An experiment was conducted at the Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during 24 March 2018 to 10 January 2019, to investigate the growth and yield of different turmeric varieties under mango trees and open control. The experiment consisted of two factors with three replications. Among the two factors, one factor was two production systems: T1=Mango + Turmeric and T2=Open control + Turmeric; the second factor was three turmeric local varieties: V1=Thailand, V2=Malshira and V3=Debipat. Interaction treatments between factor A and factor B were T1V1, T1V2, T1V3, T2V1, T2V2 and T2V3 combinations. The experiment was laid out following a Randomized Complete Block Design with three replications. Findings of the study revealed that growth and yield of turmeric significantly varied in the main effect of different agroforestry production systems. The
highest fresh weight of rhizome (11000 kg/ha) was obtained in T₂ and lowest (7055 kg/ha) in T₁. The highest dry weight of rhizome (2126 kg/ha) was found in T₂ and lowest (1456 kg/ha) was in T₁. On the other hand the highest fresh weight of rhizome was 9777 kg/ha found with (V₂) and lowest 8055 kg/ha with (V₁), the highest dry weight of rhizome was 2013kg/ha found in V₁. In case of interaction, the highest fresh rhizome weight (13611 kg/ha) and dry rhizome weight (2631 kg/ha) were recorded in T₂V₂ and T₁V₂, respectively. However, the lowest were found in T₁V₂ (5944 kg/ha) and T₁V₂ (1208 kg/ha).

Keywords: Turmeric; varieties; suitability; mango; agroforestry system; sole cropping.

1. INTRODUCTION

Turmeric (Curcuma longaL.), belongs to the Zingiberaceae family which is one of the most useful herbal medicinal plants [1]. Turmeric is a spice and a medicinal plant frequently used in Bangladesh. Common Bangladeshi people traditionally use various spices in their daily life. Among them is turmeric (Curcuma longa) which is the most important one [2]. Besides using as a spice, it is also used for medicine as a carminative and aromatic stimulant [3]. In addition, turmeric is a valued crop having local as well as export potentials. Total production of turmeric is 117000 metric tons from 21.41 thousand hectares land [4]. The demand for turmeric as domestic use is increasing daily with the ever increasing population of Bangladesh and global demand is also increasing. Turmeric has been known as shade loving spices crop of Bangladesh. It can be cultivated in most areas of the tropics and subtropics, provided that in case of inadequate rainfall, facilities for irrigation are available. It is usually grown in regions with an annual rainfall of 1000-2000 mm. Cultivation has been extended into moist areas with rainfall above 2000 mm per annum. It can be grown up to an altitude of 1220 m in the Himalayan foothills [3]. Humus-rich virgin soil of hills and forests is also suitable for turmeric production. All the above conditions for turmeric production is available in Bangladesh.

Agroforestry, the integration of tree and crop/vegetables in the same area of land is a promising production system for maximizing yield [5]. Multi-storey crops (including vegetables) can be integrated with forestry, orchard, or other agroforestry systems, but farmers face problems of growing crops after 4-5 years of tree plantations and even sometimes fail to grow under storey crops under and around trees because in agro forestry systems, among different production limitations, light availability may be the most important limitation to the performance of the understory crops/vegetables, particularly where an upperstorey perennial forms a continuous over storey canopy [6]. This problem may be overcome by introducing shade tolerant crops like ginger, and turmeric.

Mango is a tropical fruit and belongs to the genus Mangifera of the family Anacardiaceae. Mango is a major fruit in the northern part of Bangladesh, especially in the Dinajpur region due to its edaphic-climatic adaptability. In the Dinajpur region, mango is an integral component of homestead gardening. However, day by day mango gardens is increasing. Nowadays growing of different annual crops in association with mango is practiced by farmers, but without many scientific considerations. A protocol was therefore developed and findings which are beneficial for growers. Keeping this view in mind, research on mango based agroforestry system was conducted in order to select compatible ground storey crops as well as to work out the economic viability of the systems. Hence, attempts were taken to boost-up mango turmeric culture through appropriate techniques. Under these conditions, the present study was undertaken to assess the effects of mango shade on the germination, growth and yield of turmeric varieties.

2. MATERIALS AND METHODS

2.1 Experimental Site Description

The research work was carried out in a field (Under Mango trees and open control) adjacent to the HSTU Research Farm, Dinajpur during 24 March 2018 to 10 January 2019 the upland conditions, The site lies between 25°13’ 13 latitude and 88°23’ longitudes at the elevation of 38 m above sea level.

2.1.1 Soil characteristics

The experiments were laid out in a medium high land belonging to the AEZ of Himalayan piedmont plain area. The soil texture was sandy
loam with a pH of 5.0. The structure of soil was fine and the organic matter, total N, P, K, S, Zn and B contents were 1.20%, 0.06%, 29.35 µ/g soil, 0.21 µ/100 g soil, 6.13 µ/g soil, 0.73 µ/g soil and 0.27 µ/g soil respectively. The soil characteristics were determined at the Regional Laboratory, SRDI, Dinajpur.

2.1.2 Climate

The climate of the study area is characterized by a heavy rainfall during the Kharif season (April to September, 2018), while a scantly rainfall during the rest period, i.e. during the Rabi season (October to March, 2018). The mean annual rainfall was 1822mm most of which occurred in during June-September and light showers occurs during the Rabi season (October, 2018 to January, 2019).

The mean maximum temperature in the summer (March to September, 2018) was 35°C and the mean maximum temperature in the winter (November, 2018 to January, 2019) was 11.9°C. The humidity was 87% in January and 88% in July.

2.2 Experimental Designs

The experiments were laid out in a randomized complete block design (RCBD). There were two treatments in the experiment, first experiment was set with three varieties of turmeric under mango shade and second was set with three varieties under open space (control). There were three replications in each study. The size of plot was 3m x 3m. But for data analysis, the plot size was measured as 3 m x 0.6 m as necessary. The experiment consisted of 2(two) factors: Factor A: (Two production systems), T1=under mango shade+ turmeric, T2=Open space+ Turmeric. Factor B: (Three local turmeric varieties) V1= Thailand, V2=Malshira, V3=Debipat and the treatment combination was T1V1=Turmeric Thailand var. under mango shade, T1V2=Turmeric Malshira var. under mango shade, T1V3=Turmeric Debipat var. under mango shade, T2V1=Turmeric Thailand var. under open field, T2V2=Turmeric Malshira var. under open field, T2V3=Turmeric Debipat Var. under open field.

2.3 Crop Establishment

The seed-rhizomes/fingers of the turmeric were planted, maintaining a line to line distance of 60 cm, plant to plant with distance 20 cm and a depth of 10 cm under mango trees and open field/space (control). Weight of each seed/rhizome of Thailand was 20 g, Malshira was 18 and Debipat turmeric was 17 g.

2.4 Weeding and Irrigation

Weeding was done when necessary. Ear thing up was done thrice; the first one after 60, the second one after 90 and the final one after 110 days of planting. Some plants were rotten by water logging condition. This condition was controlled by drainage.

2.5 Application of Fertilizer

Recommended doses of fertilizers were used as urea (N at 135 kg/ha), TSP (P2O5 at 30 kg/ha), MP (K2O at 90 kg/ha), Gypsum (S at 10 kg/ha), zinc sulfate (Zn at 2 kg/ha), Borax (B at 1.5 kg/ha), and cow dung (5 tons/ha).

2.6 Data Collection

2.6.1 During germination period

Germination data: The number of plants was counted after 10 days after germination of turmeric plants within 140 days after planting (DAP). Germination speed was calculated as followed [2]. Germination speed was calculated as under

\[ S = (N1^1) + (N2-N1)^1/2 + (N3-N2)^1/3 + \ldots + (Nn-N(n-1))^1/n; \]

Where, N1, N2, N3, ..., Nn-1, Nn refers to the proportion of germinated rhizomes on 10 days, 20 days, 30 days, and 140 days. Data were collected of the following parameters: Number of plants, plant height (cm), Length of leaf blade (cm), Width of leaf (cm).

2.6.2 During harvesting period

Number of plants per plot: Total number of fingers per plot, Number of fingers per plant, Length of largest rhizome (cm), Width of largest rhizome (cm), Number of total nodes per rhizome, Total length of internodes per rhizome (cm), Fresh weight of rhizomes per plot, Fresh weight of rhizomes per hectare, Dry weight of rhizomes per hectare.

2.7 Light Intensity

Light intensity were measured by aLUX meter (Hanna company) before the harvesting at 10 am, 1 pm and 4 pm.
2.8 Data Analysis
Means of each parameter were separated by TUKEY HSD - multiple comparison method. A two way interaction were obtained by factorial analysis of variance (ANOVA). All data were analyzed using STATISTIX 10.

3. RESULTS AND DISCUSSION

3.1 Interaction Effect of Different Agroforestry Production Systems and Turmeric Varieties on Growth and Quality Contributing Characters of Turmeric at Different Dap

3.1.1 Plant height (cm)
The interaction effect of the different agroforestry production systems and turmeric varieties on plant height was significantly different between certain treatments at different DAP (Table 1). The tallest plant was recorded in the T1V2 combination (28.22 cm) at 60 DAP and the shortest plant was found in T2V3 combination (20.77 cm). At 90 DAP, the tallest plant was observed in T1V3 combination (70.88 cm), and shortest T2V1 combination (31.55 cm). Then, at 120 DAP, the tallest plant was recorded in T1V3 combination (97.00 cm) and the shortest plant was found in T2V1 combination (45.44 cm). Furthermore, at 180 DAP, the tallest plant was in T1V3 combination (131.33 cm), and the shortest plant was recorded in the T2V3 combination (85.56 cm) at 180 DAP.

3.1.2 Length of leaf (cm)
The length of the leaf of turmeric varied significantly by the interaction effect of different agroforestry production systems, and turmeric varieties at different DAP (Table 2). The longest leaf blade was observed in T1V3 combination (27.66 cm) and the shortest was found in T2V1 combination (16.55 cm) at 60 DAP. At 90 DAP, the longest leaf was observed in T1V3 combination (36.00 cm) and the shortest was recorded in T2V1 combination (16.33 cm). Again the longest leaf was observed in T1V3 combination (51.00 cm) and the shortest was found in T2V1 combination (25.22 cm) at 120 DAP. Moreover, at 180 DAP, the longest leaf was found in T1V3 combination (63.88 cm) and the shortest was observed in T1V3 combination (41.44 cm). It was observed that the number of leaves per plant was minimally affected by shading condition in mixed cropping of turmeric.

Table 1. Interaction effect of different agroforestry production systems and turmeric varieties on plant height at different DAP

| Interaction treatments        | 60 DAP (cm) | 90 DAP (cm) | 120 DAP (cm) | 180 DAP (cm) |
|------------------------------|-------------|-------------|--------------|--------------|
| Mango x Thailand (T1V1)      | 24.94a      | 59.77ab     | 80.00ab      | 103.44bc     |
| Mango x Malshira (T1V2)      | 28.22a      | 68.22a      | 91.00ab      | 114.33ab     |
| Mango x Debipat (T1V3)       | 25.66a      | 70.88a      | 97.00a       | 131.33a      |
| Open x Thailand (T2V1)       | 21.66a      | 31.55c      | 45.44c       | 119.11ab     |
| Open x Malshira (T2V2)       | 21.66a      | 62.66ab     | 84.66ab      | 127.67a      |
| Open x Debipat (T2V3)        | 20.77a      | 50.11b      | 74.22b       | 85.56c       |
| CV%                          | 30.74       | 18.63       | 15.9         | 13           |

In a column different letters indicate significant differences at p < 0.05, 0.01 and 0.001 by Tukey HSD test.

Table 2. Interaction effect of different agroforestry production systems and turmeric varieties on length of leaf

| Interaction treatments        | 60 DAP (cm) | 90 DAP (cm) | 120 DAP (cm) | 180 DAP (cm) |
|------------------------------|-------------|-------------|--------------|--------------|
| Mango x Thailand (T1V1)      | 21.33bc     | 28.55bc     | 39.77b       | 55.00a       |
| Mango x Malshira (T1V2)      | 25.66ab     | 33.44ab     | 48.22a       | 58.66a       |
| Mango x Debipat (T1V3)       | 27.66a      | 36.00a      | 51.00a       | 63.88a       |
| Open x Thailand (T2V1)       | 26.88ab     | 20.44de     | 33.00b       | 59.66a       |
| Open x Malshira (T2V2)       | 25.94ab     | 24.11cd     | 37.55b       | 41.44b       |
| CV%                          | 18.27       | 15.92       | 14.12        | 14.7         |

In a column different letters indicate significant differences at p < 0.05, 0.01 and 0.001 by Tukey HSD test.
3.1.3 Width of leaf (cm)

Width of leaf of turmeric plants varied significantly by the interaction effect of different agroforestry production systems, and turmeric varieties at different DAP (Table 3). The maximum width of leaf was observed in T1V1 (4.11 cm) and T2V2 (4.00 cm) combinations, which were statistically similar at 60 DAP. The minimum width of leaf was recorded in T1V3 (3.88 cm), T1V3 (3.66 cm), T2V1 (3.77 cm) and T2V3 (3.33 cm) combinations, which were statistically similar. At 90 DAP, the maximum width of leaf was in T1V1 (6.88 cm), T1V2 (6.33 cm), T1V3 (6.22 cm), T2V1 (6.33 cm) and T2V2 (6.55 cm) combinations, which were also statistically similar; and the minimum width of leaf was observed in T2V3 (5.66 cm). Then, at 120 DAP, maximum width of leaf was in T1V1 (11.88 cm), T2V1 (11.11 cm) and T2V2 (11.22 cm) combinations, they were also statistically similar, the minimum was observed in T2V3 (9.33 cm). Moreover, the maximum weight of leaf was recorded in T1V1 (17.11 cm) combinations and the minimum was found in T2V3 (13.77 cm) combinations at 180 DAP. Similar results were found by [9].

3.1.4 Number of finger and size of turmeric varieties

The number of fingers is an important quality contributing parameter. The interaction effect of different agroforestry production systems and turmeric varieties on number of finger and size was significantly varied (Table 4). The highest total number of fingers per plot during harvesting was observed in T2V2 (59.22) and the lowest total number of fingers was found in T2V3 (37.55) combination. The total number of fingers per plot were converted into number of fingers per plant. The highest number of fingers per plant were recorded in T2V2 (4.66) and T2V3 (4.43) combinations, they were statistically similar. On the other hand the lowest number of fingers per plant were found in T1V1 (3.39), T1V2 (3.92), T1V3 (3.86) and T2V1 (3.32) combinations, they were also statistically similar. Length of the largest rhizome and width of the largest rhizome are important quality contributing parameters. The longest length of the largest rhizome was found in T2V2 (28.66 cm) combination and the shortest length of the largest rhizome was observed in T1V3 (25.24 cm) combination.

Longest width of largest rhizome was observed in T2V2 (23.77 cm) combination, and the shortest width of largest rhizome was found in T1V3 (17.94 cm) combination. Similar results were found [10].

3.1.5 Quality parameters of turmeric varieties

The number of plants per plot, number of node of fingers per rhizome, length of inter-nodes per finger (cm) and number of shoots per plot are important quality parameters of turmeric. These varied significantly by different agroforestry production systems (Table 5). The highest number of plants per plot were observed T1V2 (13.22) and T1V3 (13.77) combinations, which were statistically similar. The lowest number of plants per plot was found in T2V1 (11.33) combination. None of the treatments were statistically different.

The highest number of nodes of fingers per rhizome were recorded in T1V2 (19.66), T2V1 (19.22), T2V2 (19.33) and T2V3 (19.88) combinations, and lowest was found in T1V1 (17.77). However they were statistically similar, on the other hand the lowest was found in T1V1 (17.77). The maximum length of internode per finger was recorded in T1V1 (4.28 cm), T1V2 (4.20 cm), T2V1 (4.21 cm) and T2V3 (4.44 cm) combinations, they were statistically similar and the minimum was found in T1V1 (3.66 cm) and T1V2 (3.65 cm) combinations which were also statistically similar. At the number of shoots per plot, the maximum number of shoots were observed in T2V2 (6.77) and T1V3 (6.11) combinations which were statistically similar. The minimum were observed in T1V1 (5.88), T1V2 (5.77), T1V3 (5.00) and T2V1 (5.44) combinations, and were also statistically similar. Similar result was found [10].

3.1.6 Fresh rhizome weight (kg) per plot and dry rhizome weight (g) per plot

Total fresh weight of rhizome of turmeric varieties varied significantly by the effect of different agroforestry production systems (Table 6). The highest total fresh weight of rhizomes were observed in T2V2 (2.45 kg) and T1V1 (2.09 kg) combinations but were not statistically significantly different. The lowest were observed in T1V1 (1.24 kg), T1V2 (1.07 kg), T1V3 (1.50 kg) and T2V3 (1.40 kg) combinations and were also not statistically significantly different from one another, however, “mango” treatments were significantly different from “Open” treatments, except for “Open x Debipat (T2V2).”

Dry weight of rhizome of turmeric varieties per plot varied significantly by the effect of different agroforestry production systems (Table 6). The
The highest dry weight of rhizome was observed in T$_1$V$_1$ (22.33 g) combination, and the lowest dry weight of rhizome was found in T$_2$V$_3$ (17.33 g) combination. Similar results was found that 50% shade level is suitable for the cultivation of turmeric [11].

Table 3. Interaction effect of different agroforestry production systems and turmeric varieties on width of leaf

| Interaction treatments | Width of leaf (cm) | 60 DAP | 90 DAP | 120 DAP | 180 DAP |
|------------------------|-------------------|--------|--------|---------|---------|
| Mango x Thailand (T$_1$V$_1$) | 4.11a | 6.88a | 11.88a | 17.11a |
| Mango x Malshira (T$_1$V$_2$) | 3.88a | 6.33a | 10.33ab | 15.77ab |
| Mango x Debipat (T$_1$V$_3$) | 3.66a | 6.22a | 10.00ab | 15.66ab |
| Open x Thailand (T$_2$V$_1$) | 3.77a | 6.33a | 11.11ab | 16.00ab |
| Open x Malshira (T$_2$V$_2$) | 4.00a | 6.55a | 11.22ab | 16.33ab |
| Open x Debipat (T$_2$V$_3$) | 3.33a | 5.66a | 9.33b | 13.77b |
| CV% | 19.14 | 17.46 | 15.89 | 11.64 |

*In a column different letters indicate significant differences at P $\leq$ 0.05, 0.01 and 0.001 by Tukey HSD test

Table 4. Interaction effect of different agroforestry production systems and turmeric varieties on the number of fingers and size of rhizome

| Interaction treatments | No. of fingers/plant | Length of largest rhizome (cm) | Width of largest rhizome (cm) |
|------------------------|----------------------|-------------------------------|------------------------------|
| Mango x Thailand (T$_1$V$_1$) | 42.00a | 27.38a | 19.84ab |
| Mango x Malshira (T$_1$V$_2$) | 53.33a | 28.66a | 20.50ab |
| Mango x Debipat (T$_1$V$_3$) | 53.66a | 25.24a | 17.94b |
| Open x Thailand (T$_2$V$_1$) | 37.55a | 27.11a | 20.27ab |
| Open x Malshira (T$_2$V$_2$) | 59.22a | 26.97a | 23.77b |
| Open x Debipat (T$_2$V$_3$) | 56.11a | 27.22a | 19.38b |
| CV% | 35.08 | 31.65 | 10.73 | 14.76 |

*In a column different letters indicate significant differences at P $\leq$ 0.05, 0.01 and 0.001 by Tukey HSD test

Table 5. Interaction effect of different agroforestry production systems and turmeric varieties on the quality parameters

| Interaction treatments | No. of plants/plot | No. of nodes of finger/rhizome | Length of inter node/finger (cm) | No. of shoots/plot |
|------------------------|--------------------|-------------------------------|---------------------------------|------------------|
| Mango x Thailand (T$_1$V$_1$) | 12.44ab | 17.77a | 4.28a | 5.88a |
| Mango x Malshira (T$_1$V$_2$) | 13.22a | 19.66a | 3.66a | 5.77a |
| Mango x Debipat (T$_1$V$_3$) | 13.77a | 18.66a | 3.65a | 5.00a |
| Open x Thailand (T$_2$V$_1$) | 11.33b | 19.22a | 4.20a | 5.44a |
| Open x Malshira (T$_2$V$_2$) | 12.77a | 19.33a | 4.21a | 6.77a |
| Open x Debipat (T$_2$V$_3$) | 12.77a | 19.88a | 4.44a | 6.11a |
| CV% | 7.83 | 9.94 | 18.8 | 28.03 |

*In a column different letters indicate significant differences at P $\leq$ 0.05, 0.01 and 0.001 by Tukey HSD test

Table 6. Interaction effect of different agroforestry production systems and turmeric variety on fresh rhizome weight and dry rhizome weight

| Interaction treatments | Total fresh weight of rhizomes (kg/plot) | Dry weight of rhizomes (100 g/plot) |
|------------------------|------------------------------------------|-----------------------------------|
| Mango x Thailand (T$_1$V$_1$) | 1.24bc | 22.33a |
| Mango x Malshira (T$_1$V$_2$) | 1.07c | 20.33c |
| Mango x Debipat (T$_1$V$_3$) | 1.50bc | 18.33e |
| Open x Thailand (T$_2$V$_1$) | 2.09ab | 21.33b |
| Open x Malshira (T$_2$V$_2$) | 2.45a | 19.33d |
| Open x Debipat (T$_2$V$_3$) | 1.40bc | 17.33f |
| CV% | 38.30 | 2.23 |

*In a column different letters indicate significant differences at P $\leq$ 0.05, 0.01 and 0.001 by Tukey HSD test
Table 7. Interaction effect of different agroforestry production systems and turmeric varieties on fresh rhizome weight and dry rhizome weight per hectare

| Interaction treatments | Fresh weight of rhizomes (kg/ha) | Dry weight of rhizomes (kg/ha) |
|------------------------|----------------------------------|-------------------------------|
| Mango x Thailand (T₁V₁) | 6888                             | 1538                          |
| Mango x Malshira (T₁V₂) | 5944                             | 1208                          |
| Mango x Debipat (T₁V₃) | 8333                             | 1527                          |
| Open x Thailand (T₂V₁)  | 11611                            | 2476                          |
| Open x Malshira (T₂V₂) | 13611                            | 2631                          |
| Open x Debipat (T₂V₃)  | 7777                             | 1348                          |
| CV%                    | 38.30                            | 2.23                          |

*In a column different letters are significantly different at P ≤ 0.05, 0.01 and 0.001 by Tukey HSD test.

3.1.7 Fresh rhizome weight (kg) per hectare and dry rhizome weight (kg) per hectare

Fresh weight (kg) of rhizome was converted per plant to per hectare. Therefore, maximum fresh rhizome weight per hectare was recorded in T₂V₂ (13611 kg) combination and minimum fresh weight of rhizome per hectare was found in T₁V₂ (5944 kg) combination. Dry weight of rhizome of turmeric per plot varied significantly by the interaction effect of different agroforestry production systems and turmeric varieties. The maximum dry weight of rhizome was found in T₂V₂ (2631 kg) combination. Moreover, the minimum dry weight of rhizome was observed in T₁V₂ (1208 kg) combination. Similar results were reported by [12].

4. CONCLUSION

From the results it can be concluded that between the two production systems, the growth and quality of turmeric with germination speed was better under mango shade than open conditions. On the other hand, a higher yield was found in open control plants than mango shade plants. Between turmeric varieties, Malshira performed better than Thailand and Debipat varieties. Fresh rhizome turmeric yield increased with an increasing rate of light intensity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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