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TRANSFORMING MALTA ORCHARD INTO AGROFORESTRY SYSTEM WITH DIFFERENT CROPS FOR IMPROVING PRODUCTIVITY, PROFITABILITY AND LAND USES

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Abstract

Sustainable agricultural practices like agroforestry systems are being advocated to overcome various problems of farming. A young malta (*Citrus sinensis*) orchard (3 years old) was transformed into a fruit tree-based agroforestry system in which the performances of summer (okra and Indian spinach) and autumn (mungbean and kangkong) crops and year-round spices (ginger and turmeric) were evaluated following randomized complete block design (RCBD) with three replication each and eventually compared between agroforestry systems and respective sole cropping (control) from March 2018 to February 2019 at BSMRAU field. The experimental results revealed that the yields of the associated crops deprived when grown at the closest row position from the bed of malta tree and spices. Yields of okra, Indian spinach, mungbean, kangkong, turmeric and ginger were reduced by 7.57, 6.52, 14.86, 13.26, 9.70 and 16.23%, respectively under agroforestry system as compared to control. However, malta yield was increased by 5.35% in agroforestry system than control trees. The findings also indicated that the crops in agroforestry system was less hindered by the shade effect of malta trees due to less dense canopy of young malta trees. In comparison to sole cropping system, the higher benefit-cost ratio (BCR) (2.93) and land equivalent ratio (LER) (2.83) were obtained in the studied agroforestry system that explicated higher system productivity and land uses. Notable improvement of total nitrogen and organic matter were obtained in the soil under agroforestry system. Therefore, malta-based agroforestry system can be a promising alternative to provide higher economic benefits, boosting food and nutritional security, improving soil nutrient status and utilization of land.

Keywords: Benefit-cost ratio (BCR), malta, land equivalent ratio (LER), spices, crops.

Introduction

Bangladesh is one of the most vulnerable countries to climatic catastrophes due to its geographical position near to the Bay of Bengal and Himalayas (Abdullah and Rahman, 2015; Naser *et al.,* 2019), and having a population of 163 million, which is predicted to increase 192.6 million by 2050 (BBS, 2018; UN, 2019). Agriculture is the key factor of the country's economy but it is extremely impeded by climate and human-induced hazards (Miah *et al.,* 2016; Rahman *et al.,* 2018). Despite these hazards, Bangladesh has witnessed substantial improvement in agriculture

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over the past decades, although almost 24.2 million people remain in food-scarce situation (Hassan *et al.,* 2019; Molla, 2019). Contrarily, rapid industrialization and urbanization provoke transforming of 69,000 hectares of agricultural lands to non-agricultural practices annually, and its rate is gradually increasing thereby threatening the upcoming cultivable land in the country (Khan, 2019; Muhsin *et al.,* 2018; Rahman *et al.,* 2016). Additionally, cereal crops including rice occupies more than 75% of the country's total arable land, and restrict the land for cultivation of other crops especially vegetable and fruit (Ahmad, 2017). In Bangladesh, majority of people consistently consuming only 36 g and 167 g fruits and vegetables per day, respectively, where, it is recommended to consume total average 400 g of fruits and vegetables daily (FAO/WHO, 2003; BBS, 2018). Although, the area and production of vegetable and fruit have been increased last couple of years, still there is huge gap between supply and demand. Various challenges such as climate uncertainty, improper management, land scarcity, lack of quality planting materials etc. are found in farming systems. Consequently, sustainable agricultural practices need to be developed to overwhelm the aforementioned restraints in crop production.

Agroforestry is a system where intercropping practiced between annual herbaceous crops and perennial tress, which recently come to the fore as a dynamic option for sustainable subsistence in the cue of changing climate schemes (Djanibekov *et al.,* 2015; Campanhola and Pandey, 2019). More importantly, agroforestry system carried diversified socio-ecological benefits, including eradication of poverty and unemployment, including control soil health and erosion (Singh *et al.,* 2016; Udawatta *et al.,* 2017; Miah *et al.,* 2018). Agroforestry has already been accepted by farming community by planting different trees within cropland or homestead boundaries from ancient time. Recently, many arable lands have been transformed into fruit orchards especially modern varieties of mango, lemon, orange, guava, litchi, malta etc. They can supply products for market as well as home consumption, and thus offer financial security, and also alternatives for rehabilitation of degraded land which augmented the soils fertility (Adane *et al.,* 2019; Gomes *et al.,* 2015; Qiao *et al.,* 2019). In general, farmers do not grow crops in the orchards even when there is ample space and scope. Based on the age and canopy development, these orchards can be brought under agroforestry practices with various crops for higher production and benefits.

Malta (*Citrus sinensis*) is one of the pivotal fruits, due to its nutritional enrichment specially vitamins and minerals and also a fruit having high demand in Bangladesh (Islam *et al.,* 2017; Milon, 2019). The initial stage of a systematically developed young malta orchard has plenty of space that farmers can use to grow various seasonal crops to increase the productivity, profitability and net income of the land. Okra (*Abelmoschus esculentus*) and Indian spinach (*Basella alba*) are two most popular summer crops in Bangladesh having nutritional value (Gemede *et al.,* 2015; Hasan *et al.,* 2016) and produces higher economic returns as only few vegetables are grown during the summer (Schreinemachers *et al.,* 2016). Mungbean (*Vigna radiata*) is an important short duration pulse crop including essential amino acids especially lysine, which is deficient in most of the cereal grains (Sarwar *et al.,* 2004). Kangkong (*Ipomoea aquatic*) is a perennial herb found throughout Tropical Asia. Kangkong exhibits excellent antioxidant activity in its' extracts which includes superoxide ($O_2^{\bullet-}$) and hydroxyl (OH) ion scavenging, iron chelation and electron donation (Sharmin *et al.,* 2016). Furthermore, the interspace between plant to plant can also be used for spices cultivation within the same row, particularly commercially important ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*).

Therefore, the present study was aimed to exploit the potential of the malta-based agroforestry system by evaluating: (i) the productivity of kharif season crops along with spices, (ii) the dynamics of soil nutrients (iii) the economic profitability and efficiency of land use in terms of the benefit-cost ratio (BCR), and land equivalent ratio (LER), respectively.

Materials and Methods

Study location, climate and soil

The field experimentation was conducted at the research farm of the Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh (24° 09′ N; 90° 26′ E) at the time of kharif-1 (March to June 2018), and kharif-2 (July to October 2018) seasons. The minimum and maximum temperatures of the study area over the experimental periods ranged from of 13 to 36°C, and 19 to 35°C having a total precipitation of 1086 mm, and 804 mm during the cropping seasons of kharif-1 and kharif-2, respectively (Weather data of BSMRAU, 2018).

Experimental design and treatment composition

A three-year old pre-established malta (var. *BARI Malta 1*) orchard was converted to agroforestry system to grow different crops/vegetables in between the row of malta trees (Figure 1). Malta trees were planted following 4m × 4m spacing having four trees with three separate blocks, considered as three replications. To optimize the land use, ginger (var. *BARI Adha 1*) and turmeric (var. *BARI Holud 5*) were sown at 1st week of March, 2020 on a raised bed (1m width and 50 cm height) between two trees lines maintaining 30 cm × 25 cm spacing. Furthermore, the seeds of kharif-1 crop such okra (var. *Marvelous*) and Indian spinach (var. *Pusti*) (60 cm × 25 cm spacing) and kharif-2 crops such as mungbean (var. *BU Mug 6*) and kangkong (var. *BARI Kangkong 1*) (60 cm × 15 cm spacing) were directly sown at distant regimes, i.e. 30, 90 and 150 cm from the raised bed of tree with ginger and turmeric (Figure 1).

Therefore, to evaluate the performances of different seasonal crops in malta-based agroforestry systems, four experiments were done periodically. Each of the experiment was laid out in two factorial randomized complete block design (RCBD) with three replications. Two factors include, factor A: two spices crop namely ginger and turmeric and factor B: three distance from the raised bed of tree with ginger and turmeric i.e. 30, 90 and 150 cm. Thereafter, the crop performances under the agroforestry systems were contrasted with the performances of the same crop, which was grown as sole crop (referred as control). At the same time, to evaluate the performance of different spices in malta-based agroforestry system, four different distances i.e. 50, 100, 150 and 200 cm from malta tree base for both ginger and turmeric were done in a RCBD design with three replications, afterward, compared with the yields obtained from

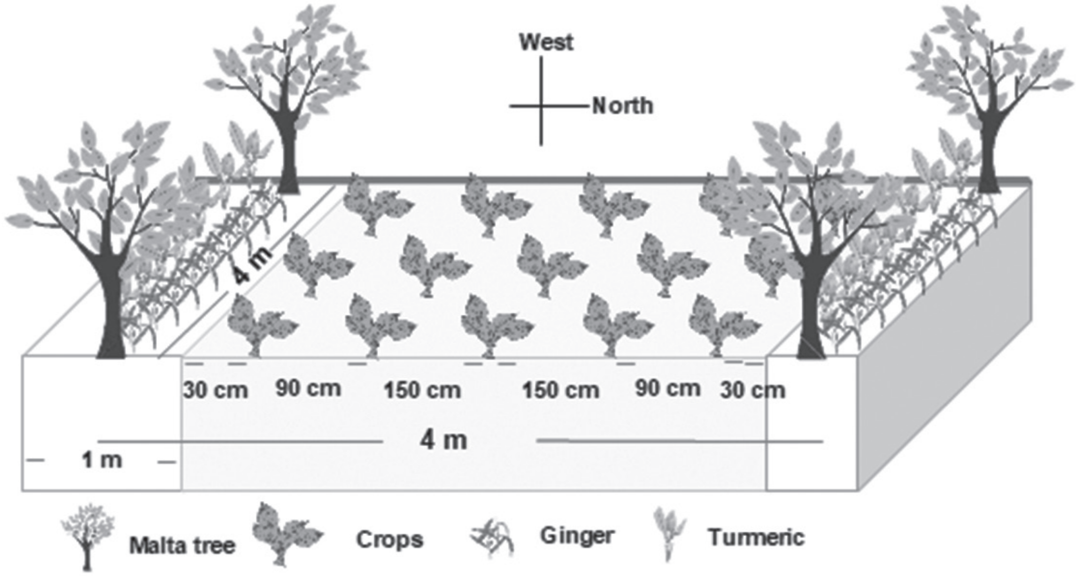

Fig. 1. Illustration of single replication/block showing the planting design of trees, crops, and spices in malta-based agroforestry system. Either ginger or turmeric was grown in between two trees (within same column) of a single replication. Okra and Indian spinach (kharif-1 season), and mungbean and kangkong (kharif-2 season) were grown at different distance regimes (30, 90 and 150 cm) from the elevated bed prepared for growing ginger or turmeric.

sole cropping. The yield of fruit trees was considered as a common source of additional income under agroforestry system. Further, growth and yield-related performance of fruit trees under agroforestry system were compared with the fruit trees, which were not brought under agroforestry system.

Field preparation, fertilizer application and intercultural operations

In each season, land preparation was done to obtain good tilth for planting of crops. Additionally, recommended doses of fertilizers (Table 1) were also applied. Full doses of cowdung and TSP and MoP were applied during final land preparation in general. However, half of urea was applied as basal dose during final land preparation, and the rest was added as two equal installments at the time before flowering and fruiting for okra and mungbean. For Indian spinach and kangkong, rest of the urea fertilizer was applied at the rate of 12 kg ha^{-1} at 15-day interval and continued till final harvest. It is worth noting that the raised beds for ginger and turmeric were prepared by intermixing of soil, cowdung, sand and rice husk at the ratio of 2:1:1:0.5 (on weight basis). Intercultural operations including irrigation, weeding and application of pesticide (specifically Dursban 20 EC at a rate of 2 mL L^{-1} of water; as a viral vector controller for respective crops) were done as per requirement of the crops. Importantly, in the agroforestry system, no supplemental management operations such as irrigation and fertilization were applied for malta trees other than pruning, when sole malta

Table 1. Applied dosage of fertilizers in crops, spices and malta trees in a hectare basis (according to Hassan *et al.*, 2012)

Name of the fertilizers	Okra	Indian spinach	Mungbean	Kangkong	Ginger and turmeric	Malta (Sole)
Cow dung (ton ha^{-1})	5	5	5	5	5	40
Urea (kg ha^{-1})	120	120	33	50	130	1000
Triple super phosphate (TSP) (kg ha^{-1})	75	50	70	50	125	1000
Muriate of potash (MoP) (kg ha^{-1})	50	50	33	50	100	500

trees received all management operations like irrigation on demand basis and recommended fertilizers doses (Table 1) during experimental period.

Growth and yield-contributing attributes of crops and trees

Yields per pant of okra and mungbean plant were recorded following each harvest, where Indian spinach and kangkong were started to harvest after one month of sowing and harvested four times with 15 days interval. All harvested data were then summed up to obtain the final yield. The rhizome weight per hill of both ginger and turmeric were recorded during final harvest. Measurement of plant height and canopy volume were done to evaluate the growth performance of malta tree following the equation of Halder (2013). Number of fruits per plant and individual fruit weight of malta were recorded at each harvesting time and subsequently averaged to obtain the yield per plant.

Assessment of soil properties, economic performances and land use efficiency

Soil samples were assembled from both the fields of agroforestry and non-agroforestry (sole) at before and after completion of the experimentations. The procedures of Jackson (1958) and Bremner (1965) were followed to estimate the contents of total nitrogen and organic matter, respectively. The economic and land use benefits of malta-based agroforestry systems were evaluated by calculating the benefit cost ratio (BCR) and land equivalent ratio (LER) following the equations reported by Miah *et al.* (2018).

Statistical analysis

All the data were analyzed by a two-way analysis of variance (ANOVA) using Statistix 10 software. Different alphabetical letters represent significant differences among the treatments at $P < 0.05$ following a least significant difference (LSD) test. All the data presented in the figures and tables are means with standard errors (SEs) of three replications for each treatment.

Results and Discussion

Performance of crops

In between the malta trees, okra, Indian spinach, mungbean and kangkong were grown at 30, 90 and 150 cm from the raised bed of tree with ginger and turmeric. In case of okra, the highest yield (700.00 g) per plant was recorded at 150 cm from the raised bed of malta-ginger agroforestry system with 6.53% improvement compared to control plant (Table 2). The highest yield was statistically similar to the values obtained for yield of 90 and 150 cm distanced plots from the raised bed of malta-ginger agroforestry system and malta-turmeric agroforestry system, respectively. In contrast, the lowest yield (490.00 g) of okra was found at 30 cm distance from the raised bed of malta-turmeric agroforestry system (Table 2). However, the highest yield per plant of Indian spinach (483.78 g) was recorded at 150 cm distance from the raised bed of malta-ginger agroforestry system, which was statistically similar to values obtained at 90 cm distance of malta-ginger and control plants. The lowest yield per plant (356.89 g) was noted at 30 cm distance from the raised bed of malta-turmeric agroforestry system (Table 2).

Concurrently, the maximum mungbean yield per plant (23.22 g) was noted at 150 cm distance from the raised bed of malta-ginger agroforestry system followed by 90 cm distance from the raised bed of malta-ginger, malta-turmeric and control. The minimum yield per plant (15.39 g) was recorded at 30 cm distance from the raised bed of malta-turmeric, which provided 32.85% less yield compared to mungbean grown in open field (Table 2). Planting distance from the bed of malta-ginger and malta-turmeric in malta-based agroforestry system had a significant effect on yield per plant of kangkong. The maximum (252.04 g) and minimum yield per plant (186.61 g) were recorded in open field and 30 cm distance from the bed of malta-turmeric agroforestry system, respectively (Table 2). However, kangkong also displayed reduction of yield per plant (22.62, 5.23 and 0.38% for malta-ginger agroforestry system, and 25.96, 19.21 and 6.35% for malta-turmeric agroforestry system, respectively) at 30, 90 and 150 cm distance, when compared with that of control plants (Table 2). Moreover, owing

Table 2. Yield of different crops in malta-based agroforestry system associated with ginger and turmeric during summer and autumn season in 2018

Associated spices	Distance (cm)	Okra		Indian spinach		Mungbean		Kangkong	
		g plant^{-1}	ton ha^{-1}	g plant^{-1}	ton ha^{-1}	g plant^{-1}	ton ha^{-1}	g plant^{-1}	ton ha^{-1}
	30	536.83 ± 0.03cd	27.00 ± 1.32de	404.89 ± 0.01c	20.24 ± 0.48d	16.96 ± 0.93c	0.85 ± 0.05c	195.03 ± 4.89b	9.75 ± 0.24c
Ginger	90	690.00 ± 0.04a	34.73 ± 2.03b	471.44 ± 0.01a	23.57 ± 0.74bc	20.88 ± 0.52ab	1.04 ± 0.03b	238.87 ± 10.83a	11.94 ± 0.54b
	150	700.00 ± 0.01a	35.03 ± 0.73b	483.78 ± 0.02a	24.19 ± 0.91b	23.22 ± 1.09a	1.16 ± 0.05b	251.07 ± 9.35a	12.55 ± 0.47b
	30	490.00 ± 0.01d	24.67 ± 0.73e	356.89 ± 0.02d	17.84 ± 0.77e	15.39 ± 0.66c	0.77 ± 0.03c	186.61 ± 7.08b	9.33 ± 0.35c
Turmeric	90	600.00 ± 0.02bc	30.01 ± 1.05cd	431.56 ± 0.01bc	21.58 ± 0.40d	20.61 ± 0.60b	1.03 ± 0.03b	203.63 ± 6.19b	10.18 ± 0.31c
	150	660.00 ± 0.04ab	33.17 ± 1.97bc	435.56 ± 0.01bc	21.78 ± 0.31cd	22.42 ± 0.84ab	1.12 ± 0.04b	236.03 ± 4.59a	11.80 ± 0.23b
Open field	Control	657.07 ± 0.02ab	43.78 ± 1.24a	459.00 ± 0.01ab	30.60 ± 0.73a	22.92 ± 0.97ab	1.53 ± 0.06a	252.04 ± 4.16a	16.80 ± 0.28a

Values are means with standard errors ($n = 3$). Statistically significant differences among the treatment are indicated by different alphabetical letters within the same column at $P < 0.05$ according to a least significant difference test. For estimating yield ton hectare in agroforestry, plant number per hectare was used according to land distributed for each component (75% area for crops and 25%for trees).

to high plant number the yield was augmented in open field by 46.54, 46.33, 60.50 and 55.80% for okra, indian spinach, mungbean and kangkong, respectively, as compared to overall agroforestry system (Table 2).

It was observed that, for all the crops except indian spinach, 90 and 150 cm distance from malta-ginger bed, 150 cm from malta-turmeric bed, and control seem to show similar yield. Besides, intercropping was not affected much due to less competition between under-storey and top-storey components for resources in the initial stage of malta orchard (Table 2). This study corroborated the findings of Rathore *et al.* (2013), Dhakar *et al.* (2013) and Saroj *et al.* (2003). Nonetheless, malta plant might exerts some negative effects on crop growth by its dense roots, which could be the reason for low yields at the closest distance (Table 2) by the competition for below-ground resources (water and nutrient) between trees and crops (Wang *et al.,* 2016; Zhang *et al.,* 2017).

Performance of malta

Malta plants brought under agroforestry system received benefits from the inputs applied for crops that were grown in sequential season of a year, exhibited enhanced canopy volume by 21.74%, fruits per plant by 3.77%, individual fruit weight by 0.69% and yield per plant by 5.35%, when compared with control plants, while a reduction was noticed for plant height (1.00%) (Table 3). The improvement in yield-attributes of malta tree under agroforestry system could be explained by the fact that malta trees simultaneously utilized a substantial amount of production inputs, particularly irrigation water and fertilizers applied for the under-storied crops. Similar to our outcomes, Sidibé *et al.* (2017) also reported that yields of jujube trees were improved significantly in jujube-sorghum-eggplant-based agroforestry system compared to mono cropped jujube orchard.

Performance of ginger and turmeric

Significantly, the maximum rhizome weight of ginger (193.60 g) was found in control plot. While the minimum weight (145.67 g) was recorded at 50 cm distance from the combination of malta-okra-mungbean (malta + OM), which was statistically similar to the weight recorded at 50 cm distance from the combination of malta-Indian spinach-kangkong (malta + IK) and at 100 cm distance from the combination of malta + OM and malta + IK (Figure 2). The present result is coherence with the previous finding of Ali *et al.* (2013) where they found the maximum 17.01% higher rhizome dry weight of ginger

Table 3. Growth and yield-contributing attributes of malta trees under agroforestry and non-agroforestry system

System	Plant height (m)	Canopy volume (m^3)	Fruits plant^{-1}	Individual fruit weight (g)	Yield (g plant^{-1})
Malta-based agroforestry	0.99 ± 0.06	0.28 ± 0.04	6.88 ± 0.29	110.13 ± 2.13	756.13 ± 32.68
Control	1.00 ± 0.06	0.23 ± 0.02	6.63 ± 0.32	109.38 ± 3.66	717.75 ± 21.75

Malta trees were planted at a spacing of 4m × 4m, in case of both agroforestry and non-agroforestry system. Values are means with standard errors (*n* = 8)

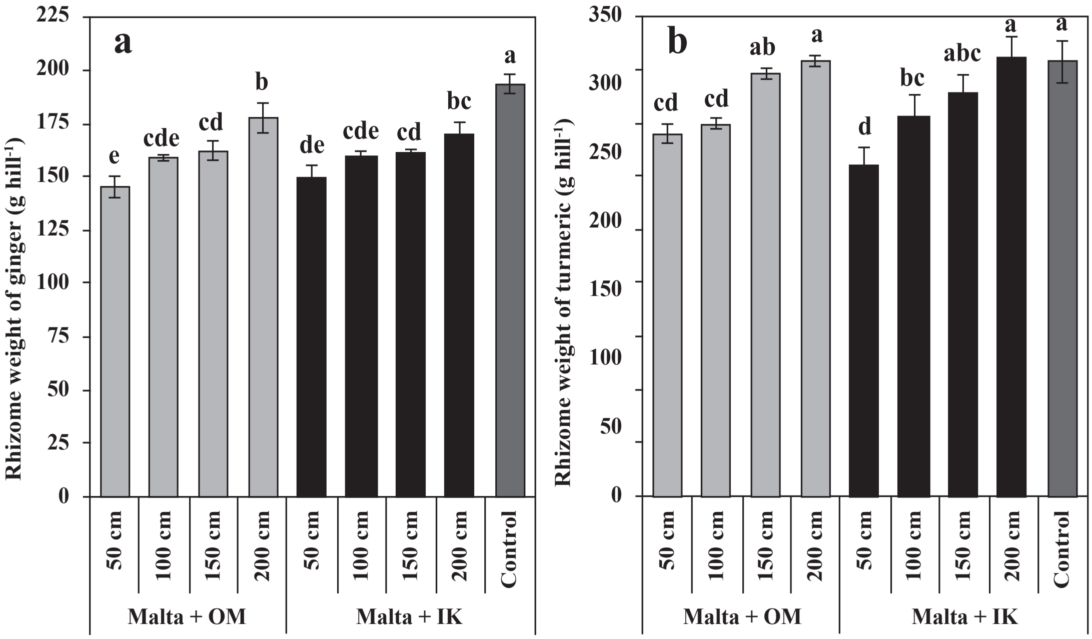

Fig. 2. Evaluating the rhizome yield of ginger and turmeric in association with okra-mungbean (OM) and Indian spinach-kangkong (IK) under malta-based agroforestry system in a distanced manner, and in open field (control). (a) Rhizome weight of ginger (g hill^{-1}) and (b) rhizome weight of turmeric (g hill^{-1}). Bars represent means with standard errors (n = 3). Statistically significant differences among the treatment are indicated by different alphabetical letters at $P < 0.05$ according to a least significant difference test. OM, okra-mungbean; IK, indian spinach-kangkong.

in sole cropping compared to agroforestry system. In response to turmeric, the highest rhizome weight per hill (319.67 g) was noted at 200 cm distance from the combination of malta + IK, which was statistically similar to the rhizome weight at 200 cm distance from the combination of malta + OM and open field. Nonetheless, rhizome weight of turmeric was recorded to decrease by 16.53, 14.00 and 2.63% for malta + OM, and by 23.68, 12.32 and 6.84% for malta + IK at 50, 100 and 150 cm from the malta tree base, respectively (Figure 2). Like our results, Kittur *et al.* (2016) also found better rhizome yield of turmeric at widely spaced bamboo trees, while the closet spacing recorded the least rhizome yield.

Agroforestry system-induced modification of soil nutrients dynamics

In case of kharif-1 season, soils were collected from both okra and Indian spinach fields exhibited higher levels of total nitrogen (by 8.09% for both okra and Indian spinach with ginger; and by 9.58 and 0.88% for okra and Indian spinach with turmeric, respectively) and organic matter (by 7.02 and 5.60% for ginger, and by 7.23 and 5.01% for turmeric, respectively), except 2.6% reduction was noted in okra-turmeric as compared to the values obtained from initial soils of malta-based agroforestry system (Figure 3). In kharif-2, mungbean and kangkong fields exhibited higher levels of total nitrogen (by 26.92 and 19.65% for ginger, and by 29.43 and

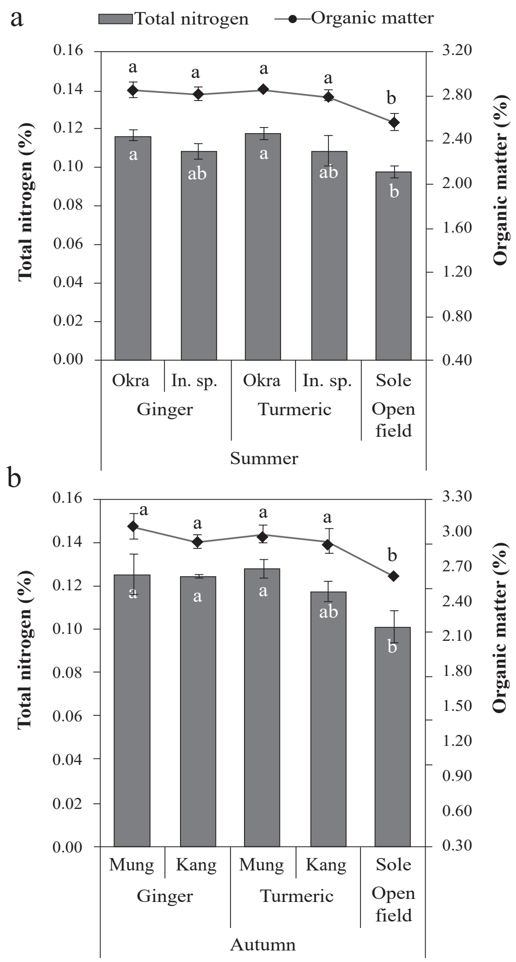

Fig. 3. Status of total nitrogen and soil organic matter of both malta-based agroforestry systems and mono cropping before and after crop cultivation in both (a) kharif-1 (summer) and (b) kharif-2 (autumn) seasons. Bars represent means with standard errors (n = 3). Statistically significant differences among the treatment are indicated by different alphabetical letters at $P < 0.05$ according to a least significant difference test. In. sp, Indian spinach; Mung, mungbean; Kang, kangkong.

18.69% for turmeric, respectively) and organic matter (by 15.13 and 9.67% for ginger, and by 12.65 and 10.30% for turmeric, respectively) as compared with the values obtained from initial soils before malta orchard undergoes to agroforestry system (Figure 3). This result may be obtained due to apply more fertilizer and other intercultural operations in the malta orchard. The present results are consistent with those documented in mango-based agroforestry system (Dhara and Sharma, 2015), guava-based intercropping system (Swain, 2016) and rubber-based agroforestry system (Tongkaemkaew *et al.,* 2018).

Economic and land use performance of malta-based agroforestry system

Sole okra-mungbean (OM) exhibited the highest production cost per hectare of land (6,87,895 Tk), while minimum cost of production (2,68,663 Tk) was recorded in sole malta (Table 4). However, malta + OM + ginger- (MS 1) based agroforestry system exhibited the utmost gross income (18,50,130 Tk) and net income (12,12,909 Tk) followed by sole OM, malta + OM + turmeric (MS 2) and malta + IK + ginger (MS 3). In contrast, the lowest values of these respective parameters were recorded in sole malta (Table 4). However, the utmost BCR (2.93) was calculated in malta + IK + turmeric- (MS 4) based agroforestry system followed by MS 3 (2.92), MS 1 (2.90) and MS 4 (2.89). It is worth noting that the overall lowest BCR was obtained from sole-malta field (0.66) owing to high cost involved during the establishment of a malta orchard (Table 4). Among the different crop-associated agroforestry systems, MS 3 received maximum LER (2.86) followed by MS 1 (2.84), while the lowest LER (2.65) was reported in both MS 2 and MS 4 agroforestry system (Table 4).

The result demonstrated that BCR of agroforestry systems were remain prominent compared to other sole crops along with

Table 4. Economic and land use performances of different malta-based agroforestry systems and monoculture

Malta-based agroforestry systems	Total Cost (Tk ha^{-1})	Gross Income (Tk ha^{-1})	Net return (Tk ha^{-1})	BCR	LER
Malta + OM + ginger (MS 1)	637221	1850130	1212909	2.90	2.84
Malta + OM + turmeric (MS 2)	607737	1756655	1148918	2.89	2.65
Malta + IK + ginger (MS 3)	534076	1562100	1028024	2.92	2.86
Malta + IK + turmeric (MS 4)	504592	1480900	976308	2.93	2.65
OM	687895	1838780	1150885	2.67	
IK	557420	1465100	907680	2.63	
Sole ginger	593695	1032560	438865	1.74	
Sole turmeric	429895	1055550	625655	2.46	
Sole malta	268663	177300	-91363	0.66	

OM, summation of okra and mungbean; IK, summation of indian spinach and kangkong; BCR, benefit-cost ratio; LER, land equivalent ratio. For estimating yield ton hectare in agroforestry, plant number per hectare was used according to land distributed for each component (75% area for crops and 25% for trees).

gross and net income (Table 4). The findings supported by the findings of Rahman *et al.* (2018) who found the highest BCR in jackfruit-eggplant-based agroforestry system. More importantly, the study showed a high LER value in the agroforestry system indicating higher land would be needed to obtain comparable production from the sole cultivation of similar components (Table 4). The elevated LER in agroforestry system was also reported by Miah *et al.* (2018) in jackfruit-papaya-eggplant based agroforestry system, and Yang *et al.* (2016) in jujube-wheat based agroforestry system.

Conclusions

After significant production of fruits in the matla orchard, the economic output of the system raises continuously as malta has higher market demand and good price throughout the year. Nonetheless, the newly established malta-based agroforestry system could be used to grow high-valued kharif-1 and kharif-2 crops into the unused space. Subsequently crops and spices yielded better with increasing distances, as well as greater malta yield obtained without the application of production inputs as they enjoy the inputs provided for associated crops. Notable improvement was obtained in soil nutrient dynamics due to judicious use of fertilizers, and the decomposition of plant residues. The higher BCR and LER in malta-based agroforestry system suggested that the combination of malta-crops-spices is economically competitive as well as ensuring better land use. Essentially, the experimental results showed that the malta-based agroforestry system could be an ideal approach for small-holding farmers in Bangladesh to boost economic profitability and land-use efficiency.

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