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Productivity and Profitability of Turmeric (*Curcuma longa*) + Okra (*Abelmoschus esculentus*) Intercropping System for Marginal Farmers in North-Western Part of Bangladesh

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The agroecological practice of intercropping, meaning farming of two or more crop simultaneously in the same field has recently reaped renewed interest for developing more sustainable cropping and food systems. This technology gained immense interest to marginal farmers of Bangladesh for better economic return from small parcel of their cultivable land. This study evaluated the variants of intercropping system of turmeric (*Curcuma longa*) + okra (*Abelmoschus esculentus)* having yield advantage and profitability. The study was conducted during the crop season of 2017 and 2018 at the Regional Agricultural Research Station, BARI, Ishurdi, Pabna, Bangladesh. Five intercropping combination, *viz* T_1 = 100% turmeric + 100% okra, T_2 = 100% turmeric + 90% okra, T_3 = 50% turmeric + 50% okra, T_4 = sole turmeric (100%), T_5 = sole okra (100%) were studied. The performance of various treatment combination was evaluated based on land equivalent ratio (LER), competitive ratio (CR), monetary advantage index (MAI) and system productivity index (SPI). The findings revealed that intercropping of okra did not affect the rhizome development stage. The T_1 and T_2 treatment gave 21.85 and 21.59 t ha^{-1} rhizome yield of turmeric, respectively. Besides, intercropping of okra @ 100 and 90% population (T_1 and T_2) enhanced 13% and 11% rhizome yield, respectively than the monoculture yield (19.38 t ha^{-1}). However, the 100% turmeric + 100% okra intercropping system exhibited maximum turmeric equivalent yield (35.43 t ha^{-1}), LER (2.12), MAI (4558.61 US$ ha^{-1}), and SPI (44.39). Intercropping indices recommended a positive association of turmeric and okra crops. The study discovered that okra could be introduced as an intercrop with turmeric to increase cropping area and enhance profitability of marginal growers.

Keywords: Monetary returns, competitive ratio, intercropping, turmeric, okra

Abbreviations: BCR –benefit-cost ratio, CR– competitive ratio, LER– land equivalent ratio, MAI– monetary advantage index, SPI– system productivity index, TEY– turmeric equivalent yield

INTRODUCTION

Global food demand is rising rapidly and so more in developing countries specially in South Asia where arable lands and resources barely produce adequate crops needed to meet demand for food (McLaughlin and Kinzelbach 2015). Sustainable crop intensification is crucial to feed the entire population through efficient mitigation of possible adverse impacts on soil and environment. In this context several innovative and efficient technologies need to be adopted for increasing food production by alleviating land use efficiency (Timmusk et al. 2017). In Bangladesh, a total of 16.33% of GDP comes from agriculture where the marginal farmers inherit only average 0.05 - 1.00 ha of land (MOA 2014). The practice of intercropping may represent a promising sustainable solution to improve crop production from such small parcel of land. Intercropping (mixed cropping, polyculture), a technique of growing two or more crops simultaneously in the same field, is an agroecological practice for sustainable crop intensification (Jensen 1996a; Bedoussac et al. 2015; Wezel et al. 2014). It also ensures efficient utilization of their resources to maximize crop production and family income (Islam et al. 2012).

Intercropping could increase 25% yield as compared to monoculture, and ensure several additional services, such as enhance nutrient use efficiency and grain quality in food systems (Jensen et al. 2015; Bedoussac et al. 2015).

Turmeric is a very popular tropical and subtropical rhizomatous species widely cultivated in Asia including Bangladesh (Islam et al. 2018). A total 28184 hectares of land cover under turmeric cultivation in Bangladesh with an annual production of 147439 MT (BBS 2020). It is a long duration wide-spaced crop that remains under the field for about 270-300 days. However, the adoption of long-duration turmeric crop challenged farmers with short duration vegetable crop like okra in the region. Turmeric is a shade tolerant crop and grows well under partial shade (Haque and Hossain 1985; Joyachandran et al. 1991). It takes 60 to 70 days to 100% emergence after planting of rhizome (Islam et al. 2018). So, farmers can easily grow another crop like okra as an intercrop with turmeric at the early growth stage (130 days). Farmers usually grow turmeric as a sole crop although higher fresh turmeric yield was reported in the intercropping situation than monoculture due to shady conditions than exposed to sunlight (Joyachandran et al. 1991).

Okra is a summer vegetable widely grown around the world. In Bangladesh, scarcity of vegetables occurred during summer (*Kharif-1*) (Islam et al. 2014) due to intensifying rice, maize, and mungbean cultivation, and competition with jute and sesame crops. However, okra may grow as an intercrop with turmeric as they inherit different growth habits, duration, and resources utilization. So, if okra can introduce as intercrop with turmeric its production area as well as productivity would be increased. It will also help to retain vegetables and spices crops in the existing cropping pattern and play an important role to ensure the highest productivity per unit area as well as supply vegetable in diet. Currently, the daily requirement of vegetable is 220g per day for sound health but only 55g is available leading to malnutrition (FAO 2011). Previous studies demonstrated that the success of intercropping system facilitates have high potential yield improvement corresponding to monocropping by yield stability and enhanced yield in tropical and sub-tropical areas (Nazir et al. 2002; Malik et al. 2002). The relevant literature on turmeric + okra intercropping practice for crop intensification still scarce thus, this experiment has been undertaken to evaluate the turmeric + okra intercropping system for optimum crop density, yield advantage, and profitability using intercropping indices.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted in the Regional Agricultural Research Station, BARI, Ishurdi, Pabna during 2017 and 2018 to find out the suitable planting densities for higher productivity and economic returns of turmeric + okra intercropping system. The trial site was located under 24° 03′ North latitude, 89° 05′ East longitudes with 16 meters elevation above the sea level. The meteorological data during the growing periods of the crops recorded in the meteorological station of the Bangladesh Sugar Crops Research Institute campus situated about 400 m from the experimental field have been furnished in Fig. 1. The soil of the experimental site belonging to Ishurdi series under High Ganges River Floodplain soil (Agro-ecological Zone-11) in Bangladesh and has been classified as Calcareous Dark Gray Floodplain soil (FRG 2012). The soil is clay loam and slightly alkaline having a field capacity of 29%, permanent wilting point of 13% and a bulk density of 1.42 g cm^{-1}. Experimental soil was analyzed before planting/sowing the crops within the initial year. The initial soil chemical properties of experimental fields is in Table 1.

Experimental Plan and Crop Managements

The experiment was set up in a Randomized Complete Block (RCB) design with three replications. Five different treatments *viz*. T_1 = 100% turmeric + 100% okra, T_2 = 100% turmeric + 90% okra, T_3 = 50% turmeric + 50% okra, T_4 = sole turmeric (100%), T_5 = sole okra (100%) were studied. Plot size was 5 × 4 m. In the study, turmeric was used as the main crop and okra was used as the intercrop. Okra was intercropped with turmeric at 100% (50000 plants ha^{-1}), 90% (45000 plants ha^{-1}), and 50% (25000 plants ha^{-1}) population densities (T_1, T_2, and T_3). At sole turmeric (100%) plant density was 80000 ha^{-1}. In T_1, turmeric and okra were planted/sown in the same line maintaining 50 × 25 cm and 50 × 40 cm spacing, respectively. Similarly, in T_2 okra was intercropped in between the turmeric rows. In T_3 okra was intercropped in every alternative row arrangement of turmeric.

Table 1. Initial soil chemical properties of the experimental soil during 2017.

Items	pH	Organic Matter (%)	K meq/100 g Soil	Total N (%)	P	S	Zn	B
					μg g^{-1}			
Initial soil	7.43	1.16	0.27	0.069	21.4	18.75	1.72	0.32
Critical limit	-	-	0.12	0.12	10	10	0.6	0.2
Interpretation-[1]	Slightly Alkaline	Low	Medium	Very low	Medium	Medium	Optimum	Medium

[1]Qualitative interpretation of soil analysis based on FRG 2012.

The monoculture of turmeric and okra were planted/ sown maintaining 50 × 25 cm and 50 × 40 cm spacing, respectively. Turmeric (BARI Halud-4) and Okra (BARI dheros-1) were planted/sown simultaneously on 25 March 2017 and 25 March 2018, respectively. The seed rate of sole turmeric and okra was 3000 kg ha^{-1} (consider 40-45 g rhizome) and 5 kg ha^{-1}, respectively. Fertilizer was applied for sole turmeric and intercrops plot at the rate of 140-54-117 kg ha^{-1} of N-P-K with 5 t ha^{-1} cow dung, and sole okra at the rate of 70-20-75 kg ha^{-1} of N-P-K with 5 t ha^{-1} cow dung (BARI 2014). The full amount of P, 1/4 N and 1/4 of K with 5 t ha^{-1} cow dung was applied as basal during final land preparation in case of intercropped as well as monocropped turmeric plots. The remaining N and K applied three equal installments at 70, 90, and 110 days after planting of turmeric. Furthermore, additional 50 kg N and 40 kg K ha^{-1} were applied in two equal installments, at 140 and 160 days after planting of turmeric. Likewise, under sole okra, full amount of P, 1/4 N and 1/4 of K with 5 t ha^{-1} cow dung were applied during final land preparation. The rest of N and K were applied into three equal components at 40, 60, and 80 days after sowing.

Irrigations were done three times in the experimental field. The first was applied in all treatments after planting/sowing of the crops to ensure proper germination. The second and third irrigation was applied at 40 and 60 days after sowing (DAS) of okra. Weeding was done to keep the plot reasonably weeds free throughout the growing period. Other intercultural operations were also done as per the requirement of the crops. Insecticide Imidachloprid (Imitaf 20 SL) @ 0.5 ml/ liter of water was sprayed on okra for control of fruit borer at 50, 70, and 90 days after sowing. Turmeric was harvested on 30 December 2017 and 29 December 2018, respectively. Harvesting of okra started on 24-26 May (60-62 days after sowing) in both years, respectively. A total of twenty times harvest was done for okra while maintaining three to four days intervals. Thereafter, the okra plant was cut to the soil level. After cutting the okra, earthing up was done to the turmeric.

Measurement of Intercropping Indices

Turmeric equivalent yield (TEY) was estimated by converting the yield of intercrops based on the current market value of the respective crop following the formula (Islam et al. 2018):

$$\text{TEY} = \text{Yield of intercrop turmeric} + [(Yi \times Pi)/\text{Price of okra}]$$

where, Yi = yield of intercrops and Pi = price of intercrop.

Land equivalent ratio (LER) is the relative benefit of intercropping compared to sole culture was estimated for each proportion on a plot basis (Mead and Willey 1980). Caballero et al. (1995) reported that the value of LER > 1, indicated higher land use efficiency, and the combinations favor the growth and yield of the species. Besides, value < 1, indicated the combinations negatively affect the growth and yield of crops grown in mixtures.

$$\text{LER} = RY_t + RY_i = (T_{IY}/T_{SY}) + (O_{IY}/O_{SY})$$

where, RY_t = relative yield of turmeric (main crop), RY_i = relative yield of intercrops (okra), T_{IY} = intercrop yield of turmeric, T_{SY} = sole crop yield of turmeric, O_{IY} = intercrop yield of okra, O_{SY} = sole crop yield of okra.

The monetary advantage index (MAI) offers a sign of the economic benefit of the intercropping system. The higher MAI value represents more beneficial is the cropping system (Ghosh 2004). The MAI predicted according to Gosh (2004) was as follows:

$$\text{MAI} = \text{Value of combined intercrop yield} \times (\text{LER}-1)/\text{LER}$$

where, MAI = Monetary advantage index, LER = Land equivalent ratio.

The competitive ratio (CR) amongst the several intercropped plots was measured according to Willey and Rao (1980). It is a very effective tool that offers a better degree of competitive capability of the crops as well as assessment of whether the relationship of the two-component crops is profitable or not (Mahapatra 2011).

$$\text{CR} = \text{LER of crop (a)}/\text{LER of crop (b)}$$

The system productivity index (SPI) was measured as follows (Odo 1991):

$$\text{SPI} = (M_T/M_O)(Y_O+Y_T)$$

where, M_T = mean yield of turmeric in sole culture, M_O = mean yield of okra in sole culture, Y_T = mean yield of turmeric in mixed culture, Y_O = mean yield of okra in mixed culture.

Data Analysis

Data on yield and yield contributing characters of components crops were taken and analyzed statistically through computer using R-stat software program (version 3.1.2) following the basic procedure outlined by Gomez and Gomez (1984). Significant effects of treatments were determined by analysis of variance (ANOVA), and treatments were compared by Least Significant Difference (LSD) Test at 0.05 levels of probability. Correlation analysis was done to study the relationship between desired variables.

RESULTS AND DISCUSSION

Climatic Scenario of the Study Period

The climate of the experimental site is sub-tropical monsoon. The distribution of the air temperature (maximum and minimum), rainfall, and relative humidity during the growing period of 2017 and 2018 is shown in Fig. 1. The results demonstrated that both turmeric and okra thrived well at particular climatic conditions which has been supported by several investigations. For instance, Ishimine et al. (2004) reported that the optimum temperature ranges from 25-35°C for the sprouting of turmeric rhizome-buds, and sprouting does not take place below 10°C or above 40°C, whereas temperature between 20-30°C is well in the seedling growth. Jayashree et al. (2015) also mentioned that turmeric can grow well in a temperature range of 20-35°C with an annual rainfall of 1500 mm or more under rainfed or irrigated conditions and needs a humid climate (Krishna et al. 2019). On the contrary, an average of 32°C temperature is optimum for proper growth and development of okra (Katung 2007) while 70 to 85% relative humidity enhance the performance of okra (Ezeakunne 2004). Ahmad et al. (2016) and Dhankhar et al. (2012) also reported that okra grows best under warm summer with a minimum and maximum mean temperature of 18°C (65°F) and 35°C (95°F), respectively. In addition, the maximum fruit yield of okra can be achieved with an annual rainfall of 1150 to 1250 mm (Singh et al. 2018). The meteorological data during the growing period of the study (Turmeric and okra) exhibited in 2017 and 2018 ranged within the optimum required by the crops (Fig.1).

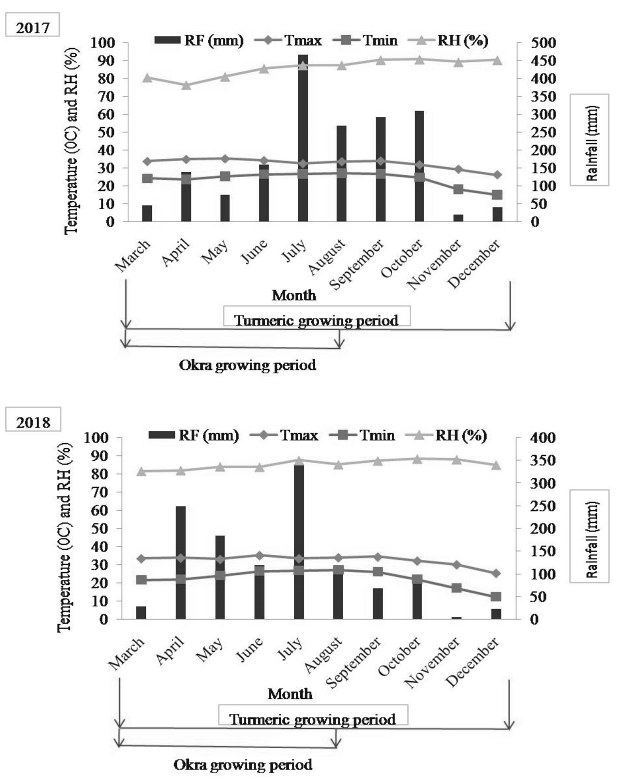


Fig. 1. Monthly average temperature, relative humidity (RH) and rainfall (RF) prevailed during the growing period of turmeric and okra in two consecutive years (T_{max} = maximum temperature, T_{min} = minimum temperature).

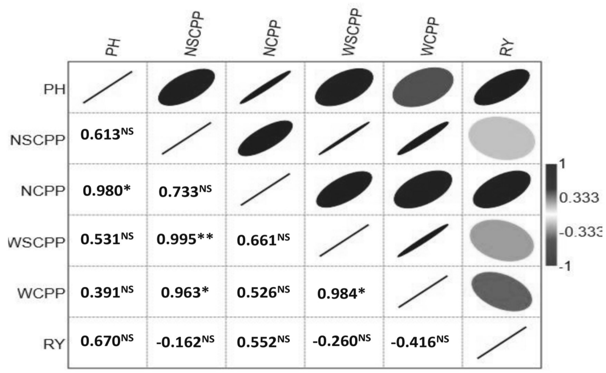
Chemical Properties of the Experimental Soil

The *pH* and organic matter of the study soil was 7.43 and 1.16%, respectively. All the nutrients were on top of the critical levels except total N. The standing of total N was terribly low. Overall nutrient standing values indicated that fertility in experimental soil was moderately good (Table 1).

Yield and Yield Parameters of Turmeric

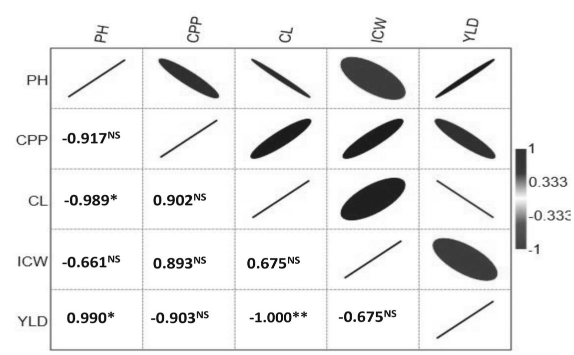
Yield contributing traits and rhizome yield of turmeric notably varied due to intercropping of okra in different planting densities (Table 2). The values of the number of secondary corms plant^{-1}, the weight of secondary corms plant^{-1}, and weight of cormels plant^{-1} were at maximum at intercropped lower population (50%) of okra (T_3), as compared to monocropping (T_4), and others intercropping system (T_1 and T_2). It happened to this treatment because of the higher spaced between the lines that enhanced better growth and development of the turmeric plant. Plant height and number of cormels plant^{-1} were higher when 100% okra intercropped with turmeric (T_1). The result revealed that intercropping of okra at the rate of 100% and 90% population (T_1 and T_2) produced the maximum rhizome yield of turmeric (21.85 and 21.59 t ha^{-1}) which was 13% and 11% higher than the monoculture yield (19.38 t ha^{-1}).

The findings proved that intercropping okra did not affect the rhizome yield of turmeric. Monoculture of turmeric fails to produce higher rhizome yield than 100 and 90% okra intercropping treatments. It might be owing to an open field condition (monoculture turmeric) that the growth and development was poorer than the intercropped situation. Moreover, the emergence of turmeric plants was quicker in turmeric-okra intercropping conditions than monoculture turmeric. Consequently, it enhances better growth and development as well as higher rhizome yield in the intercropping situation compared to sole turmeric. The results agree with the findings where they noticed that higher rhizome yield was obtained in the intercropping situation than monoculture due to the shady condition than those in open field condition (Islam et al. 2018; Islam et al. 2016a; Joyachandran et al. 1991).



Note: PH = plant height, NSCPP = number of secondary corms plant^{-1}, NCPP = number of cormels plant^{-1}, WSCPP = weight of secondary corms plant^{-1}, WCPP = weight of cormels plant^{-1}, RY= rhizome yield.

Fig. 2. Correlation coefficients of yield-on-yield components in turmeric. The color scale displaying the dark blue color a high positive association and the dark red color a high negative correlation between traits (Fig. 1&2), and as the color intensity decreases, the treatments show declining strengthens of association in both the positive and negative ranges.



Note: PH = plant height, CPP = capsules plant^{-1}, CL = capsule length, ICW = individual capsule weight, YLD = yield.

Fig. 3. Pearson correlation coefficients of the five characters studied in okra.

al. (2012) in turmeric. It is also worthwhile to mention the work of Panja et al. (2002) who found that number and weight of secondary corms plant^{-1} were highly significant and positively correlated with rhizome yield. The weight of cormels plant^{-1} exhibited a significant positive correlation with secondary corm weight plant^{-1} (0.984) and a negative association with rhizome yield (-0.260). Plant height (0.670) and the number of cormels plant^{-1} (0.552) were positively related with rhizome yield, while other traits had a negative correlation with rhizome yield.

The significant positive association observed between plant height and yield (0.990) and the significant negative correlation with capsule length (-0.989) also indicated a negative association (Fig. 3). Capsule plant^{-1} demonstrated a non-significant negative relationship with yield (-0.903) and a positive association with capsule length (0.902) and an individual capsule weight (0.893). Capsule length showed a non-significant negative relationship with yield (-0.100) and a positive association with an individual capsule weight (0.675). The okra yield exhibited a non-significant negative correlation with the weight of the individual capsule (0.675). Nwangburuka et al. (2011) and Ahiakpa et al. (2012) suggested that negative association of traits was difficult or practically impossible to improve through simultaneous selection of those traits. Fozia (2018) reported that yield had positive and significant correlation with plant height, capsule length, internod length, number of capsule plant^{-1} and number of seed capsule^{-1}.

Turmeric Equivalent Yield

Regarding the relative efficiency of several treatments the yield of the component crop was converted into Turmeric equivalent yield (TEY) based on existing market sell value, and which called to total productivity. The highest mean TEY (35.43 t ha^{-1}) was recorded in 100% turmeric + 100% okra combination (T_1) which was identical to 100% turmeric + 90% okra (T_2) combination (34.57 t ha^{-1}). Mono crop of okra gave the lowest TEY of 13.73 t ha^{-1} (Table 4). Results indicated that intercropping of okra with turmeric (T_1) produced 83% and 158% higher output in terms of TEY as compared to T_4 and T_5, respectively (both sole stands). It has happened because of the higher biomass production; efficient land use and resource availability was taken place under intercropping than mono-cropping. The results are in line with the earlier findings (Islam et al. 2018; Islam et al. 2016a). Between the sole component crops, turmeric showed a higher TEY (19.38 t ha^{-1}) than okra (13.73 t ha^{-1}).

Land Equivalent Ratio

Land equivalent ratio (LER) is the *ratio* of the area under mono-cropping to the area under intercropping is required to produce equal amounts of yield at the same management level (Mead and Willey 2008). In this study, LER within the intercropping combinations were very efficient having values of more than 1.0 (Table 4) indicating the yield benefit of intercropping over mono-cropping of both the component crops. Moreover, increasing of LER value over 1 (unity) indicated more land use efficiency in intercropping over sole cropping land (Mian 2008). Thus, intercropping performed better productivity than their sole stand. Within the different planting combinations, the highest LER value (2.12) was

Table 2. Yield s and yield parameters of turmeric under different planting densities (pooled average of 2017 and 2018).

Treatment	Plant Height (cm)	Number of Secondary Corms Plant^{-1}	Number of Cormels Plant^{-1}	Weight of Secondary Corms Plant^{-1} (g)	Weight of Cormels Plant^{-1} (g)	Rhizome Yield (t ha^{-1})
T_1	121.56	7.65	17.64	231.42	375.86	21.85
T_2	120.84	7.54	17.51	230.15	372.46	21.59
T_3	118.95	7.86	16.59	236.89	386.72	14.3
T_4	118.23	5.98	15.9	209.87	351.54	19.38
LSD(0.05)	2.44	0.57	1.28	4.47	8.26	1.4
CV (%)	1.62	6.27	6.01	1.56	1.77	5.75
V_T	14.66 *	4.46***	4.03*	841.4***	1299.8***	73.50***

Note: *Significant at p=0.05; ***Significant at p=0.001; VT = Variance due to treatment; LSD = Least significant difference; CV = Coefficient of variation; T_1 = 100% turmeric + 100% okra; T_2 = 100% turmeric + 90% okra; T_3 = 50% turmeric + 50% okra; T_4 = sole turmeric (100%).

Yield and Yield Parameters of Okra

A significant difference was observed in the case of plant height and yield while capsules plant^{-1}, capsules length, and individual capsule weight has not varied significantly (Table 3). The highest plant height was obtained in the sole okra plot (236.55 cm). Among the intercropping systems, maximum plant height (235.65 cm) was observed in T_1 where 100% okra was intercropped with turmeric. The lowest (230.87 cm) was recorded where 50% okra was intercropped with turmeric (T_3). Results revealed that an increased in okra population, plant height increased simultaneously. It might be due to a dense population plant expanded more vertically than partial expansion, the reason why in higher population condition plant height gave more. The capsules plant^{-1}, capsule length, and individual capsule weight ranged from 30.52 - 32.66, 15.66 - 16.32 cm, and 11.98 - 12.53 g, respectively within the monocropped and intercropping systems. However, numerically higher values were observed in T_3 where 50% okra intercropped with turmeric maintaining alternative row arrangement. In this treatment, the okra plant got more space between the rows as compared to others which enhanced comparatively more growth and development. Results also exhibited that an increased plant population of okra, capsules plant^{-1}; capsule length, and individual capsule, weight was reduced. The yield was maximum (13.73 t ha^{-1}) in the sole stand (T_5). As okra population increased, the yield also increases. Data revealed that 100%, 90%, and 50% okra intercropped with turmeric (T_1-T_3) reduced fruit yield of 1%, 5%, and 32%, respectively as compared to monocropping. The higher cumulative yield of ginger and okra was recorded from the intercrop when compared with the sole crop (Asawalam and Chukwu 2012).

Correlation Among the Study Traits of Component Crops

The correlation indicated the relative performance of the treatments under both situations for which the data was observed. Also, correlated traits are the key importance because of genetic causes of correlations through pleiotropic action or developmental interactions of genes and changes brought about by a natural or artificial selection (Falconer and Mackay 1996; Sharma1998). The study revealed that the plant height indicated a significant positive correlation with the number of cormels plant^{-1} (0.98) and other characteristics were shown a non-significant positive association with plant height (Fig. 2). The weight of secondary corms plant^{-1} (0.995) and the weight of corms plant^{-1} (0.963) were significantly and positively correlated with the number of secondary corms plant^{-1}. The number of corms plant^{-1} demonstrated a positive correlation with the number of secondary corms plant^{-1} (0.733), the weight of the secondary corms plant^{-1} (0.661), the weight of the corms plant^{-1} (0.526), and the rhizome yield (0.552). The findings are in accordance with Pandey et al. (2012) and Singh et

Table 3. Yield parameters and capsule yield of okra under different planting densities (pooled average of 2017 and 2018).

Treatment	Plant Height (cm)	Capsules Plant^{-1}	Capsule Length (cm)	Individual Capsule Weight (g)	Yield (t ha^{-1})
T_1	235.65	30.52	15.68	11.98	13.58
T_2	234.89	31.78	15.77	12.48	12.98
T_3	230.87	32.66	16.32	12.53	9.39
T_5	236.55	30.64	15.66	12.24	13.73
LSD(0.05)	2.86	2.25	0.99	0.88	1.18
CV (%)	0.97	5.7	4.97	5.69	7.56
V_T	37.71**	6.168^{ns}	0.58^{ns}	0.38^{ns}	25.11***

Note: ns = non-significant at P = 0.05; **significant at P = 0.01; ***significant at P = 0.001; VT = variance due to treatment; LSD = least significant difference; CV = coefficient of variation; T_1 = 100% turmeric + 100% okra, T_2 = 100% turmeric + 90% okra, T_3 = 50% turmeric + 50% okra, T_5 = sole okra (100%).

Table 4: Turmeric equivalent yield (TEY), land equivalent ratio (LER), monetary advantage index (MAI), competitive ratio (CR) and system productivity index (SPI) of turmeric + okra intercropping system (average of two years).

Treatment	TEY (t ha^{-1})	LER	MAI (US$ ha^{-1})	Competitive Ratio (CR)			SPI
				Turmeric	Okra	Difference	
T_1	35.43	2.12	4558.61	1.14	0.88	0.26	44.39
T_2	34.57	2.06	4337.48	1.18	0.85	0.33	43.42
T_3	23.69	1.42	1714.09	1.08	0.93	0.15	29.55
T_4	19.38	1	-	-	-	-	-
T_5	13.73	1	-	-	-	-	-

Note: T_1 = 100% turmeric + 100% okra; T_2 = 100% turmeric + 90% okra; T_3 = 50% turmeric + 50% okra; T_4 = sole turmeric (100%); T_5 = sole okra (100%).

found in the 100% turmeric + 100% okra intercropping system. The minimum LER (1.42) was in 50% turmeric + 50% okra intercropping system. Results indicated that the yield advantages ranged between 142 to 212%. The LER value 2.12 also exhibited that by intercropping turmeric + okra, a producer could achieve 21.85 tons of turmeric and 13.58 tons of okra from one hectare of land instead of growing them separately in 2.12 hectares of land to obtain the same combined yield. The outcome is in line with the previous findings, where LER values were obtained more than unity compared to that sole stand (Islam et al. 2018; Islam et al. 2016a and 2016b; Islam et al. 2015; Islam et al. 2013; Juskiw et al. 2000; Hossain and Bari 1996; Hashem et al. 1990; Quayyum et al. 1987).

Monetary Advantage Index

Monetary advantage index (MAI) is a very effective tool that reflects the economic advantage of the intercropping system (Islam et al. 2018; Islam et al. 2016a). It was determined to find out the yield advantages under sole and intercropping if profitable or not. The MAI values in this study were positive for the entire intercropping systems. However, among the intercropped combinations the highest MAI (US$ 4558.61 ha^{-1}) was in 100% turmeric + 100% okra combination (T_1) over all other intercropped systems (Table 4.). The reason for higher MAI to this combination is perhaps due to higher LER value. It also exhibited that the mixture of 100% turmeric + 100% okra was highly economical and advantageous. The minimum MAI (US $ 1714.09 ha^{-1}) was recorded in 50% turmeric + 50% okra intercropped system. So, concerning monetary advantage 100% turmeric + 100% okra combination showed the highest profitability and could be proposed as the best intercropping system.

System Productivity Index

System Productivity Index (SPI) is a system measuring the yield benefit of the secondary crop (okra) in terms of the primary crop (turmeric) and identified the intercropping system that effectively utilized the growth resources (Islam et al. 2018). The maximum SPI (44.39) was obtained in 100% turmeric + 100% okra intercropping system as compared to the other combinations. The lowest SPI (29.55) was observed in the 50% turmeric + 50% okra intercropping system (Table 4). The results exhibited that intercropping okra with the high population (100%) with turmeric utilized resources more effectively over the rest of the combinations, and hence had a higher SPI.

Competitive Ratio

Competitive ratio (CR) is an effective intercropping index that determines the level of competes of a crop with another. In this study, turmeric showed a higher value of CR (1.08-1.18) than the okra (0.85-0.93) crop in the entire intercropping system (Table 4). It means that turmeric is the best competitor to okra. The maximum CR value (1.18) of turmeric was recorded in 100% turmeric + 90% okra intercropped combination. Likewise, the maximum CR value of okra (0.93) was found in 50% turmeric + 50% okra intercropped combination. The minimum difference of CR values indicated better utilization of growth resources. However, 100% turmeric + 100% okra intercropped combination produced higher productivity in terms of turmeric equivalent yield (35.43 t ha^{-1}) with CR difference of 0.26. 50% turmeric + 50% okra intercropped system failed to produce higher productivity although CR difference was minimum (0.15). It happened due to less okra population intercropped with turmeric which resulted in a lower yield of okra. The CR > 1 (unity) indicates the species as a good competitor while < 1 (unity) indicates the species as a poor competitor when grown in the mixture (Jedel et al. 1998).

Profitability Analysis

The entire intercropping system gave the highest economic return compared to sole cropping (Table 5). The maximum gross return (US$ 8641.46 ha^{-1}) and gross margin (US$ 5667.51 ha^{-1}) was showed in 100% turmeric + 100% okra combination (T_1) which was followed by 100% turmeric + 90% okra intercropping system (T_2). The combination of 50% turmeric + 50% okra (T_3) produced higher BCR (3.27) as compared to T_1 and T_2. It was generally due to less cost required for the amount of

Table 5. Economic evaluation of turmeric + okra intercropping system (prediction from pooled average yield data of 2017 and 2018).

Treatment	Gross return (US$ ha^{-1})	Total variable cost (US$ ha^{-1})	Gross margin (US$ ha^{-1})	BCR
T_1	8641.46	2973.95	5667.51	2.91
T_2	8431.71	2925.17	5506.54	2.88
T_3	5778.05	1764.8	4013.24	3.27
T_4	4726.83	2016.63	2710.2	2.34
T_5	3348.78	1603.24	1745.54	2.09

Market price: 1 US$ = 82 Tk; turmeric: US$ 0.24 kg^{-1} and okra: US$ 0.24 kg^{-1}; T_1 = 100% turmeric + 100% okra; T_2 = 100% turmeric + 90% okra; T_3 = 50% turmeric + 50% okra; T_4 = sole turmeric (100%); T_5 = sole okra (100%).

seeds, sowing, and harvesting expenditure of the component crops in this treatment which led to lower total variable cost. The lowest gross return (US$ 3348.78 ha^{-1}), gross margin (US$ 1745.54 ha^{-1}), and BCR (2.09) were found in sole okra.

CONCLUSION

Smallholder farmers of developing countries represents domination in farming community and their ever shrinking arable unable to meet up annual food requirements. Intercropping system offer potential benefits for increasing cropping intensity, total productivity, and economic return per unit area. In the turmeric + okra intercropping system, slow rate of germination of turmeric facilitates okra to grow in the inter row space without competition prior to occupy the canopy. The outcomes of this investigation bear noteworthy significance which demonstrated that rhizome yield of turmeric improve 13% and 11% in 100% turmeric + 100% okra and 100% turmeric + 90% okra intercropping system, respectively than in monocrop of 100% turmeric. Moreover, the intercropping turmeric + okra systems contributed a maximum yield of both the crop as well as TEY, better land-use efficiency and MAI. Therefore, the combinations of 100% turmeric + 100% okra or 100% turmeric + 90% okra could be a better combination for intercropping system.

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