Growth Performance of Two Ginger (*Zingiber officinale* Roscoe) Varieties under Different Agroforestry Systems in Bangladesh

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Authors’ contributions

This work was carried out in collaboration among all authors. Authors SH and MSR designed the study, conducted the field experiment and performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MMA managed the analyses of the study and prepare the final manuscript. Authors KNK and NA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The experiments was conducted at a farmers' field adjacent to the HSTU Research Farm, Dinajpur during 28th April to 13th December 2018 to evaluate growth and quality of two ginger (*Zingiber officinale* Roscoe) varieties under different tree such as ghoraneem, litchi and mango based Agroforestry systems. The experiment was two factors RCBD where Factor A (four Agroforestry systems) and Factor B (two ginger varieties). Factor A (Agroforestry system) were- T1=under Ghoraneem, T2= under Litchi, T3= under Mango and T4= Open field (control). Again, factor B (variety) were- V1= Deshi and V2= China. Therefore, the treatment combinations were T1V1, T1V2, T2V1, T2V2, T3V1, T3V2, T4V1 and T4V2. The experiment results revealed that the growth and quality

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of ginger were significantly varied by the main effect of different Agroforestry systems. The highest germination speed, plant height was higher under Ghoraneem (T1) but the highest fresh rhizome weight (21600 kg/ha) was found under Mango based System (T3), whereas the highest dry rhizome weight (20%) was found under Open field condition (T4). The main effect of varieties on growth and quality of ginger were significantly varied. Germination speed, plant height, fresh rhizome weight was higher in deshi ginger (V1) but highest dry rhizome weight was found in china ginger (V2). The interaction effect of Agroforestry systems and ginger varieties was also significant. The highest germination found in T1V1. Again, the tallest plant was recorded in T1V3. The highest fresh rhizome weight (20865 kg/ha) was found in T3V1 but the highest dry rhizome weight was found in T2V1 (21.25 %). The relationship between light intensity and fresh ginger rhizome yield was inversely proportional. The highest ginger rhizome yield (21600 kg/ha) was found when the total light intensity was 115.50 LUX under Mango (T1) and the lowest ginger rhizome yield (18366 kg/ha) was when the total light intensity was 321.50 LUX in open field (T4).

Keywords: Ginger; agroforestry system; growth; light intensity; yield.

1. INTRODUCTION

Ginger (Zingiber officinale Roscoe) is a flowering plant that is widely used as a spice and folk medicine. It is used all over the world, since antiquity, for a wide array of unrelated ailments including arthritis, cramps, rheumatism, sprains, sore throats, muscular aches, pains, constipation, vomiting, hypertension, indigestion, dementia, fever and infectious diseases [1].

Ginger is also a common spice in Bangladesh where total production is about 49,405 M tons annually from about 19,055 hectares of land [2]. In Bangladesh ginger is cultivated as a rain-fed annual crop in uplands and hill slopes. Dinajpur, Rangpur, Tangail, Chittagong and Rangamati are important ginger-growing districts. Ginger requires a warm and humid climate. Ginger is cultivated in the tropics from sea-level up to 1500 m altitude, in areas with an annual rainfall of 1500 mm or more (with only a short dry season) and high temperatures for at least part of the year [3].

All the above conditions are available are in Bangladesh for ginger productions. But most of lands are engaged to produce food crops. So, there is little scope to increase the area of ginger production. Hence, attempt should be taken to boost-up their culture through appropriate local techniques. These crops can be grown in association with trees or shrubs in and around the homestead and / or farmland. Agroforestry systems may be one of the ways in land constrains situations like Bangladesh. Therefore this study was undertaken to evaluate growth performance of two ginger (Zingiber officinale roscoe) varieties under different agroforestry systems.

2. MATERIALS AND METHODS

The experiments were carried out at a farmers’ field (Ghoraneem woodlot, Litchi trees, Mango trees and open control) adjacent to the HSTU Research Farm, Dinajpur during 28th April to 13th December 2018 in upland conditions. The geographical location of the site was between 25° 13’ latitude and 88° 23’ longitude, and about 37.5m above the sea level. The soil texture was sandy loam with a pH of 5.0 (very acidic). The structure of soil was fine and the organic matter, total N, P, K, S, Zn and B contents were 1.20%, 0.06%, 29.35µ/g soil, 0.21µ/100g soil, 6.13µ/g soil, 0.73µ/g soil and 0.27µ/g soil respectively. The woodlot was 11 years old. The average height of ghoraneem was 12 m and average diameter at breast height was 38 cm. The average height of litchi tree was 6 m and average diameter at breast height was 27 cm and the average height of mango tree was 7m and average diameter at breast height was 32 cm. Each tree was pruned every year. The experiments were laid out in two factors Randomized Complete Block Design (RCBD) with four replications. Factor A was two varieties of ginger deshi (V1) and china (V2) and factor B was four production systems. So the experiment setup was two varieties of ginger deshi (V1) and china (V2) under three agroforestry systems viz. ghoraneem trees (T1), litchi trees (T2), mango (T3), and open field condition (T4). Open field condition treatment was considered as control treatment. Therefore, the treatment combinations were T1V1, T1V2, T2V1, T2V2, T3V1, T3V2, T4V1, and T4V2. The size of the unit plot was 2m×2m and plant spacing was 15cm × 40cm. Standard intercultural operation and fertilizer application were done. Data was collected on Light intensity, Germination speed, Plant height (cm), Number of
tiller/plant, leaf size, Number of rhizome/plant, Size of the Rhizome, finger per rhizome, Fresh and dry weight of the Rhizome/plant and yield ton/ha. All data were analyzed by the help of computer system Statistix-10 and mean was separated by Tukey-HSD test.

3. RESULTS AND DISCUSSION

3.1 Germination Speed

Maximum ginger growth was recorded under ghoraneeem (T1) followed by under litchi (T2) and mango (T3), and the minimum in open condition (T4). In case of variety, the higher ginger growth was found from desi variety (V1), whereas lower in china variety (V2). The interaction of different Agroforestry production systems and ginger varieties was also found significant. The highest growth was found under ghoraneeem and desi variety (T1V1) followed by litchi and desi ginger variety (T2V1). Lowest germination percent was found under litchi and china variety (T2V2). (Figs. 1, 2 and 3). Germination speed varied due to genotypic characteristics of the varieties may also for different moisture retention capacity due to different level of shade and light intensity. Ahmed [4] reported high seed germination percentage under higher shade level.

3.2 Plant Height (cm)

The plant height of ginger was significantly influenced by the effect of different Agroforestry production systems. The tallest plants (30.63 cm and 59.13 cm) were recorded under ghoraneeem (T1) at 60 and 120 days after plantings (DAPs). At 180 DAP, the tallest plant was observed under ghoraneeem (T1) (69.63 cm). On the contrary,
Significantly the shortest plants were observed with litchi (18.00 cm) ($T_2$) and open control (18.25 cm) ($T_4$) at 60 DAP which were almost statistically similar. On the other hand, the shortest plant was found with open control ($T_4$) (48.00 cm) at 120 DAP. Other shortest plant was found in open control ($T_4$) (53.25 cm) at 180 DAP (Table 1). An increase in plant height due to increase in shade intensity was observed earlier in ginger [5]. In case of variety the Plant height was not significantly differ. However, the interaction effect of the different Agroforestry production systems and ginger varieties on the plant height of ginger was found significantly different at different days after planting (DAP). The tallest plant was recorded in $T_1V_2$ (ghora neem x china ginger) (32.00 cm) combination at the 60 DAP followed by $T_1V_1$ (ghora neem x deshi ginger) (29.25 cm) combination. Again, the tallest plant (65.75 cm) was observed in $T_1V_2$ combination at 120 DAP. Moreover, at 180 DAP, the tallest plant was obtained in $T_1V_1$ (72.75 cm) combination followed by $T_1V_2$ (69.00 cm) combination. On the other hand, the shortest plant (17.00 cm) was found in $T_2V_1$ (open field x deshi ginger) combination at 60 DAP. Other shortest plants (44.50 cm and 48.25 cm) were found in $T_2V_1$ (litchi x deshi ginger) combinations at 120 and 180 DAPs. Such an increase in plant height due to reduced light intensities was observed by Aclan and Quisumbig [6] (Table 1). This might be due to genetic constitution of the varieties and genotypic potential and availability of nutrients in the soil, which were influenced by low light intensity and high relative humidity condition under shade net situation [7].

### 3.3 Length of Leaf Blade (cm)

Length of leaf blade was varied significantly by different Agroforestry production systems where the longest leaf blades were found under mango ($T_3$) (12.13 cm) at 60 DAP which were statistically similar to other treatments. At 120 and 180 DAPs, the longest leaf blades were recorded in under litchi ($T_2$) (21.69 cm) and under mango ($T_3$) (24.44 cm). On the other hand, the shortest leaf blade was found under ghoraneem ($T_1$) (11.25 cm) at 60 DAP. But at 120 DAP, the shortest leaf blade was recorded under ghoraneem ($T_1$) (19.00 cm). At 180 DAP, another shortest leaf blade was found under open control ($T_2$) (23.69 cm) (Table 1). Ali et al. [1] observed that ginger leaf length was higher under gamar and guava trees as compared to full sunlight.

The length of leaf blade showed almost similar pattern of variations at different days after planting (DAP) by the effect of ginger varieties. The longer leaf blade was obtained from China variety ($V_2$) (12.13 cm) and lower was from deshi variety ($V_1$) (11.50 cm) at 60 DAP. Moreover, length of leaf blade were $V_1$ (21.97 cm) and $V_2$ (21.09 cm) at 120 DAP which were almost statistically similar. At 180 DAP, length of leaf blade in $V_1$ (24.22 cm) and $V_2$ (24.81 cm) were also shows almost statistically similar result (Table 1). Sasikumar et al. [8] studied the 100 collection of ginger evaluated for variability and character association of traits the result revealed that plant leaf length and width revealed good variability for tiller number and rhizome yield.

Length of leaf blade of ginger plant varied significantly by the interaction effect of different Agroforestry production systems and ginger varieties at different days after planting (DAP). The longest leaf blades were observed in $T_1V_2$ (mango x china ginger) (13.00 cm) which were almost statistically similar at 60 DAP. The longest leaf blade were recorded in $T_2V_1$ (23.50 cm) and $T_2V_2$ (23.63 cm) combinations which were almost statistically same followed by $T_2V_1$ (litchi x deshi ginger) (22.63 cm) and $T_3V_1$ (22.00 cm) combinations at 120 DAP. Moreover, at 180 DAP, the longest leaf blade were observed in $T_1V_2$ (25.75 cm) and $T_2V_2$ (25.75 cm) combinations which were statistically similar followed by $T_1V_1$ (24.75 cm), $T_1V_2$ (24.75 cm), $T_2V_1$ (24.38 cm) and $T_2V_1$ (23.62 cm) combinations. On the other hand, the shortest leaf blade (10.50 cm) was observed in $T_1V_2$ combination at 60 DAP. At 120 DAP, the shortest leaf blades were found in $T_3V_1$ (19.50 cm) and $T_1V_2$ (19.75 cm) combinations which were statistically similar. Again, shortest leaf blades were recorded in $T_2V_2$ (23.00 cm) and $T_3V_1$ (23.13 cm) combinations at 180 DAP which were also almost statistically similar (Table 1).

### 3.4 Breadth of Leaf Blade (cm)

The breadth of leaf blade of ginger was also varied significantly by different Agroforestry production systems at different days after planting (DAP). At 60 DAP, the maximum breadth of leaf blade (1.45 cm) was recorded under litchi ($T_2$) followed by 1.43 cm under ghoraneem ($T_1$). At 120 DAP, 2.06 cm was maximum breadth of leaf blade under ghoraneem ($T_1$) and at 180 DAP, 2.48 cm was maximum in open field ($T_4$) followed by $T_1$ (2.48 cm). On the other hand, minimum breadth of leaf blade at 60...
DAP in open field (T₄) (1.28 cm), at 120 DAP, 1.80 cm was lowest under mango (T₃) and at 180 DAP, 2.29 cm was minimum under mango (T₃) observed (Table 1). Leonardi [9] found that shading density increased leaf length and breadth.

The effect of varieties on breadth of leaf blade of ginger under different Agroforestry trees also showed almost similar pattern of variations at different days after planting (DAP). At 60 DAP, breadth of leaf blade of deshi variety (V₁) (1.34 cm) and china variety (V₃) (1.38 cm) which were almost statistically similar. On the other hand, maximum breadth of leaf blade was observed in V₁ (2.00 cm) and minimum breadth of leaf blade was found in V₁ (1.92 cm) at 120 DAP. But at 180 DAP, breadth of leaf blades of V₁ (2.40 cm) and V₂ (2.44 cm) which showed almost statistically similar results (Table 1).

The interaction effect of different Agroforestry production systems and ginger varieties on the breadth of leaf blade of ginger plants were found significantly similar at different days after plantings (DAPs). At 60 DAP, the breadth of leaves were T₁V₁ (1.68 cm), T₁V₂ (1.20 cm), T₂V₁ (1.20 cm), T₂V₂ (1.68 cm), T₃V₁ (1.25 cm), T₃V₂ (1.35 cm), T₄V₁ (1.25 cm) and T₄V₂ (1.30 cm) combinations which were almost statistically similar. Moreover, the maximum were observed in T₁V₁ (ghora neem x deshi ginger) (2.48 cm) and T₂V₂ (litchi x deshi ginger) (2.28 cm) which were almost statistically similar at 120 DAP. On the other hand, minimum breadth of leaf blades were observed in T₁V₂ (1.65 cm), T₂V₁ (1.78 cm), T₃V₁ (1.80 cm), T₃V₂ (1.80 cm), T₄V₁ (1.95 cm) and T₄V₂ (1.95 cm) at 120 DAP. Furthermore, at 180 DAP, the breadth of leaves were T₁V₁ (2.75 cm), T₁V₂ (2.20 cm), T₂V₁ (2.18 cm), T₂V₂ (2.68 cm), T₃V₁ (2.20 cm), T₃V₂ (2.38 cm), T₄V₁ (2.45 cm) and T₄V₂ (2.53 cm) combinations which were almost statistically similar (Table 1). Bisht et al. [10] observed that yield character of ginger was affected significantly by different fodder trees.

### 3.5 Number of Tiller Per Plant

Number of tiller during harvesting time was significantly influenced by different Agroforestry production systems of ginger varieties. The highest number of tiller per plant was observed under ghoraneem (T₁) (4.37). On the other hand, the lowest number of tiller per plant was found in open control (T₄) (3.37) (Table 2). The effect of ginger varieties on the number of tiller under different Agroforestry trees was significantly varied. Higher number of tiller per plant during harvesting was observed in deshi variety (V₁) (4.19) and lower number of tiller per plant was observed in china variety (V₂) (3.70) (Table 2).

The interaction effect of different Agroforestry production systems and ginger varieties on the number of tiller per plant was not significantly varied. However the highest number of tiller per plant was observed in T₁V₁ (ghora neem x deshi) (4.50), T₁V₂ (ghora neem x china) (4.50), (litchi x deshi) T₂V₁ (4.25) and (litchi x china) T₂V₂ (4.25) combinations which were almost similar. On the other hand, lowest number of tiller per plant was found in T₃V₁ (3.75), T₃V₂ (3.75), T₄V₁ (3.50) and T₄V₂ (3.25) combinations which were also almost similar (Table 2).

### 3.6 Total Number of Rhizome Per Plant and Number of Finger Per Rhizome

Number of finger is an important quality contributing parameter. There were significant variations due to effect of different Agroforestry production systems. Significantly highest total number of finger per rhizome during harvesting time was 20.38 under litchi (T₂). The lowest total number of finger per rhizome was 18.25 in open control (T₄). Moreover, highest number of rhizome per plant was found in open control (T₄) (5.45) and under mango (T₃) (5.04) which were statistically almost similar. The lowest were observed under ghoraneem (T₁) (4.38) and under litchi (T₂) (4.80) which were statistically similar (Table 2). Pandey et al. [11] observed that number of finger of ginger rhizome was higher under Sapota + Jatropha or Jatropha based agroforestry systems as compared to their sole cropping.

There were significant variations due to effect of ginger varieties. Significantly higher total number of finger per rhizome during harvesting time was found in deshi variety (V₁) (19.75). The lower total number of finger per rhizome was observed in china variety (V₂) (18.93). Moreover, higher number of rhizome per plant was recorded in V₂ (5.09) and lower was observed in V₁ (4.78) (Table 2). Kumar et al. [12] found that higher number of ginger fingers was recorded under intercropping compared to sole cropping.
Table 1. Main effect of different Agroforestry systems, varieties and interactions on the plant height, length and breadth of leaf blade of ginger varieties at different Varieties

| Systems | Plant height | Leaf length | Leaf breadth |
|---------|--------------|-------------|--------------|
|         | 60 DAP | 120 DAP | 180 DAP | 60 DAP | 120 DAP | 180 DAP | 60 DAP | 120 DAP | 180 DAP |
| T1      | 30.63a | 59.13a | 69.63a | 11.25a | 19.75c | 23.75b | 1.43a | 2.06a | 2.48a |
| T2      | 18.00c | 56.38a | 66.38a | 11.75a | 21.69a | 23.69b | 1.45a | 2.03a | 2.43a |
| T3      | 26.75b | 55.25a | 65.00a | 12.13a | 21.13ab | 24.44ab | 1.30a | 1.80a | 2.29a |
| T4      | 18.25c | 48.00b | 53.25b | 11.25a | 19.97c | 23.19b | 1.28a | 1.95a | 2.49a |
| CV      | 8.22  | 7.39   | 8.22   | 6.97   | 6.21   | 6.21   | 5.59  | 5.59  | 6.21  |

| Varieties | Plant height | Leaf length | Leaf breadth |
|-----------|--------------|-------------|--------------|
|           | 60 DAP | 120 DAP | 180 DAP | 60 DAP | 120 DAP | 180 DAP | 60 DAP | 120 DAP | 180 DAP |
| V1        | 23.19a | 50.50b | 62.88a | 11.50a | 21.97a | 24.22a | 1.34a | 1.62a | 2.40a |
| V2        | 23.63a | 58.88a | 64.25a | 12.13a | 21.09b | 24.81a | 1.38a | 1.61a | 2.44a |
| CV        | 7.39  | 8.08   | 6.97   | 11.39  | 4.59   | 6.37   | 3.39  | 8.88  | 6.17  |

| System × Variety | Plant height | Leaf length | Leaf breadth |
|------------------|--------------|-------------|--------------|
| T1V1             | 29.25ab | 52.50bcd | 63.75ab | 12.00ab | 19.75c | 24.75ab | 1.68a | 2.48a | 2.75a |
| T1V2             | 32.00a  | 65.75a   | 69.00a  | 10.50b  | 19.75c | 24.75ab | 1.20a | 1.65c | 2.20a |
| T2V1             | 18.50c  | 44.50d   | 48.25c  | 11.75ab | 23.50a | 24.38ab | 1.20a | 1.78bc | 2.18a |
| T2V2             | 17.50c  | 51.50bcd | 58.25bc | 11.75ab | 23.63a | 25.75a  | 1.68a | 2.28ab | 2.68a |
| T3V1             | 28.00ab | 49.75cd  | 66.75ab | 11.25ab | 22.00abc | 23.13b | 1.25a | 1.80bc | 2.20a |
| T3V2             | 25.50b  | 60.75ab  | 63.25ab | 13.00ab | 20.25bc | 25.75a  | 1.35a | 1.80bc | 2.38a |
| T4V1             | 17.00c  | 55.25bc  | 62.75ab | 11.00ab | 19.77c  | 23.13b  | 1.25a | 1.95abc | 2.45a |
| T4V2             | 19.50c  | 57.50abc | 66.50ab | 11.25ab | 19.87c  | 23.00b  | 1.30a | 1.95abc | 2.53a |
| CV               | 11.71   | 16.31    | 15.59   | 9.59    | 3.22    | 7.39    | 8.08  | 6.97  | 8.17  |

In a column different letters are significantly different at P≤0.05 by Tukey HSD test
Significantly highest total numbers of finger per rhizome were found in $T_3V_2$ (20.75), $T_5V_2$ (20.00) and $T_3V_1$ (20.00) combinations which were also almost similar. The lowest total number of finger per rhizome were recorded $T_1V_2$ (18.75), $T_3V_1$ (18.05) and $T_5V_2$ (18.00) combinations. Moreover, highest number of rhizome per plan were found in $T_2V_3$ (5.51), $T_2V_1$ (5.41) and $T_2V_2$ (5.17) which were almost statistically similar. The lowest were observed in $T_1V_1$ (4.44), $T_1V_2$ (4.31), $T_2V_1$ (4.35) and $T_3V_1$ (4.91) which were also almost statistically similar (Table 2).

### 3.7 Fresh Rhizome Weight (g) Per Plant

Fresh rhizome weight of ginger per plot was varied significantly by the effect of different Agroforestry production systems. The highest fresh rhizome weight was observed in ghoraneem ($T_1$) (504.43 g) followed by under mango ($T_2$) (487.13 g). On the other hand, the lowest fresh rhizome weight of ginger varieties was found in open control ($T_3$) (362.50 g) (Table 2). Jayachandran et al. [13] reported that ginger cultivated under the coconut (Cocosnocifera L.) tree species gave good returns and under artificial 25% shade ginger were 11-27% higher than in open field.

Fresh rhizome weight of ginger per plot was varied significantly by the effect of ginger varieties under different Agroforestry production systems. The higher fresh rhizome weight was observed in deshi variety ($V_1$) (476.75 g). On the other hand, the lower fresh rhizome weight of ginger was found in china variety ($V_2$) (442.62 g) (Table 2). Seyie et al. [14] studied the effect of nitrogen, phosphorus and potassium on growth yield and quality of two cultivars Akya Local and Suprabha. The cultivar Akya Local was found better than Suprabha in terms of growth, yield and quality attributes.

Fresh rhizome weight of ginger per plot was varied significantly by the interaction effect of different Agroforestry production systems and ginger varieties. The highest fresh rhizome weight was recorded in $T_1V_1$ (ghoraneem x deshi) (528.00 g) combination. On the other hand, the lowest fresh rhizome weight of ginger was found in $T_2V_2$ (ghoraneem x china) (335.00 g) combination (Table 2). Rahman [15] observed that harvested bumper yield of ginger (32.88t/ha) from the partial shade conditions while the least yield (18.75 t/ha) was recorded from the severe shaded conditions.

### 3.8 Fresh Rhizome Yield (kg/ ha)

Fresh rhizome weight of ginger per hectare was varied significantly by the effect of different Agroforestry production systems. The fresh rhizome yield per hectare was highest under mango ($T_3$) (21600) and the fresh rhizome yield per hectare were recorded lowest in open field ($T_3$) (18366). Pandey et al.[11] found similar finding in their study, that the number of finger of ginger plant was higher agro-forestry systems as compared to their sole cropping. On the other hand, in case of varietal effect the highest fresh rhizome yield per hectare was higher in $V_1$ (20028) and lower in $V_2$ (18833). Kumar et al. [12] found that higher number of ginger fingers was recorded under intercropping compared to sole cropping. In case of interaction Fresh rhizome yield per hectare was highest in $T_3V_1$ (Mango x Deshi) (20865) and the Fresh rhizome yield per hectare was recorded lowest in $T_1V_2$ (17907) (Table 2).

### 3.9 Dry Rhizome Weight (g)

Dry weight rhizome weight of ginger per plot was also varied significantly by the effect of different Agroforestry production systems. The maximum dry rhizome weight per 100g was recorded under open condition ($T_3$) (20.00 g). Moreover, the minimum dry rhizome weight per 100 g was found under mango ($T_3$) (15.88 g) (Table 2). Zhang et al. [16] observed that decreasing in the light intensity also decreasing dry weight.

Dry weight rhizome weight of ginger per plot was also varied significantly by the effect of ginger varieties. The maximum dry rhizome weight per 100 g was recorded from china variety ($V_3$) (19.38 g) (Table 2). The minimum dry rhizome weight per 100 g was found from deshi variety ($V_1$) (16.19 g).

Again, dry weight rhizome weight of ginger per plot was also varied significantly by the interaction effect of different Agroforestry production systems and ginger varieties. The maximum dry rhizome weight per 100 g was found in $T_3V_1$ (mango x Deshi) (21.25 g). Moreover, the minimum dry rhizome weight per 100 g were recorded in $T_2V_3$ (15.50 g), $T_2V_1$ (15.50 g) and $T_3V_1$ (15.00 g) combinations which showed almost statistically similar results (Table 2).
Table 2. Effect of different Agroforestry systems, ginger varieties and their interactions on the number of tiller and total number of rhizome per plant, number of finger per rhizome, fresh rhizome weight per Plant g), Fresh rhizome yield ton/ha and dry weight of rhizome per/100 g

| Systems | Number of tiller per plant | Number of rhizome per plant | Number of finger per rhizome | Fresh rhizome weight per plant (g) | Fresh rhizome yield kg/ha | Dry weight of rhizome / 100 g |
|---------|-----------------------------|-----------------------------|-----------------------------|-----------------------------------|--------------------------|-------------------------------|
| T1      | 4.37a                       | 4.38a                       | 19.25ab                     | 504.43a                           | 19140 ab                 | 17.13b                        |
| T2      | 4.12ab                      | 4.80a                       | 20.38a                      | 487.13a                           | 19776b                   | 17.13b                        |
| T3      | 4.00ab                      | 5.04a                       | 19.50ab                     | 484.50a                           | 21600a                   | 18.68b                        |
| T4      | 3.37b                       | 5.45a                       | 18.25b                      | 362.50b                           | 18366c                   | 20.00a                        |
| CV      | 15.21                       | 5.30                        | 16.83                       | 5.30                              | 16.83                    | 3.11                          |

Varieties

| V1      | 4.19a                       | 4.78b                       | 19.75a                      | 476.75a                           | 20028 a                  | 16.19b                        |
| V2      | 3.70a                       | 5.09a                       | 18.93b                      | 442.62b                           | 18833 b                  | 19.38a                        |
| CV      | 6.31                        | 3.76                        | 5.91                        | 5.59                              | 12.31                    | 3.41                          |

System × Variety

| T1V1    | 4.50a                       | 4.44a                       | 19.75ab                     | 528.00a                           | 19980 b                  | 15.50c                        |
| T1V2    | 4.50a                       | 4.31a                       | 18.75ab                     | 481.25a                           | 19395b                   | 18.75b                        |
| T2V1    | 4.25a                       | 4.35a                       | 20.75a                      | 499.50a                           | 18487c                   | 15.50c                        |
| T2V2    | 4.25a                       | 5.38a                       | 20.00ab                     | 474.75a                           | 18412b                   | 18.75b                        |
| T3V1    | 3.75a                       | 4.91a                       | 20.00ab                     | 479.50a                           | 18385b                   | 15.00c                        |
| T3V2    | 3.75a                       | 5.17a                       | 19.00ab                     | 489.50a                           | 19385b                   | 15.00c                        |
| T4V1    | 3.50a                       | 5.41a                       | 18.05ab                     | 390.00b                           | 18935c                   | 21.25a                        |
| T4V2    | 3.25a                       | 5.51a                       | 18.00 b                     | 335.00b                           | 17907d                   | 20.75b                        |
| CV      | 9.46                        | 4.13                        | 5.05                        | 10.41                             | 17.25                    | 2.21                          |

In a column different letters are significantly different P<0.05 by Tukey HSD test

Table 3. Effect of light intensity on different Agroforestry production systems of ginger

| Treatment | Light intensity (LUX) | Total light intensity (LUX) |
|-----------|------------------------|-----------------------------|
|           | 10am                   | 1pm                         | 4pm                         |
| Under ghoraneem(T1) | 30.38c               | 58.75b                      | 17.00d                      | 106.12c                     |
| Under litchi(T2)     | 35.25b               | 53.00b                      | 21.75b                      | 110.00bc                    |
| Under mango(T3)      | 36.13b               | 54.00b                      | 25.38b                      | 115.50b                     |
| Open field (control )(T4) | 87.00a           | 182.88a                     | 51.63a                      | 321.50a                     |
| CV %                | 5.67                  | 5.08                        | 7.6                         | 3.58                         |

In a column different letters are significantly differ at P<0.05 by Tukey HSD test

3.10 Effect of Light Intensity on Different Agroforestry Systems of Ginger Production

Light intensity at different time of the day was varied significantly in different Agroforestry systems of ginger production. Statistically, highest light intensity was recorded in open control (T4) (87.00 LUX) and lowest was found under mango (T3) (30.38 LUX) at the time of 10.00am (Table 3). Again, highest light intensity was recorded in open control (T4) (182.88 LUX) and lowest was found under litchi (T2) (53.00 LUX) at the time of 1pm. Moreover, highest light intensity was observed in open control (T4) (51.63 LUX) at the time of 4pm. The lowest light intensity were found under ghoraneem (T1) (17.00 LUX) at the time of 4pm. Overall, the total light intensity was recorded highest in open control (T4) (321.50 LUX) and lowest was observed under ghoraneem (T1) (106.12 LUX). Earlier workers, using either inanimate shade materials or field crops such maize, peas or okra as shade providers have reported widely varying shade requirements for ginger ranging from 25% to 66% of full sunlight. Presumably there are variety differences in the shade requirement of ginger [17].
3.11 Relationship between Light Intensity (LUX) and Fresh Ginger Rhizome Yield (kg/ha)

Fig. 4 shows that the fresh ginger rhizome yields were increased by the decreasing rate of total light intensity. Here, fresh ginger rhizome weight (kg/ha) (Table 3) was considered as fresh ginger rhizome yield (kg/ha). The highest ginger yield was 21600 kg/ha when the total light intensity was 115.13 LUX under mango (T3). On the other hand, the lowest ginger yield was 18366 kg/ha when the total light intensity was 321.50 LUX in T4 (open field). So, highest light intensity was decreased with the increasing of the fresh ginger rhizome yield. Ginger being a shade loving crop and reduced effect of unwanted accumulation of gases during night hours favored much for incident solar radiation through shade net which increased fresh rhizome yield [18].

4. CONCLUSION

The study concluded that the growth and quality of ginger varied by the effect of different Agroforestry systems, ginger varieties and interaction between them. Ginger was grown better and gave maximum yield at the floor of mango woodlot. The rhizome growth was highest under litchi tree and dry weight of rhizome was highest under control condition. Moreover, between two ginger varieties, deshi ginger performed better than china ginger. Therefore, deshi ginger with mango based agroforestry was an effective production system. Interestingly, the relationship between light intensity and fresh ginger rhizome yield was inversely proportional. It was meant that the fresh rhizome ginger yield was increased with the decreasing rate of light intensity. Ginger rhizome yield was highest under mango woodlot when light intensity was lower there than of control treatment. On the other hand, in open field, ginger rhizome yield was lowest when light intensity was highest there. Finally it might be ranked in the context of growth and quality performance that mango > litchi > Ghoraneem > open field (control).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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