



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= Deshiand 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 T₁V₂. The highest fresh rhizome weight (20865 kg/ha) was found in T₃V₁ but the highest dry rhizome weight was found in T₄V₁ (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 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%, 29.35µg/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 ghoraneem (T_1) followed by under litchi (T_2) and mango (T_3), and the minimum in open condition under the control treatment (T_4). In case of variety, the higher ginger growth was found from deshi variety (V_1), whereas lower in china variety (V_2). The interaction of different Agroforestry production systems and ginger varieties growth was also found significant. The highest Growth

was found under ghora neem and deshi variety (T_1V_1) followed by litchi and deshi ginger variety (T_2V_1). Lowest germination percent was found under litchi and china variety (T_2V_2). (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 ghora neem (T_1) at 60 and 120 days after plantings (DAPs). At 180 DAP, the tallest plant was observed under ghora neem (T_1) (69.63 cm). On the contrary,

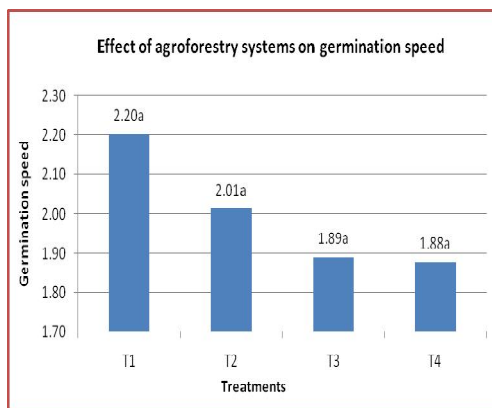


Fig. 1. Germination speed of ginger under different agroforestry system

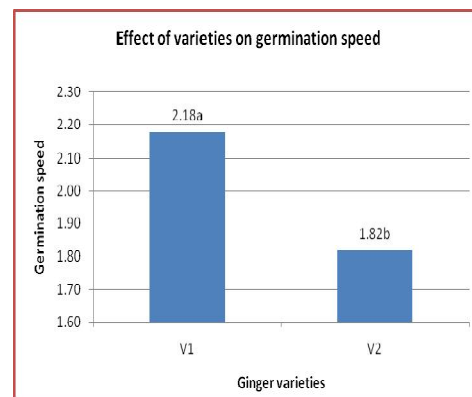


Fig. 2. Germination speed of two ginger varieties

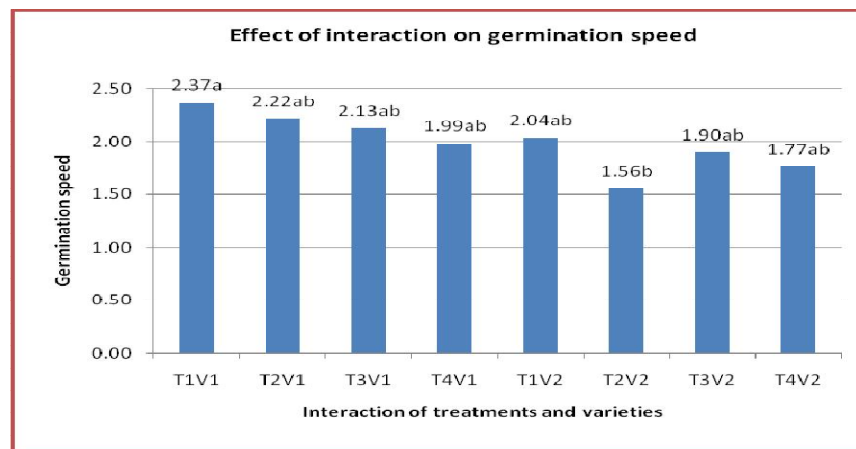


Fig. 3. The interaction of different Agroforestry production systems and ginger varieties for germination speed

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_4V_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_4V_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 the shortest leaf blade was found under open control (T_4) (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_3V_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 blades were observed in T_3V_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_4V_1 (24.32 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_4V_1 (19.50 cm) and T_1V_2 (19.75 cm) combinations which were statistically similar. Again, shortest leaf blades were recorded T_4V_2 (23.00 cm) and T_4V_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 (T_4) (1.28 cm), at 120 DAP, 1.80 cm was lowest under mango (T_3) and at 180 DAP, 2.29 cm was minimum under mango (T_3) 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 (V_1) (1.34 cm) and china variety (V_2) (1.38 cm) which were almost statistically similar. On the other hand, maximum breadth of leaf blade was observed in V_1 (2.00 cm) and minimum breadth of leaf blade was found in V_1 (1.92 cm) at 120 DAP. But at 180 DAP, breadth of leaf blades of V_1 (2.40 cm) and V_2 (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 T_1V_1 (1.68 cm), T_1V_2 (1.20 cm), T_2V_1 (1.20 cm), T_2V_2 (1.68 cm), T_3V_1 (1.25 cm), T_3V_2 (1.35 cm), T_4V_1 (1.25 cm) and T_4V_2 (1.30 cm) combinations which were almost statistically similar. Moreover, the maximum were observed in T_1V_1 (ghora neem x deshi ginger) (2.48 cm) and T_2V_2 (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 T_1V_2 (1.65 cm), T_2V_1 (1.78 cm), T_3V_1 (1.80 cm), T_3V_2 (1.80 cm), T_4V_1 (1.95 cm) and T_4V_2 (1.95 cm) at 120 DAP. Furthermore, at 180 DAP, the breadth of leaves were T_1V_1 (2.75 cm), T_1V_2 (2.20 cm), T_2V_1 (2.18 cm), T_2V_2 (2.68 cm), T_3V_1 (2.20 cm), T_3V_2 (2.38 cm), T_4V_1 (2.45 cm) and T_4V_2 (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 (T_1) (4.37). On the other hand, the lowest number of tiller per plant was found in open control (T_4) (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 (V_1) (4.19) and lower number of tiller per plant was observed in china variety (V_2) (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 T_1V_1 (ghora neem x deshi) (4.50), T_1V_2 (ghora neem x china) (4.50), (litchi x deshi) T_2V_1 (4.25) and (litchi x china) T_2V_2 (4.25) combinations which were almost similar. On the other hand, lowest number of tiller per plant was found in T_3V_1 (3.75), T_3V_2 (3.75), T_4V_1 (3.50) and T_4V_2 (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 (T_2). The lowest total number of finger per rhizome was 18.25 in open control (T_4). Moreover, highest number of rhizome per plant were found in open control (T_4) (5.45) and under mango (T_3) (5.04) which were statistically almost similar. The lowest were observed under ghoraneem (T_1) (4.38) and under litchi (T_2) (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 (V_1) (19.75). The lower total number of finger per rhizome was observed in china variety (V_2) (18.93). Moreover, higher number of rhizome per plant was recorded in V_2 (5.09) and lower was observed in V_1 (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									
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									
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	19.77.c	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 differat $P \leq 0.05$ by Tukey HSD test

Significantly highest total numbers of finger per rhizome were found in T_2V_1 (20.75), T_2V_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_4V_1 (18.05) and T_4V_2 (18.00) combinations. Moreover, highest number of rhizome per plan were found in T_4V_2 (5.51), T_4V_1 (5.41) and T_3V_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 under 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_4) (362.50 g) (Table 2). Jayachandran et al. [13] reported that ginger cultivated under the coconut (*Cocosnecifera* 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_4V_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_4) (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_4V_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_4) (20.00 g). Moreover, the minimum dry rhizome weight per 100 g was found under mango (T_3) (16.88 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_2) (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_4V_1 (mango x Deshi) (21.25 g). Moreover, the minimum dry rhizome weight per 100 g were recorded in T_1V_1 (15.50 g), T_2V_1 (15.50 g) and T_4V_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	16.88b
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	489.50a	20865a	18.75b
T3V2	3.75a	5.17a	19.00ab	479.50a	19387b	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 differ at $P \leq 0.05$ 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(T ₁)	30.38c	58.75b	17.00d	106.12c
Under litchi(T ₂)	35.25b	53.00b	21.75b	110.00bc
Under mango(T ₃)	36.13b	54.00b	25.38b	115.50b
Open field (control)(T ₄)	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 $P \leq 0.05$ 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].

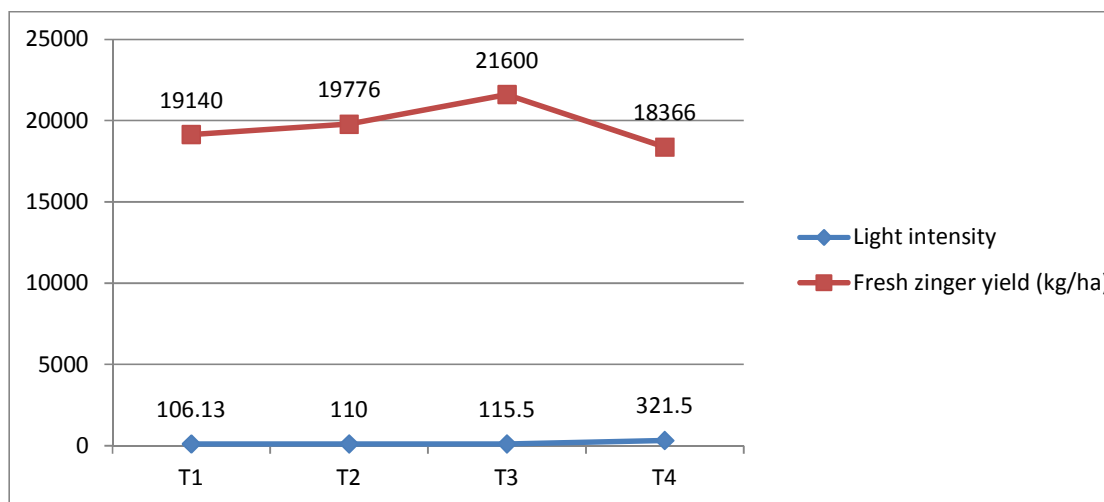


Fig. 4. Relationship between light intensity (LUX) and fresh ginger rhizome yield (kg/ha/year) under different tree based agroforestry systems

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 (T_3). On the other hand, the lowest ginger yield was 18366 kg/ha when the total light intensity was 321.50 LUX in T_4 (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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