0.42ab          |
| T4         | 15.67b                            | 53.17ab          | 21.33b            | 14.50a            | 0.44a           |
| T0         | 19.67a                            | 54.67a           | 24.00a            | 15.33a            | 0.48a           |
| CV%        | 9.88                              | 5.04             | 7.23              | 9.09              | 16.80           |

*Mean values followed by a common letter are not statistically different at the 5% level of significance by LSD*

#### Table 2. Morphological characters of cabbage in lemon-based agroforestry and sole cropping system

| Treatments | Number of outer leaves plant \(^{-1}\) | Leaf length (cm) | Leaf breadth (cm) | Head diameter (cm) | Head weight (kg) |
|------------|----------------------------------------|------------------|-------------------|-------------------|-----------------|
| T1         | 21.13a                                 | 25.67b           | 23.30b            | 18.51b            | 1.14b           |
| T2         | 19.27b                                 | 27.83ab          | 26.17a            | 19.67b            | 1.33ab          |
| T3         | 18.67b                                 | 28.83a           | 24.83ab           | 19.38b            | 1.18b           |
| T4         | 17.80b                                 | 29.17a           | 26.00a            | 20.67ab           | 1.48a           |
| T0         | 17.33b                                 | 30.50a           | 27.10a            | 22.00a            | 1.58a           |
| CV%        | 6.42                                   | 10.55            | 6.00              | 6.16              | 5.67            |

*Mean values followed by a common letter are not statistically different at the 5% level of significance by LSD*
3.4 Performance of Ginger and Turmeric

Ginger and turmeric cultivated in agroforestry system grew more vigorously than respective sole cropping system (Table 4). Numbers of tiller and rhizome weight per hill are the most important growth and yield contributing characters for rhizome crops. Both the number of tiller and rhizome weight per hill of ginger and turmeric were increased gradually with the increasing of distance from lemon tree base in agroforestry systems. The highest rhizome weight per hill of ginger (123.32 g) and turmeric (170.89 g) were measured at 150 cm (T₁) and 200 cm (T₂) distances from tree base, respectively in lemon-based agroforestry system. However, the rhizome weight of ginger per hill was augmented by 4.18, 19.43 and 15.11% at 100, 150 cm and 200 cm distances respectively, while reduced by 8.18% at 50 cm distance from lemon tree base under agroforestry as compared to respective sole cropping system.

In agroforestry system, turmeric planted at 50, 100, 150 and 200 cm distances from lemon tree base showed a significant increment in rhizome weight per hill by 2.66, 7.61, 16 and 23.38%, respectively when compared to sole cropped field. The positive effect of lemon-based agroforestry on the performances of ginger and turmeric might be due to suitable microclimatic condition. In shaded condition under tree, the growth and yield performances of turmeric and ginger increased than their respective open field [15-17]. Two authors have been reported similar effect of planting distances from tree base and higher yields of ginger and turmeric were reported in two different agroforestry systems [7,18].

3.5 Performance of Lemon

To evaluate the performance and profitability of the lemon tree under both the agroforestry and sole cropping system, several yield-related parameters were measured (Table 5). The maximum (112.11) fruits per plant were counted from ginger associated lemon field and the minimum (93.03) in sole lemon field. Though the fruit weight, length and diameter of lemon were insignificant among the treatments, superior sized fruits were harvested from agroforestry compared to sole lemon fields. However, all of these attributes caused an increment of yield per plant by 17.60% and 20% in ginger and turmeric associated lemon-crop agroforestry system respectively. The yield improvement of lemon in agroforestry system might be due to the fact that lemon trees simultaneously enjoyed a substantial amount of supplied inputs (water and fertilizers) to the seasonal crops. External inputs like fertilizers and irrigation applied to crop components in fruit tree-based agroforestry system increased the fruit yield of perennials components [19].

3.6 Economic and Land use Performances

Economic performances in terms of BCR and LER of different crop associated lemon-based agroforestry and sole cropping systems were calculated and presented in Table 6. The net returns were much higher in agroforestry system over their respective sole cropping systems. Among all cropping systems, the highest BCR (2.91) was recorded in lemon+ginger+broccoli agroforestry system and the lowest (1.55) in sole okra. LER was calculated on the basis of total yield produced from the systems.
Table 4. Growth and yield attributes of ginger and turmeric in lemon-based agroforestry and sole cropping systems

| Treatments     | Ginger | Turmeric |
|----------------|--------|----------|
|                | Number of tiller hill\(^1\) | Rhizome weight hill\(^1\) (g) | Number of tiller hill\(^1\) | Rhizome weight hill\(^1\) (g) |
| T\(_1\) (50 cm DTB) | 7.25b  | 94.80c   | 4.96b   | 151.25c  |
| T\(_2\) (100 cm DTB) | 8.15ab | 107.57b  | 5.21b   | 158.55b  |
| T\(_3\) (150 cm DTB) | 9.38a  | 123.32a  | 5.77ab  | 170.89ab |
| T\(_4\) (200 cm DTB) | 9.42a  | 117.85a  | 7.10a   | 181.78a  |
| T\(_0\) (Sole)    | 7.80ab | 103.25b  | 4.75b   | 147.33c  |
| CV\%            | 9.18   | 6.54     | 20.86   | 5.33     |

Mean values followed by a common letter are not statistically different at the 5% level of significance by LSD.

Table 5. Yield and yield attributes of lemon in agroforestry and sole cropping system

| Treatments      | Number of fruits plant\(^1\) | Fruit length (mm) | Fruit diameter (mm) | Single fruit weight (g) | Yield per plant (kg) |
|-----------------|-------------------------------|-------------------|---------------------|-------------------------|----------------------|
| Lemon+ginger    | 112.11a                       | 84.54             | 59.74               | 157.24                  | 17.84a               |
| Lemon+turmeric  | 104.98a                       | 87.36             | 61.77               | 171.53                  | 18.20a               |
| Sole lemon      | 93.03b                        | 78.89             | 55.46               | 152.34                  | 15.17b               |
| LSD             | 6.52                          | 8.00              | 8.28                | 25.69                   | 2.87                 |
| CV\%            | 2.79                          | 4.14              | 6.21                | 7.06                    | 7.64                 |

Mean values followed by a common letter are not statistically different at the 5% level of significance by LSD.

Table 6. Economic comparison of different crop associated lemon-based agroforestry and sole cropping systems

| Systems            | Total cost (BDT/ha)* | Total return (BDT/ha)* | Net return (BDT/ha)* | BCR | LER |
|--------------------|----------------------|------------------------|----------------------|-----|-----|
| Lemon+ginger+broccoli | 390666               | 1136650                | 745984               | 2.91| 2.08|
| Lemon+ginger+cabbage       | 388735               | 1095990                | 707255               | 2.82| 2.05|
| Lemon+ginger+okra        | 394295               | 1100150                | 705855               | 2.79| 2.09|
| Lemon+turmeric+broccoli  | 369371               | 984700                 | 615329               | 2.66| 2.07|
| Lemon+turmeric+cabbage   | 367440               | 944040                 | 576600               | 2.57| 2.04|
| Lemon+turmeric+okra      | 373000               | 948200                 | 575200               | 2.54| 2.10|
| Sole broccoli           | 238080               | 475200                 | 237120               | 2.00| -   |
| Sole cabbage            | 234961               | 417120                 | 182259               | 1.78| -   |
| Sole okra               | 244129               | 376880                 | 134751               | 1.55| -   |
| Sole turmeric           | 255273               | 529200                 | 273927               | 2.07| -   |
| Sole ginger             | 326113               | 855000                 | 528887               | 2.62| -   |
| Sole lemon              | 214327               | 455100                 | 240773               | 2.12| -   |

* 1 US$ = 84 BDT

The LER was more than two times higher in agroforestry systems compared to respective sole cropping systems, as it is assumed that the LER of monocropping system is 1. The highest LER was 2.10 in lemon+ginger+okra agroforestry system which indicated that 2.10 times higher land would be required to get similar production from sole cropping as compared to agroforestry system. Higher BCR and LER in agroforestry were due to satisfactory yield from seasonal crops and improved yield of ginger, turmeric and lemon. Fruit tree-based agroforestry systems are potent to provide higher economic returns than other annual crops [20,21]. Several authors have been reported higher economic and land use benefits in different fruit tree-based agroforestry systems than sole cropped systems [22-24].

4. CONCLUSION

In a resource limited country like Bangladesh, lemon-based agroforestry systems can play a vital role in the production of multiple yield component throughout the year. Despite the sole cropping systems of seasonal crops provided
higher yield than their respective agroforestry, but the total system's production was higher in lemon-based agroforestry systems. The net return, benefit cost and land equivalent ratio were superior in agroforestry systems compared to sole cropping systems. So seasonal and annual crops could be successfully grown in lemon-based agroforestry and farmers might be encouraged to practices these systems for higher production, income generation and land use maximization.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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