



Performance of Sunflower (*Helianthus annuus* L.) Under a Moringa-based Agroforestry System

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Abstract: Sunflower (*Helianthus annuus* L.) is a widely cultivated oilseed crop with considerable economic importance due to its diverse industrial and nutritional applications. This study evaluated the growth performance, yield, and economic feasibility of sunflower cultivated under a Moringa (*Moringa oleifera* L.)-based agroforestry system at different distances from the base of the tree. This experiment was conducted with four treatments—sunflower cultivation was arranged at planted at 50 (D₁), 100 (D₂), 150 (D₃) cm away from the base of moringa trees, and an open-field control (D₄) and a randomized complete block design (RCBD) was employed for the experimental layout. All measured growth attributes of sunflower, including plant size, canopy coverage, total biomass, and stem girth, showed a significant decline as plants were positioned closer to the Moringa trees, primarily due to increased shading and below-ground competition. The highest seed yield (3.17 t ha⁻¹) was obtained under open-field condition, while a yield of 2.73 t ha⁻¹ was observed at 50cm (D₃) produced a yield statistically similar to the control treatment, suggesting that competitive effects were minimized at wider spacing. Economic assessment were further indicated that agroforestry-based intercropping substantially improved profitability, with the highest net return (Tk. 787600 ha⁻¹) and benefit-cost ratio (6.5) achieved under the D₃ treatment, largely due to the combined income from sunflower and Moringa pod production. Although sole sunflower yielded more, intercropping with moringa at 150 cm optimized land-use efficiency and overall profitability. Thus, the study concludes that moringa-sunflower based agroforestry, particularly with 150 cm spacing, is a sustainable production system in Bangladesh.

Keywords: Sunflower; Moringa; Yield; Gross return; Benefit cost ratio

INTRODUCTION

Bangladesh is highly vulnerable to climatic hazards due to its location in the Bay of Bengal and its large population, which is projected to rise to 192.6 million by 2050 (Abdullah and Rahman, 2015; Naser *et al.*, 2019; UN, 2019). Agriculture continues to be a dominant sector of the national economy, but climate change and human-induced stresses strongly threaten its sustainability (Miah *et al.*, 2016; Rahman *et al.*, 2018). Although agricultural productivity has improved substantially in recent decades, food insecurity still affects approximately 24.2 million people nationwide (Hasan *et al.*, 2019). Agroforestry has emerged as an

effective ecological approach to enhance productivity and ensure environmental sustainability. It is defined as a system that integrates trees with crops to optimize land use, improve soil fertility, and strengthen resilience to environmental stresses (Hanif *et al.*, 2010). This practice offers not only ecological services but also significant social and economic benefits to farming communities.

In Bangladesh, *Moringa oleifera* L., is recognized as a promising agroforestry species, owing to its multipurpose uses and its richness in essential nutrients such as proteins, vitamins, minerals, and antioxidants. *Moringa* leaves are exceptionally rich in nutrients, containing several-fold

higher leaves of vitamin C, vitamin A, calcium, and iron compared to common fruits and vegetables (Foidl, 2001). In addition, Moringa improves soil fertility when used as green manure and promotes crop growth due to cytokinins such as zeatin (Phiri, 2010; Phiri and Mbewe, 2010). Its tolerance to adverse conditions and rapid biomass production make it highly suitable for integration into farming systems (Makkar and Becker, 1996).

Sunflower (*Helianthus annuus* L.) is a promising crop for agricultural and stands out globally as an important oilseed crop offering high quality edible oil, protein and dietary fiber (Khan et al., 2015; pal et al., 2015). Global demand for sunflower oil is rising steadily (Taher et al., 2017). Although sunflower seeds contain anti-nutritional compounds, proper processing reduces them to safe levels, making sunflower products suitable for human consumption (Adesina, 2018; Grasso et al., 2019). Its deep taproot system provides drought tolerance and rapid recovery under moisture stress, enabling survival under adverse climatic conditions (Hussain et al., 2018). In Bangladesh, sunflower cultivation is still limited, covering only 3330 acres with a production of 1449 metric tons in 2019-2020 (BBS, 2020), which is insufficient to meet national demand.

As cropland expansion is not feasible in Bangladesh, integrated production systems are required. Agroforestry can maximize land productivity and support climate resilience. However, Moringa-based agroforestry has not yet been evaluated with sunflower as an intercrop. This study was therefore designed to investigate the potential of sunflower as an understory crop in Moringa-based agroforestry, focusing on enhancing land use efficiency and promoting sustainable agriculture in Bangladesh. This study further evaluated the yield performance of sunflower under diverse Moringa-based agroforestry configurations and assessed the economic viability of the Moringa-sunflower agroforestry system through cost-benefit analysis.

MATERIALS AND METHODS

Study area: The study was conducted from November 2020 to March 2021 at the Agroforestry Field Laboratory of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh (23°74' N, 90°35' E; 8.2 m above sea level). The experimental field falls within the Tejgaon soil series of Agro-Ecological Zone 28 (Modhupur Tract), distinguished by red soils, gently undulating terrain, and floodplain sedimentation. The climate is subtropical monsoon with 2052 mm annual rainfall and 1286 mm potential evapotranspiration. Mean annual temperature range from minimum 14-21°C to maximum 30-35°C (BBS, 2021). The soil was silty clay (pH 6.1).

Planting materials: Young *Moringa oleifera* trees were selected from established plantations in Rajshahi. High-quality, certified seeds of sunflower (*Helianthus annuus* L., var. BARI Surjamukhi-3) were collected from the Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh.

Experimental design and treatments: The study was conducted following a randomized complete block design (RCBD) to ensure precise and unbiased treatment comparisons. Four treatments were evaluated in this study, where sunflower was established at three spatial distances- 50 cm (D₁), 100 cm (D₂), and 150cm (D₃)-from the base of Moringa trees, in addition to an open-field control (D₄). The experimental field measured 1080 × 540 cm, with plots of 50 × 90 cm and 60 cm spacing between blocks.

Crop establishment and management: Land was prepared manually, incorporating cow dung (10 t ha⁻¹). Seeds were sown on 19 December 2020 at 25 cm × 50 cm spacing. The nutrient application consisted of urea, TSP, MoP, and Boron at 200, 180, 170, 12 kg ha⁻¹, respectively in addition to manure. Thinning (20 DAS), weeding, and irrigation were carried out as needed. No major pest or disease incidence was observed.

Data collection: Growth data included plant height, leaf length, leaf breadth, internode number, internode length, stem diameter, shoot and root biomass (fresh and dry). Yield data included number and weight of seeds per plant and seed yield (t ha⁻¹). Seed yield was calculated as:

$$\text{Seed yield (t ha}^{-1}\text{)} = \frac{\text{Seed yield per plot(kg)} \times 10000}{\text{Plot area (m}^2\text{)} \times 1000}$$

Economic analysis: Production cost was estimated including land lease and 10% interest on working capital. The benefit cost ratio (BCR) was calculated as follows:

$$\frac{\text{Benefit}}{\text{Total cost of production per hectare (Tk.)}} = \frac{\text{Cost}}{\text{Gross return per hectare (Tk.)}} = \text{Ratio}$$

Data analysis: Data were analyzed using MSTAT software, and treatment effects were assessed through ANOVA. Mean comparisons were performed using Duncan's Multiple Range Test at the 5% significance level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height: Sunflower plants exhibited significant variation in height due to different distances from the moringa tree base (Table 1). Plant height increased progressively with age, reaching 90-95 cm at harvest. The tallest plants were consistently observed under control (open field, D₄), while the shortest occurred at 50 cm from the tree base (D₁). Similar results were reported by Akter et al. (2013), who found carrot height improved with increasing distance from trees. The plant height of sunflower progressively declined with proximity to the moringa tree base. The reduced performance near trees, particularly at 50 cm, can be attributed to above- and belowground competition for light, water, and soil nutrients. The open-field control (D₄) exhibited the best performance due to unrestricted access to sunlight and nutrients, resulting in taller plants (95 cm) of sunflower. Similar patterns were

stated by Schroth *et al.* (2008), who described how shading and root overlap reduce crop vigor in tree-crop systems.

Leaf length and leaf breadth: Leaf length and breadth were also significantly affected by distance (Table 1). At harvest, D₄ plants produced the longest leaves (24.20 cm) and widest leaves (20 cm), while D₁ had the smallest (22.1 cm length, 17.5 cm breadth). D₃ again performed comparably to control, with leaf dimensions statistically similar. These differences are linked to shading intensity and nutrient competition near the tree base. Reduced radiation interception under closer spacing lowered photosynthesis and hence leaf development. Reduced light availability under moringa shade likely restricted photosynthetic activity, chlorophyll development, and leaf expansion. Akter *et al.* (2013) and Anwar *et al.* (2013) reported similar findings for carrot and bottle gourd grown near tree canopies, where shading reduced leaf area and internode elongation.

Internode number and length: Internode development followed a similar trend were mentioned in Table 1. Maximum number (11.6) and length (10.3 cm) of internodes at 90 DAS were recorded in D₄, while D₁ had the lowest values (9.0 internodes, 8.16 cm length). The D₃ remained statistically close to control. Tree shading near the base likely reduce light availability, restricting internode elongation and node production. Hussain *et al.* (2018) highlighted that as light controls carbon uptake and subsequent biomass accumulation, the growth and development of sunflower is strongly dependent on adequate radiation.

Canopy area: Canopy expansion increased with crop age and was significantly influenced by tree distance (Table 1). At harvest, control plants developed the largest canopy area (44 cm²), while the smallest was recorded at 50 cm from tree base (40 cm²). Plants at 150 cm distance (D₃) maintained

Table 1. Effect of distance from moringa tree base on growth parameters of sunflower

Treatments	Plant height (cm)	Leaf length (cm)	Leaf Breadth (cm)	Internode Number	Internode Length (cm)	Canopy area (cm ²)	Stem Diameter (cm)
D ₁	90.00 d	22.10 d	17.50 d	9.00 d	8.16 d	40.00 c	3.10 d
D ₂	91.00 c	22.50 c	18.10 c	9.66 c	9.00 c	41.00 c	3.33 c
D ₃	93.10 b	23.50 b	18.80 b	11.00 b	9.66 b	42.30 b	3.70 b
D ₄	95.00 a	24.20 a	20.00 a	11.60 a	10.3 a	44.00 a	4.10 a
CV (%)	0.060	0.37	0.30	3.22	2.75	1.52	1.81

In a column, values with same letter(s) do not differ significantly at 5% level by LSD

Fresh weight of shoot: The data demonstrates that when the planting distance from tree base increased, a significant increase was observed in fresh weight of shoot in tree crop interaction. Maximum fresh weight of shoot (168 g) was recorded in treatment D₄ (control) and D₁ recorded minimum (150.7 g) fresh weight of shoot.

canopy size close to control, reflecting reduced shading stress. The open-field control (D₄) exhibited a greater canopy area (44 cm²) due to due to proper light penetration and nutrients uptake. Comparable findings were observed by Hanif *et al.* (2010) in okra-litchi systems and Rahman *et al.* (2018) in jackfruit-eggplant agroforestry, where intercrops farther from tree bases performed better. They observed the suppressive vegetative growth due to the reduced light interception and nutrient competition. Despite this, sunflower plants at 150 cm distance (D₃) exhibited growth parameters statistically similar to the open-field control, suggesting that moderate spacing between moringa and sunflower can minimize competitive stress. The moringa tree, characterized by an open crown and light canopy structure, allows partial sunlight penetration to the understory crop. Additionally, the deep root structure of moringa may lessen direct root rivalry with crops like sunflower that have shallow roots, allowing for complementary use of soil resources. Phiri (2010) and Phiri and Mbewe (2010) also documented positive effects of moringa leaf extracts on crop growth, attributed to growth-promoting hormones like zeatin, which could further enhance physiological performance of nearby crops.

Stem diameter: Stem girth followed the same pattern (Table 1). At harvest, maximum diameter (4.1 cm) was recorded in D₄, while D₁ produced the lowest (3.1 cm). Plants in D₃ again performed better than those at closer distances, showing the advantage of reduced competition for light, moisture, and nutrients. The thinnest stems were observed at 50 cm distance (D₁), while the open-field control (D₄) produced the most vigorous plants. The observed growth depression under close spacing may be due to the combined effects of shading and belowground competition. Similarly, Schroth *et al.* (2008) described how shading and root overlap reduce crop vigor in tree-crop systems.

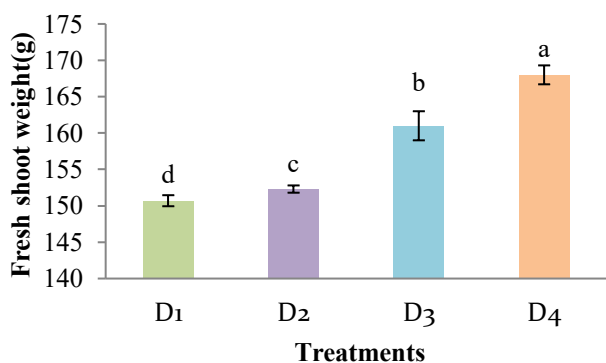


Figure 1. Effect of distance from moringa tree base on fresh shoot weight at harvest ($LSD_{0.05} = 0.94$)

Fresh weight of root: As expectation, similar trends were also recorded in fresh weight of root of sunflower at harvest. In tree crop association, maximum fresh weight of root (32.37 g) was found in D₃ treatment and minimum root fresh weight (29.17 g) was recorded in D₁ treatment. Schroth *et al.* (2008) noted that in tree-crop systems, trees with extensive root systems often compete with crops for moisture and nutrients, especially in upper soil horizons.

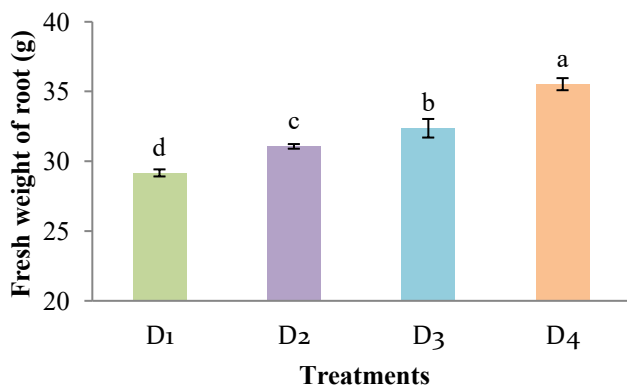


Figure 2. Effect of different distance from moringa tree base on fresh weight of root at harvest ($LSD_{0.05} = 0.29$)

Dry weight of shoot: In the present study, open-field control (D₄) sunflower achieved the highest dry shoot weight (42.67 g). The D₁ treatment gave the lowest (37.67 g) dry shoot weight at harvest. The relatively lower yield under closer spacing could also be attributed to a reduction in dry matter and root biomass accumulation. In the current study, the lowest shoot and root weights were recorded at 50 cm distance, supporting the hypothesis of strong belowground competition for water and nutrients. Schroth *et al.* (2008) noted that tree roots can deplete upper soil layers, limiting nutrient access for intercrops, particularly during dry periods. Conversely, wider spacing allows roots of both species to exploit separate soil zones, reducing competition.

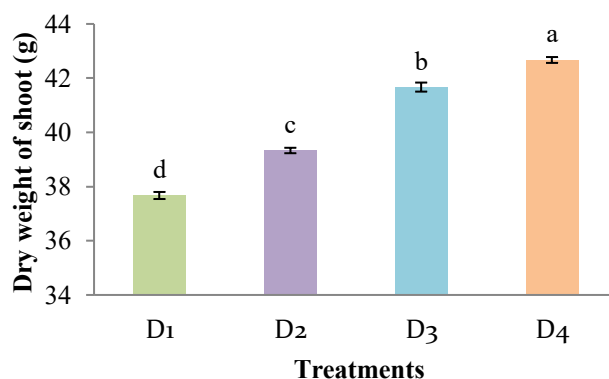


Figure 3. Effect of distance from moringa tree base on shoot weight ($LSD_{0.05} = 0.99$)

Dry weight of root: As expectation, similar trends were also recorded in fresh weight of root of sunflower at harvest. In tree crop association, maximum dry root weight (13 g) was recorded in treatment D₃ and minimum fresh root weight (11.13 g) was found in D₁ treatment.

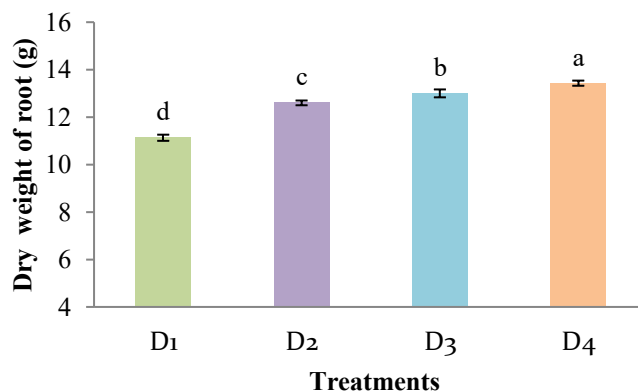


Figure 4. Effect of different distance from tree base on dry root weight of sunflower at harvest ($LSD_{0.05} = 0.99$)

Number of seeds plant⁻¹: The maximum seeds plant⁻¹ (451.7) was obtained in D₄ treatment (control) and the lowest (356.30) was found in D₁ treatment. Number of seeds was increased with increasing planting distance.

Number of filled seed per plant: There was a significant variation among the treatment due to different planting distance (Table 2). Maximum number of filled seed per plant (320.00) was recorded in control treatment and minimum number of filled seed per plant (175.30) was found in D₁ treatment. In tree crop interaction, maximum result was found in D₃ treatment.

Number of unfilled seed per plant: There was a significant variation due to various distances in respect of the number of unfilled seed per plant (Table 2). The maximum number of unfilled seed plant⁻¹ (181.00) was obtained in

treatment D₁ and the minimum result (11.8) was found in control treatment.

1000 seed weight: In tree crop interaction, maximum weight was found in D₃ treatment which is statistically similar with D₂ treatment and the minimum result was obtained in D₁ treatment.

Table 2. Effect of different distance from tree base on yield contributing character of sunflower.

Treatment	Total number of seeds plant ⁻¹	Number of filed seed plant ⁻¹	Number of unfilled seed plant ⁻¹	1000 seed weight (g)
D ₁	356.3d	175.3d	181a	100.00c
D ₂	380.7c	216.3c	164.3b	109.00b
D ₃	424.7b	270b	154.7c	110.00b
D ₄	451.7a	320a	131.7d	115.00a
CV (%)	1.60	5.08	2.78	1.57

In a column, values with same letter(s) do not differ significantly at 5% level by LSD

Seed weight per plant: Seed is an important yield parameter which also follows similar trends as other parameter. In this experiment, different distance had significant effect on seed weight (Figure 5). Minimum seed weight plant⁻¹ (41.67 g) was found in D₁ treatment and maximum result (48.33 g) was found in D₄ treatment.

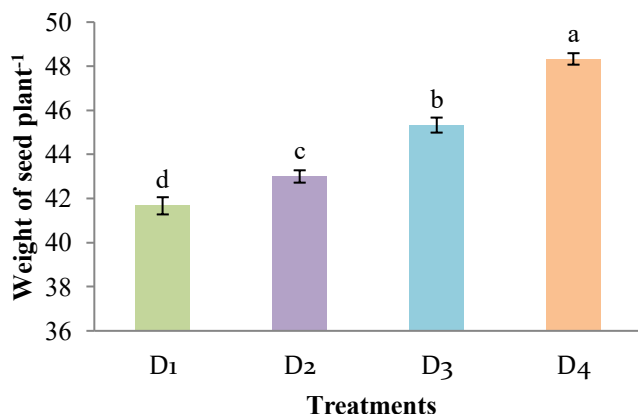


Figure 5. Effect of different distance from tree base on weight of seed plant⁻¹ of sunflower (LSD_{0.05}= 0.84)

Seed yield: Yield components were similarly affected by distance and the highest seed yield (3.17 t ha⁻¹) was recorded in the open field, while the lowest seed yield (2.73 t ha⁻¹) occurred near the tree base (D₁) were mentioned in the Figure 6. The decrease in yield near the tree base can be explained by shading effects and root competition that limits nutrient uptake, flower initiation, seed filling, and oil accumulation in sunflower heads. These findings are consistent with Akter *et al.* (2013), who reported reduced carrot yield near *Xylia dolabriformis* trees, and Anwar *et al.* (2013), who found similar effects on bottle gourd under *Acacia auriculiformis*. Tanni *et al.* (2010) also noted decreased yield of radish with closer proximity to tree bases. Hussain *et al.* (2018) emphasized that adequate light and nutrient availability are essential for optimal sunflower seed development and oil accumulation, supporting the current study's results. In the current study, interestingly sunflower cultivated at 150 cm distance (D₃) produced yields

statistically comparable to the open field, suggesting that moderate shade may not severely impact productivity when tree spacing is sufficient. Furthermore, crop performance in the area can be enhanced by the biological characteristics of the moringa tree, such as its deep rooting system and the release of growth-promoting compounds (zeatin and other cytokinins) were previously described (Phiri, 2010; Phiri & Mbewe, 2010). Thus, wider spacing between moringa trees balances competition and facilitation, enabling sustainable intercropping without significant yield loss.

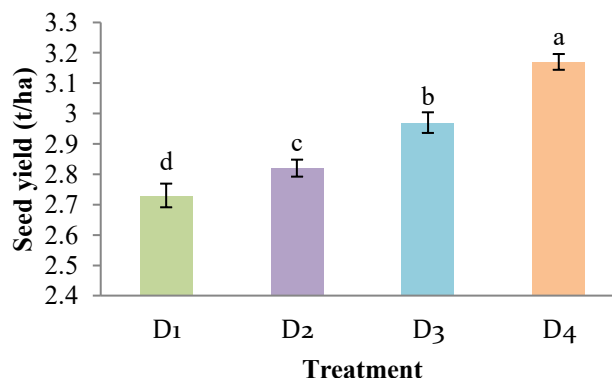


Figure 6. Effect of distance from tree base on seed yield of cauliflower (LSD_{0.05}=0.04)

Cost: A single moringa tree produced an average of 166 fruits with an average yield of 11 t/ha. The pods of moringa were harvested from January to March for 3 months and pods length were about 20-40 cm with a girth of 6.40 cm and the average weight was about 280 gm.

- Size of dig pit: 45cm × 45 cm × 45 cm
- Number of plants ha⁻¹ = 166
- Spacing: 6 × 10 m²
- Yield plant⁻¹ = 67 kg

Total cost of production (sunflower)

Non-material cost	Material cost		Total input cost (A)	Interest on input cost @ 12.5% for 6 month (B)	Miscellaneous cost is 5% of total input cost (C)	Overhead cost (6 month) (D)	Total cost of production (A+B+C+D)
	i	ii					
16500		33480	49980	3124	2499	12500	68103

Total cost of production (Interaction)

Non-material cost	Material cost		Total input cost (A)	Interest on input cost @ 12.5% for 6 month (B)	Miscellaneous cost is 5% of total input cost (C)	Overhead cost (6 month) (D)	Total cost of production (A+B+C+D)
	Moringa	Sunflower					
16500	46700	33480	96680	6043	4834	12500	120057

Gross return from sunflower cultivation

Moringa pods = 1 kg 50 Tk. so 1 ton = 50000 Tk.

Sunflower = 1 kg 80 Tk. so 1 ton = 80000 Tk.

Treatment	Moringa pods yield (t/ha)	Value	Sunflower yield (t/ha)	Value	Gross return (Tk.)
D ₁	11	550000	2.73	218400	768400
D ₂	11	550000	2.82	225600	775600
D ₃	11	550000	2.97	237600	787600
D ₄	0	0	3.17	253600	253600

Profitability of moringa sunflower intercropping

Treatment	Gross return (Tk.)	Total cost of production	Net return	BCR
D ₁	768400	120057	648343	6.40
D ₂	775600	120057	655543	6.46
D ₃	787600	120057	667543	6.56
D ₄	253600	68103	185497	3.72

Gross return: Economic analysis revealed substantial differences among treatments. Gross return: Highest in D₃ (Tk. 787,600) due to combined returns from sunflower and moringa pods, followed by D₂ (Tk. 775,600). D₄ recorded the lowest (Tk. 253,600) because it lacked moringa yield.

Net return: D₃ again achieved the highest (Tk. 667,543), followed by D₂ (Tk. 655,543). The lowest was in D₄ (Tk. 185,497).

Benefit Cost Ratio (BCR): Maximum in D₃ (6.56), followed by D₂ (6.46), while the lowest was in D₄ (3.72). Thus, while sunflower alone performed best in open field conditions, the combined returns from sunflower and

moringa made intercropping at 150 cm spacing (D₃) the most profitable system. Schroth *et al.* (2008) discusses how competition changes over time between trees and crops, especially when roots of crop are still developed poorly. The moderate spacing (150 cm, D₃) minimized these effects and ensured yields statistically similar to open field control.

However, the economic evaluation revealed that the moringa–sunflower intercropping system was more profitable than sole sunflower cultivation. Although sunflower yield alone was highest in the open field, the combined returns from moringa pods and sunflower grains substantially increased the total gross and net returns in intercropped plots. The maximum gross return (Tk. 787,600 ha⁻¹), net return (Tk. 667,543 ha⁻¹), and benefit-cost ratio (6.56) were achieved at 150 cm spacing (D₃), followed by 100 cm spacing (D₂). In contrast, the open-field sunflower (D₄) showed a lower BCR (3.72) due to the absence of moringa yield. These results align with Rahman *et al.* (2018), who reported higher overall profitability and resource-use efficiency from agroforestry systems compared to sole cropping, and confirm that integrating moringa into sunflower cultivation enhances overall economic sustainability. In previous, Anwar *et al.* (2013) found that wider spacing or strategic orientation of crop rows relative to tree lines significantly, improved intercrop yields. Similarly, Hanif *et al.* (2010) observed higher returns from okra intercropped with litchi trees due to additional tree-based income. Thus, from a socio-economic standpoint, the moringa–sunflower system ensures more stable and diversified income streams, an essential feature for smallholder resilience in the context of climate variability in Bangladesh (Abdullah & Rahman, 2015; Miah *et al.*, 2016).

CONCLUSION

The experiment demonstrated that sunflower growth and yield were significantly affected by distance from moringa trees in an agroforestry system. A gradual reduction in plant height, leaf size, canopy expansion, biomass, and seed yield was observed as sunflower plants were located nearer to the trees, reflecting competition for light, nutrients, and moisture. The highest sunflower performance was recorded in sole cropping (control), while the lowest was near the tree base (50 cm). However, intercropping with moringa at 150 cm distance (D₃) produced yields statistically comparable to control, while also generating superior economic benefits. This treatment generated the highest gross and net returns as well as the benefit-cost ratio, underscoring the superior economic performance. Collectively, the results suggest that appropriately spaced (150 cm) Moringa-sunflower intercropping systems can improve land use efficiency and profitability while maintaining acceptable yield levels. Hence, it represents an ecologically and economically sustainable practice for smallholder farmers aiming to enhance resilience and optimize resource use in Bangladesh.

REFERENCES

- Abdullah, H.M. and Rahman, M. 2015. Initiating rain water harvest technology for climate change induced drought resilient agriculture: Scopes and challenges in Bangladesh. *J. Agric. Environ. Inter. Develop.* 109: 189-208.
- Adesina, S. 2018. Effect of processing on the proximate composition of sunflower (*Helianthus annuus*) seeds. *Agro. Sci.* 17(3): 27-33.
- Akter, A., Rahman H. M. S., Wadud Md. A. and Rahman G. M. M. 2013. Effect of five years old Lohakat (*Xylia dolabriformis*) tree on the growth and yield of carrot (*Daucus carota*). *J. Agrofor. Environ.* 7(2): 19-22.
- Anwar, R., Bithi, F., Alam, Z., Wadud, M.A. and Rahman, G.M.M. 2013. Bottle gourd cultivation along with Akashmoni (*Acacia auriculiformis*) tree as agroforestry system. *J. Agrofor. Environ.* 7(2): 103-106.
- BBS 2020. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Ministry of Planning, Government of the people's Republic of Bangladesh, Dhaka, Bangladesh.
- BBS 2021. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Ministry of Planning, Government of the people's Republic of Bangladesh, Dhaka, Bangladesh. p 1-12.
- BBS 2018. Statistical Year Book Bangladesh. Ministry of Planning, Govt. of Peoples Republic of Bangladesh, Dhaka, Bangladesh Bureau of Statistics.
- Foidl, N., Makkar, H.P.S. and Becker, K. (2001). The potential of *Moringa oleifera* for agricultural and industrial uses. *American J. Food Sci. Tech.* 3(6):145-149.
- Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research (2nd Edn). John Wiley and Sons, New York. p 139-240.
- Grasso, S., Omoarukhe, E., Wen, X., Papoutsis, K. and Methven, L. 2019. The use of up cycled defatted sunflower seed flour as a functional ingredient in biscuits. *Foods*, 8(8): 305.
- Hanif, M.A., Amin, M.H.A. Bari, M.S. Ali, M.S. and Uddin, M.N. 2010. Performance of okra under litchi based agroforestry system. *J. Agrofor. Environ.* 4(2): 137-139.
- Hassan, N., Irfan, N.M., Roy, S. and Shaheen, N. 2019. Cross country study on food consumption patterns and rice away from home: The case of Bangladesh. *World Food Policy*, 5: 6-15.
- Hussain, M., Farooq, S., Hasan, W., Ul-Allah, S., Tanveer, M., Farooq, M. and Nawaz, A. 2018. Drought stress in sunflower: Physiological effects and its management through breeding and agronomic alternatives. *Agric. Water Manage.* 201: 152-166.
- Khan, S., Choudhary, S., Pandey, A., Khan, M. K. and Thomas, G. 2015. Sunflower oil: Efficient oil source for human consumption. *Emergent Life Sci. Res.* 1:1-3.
- Makkar, H.P.S. and K. Becker, (1996). Nutritional value and antinutritional components of whole and ethanol extracted *Moringa oleifera* leaves. *Anim. Feed Sci. Tech.* 63: 211-228.

- Miah, M.G., Rahman, M.A., Rahman, M.M. and Saha, S.R. 2016. Impacts of climate variability on major food crops in selected agro-ecosystems of Bangladesh. *Ann. Bangladesh. Agric.* 20: 61-74.
- Naser, M.M., Swapan, M.S.H., Ahsan, R., Afroz, T. and Ahmed, S. 2019. Climate change, migration and human rights in Bangladesh: perspectives on governance. *Asia Pac. View*, 60: 75-190.
- Pal, U., Patra, R., Sahoo, N., Bakhara, C. and Panda, M. 2015. Effect of refining on quality and composition of sunflower oil. *J. Food Sci. Tech.* 52(7): 4613-4618.
- Phiri, C. 2010. Influence of *Moringa oleifera* leaf extract on germination and early seedling development of major cereals. *Agricultural and Biological Journal of North America*, 1(5): 774-777.
- Phiri, C. and Mbewe, D.N. 2010. Influence of *Moringa oleifera* leaf extract on germination and survival of three common legumes. *Int. J. Agric. & Biol.* 12(2): 315-317.
- Phiri, C. 2010. Influence of *Moringa oleifera* leaf extraction, germination and early seedling development of major cereals. *Agric. Biol. J. Nut.* 1 (5): 774-777.
- Rahman, M. A., Rahman, M.A., Miah, M.G., Hoque, M.A. and Rahman, M.M. 2018. Productivity and profitability of jackfruit eggplant agroforestry system in the terrace ecosystem of Bangladesh. *Turkish J Agri.-Food Sci. Techno.* 6: 124-129.
- Schroth, G., Schaller, M. and Jiménez, F. 2008. Belowground interactions in tree-crop agroforestry: Need for a new approach. In D. R. Batish, R. K. Kohli, S. Jose, & H. P. Singh (Eds.), *Ecological Basis of Agroforestry* (pp. 159-170). CRC Press.
- Taher, M., Javani, M., Beyaz, R. and Yildiz, M. 2017. A new environmental friendly production method in sunflower for high seed and crude oil yields. *Fresenius Environ. Bull.* 26(6): 4004-4010.
- Tanni, A. D., Wadud, M. A., Sharif, M. O., Mondol, M. A. and Islam, M. T. 2010. Influence of Lohakat (*Xylia dolabriformis*) tree on the growth and yield of four winter crops. *J. Agrofor. Environ.* 4(2): 63-67.
- UN 2019. United Nations, Department of Economic and Social Affairs, Population Division. *World Population Prospects and Probabilistic Population Projections based on the World Population Prospects* <http://population.un.org/wpp/>.

