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Productivity and Profitability of Moringa-Brinjal-Based Agroforestry Farming System

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Abstract

An investigation was carried out to assess the productivity and profitability of brinjal during the initial phase of Moringa establishment. Experimental design employed a Randomized Complete Block Design with four distinct treatments: (i) T_1 (30 cm distance from the tree base), (ii) T_2 (40 cm distance from the tree base), (iii) T_3 (50 cm distance from the tree base), and (iv) T_4 (open field, control), each treatment being replicated four times. Data were systematically collected from randomly selected plants within each plot and subjected to statistical analysis. The findings indicated that the T_4 (control) treatment exhibited superior performance for various parameters, namely plant height, leaf number, branch number, fruit number, fruit weight, and yield. Treatment T_4 produced the highest values for fruit weight per plant (1.9 kg), single fruit weight (72.6 g), and fruit yield (34.2 t/ha). Following closely, T_3 ranked second with values of 1.6 kg, 67.4 g, and 28.3 t for fruit weight per plant, single fruit weight, and fruit yield per hectare, respectively. In contrast, T_1 yielded the lowest results in fruit weight per plant (0.76 kg), single fruit weight (59.6 g), and fruit yield (13.4 t/ha). The analysis of the land equivalent ratio revealed that treatment T_3 achieved the highest ratio at 1.81, indicating a positive correlation between a greater distance from the Moringa tree base and an increased brinjal yield. The study concludes that cultivating brinjal in association with one-year-old Moringa trees, while maintaining a 50 cm distance from the tree base, results in optimal yield.

Keywords: Drumstick, Brinjal, Growth parameters, Yield, Agroforestry.

Introduction

Farmers traditionally cultivate a variety of trees and vegetables in their fields, homesteads, and surrounding areas. However, the productivity of both trees and crops in these regions is often suboptimal due to the lack of suitable tree-crop combinations. In our country, *Moringa oleifera* Lam is deemed a neglected and underutilized species, despite its global recognition as a superfood (Rudebjer et al., 2013). This oversight is attributed to the limited attention it receives from researchers and policymakers, the erosion of local knowledge, and the absence of established varieties (Padulosi et al., 2013). Nonetheless, *M. oleifera* holds the potential to function as a promising agroforestry tree species when integrated with agricultural crops. Its rapid growth, high coppicing ability, and deciduous characteristics position it as an ideal candidate for agroforestry practices (Bashir et al., 2014). Despite its international superfood

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status, *M. oleifera* has not received due consideration locally. Rectifying this requires recognizing its adaptability and incorporating it into agroforestry practices, thereby boosting overall agricultural productivity.

Moringa is a versatile and highly nutritious plant that is native to parts of Asia and Africa. The leaves of the Moringa tree are rich in essential nutrients, including vitamins A, C, and E, calcium, potassium, and protein, making it a valuable dietary supplement (Afolabi *et al*., 2013; Ahmad *et al*., 2014). Moringa is recognized for its exceptional antioxidant properties, helping to combat oxidative stress and inflammation in the body (Adejumo *et al*., 2012). The plant has been traditionally used in various cultures for its medicinal properties, including its potential to lower blood sugar levels and reduce cholesterol (Popoola and Obembe, 2013; Hussain *et al*., 2014; Stohs and Hartman, 2015). Moringa is an excellent source of plant-based protein, which is important for vegetarians and vegans seeking alternative protein sources. Its leaves contain high levels of chlorophyll, promoting detoxification and supporting a healthy immune system. Moringa has been studied for its anti-cancer properties, with some research suggesting that it may have protective effects against certain types of cancer. The plant is known for its ability to purify water due to its antimicrobial properties, providing a sustainable and natural solution for water treatment in some regions. Moringa oil, extracted from the seeds, is rich in antioxidants and has moisturizing properties, making it beneficial for skincare and haircare (Fernandes et al., 2015). The cultivation of Moringa is environmentally friendly, as it is a fast-growing tree that requires minimal water and can thrive in various soil conditions, contributing to sustainable agriculture practices (Akinbamijo *et al*., 2004).

Eggplant is an essential and valuable vegetable crop grown in Bangladesh. It is rich in essential vitamins and minerals, including Vitamin A, C, E, and Iron, which makes it a potent antioxidant. Eggplant is also abundant in iron, making it helpful in combating anemia. Vitamin A helps maintain ocular health, protecting against various eye diseases. Eggplant is also rich in calcium and magnesium, promoting dental and skeletal well-being. Its high dietary fiber content facilitates digestion and alleviates constipation. However, people with arthritis, asthma, or allergies should be cautious, as Uddin (2022) has outlined.

It is important to examine whether growing Moringa trees alongside brinjal affects productivity and yield. Studies by Taye and Tesfaye (2021), Vijaykumar et al. (2021), and Bania et al. (2023) have looked into this. In the early stages of Moringa's growth, which lasts for 1-2 years, vegetables may thrive near the tree since competition for resources such as water, nutrients, and light is minimal. The goal of this research is to determine how Moringa affects the growth and yield of brinjal and to find the optimal distance between the tree base and the brinjal plants for intercropping.

Materials and Methods

Experimental site

The experiment was carried out at the Agroforestry Field Laboratory under the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2020 to May 2021. The location of the site was $23^{o}74'$/N latitude and $90^{o}35'$/E longitude with an elevation of 8.2 meter from sea level. The experimental field was situated under monsoon climate characterized by scanty rainfall during the months from November to May. The structure of the soil was fine with an organic carbon content of 0.45%. The texture was silty clay with a pH of 5.6. The general soil type was non-calcareous dark grey.

Planting materials

Variety of *M. oleifera* L. were collected from Rajshahi which established one year ago. The seedlings of brinjal (*Solanam melongena* variety Singhnath) was purchased from Horticulture centre, DAE, Asad gate, Dhaka.

Land preparation

All operations were done by spades. Then the land was left fellow for one month. During this time all residues and weeds were removed from the land, broken stones and bricks were sorted out and finally 20 cm raised bed was leveled properly for brinjal plantation.

Crop Establishment and Management

Fertilizer application

Cowdung (20 t/ha) was applied into the experimental field during final land preparation. Besides, recommended doses of fertilizers were used in this experiment.

Pest and Disease Management

Actara 25 WG @0.25gm/liter was used to control insects and pest during the growing season.

Weeding and irrigation

Weeding was done as necessary to keep the field free from weed during the experimental period. To maintain optimum soil moisture all plots were irrigated as necessary by using watering cane.

Procedure of recording data

Plant Height (cm) – Plant height was measured in centimeter (cm) by using a scale at 30, 60, 90 and 115 DAT (days after transplanting) from the ground level to the tip of the plant leaf. *Number of leaf per plant*–Five plants from each plot were selected randomly and tagged properly. The leaf number was counted precisely for each plant. *Number of branches per plant* –The number of branches of sample plant was counted at 60, 90 and 115 DAT and the average number of leaves produced per plant was recorded. *Days to 1st flowering* –The interval between transplanting to first flowering from each replication was calculated and expressed in days. *Days to 50% flowering* – Daily observations were made on the five randomly selected and tagged plants for flowering. The day on which 50 per cent of plants showed flower initiation were considered as 50 per cent flowering. The number of days taken from the date of transplanting to flowering was recorded and expressed in number as days taken for 50 per cent flowering. *Days to 1st fruiting* –The interval between transplanting to 1st fruiting from each replication was calculated and expressed in days. *Fresh weight of shoot (g)*–After harvest randomly five plants were selected from each plot. Then shoot weight was weighted separately by balance. The sum of the fresh weight of five plants was divided by five then it was recorded as fresh weight of single plant. Fresh weight of shoot was expressed in gram (g). *Dry weight of shoot (g)* – After harvesting selected plant shoots were put into paper packet and placed in oven and dried at 60^{0}C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken. Average weight was measured in gram (g) and expressed as dry weight per plant. *Fresh weight of root (g)* – After harvest randomly five plants were selected from each plot and root was separated. Then root weight was weighted separately by balance. The sum of the fresh weight of five plant roots was divided by five then it was recorded as fresh weight of root per plant. Fresh weight of root was expressed in gram (g). *Dry weight of root (g)* – After harvesting selected plant roots were put into paper packet and placed in oven and dried at 60^{0}C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken. Average weight was measured in gram (g) and expressed as dry root weight per plant. *Number of fruits per plant* –Total number of fruits were counted at different dates of harvest from the selected plants and average value was expressed as number of fruits per plant. *Weight of fruits per plant (g)* – Total weight of fruits (g) of five plants was recorded and weight of fruits per plant was calculated. *Single fruit weight (g)* – Based on the ten representative fruits, individual fruit weight in gram was calculated. *Fruit yield per plot (kg)* –Total fruit weight of whole plants in each plot was recorded and yield per plot was calculated. *Fruit yield ha^{-1} (t)* – It was measured by the following formula –

$$\text{Fruit yield (t ha}^{-1}\text{)} = \frac{\text{Fruit yield per plot (kg)} \times 1000}{\text{Area of plot in square meter} \times 1000}$$

Land equivalent ration (LER) was calculated by using the following formula (Islam et al., 2004). Land equivalent ration (LER) was measured as:

$$\text{Land equivalent ration} = \frac{\text{Ci}}{\text{Cs}} + \frac{\text{Ti}}{\text{Ts}}$$

Where, Ci was crop yield under agroforestry, Cs was crop yield under sole cropping, Ti was tree yield under agroforestry, and Ts was tree yield under sole cropping.

Experimental design and treatments

Brinjal seedlings in association of one year old Moringa tree (8 feet×6 feet) were planted around the tree by following the Randomized Complete Block Design (RCBD) (Sumona et al.; 2020Ahmed et al., 2021). The total plot size was 48 feet ×8 feet. Individual block size was 12 feet×8 feet. Each of the four treatments was replicated four times. Four treatments which used in this study were, T_1= 30 cm distance from tree base, T_2= 40 cm distance from tree base, T_3= 50 cm distance from tree base, and T_4= Open field as control (brinjal plant to plant distance 60 cm).

Analysis of data

All the data were subjected to analysis of variance (ANOVA) and tested for significance by Least Significant Difference (LSD) using R-3.5.1 software (R Core Team, 2013).

Results and discussion

Plant height

Significant variations in brinjal plant height were observed at various days after transplanting (DAT) based on the distance of the brinjal plot from the Moringa tree base, except at 30 DAT (Table 1). Plant height exhibited a gradual increase as the crop advanced in growth. The T4 treatment (control) consistently resulted in the highest plant height at all growth stages (40.60, 55.36, and 63.50 cm at 60, 90, and 115 DAT, respectively). This was statistically at par with the T_3 treatment at all growth stages. Conversely, the T_1 treatment led to the lowest plant height (21.42, 38.77, and 48.76 cm at 60, 90, and 115 DAT, respectively). However, in the context of the tree-crop association, the T_3 treatment yielded the highest plant height (38.53, 52.44, and 61.67 cm at 60, 90, and 115 DAT, respectively).

Table 1. Effect of Moringa tree on brinjal plant height at various measurement dates

Treatment	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	115 DAT
T_1	10.33	21.42 c	38.77 c	48.76 c
T_2	10.50	28.36 b	44.62 b	55.33 b
T_3	12.33	38.53 a	52.44 a	61.67 a
T_4	13.10	40.60 a	55.36 a	63.50 a
$LSD_{0.05}$	2.114	2.276	2.521	2.714
CV (%)	6.37	8.24	10.56	9.62

T_1 = 30 cm from the base of tree, T_2 = 40 cm from the base of tree, T_3 = 50 cm from the base of tree, T_4 = without tree considered as control.

Leaf number

The number of leaves per plant showed significant variations among the treatments on different days after transplanting (DAT) (Table 2). Brinjal plants cultivated under control conditions, without association with the Moringa tree (T4 treatment), displayed the highest leaf count per plant throughout various growth stages (4.12, 46.72, 67.33, and 88.60 at 30, 60, 90, and 115 DAT, respectively). This count was statistically comparable to the T3 treatment but significantly exceeded the counts in the T_1 and T_2 treatments. This phenomenon can be attributed to the closer proximity of brinjal plants to the tree base. Conversely, the T_1 treatment recorded the lowest leaf count per plant (3.88, 31.40, 49.84, and 62.48 at 30, 60, 90, and 115 DAT, respectively).

Table 2. Effect of Moringa tree on number of leaves of brinjal at various dates after transplanting (DAT)

Treatment	Number of leaves per plant			
	30 DAT	60 DAT	90 DAT	115 DAT
T_1	3.88 b	31.40 c	49.48 c	62.48 c
T_2	3.92 b	36.29 b	59.52 b	76.44 b
T_3	4.00 a	45.38 a	64.27 a	86.77 a
T_4	4.12 a	46.72 a	67.33 a	88.60 a
$LSD_{0.05}$	0.236	1.528	3.674	3.278
CV(%)	5.74	8.29	7.624	10.38

T_1 = 30 cm from the base of tree, T_2 = 40 cm from the base of tree, T_3 = 50 cm from the base of tree, T_4 = without tree considered as control.

Branch number

Variations in the number of branches per plant were observed among the treatments (Table 3). Brinjal plants planted in the control plot (T_4) exhibited the highest number of branches per plant at all growth stages (4.30, 5.48, and 7.80 at 60, 90, and 115 DAT, respectively). In the context of tree-crop association, the favorable outcome was achieved with T_3 treatment (4.18, 5.32, and 7.10 at 60, 90, and 115 DAT, respectively), showing a significant parity with T_4 treatment (control). Treatment T_3 resulted in a significantly greater number of branches per plant compared to T_1 and T_2 treatments. The lowest number of branches per plant (2.92, 3.78, and 4.88 at 60, 90, and 115 DAT, respectively) was documented in T_1 treatment.

Table 3. Effect of Moringa-brinjal association on number of branches of brinjal at various dates after transplanting (DAT)

Treatment	Number of branches per plant		
	60 DAS	90 DAS	115 DAS
T_1	2.92 c	3.78 c	4.88 c
T_2	3.40 b	4.20 b	5.78 b
T_3	4.18 a	5.32 a	7.10 a
T_4	4.30 a	5.48 a	7.80 a
$LSD_{0.05}$	0.214	0.522	0.682
CV (%)	6.72	5.36	8.29

T_1 = 30 cm from the base of tree, T_2 = 40 cm from the base of tree, T_3 = 50 cm from the base of tree, T_4 = without tree considered as control.

Brinjal plants within the control treatment (T_4) consistently exhibited superior morphological characteristics compared to those in agroforestry treatments. The enhanced growth performance of plants in the control treatment can be attributed to their utilization of a substantial amount of resources, particularly light, irrigation water, and organic amendments, without encountering any challenges from the Moringa tree.

Throughout the experimental period, all the assessed parameters exhibited significant variations among the treatments. This observation confirmed the evident above and below-ground competition for resources between the tree and crop in the different treatments, as documented by Noman et al. (2018). At harvest, the number of branches in the T_3 treatment was 9.8 % lower than that in the control condition. Additionally, all the growth characteristics were higher in the control condition (T_4 treatment), followed by T_3, T_2, and T_1 treatments, respectively. These research findings align with previous studies, such as Dola et al. (2016), who observed increasing trends in plant growth parameters with the distance from the tree base. In tree-crop association, various ecological interactions between trees and crops, as highlighted by Jose et al. (2004), result in adverse effects on the physiology of both. Competitive behaviors manifest at different levels, influencing morphological responses (plant growth), biochemical responses (plant defense), and resource allocation (Yamawo, 2015). According to Jose et al. (2004), systems managed with high inputs of inorganic or organic nutrient supplements experience minimal competition for nutrients.

Treatment T_3 emerged as the most effective among the Agroforestry treatments. Agroforestry systems play a crucial role in reducing evaporation through temperature and wind control (Lin, 2010). They contribute to improved water and nutrient cycling, provide radiation protection, and enhance soil organic carbon and the activity of beneficial soil organisms through accelerated decomposition. This creates a more favorable environment for crop components (Barrios et al., 2012). Additionally, plants with deep roots engage in hydraulic lift redistributing water to upper layers and potentially serving as bioirrigators for neighboring plants (Bayala and Prieto, 2020).

Biodiverse ecosystems demonstrate greater efficiency in resource utilization (water and nutrients) and exhibit increased resilience to various environmental stresses, including weather extremes, pests, and diseases, compared to monocrops (Gaba et al., 2015). This enhanced resilience is likely attributed to diverse traits associated with complementary functions (Lohbeck et al., 2016).

Days to the first flowering

Significant variations in the days to the first flowering of brinjal were observed among different treatments involving brinjal and Moringa, with or without their association (Table 4). The results revealed that the T_1 treatment had the highest number of days to the first flowering, recording 77 days, which was significantly different from the other treatments, with T_2 following closely. Conversely, the T_4 (control) treatment exhibited the lowest days to the first flowering at 72 days, and this was statistically identical to the plants under the T_3 treatment.

Days to 50% flowering

Significant variations in the days to 50% flowering of brinjal were observed in the association of brinjal and Moringa (Table 4). The highest number of days to 50% flowering was noted in the T_1 treatment (92.50 days), and this was significantly different from the other treatments, with T_2 following closely. In contrast, the T_4 (control) treatment exhibited the lowest days to 50% flowering at 86.50 days, and this was statistically identical to T_3.

Days to the first fruiting

Significant variations in the days to the first fruiting of brinjal were observed among different treatments (Table 4). The results indicated that the T_1 treatment had the highest number of days to the first fruiting (85.50 days), which was significantly different from other treatments. Conversely, the T_4 (control) treatment exhibited the lowest days to the first fruiting (79.25 days), and this was statistically at par to the T_3 treatment. In the context of tree crop association, the T_3 treatment also showed the lowest days to the first fruiting at 80.50 days.

Table 4. Effect of Moringa-brinjal association tree on days to 1st flowering, 50% flowering and 1st fruiting of brinjal

Treatments	Yield contributing parameters of brinjal		
	Days to 1st flowering	Days to 50% flowering	Days to 1st fruiting
T_1	77.00 a	92.50 a	85.50 a
T_2	75.75 b	90.00 b	83.25 b
T_3	73.50 c	87.25 c	80.50 c
T_4	72.00 c	86.50 c	79.25 c
$LSD_{0.05}$	1.67	1.52	1.71
CV (%)	8.28	7.56	10.44

T_1 = 30 cm from the base of tree, T_2 = 40 cm from the base of tree, T_3 = 50 cm from the base of tree, T_4 = without tree considered as control.

Shoot fresh weight (g)

Varying distances of brinjal plantation from the Moringa tree significantly influenced the brinjal shoot fresh weight (Table 5). Among the various treatments, the open field condition (T_4, control) exhibited the highest fresh shoot weight at 995.21 g, while the lowest fresh shoot weight, recorded at 443.40 g, was associated with the T_1 treatment. In terms of tree-crop association treatments, brinjal plants in the T3 treatment demonstrated the highest fresh shoot weight at 625.23 g.

Root fresh weight (g)

Statistically significant variations in the root fresh weight of brinjal was observed due to varying distances of brinjal plantation from the Moringa tree (Table 5). The open field condition (T_4; control) recorded the highest fresh root weight at 155.85 g, whereas the T_1 treatment exhibited the lowest fresh root weight with the value of 100.00 g. In the context of tree-crop association, T_3 resulted in the highest fresh shoot weight of 118.20 g.

Shoot dry weight (g)

Distance of brinjal plantation from Moringa tree had a significant effect on the shoot dry weight of brinjal (Table 5). Across all treatments, the control treatment (T_4) exhibited the highest dry weight of shoot at 238.40 g, while the lowest dry weight of shoot, recorded at 128.700 g, was associated with the T_1 treatment. As expectation, in terms of tree-crop association treatments, T_3 yielded the highest dry weight of shoot at 170.75 g.

Root dry weight (g)

Varying distances of brinjal plantation from the Moringa tree, had a statistically significant effect on the root dry weight of brinjal (Table 5). Open field condition (T_4; control) recorded the highest dry weight of root at 68.27 g, while the T_1 treatment exhibited the lowest dry weight of root at 36.62 g. In terms of tree-crop association treatments, T_3 demonstrated the highest dry weight of shoot at 45.66 g.

Fruit number per plant

The brinjal plantation, whether with or without of Moringa trees, had a significant impact on the number of fruits per plant for brinjal (Table 6). In the control treatment (T_4), the highest number of fruits per plant (26.50) was observed. However, in agroforestry practice involving Moringa-brinjal interaction, treatment T_3 exhibited the highest number of fruits per plant (23.60) compared to T_1 and T_2. The lowest number of fruits per plant (12.72) was recorded in T_1 treatment, representing a 40.41% reduction compared to T_4 and a 31.86% decrease compared to T_3 treatment.

Table 5. Effect of Moringa-brinjal agroforestry farming system on fresh and dry weight of brinjal plant

Treatments	Fresh weight (g)		Dry weight (g)	
	Shoot (g)	Root (g)	Shoot (g)	Root (g)
T_1	443.40 d	100.00 d	128.70 d	36.62 c
T_2	489.00 c	110.50 c	142.94 c	38.38 c
T_3	625.23 b	118.20 b	170.75 b	45.66 b
T_4	995.21 a	155.85 a	238.40 a	68.27 a
$LSD_{0.05}$	6.14	3.36	5.23	2.17
CV (%)	10.58	8.36	9.27	7.57

T_1 = 30 cm from the base of tree, T_2 = 40 cm from the base of tree, T_3 = 50 cm from the base of tree, T_4 = without tree considered as control.

Fruit weight per plant (g)

Various plantation distances of brinjal from the tree base of Moringa resulted in significant variations in the weight of fruits per plant (Table 6). The findings revealed that the greatest fruit weight per plant (1923.90 g) occurred without tree-crop interaction, specifically in the control treatment T_4. However, in the presence of tree-crop interactions, the highest fruit weight per plant (1592.53 g) was observed in T_3 treatment, ranking as the second-highest among all treatments. The lowest fruit weight per plant (758.11 g) was documented in T_1 treatment, representing a 60.58% reduction compared to the control treatment and a 52.39 % decrease compared to T_3 treatment.

Single fruit weight (g)

Substantial differences in single fruit weight were noted based on the distance of the brinjal plant from the Moringa tree base (Table 6). The maximum single fruit weight (72.60 g) was documented in T_4 treatment, while the minimum single fruit weight (59.60 g) was observed in T1 treatment. In the context of tree-crop interaction, T_3 treatment exhibited a higher single fruit weight (67.48 g), ranking as the second-highest among all treatments.

Plants in treatment T_1 taken maximum duration to the first fruiting, as evidenced by increased days to first flowering and days to 50% flowering. The prolonged time for first fruiting in the close proximity of brinjal plants to Moringa may be attributed to nutritional competition between the tree-crop, leading to nutrient deficiency in brinjal. Reduced distances between brinjal and Moringa intensified nutrient competition, potentially contributing to the lower number of fruits per plant and overall yield in T_1 treatment. Conversely, T_4 (open field) and T_3 treatments, with greater distances, displayed higher numbers of fruits per plant and increased yield. As suggested by van Noordwijk et al. (1996), belowground competition arises when species develop specialized root systems, directing them to explore the same rhizosphere for resources. In cases where incompatible species combinations are chosen, it can result in poor growth for both components, as noted by Gonçalves et al. (2021). Resource competition emerges as a critical factor influencing plant community diversity and dynamics, often leading to a reduction in the overall productivity of the system, as emphasized by Schluter (2000).

Table 6. Yield contributing parameters of brinjal as influenced by Moringa-brinjal agroforestry farming system

Treatments	Yield contributing parameters of brinjal			
	Number of fruits/plant	Weight of fruits/plant (g)	Single fruit weight (g)	Fruit yield/ plot (kg)
T_1	12.72 d	758.11 d	59.60 d	3.03 d
T_2	18.84 c	1209.53 c	64.20 c	4.84 c
T_3	23.60 b	1592.53 b	67.48 b	6.37 b
T_4	26.50 a	1923.90 a	72.60 a	7.70 a
$LSD_{0.05}$	1.26	8.53	1.87	0.63
CV(%)	6.89	11.54	9.37	7.56

T_1 = 30 cm from the base of tree, T_2 = 40 cm from the base of tree, T_3 = 50 cm from the base of tree, T_4 = without tree considered as control.

Fruit yield (t/ha)

Statistically significant variations in fruit yield per plot were observed among different treatments, attributed to varying distances of brinjal plantation from the Moringa tree (Table 7). The highest fruit yield per plot (7.70 kg) was documented in the T_4 treatment. In the context of agroforestry practices involving tree-crop interaction, the optimal fruit yield per plot (6.37 kg) was observed in the T_3 treatment, ranking as the second-highest among all treatments. Conversely, the lowest fruit yield per plot (3.03 kg) was recorded in plants subjected to the T_1 treatment, indicating a 60.64% reduction compared to the control treatment and a 52.43% decrease compared to the T_3 treatment.

Significant variations were observed in both fruit yield per hectare and the land equivalent ratio (LER) across different Moringa-brinjal agroforestry farming systems, influenced by varying distances of brinjal plantation from the Moringa tree (Table 7). The maximum brinjal yield (34.20 t/ha) was noted in the T_4 treatment, representing a sole brinjal plot. However, within the agroforestry system involving tree-crop interaction, the highest brinjal yield (28.31 t/ha) was achieved in the T_3 treatment, ranking as the second-highest among all treatments and being 17.22% lower than the control treatment. Conversely, the minimum brinjal yield (13.48 t/ha) was recorded in the T_1 treatment, showcasing a 60.58% reduction compared to the control treatment and a 52.38% decrease compared to the T_3 treatment.

The highest Moringa yield was recorded in sole Moringa tree with the value of 1.33 t/ha. Treatments T_3 and T_2 produced the 2nd highest Moringa yield followed by T_1 treatment with the value of 1.30 t/ha (Table 7). The LER signifies the relative productivity of intercropping compared to sole cropping. Agroforestry system followed in T_3 treatment has the significantly highest LER (1.81) which was statistically at par with the agroforestry system followed in T_2 treatment, and the least LER (1.37) was found in T_1 treatment.

Table 7. Fruit yield and land equivalent ratio (LER) in Moringa-brinjal agroforestry farming systems

Treatments	Fruit yield and land equivalent ratio		
	Brinjal (t/ha)	Moringa (t/ha)	LER
T_1	13.48 d	1.30	1.37 b
T_2	21.50 c	1.31	1.61 a
T_3	28.31 b	1.31	1.81 a
T_4	34.20 a	1.33	-
$LSD_{0.05}$	1.56	-	0.23
CV(%)	10.44	8.85	8.39

T_1 = 30 cm from the base of tree, T_2 = 40 cm from the base of tree, T_3 = 50 cm from the base of tree, T_4 = without tree considered as control.

Optimum plant nutrition is essential for successful crop production. Under control treatment, plant nutrition was available and there was no competition for nutrient with Moringa tree and resulted higher brinjal yield. Lower distance of crop from tree increases nutrition competition between them and might be nutrient deficiency was occurred and resulted lower fruit yield/ha of brinjal under tree-crop association. An LER value greater than 1 indicates the advantage of intercropping in utilizing land more efficiently. Treatments (T_1, T_2, and T_3) evaluated in Moringa-brinjal association displayed increasing fruit yields for both crops as well as increasing LER, indicating improved productivity compared to sole cropping. In this experiment, the total LER for the T_3 treatment (Moringa- brinjal association) was 1.81. This means that the combined yield of Moringa and Brinjal in the Moringa- brinjal agroforestry system was 1.81 times higher compared to growing them separately in a monoculture over the same area.

Conclusions

The Study aimed to assess the relationship between trees and crops, specifically Moringa and Brinjal. The findings of the experiment indicated that during the initial stage of Moringa tree growth, planting them at various distance resulted in negative interactions with crops. However, the Land Equivalent Ratio (LER) exceeded 1 for all Moringa-Brinjal agroforestry systems. Moreover, the experiment showed that the yield of Brinjal increased as the distance from the Moringa tree base expanded. Therefore, it is recommended that cultivation of Brinjal-Moringa is a viable option, with an optimal distance of 50 cm from the base of a one-year-old Moringa tree.

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Conflict of Interests

The authors declare no conflict of interst.

Statement of Author's Credit

Concept−G.J. Helal and H. Kausar; Data Collection, Analysis and Methodology−M. Roy and M. Helal; Supervision−G.J. Helal, Writing−Original Draft, M. Roy; Writing, Review and Editing−M. Roy, G. J. Helal and H. Kausar. All authors have read and agreed to the published version of the manuscript.

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