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Intercropping of Sesame with Mungbean Increased System Productivity and Farm Profit in Coastal Region of Bangladesh

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Intercropping is an innovative and sustainable classic agricultural practice that can strengthen and stabilize agro-ecosystems under changing climate through optimizing resource use efficiency and enhancing productivity by cropping diversity. The experiment was conducted at Kuakata, Patuakhali and Amtali, Barguna villages during winter (*Rabi*) seasons of 2020-21 and 2021-22 to determine the yield and profitability for intercropping of mungbean and sesame on coastal saline soils. Four combinations *viz.*, T_1 = 100% mungbean sown in rows (30 cm × 5 cm) + broadcasting of sesame at 50% of recommended seed rate, T_2 = 100% mungbean in rows (30 cm × 5 cm) + broadcasting of sesame at 25% of the recommended seed rate, T_3 = sole crop of mungbean in row (30 cm × 5 cm) (100% mungbean) and T_4 = Sole crop of sesame in row (30 cm x 5 cm) (100% sesame) were evaluated at each location. Sole mungbean and sesame offered higher yields than each crop in the intercropping combinations at both locations. Intercropping increased mungbean equivalent yield (MEY) and land equivalent ratio (LER) compared to sole cropping. Over the locations, the highest MEY (2.33 t ha^{-1}), LER (2.09), and benefit: cost ratio (1.88) were obtained from T_1 (100% mungbean in rows of 30 cm × 5 cm + 50% sesame by broadcasting). However, mungbean yield was higher in the plots of intercropped 100% mungbean sown in rows (30 cm × 5 cm) with broadcasted 25% sesame seeds (T_2: 1.65 - 1.69 t ha^{-1} compared to the intercropping with 50% broadcasted sesame seeds (T_1: 1.24 - 1.25 t ha^{-1}). In the case of sesame intercropping, 50% seeding rate (T_1) offered a higher seed yield over 25% seeding rate (T_2). Therefore, intercropping of sesame with mungbean (100% mungbean sown in rows (30cm × 5 cm) + broadcasting of sesame at 50% of recommended seed rate) could be an excellent option for increasing system productivity and income for coastal farmers of Bangladesh.

(***Key words:*** *Coastal cropping, Intercropping, Mungbean, Productivity, Sesame)*

Intercropping is an innovative agricultural practice to grow more than one crop simultaneously in alternate rows of the same field (Beets, 1990). In this technique the available resources could be utilized more efficiently with productivity improvement compared to monoculture (Launay *et al.,* 2009; Mucheru *et al.,* 2010), even under adverse conditions. Cereal and legume intercropping is recognized as a common cropping system by small-scale farmers in developing countries (Tsubo *et al.,* 2003).

Intercropped legumes fix most of their N from the atmosphere, not competing with cereals for N resources (Vesterager *et al.,* 2008). Increased leaf cover in intercropping systems helps to reduce weed populations once the crops are established (Beets, 1990). Having a variety of root systems in the soil reduces water loss, increases water uptake, and increases transpiration. This is important during times of water stress, as inter cropped plants use a larger percentage of available water from the field than mono-cropped plants. Rows of maize in a field with a shorter crop will reduce the wind speed above the shorter crops and thus reduce desiccation (Beets, 1990). Cereal-grain legume intercropping has the potential to address soil nutrient depletion on smallholder farms (Sanginga and Woomer, 2009). Flexibility, maximization of profit, minimization of risk, soil conservation and soil fertility improvement are some of the principal reasons for small holder farmers to intercrop their farms / crops (Matusso *et al.,* 2014).

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Mungbean (*Vigna radiata* L.) and sesame (*Sesamum indicum* L.) are essential food crops for cultivation and became the major component of protein diet (Choudhary *et al.,* 2011). Intercropping is the means of producing more food from a limited area of land by cultivating multiple crops simultaneously. It ensures improved use of land, labor and resources. The system of inter cropping not only improves the yield and returns but also reduces the risk of complete crop failure as compared to the sole cropping system (Rao and Singh, 1990). In inter cropping, growth resources are used efficiently, weeds, disease and pest incidences are suppressed (Paoline *et al.,* 1988).

The southern districts of Bangladesh lie in the coastal region that are vulnerable to the rapid climate change and crop production is the biggest challenge at that locality mostly for soil salinity, waterlogging, and also for often the occurrence of natural calamities. Therefore, sole crop cultivation often found risk for the farmers of the coastal area. Moreover, sesame can tolerate salinity and is a safer crop to grow in the coastal region compared to the mungbean. However, sesame is very sensitive to water logging conditions. Therefore, inter cropping mungbean with sesame could be a good option to overcome the risk of crop failure or economic loss over the mono-crop culture.

The adoption of intercropping technology can increase the total crop productivity, land use efficiency and farm profit of the coastal region; however, the ratio of the intercrops is the major concern to attain optimum system yield. Therefore, an experiment was designed and executed to find suitable intercrop combination of mungbean and sesame to increase the total crop productivity of the coastal region to reduce the risk of sole crop failure.

MATERIALS AND METHODS

The experiment was conducted at two multi-location testing (MLT) sites named Kuakata under Kalapara upazila of Patuakhali district (21°51′20″ N, 90°08′01″ E; 4.05 m elevation) and at Amtali upazila of Barguna district (22°11′00″ N, 96°16′32″ E; 3.24 m elevation) of Bangladesh (Fig. 1) during the late winter (*Rabi*) season of 2020-21 and 2021-22. The soils of both experimental sites were clay loam in nature with 0.98% organic matter content at Kuakata and 1.57% at Amtali. The range of soil pH was 5.3 - 6.8 at Kuakata,

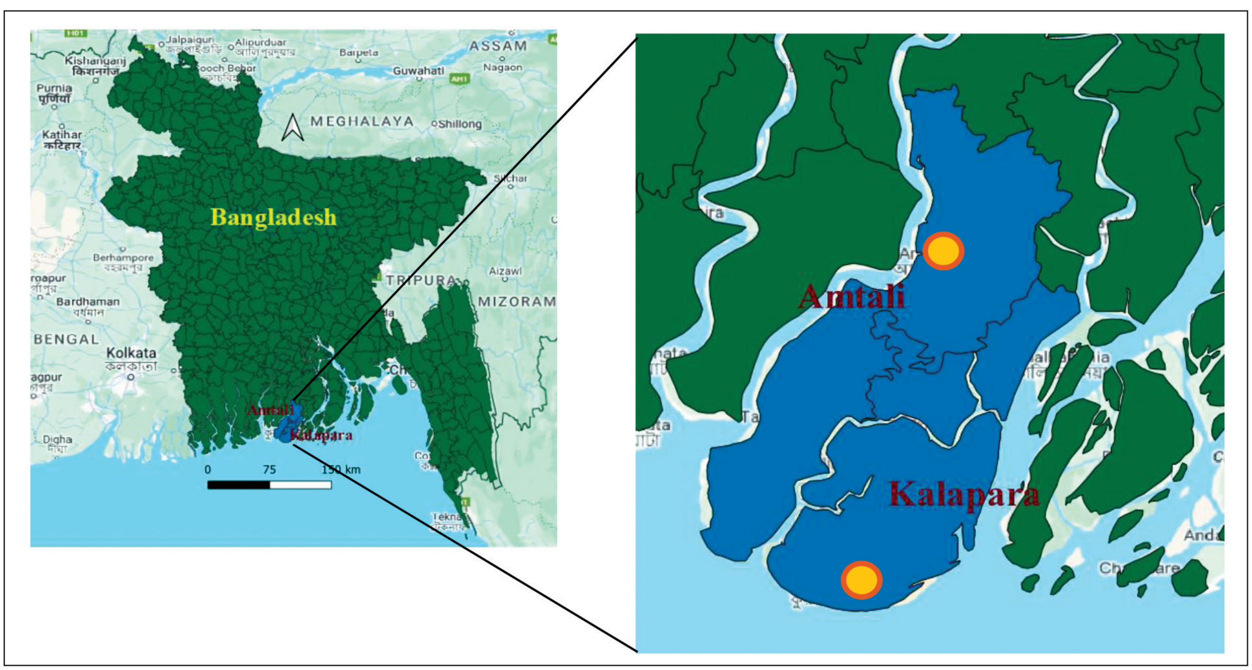

Fig 1: *Location of field experiments (Source: Google map)* ● *indicates the experimental site*

Patuakhali and 6.2-7.4 at Amtali, Barguna.

The study was carried out from January 2020 to May 2022. The coldest month of the study period was January, thereafter the temperature started to increase and was at its peak in May (Fig. 2a). A very limited amount of rainfall (240 mm in 2020; 04 mm in 2021; 47 mm in 2022) was recorded from January to April (Fig. 2b).

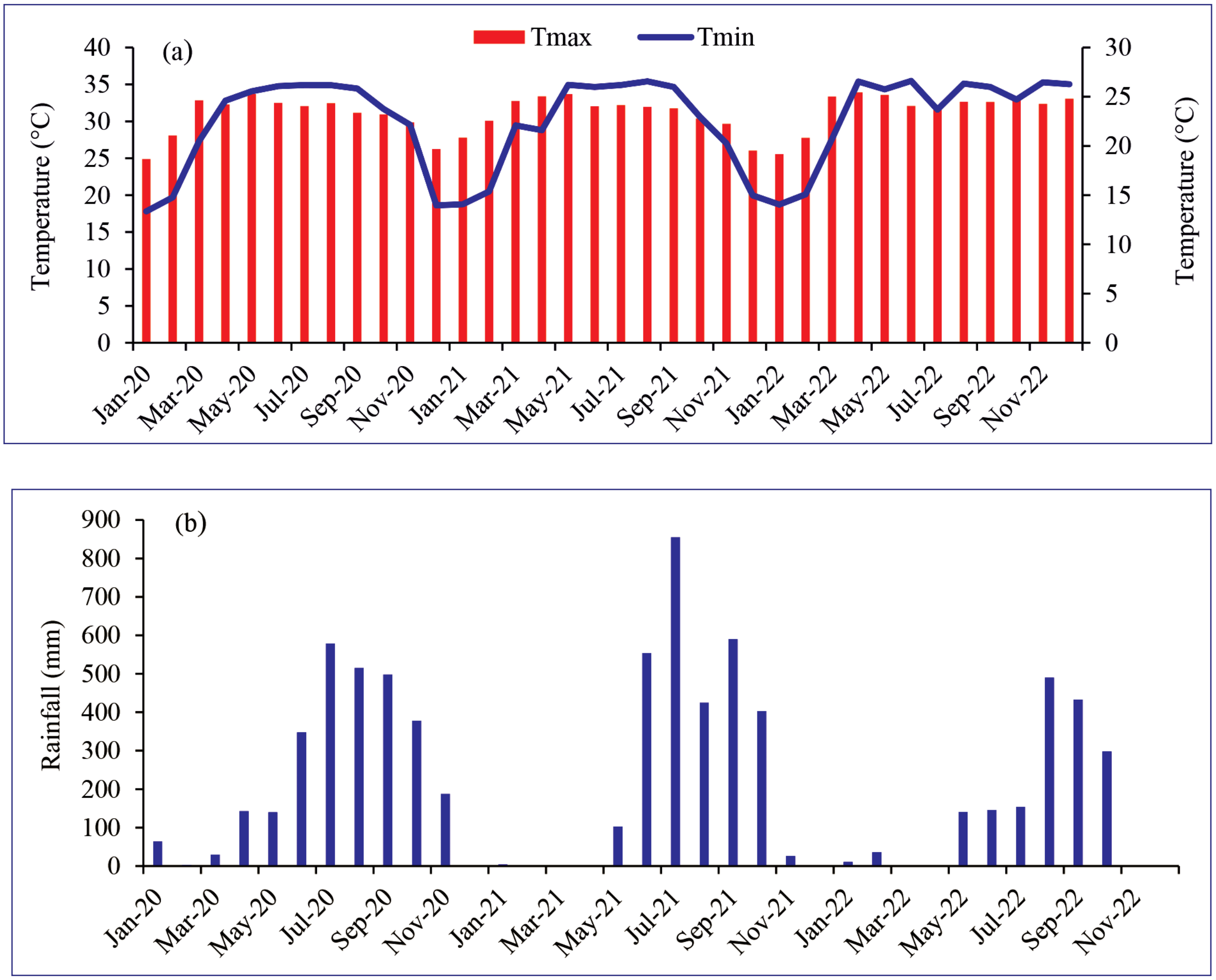

Fig. 2. *Monthly (a) average of maximum and minimum temperature and (b) total rainfall of the southern coastal region of Bangladesh from January 2020 to December 2022*

The study evaluated the performance of intercropping in four treatment combinations *viz.*, T_1 = 100% mungbeansown in rows (30 cm × 5 cm) + broadcasting of sesame at 50% of recommended seed rate, T_2 = 100% mungbean in rows (30 cm × 5 cm) + broadcasting of sesame at 25% of the recommended seed rate, T_3 = Sole crop of mungbean in row (30 cm × 5 cm) (100% mungbean) and T_4 = Sole crop of sesame in row (30 cm x 5 cm) (100% sesame).

BARI Mungbean-6 and BARI Til-4 were the varieties of mungbean and sesame, respectively. The experiment was laid out in a randomized complete block design with three replications. The unit plot size was 5 m x 4 m. Seeds were sown according to treatments on 01 February and 29 January at Kuakata and Amtali, respectively. In sole mungbean and intercrop plots, the land was fertilized with nitrogen, phosphorus and potassium at 23, 17 and 17.5 kg ha^{-1}, respectively at the time of final land preparation.

In the case of sesame, nitrogen, phosphorus, potassium, sulphur, zinc and boron fertilizers were applied at the rate of 57.6, 30, 25, 19.8, 1.05 and 1.7 kg ha^{-1}, respectively. All intercultural operations were carried out according to recommended practice (Azad *et al.,* 2019). Harvest of mungbean seeds started during 02-06 April and sesame was harvested during 05-10 May. The data on yield and yield contributing characters were analyzed using the statistical program R, and treatment means were separated by the critical difference (CD) at a 5% significance level.

Mungbean equivalent yield (MEY) was calculated by converting the yield of sesame into the yield of mungbean on the basis of the prevailing market price using the following formula of Anjaneyulu *et al.* (1982) as given in Eq. 1. Land equivalent ratio (LER) was calculated was calculated using the following formula of Willey (1981) as given in Eq. 2. The replacement value of intercropping (RVI) was calculated as given in Eq. 3 according to Moseley (1994) and Vandermeer (1989). The monetary advantage index (MAI) was calculated using Eq. 4 as described by Ghosh (2004).

$$MEY = Y_m + \frac{Y_{int} \times P_{int}}{P_m} \qquad \ldots 1$$

where, Y_m = yield of mungbean, P_m = sales price of mungbean, Y_{int} = yield of intercrop (sesame), and P_{int} = price of intercrop (sesame).

$$LER = \frac{\text{Yield of inter crop (mungbean)}}{\text{Yield of sole crop (mungbean)}} + \frac{\text{Yield of inter crop (sesame)}}{\text{Yield of sole crop (sesame)}} \qquad \ldots 2$$

$$RVI = \frac{aP_1 \times bP_2}{aM_1 - C} \qquad \ldots 3$$

where, P_1 & P_2 are the yield of intercrops and a & b are the respective prices of these crops, M_1 is the yield and C is the input cost the primary (main) crop in sole stand.

$$MAI = \text{Value of combined intercrop yield x (LER-1)/LER} \qquad \ldots 4$$

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

RESULTS AND DISCUSSION

Performance of mungbean

Plant height of mungbean under sole crop and intercrop condition was monitored (Table 1) and it was observed that plants in 100% mungbean in rows (30 cm × 5 cm) + broadcasted sesame at 25% of the recommended rate (T_2) treated plots were the shortest. Interestingly, mungbean plants under this T_2 treatment took the longest days to first flowering (48 days) and harvesting (80-81 days). All the values of yield contributing characters of mungbean were highest in T_3 treatment *i.e.*, 100% mungbean in rows (30 cm × 5 cm) compared to intercropping combinations at both Amtali and Kuakata (Table 1). The recorded mungbean yield was 1.73 -1.76 t ha^{-1}. 100% mungbean in rows (30 cm × 5 cm) + broadcasting sesame at 25% of the recommended rate (T_2: 1.69 t ha^{-1} at Kuakata and 1.65 t ha^{-1} at Amtali) offered higher yield than 100% mungbean in rows (30 cm × 5 cm) + broadcasting sesame at 50% of the recommended rate (T_1: 1.25 t ha^{-1} at Kuakata and 1.24 t ha^{-1} at Amtali). The lowest mungbean yield (1.25 t ha^{-1}) was recorded from T_1 treatment *i.e.*, 100% mungbean in rows (30 cm × 5 cm) + broadcasting sesame at 50% of the recommended seed rate. However, the highest total intercrop yield (2.42 t ha^{-1} at Kuakata and 2.32 t ha^{-1} at Amtali) was recorded from 100% mungbean in rows (30 cm × 5 cm) + broadcasting sesame at 50% of the recommended seed rate (T_1). This might have happened because of better sesame yield from intercropping of sesame at 50% broadcasted seeding rate with mungbean compared to the sesame intercropping at 25% broadcasted seeding rate. Xie *et al.* (2021) also recorded maximum yield from intercropping potato with maize; however, they reported the benefits of using mulch in the intercropping system for getting good water use efficiency.

Performance of sesame

The maximum number of pods $plant^{-1}$ (87) was recorded in sole sesame followed by 25% sesame seed rate plus 100% mungbean in rows (30 cm × 5 cm) at both Kuakata and Amtali (Table 2). The number of pods $plant^{-1}$ was decreased by 15 - 20% with100% mungbean in rows (30 cm × 5 cm) + 50% sesame at Kuakata and Amtali. The maximum number of seeds pod^{-1} (55 and 52) was recorded in sole sesame (100%) followed by 100% mungbean in rows (30 cm × 5 cm) + 25% sesame (50 and 49) intercropping at Kuakata and Amtali respectively. The higher number of seeds pod^{-1} in combination witha lower population of sesame might be due to the greater plant height of sesame plants as compared to the denser population.

The highest seed yield of sesame (1.18 and 1.15 t ha^{-1}) was recorded from the sole cropping both at Kuakata and Amtali. The lowest seed yield at Kuakata (0.42 t ha^{-1} and at Amtali 0.45 t ha^{-1}) was recorded in the intercropping 100% mungbean in rows (30 cm × 5 cm) + broadcasting 25% sesame because of having the lowest plant population of sesame in per unit area.

Table 1. *Performance of mungbean considering plant height, days to first flowering and harvest, yield contributing characters and yield under sole crop and intercrop combinations at Kuakata, Patuakhali and Amtali, Barguna (average of two years)*

Treatments	Plant height (cm)	Days to first flowering	Days to first harvest	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	1000-seed wt. (g)	Yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
Kuakata, Patuakhali									
T_1	28.5	42	74	18	10	48.7	1.25	2.55	33.1
T_2	26.0	48	81	20	11	50.7	1.69	2.89	36.8
T_3	28.1	45	78	21	11.7	51.3	1.73	3.03	37.9
T_4	-	-	-	-	-	-	-	-	-
CV (%)	1.43	0.73	0.85	3.18	5.42	1.75	3.55	3.77	4.16
$CD_{0.05}$	0.90	0.76	1.51	1.40	1.31	1.99	0.12	0.24	3.38
Amtali, Barguna									
T_1	28.0	42	73	18	10	47.3	1.24	2.56	48.44
T_2	25.8	48	80	20	10	49.3	1.65	2.71	60.89
T_3	27.7	45	79	20	11	50.5	1.76	2.94	59.87
T_4	-	-	-	-	-		-	-	-
CV (%)	2.14	1.52	1.69	4.49	5.49	2.46	4.27	3.98	7.56
$CD_{0.05}$	1.54	0.98	2.09	1.87	1.98	1.94	0.78	0.27	1.89

Means were separated by critical difference (CD) values at 5% level of significance. T_1 = 100% mungbean in rows (30 cm × 5 cm) + 50% sesame as broadcast, T_2 = 100% mungbean in rows (30 cm × 5 cm) + 25% sesame as broadcast, T_3 = Sole crop of mungbean in row (30 cm × 5 cm) (100% mungbean), T_4 = Sole crop of sesame in row (30 cm × 5 cm) (100% sesame)

Table 2. *Performance of sesame considering plant height, yield contributing characters, and yield under sole crop and intercrop combinations at Kuakata, Patuakhali and Amtali, Barguna (average of two years)*

Treatments	Plant height (cm)	Number of pods plant^{-1}	Number of seeds pod^{-1}	1000-seed wt. (g)	Yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
Kuakata, Patuakhali							
T_1	96.5	74	46	3.24	0.73	3.64	20.06
T_2	104.5	82	50	3.54	0.42	2.69	15.62
T_3	-	-	-	-	-	-	-
T_4	107.7	87	55	3.55	1.18	5.98	19.74
CV (%)	5.24	4.07	3.65	5.96	7.68	3.45	6.37
$CD_{0.05}$	0.04	2.42	0.29	0.02	2.58	1.05	2.03
Amtali, Barguna							
T_1	94.6	70	44	3.21	0.67	3.52	19.04
T_2	103.3	82	49	3.49	0.45	2.65	16.99
T_3	-	-	-	-	-	-	-
T_4	104.4	87	52	3.54	1.15	5.52	20.84
CV (%)	4.69	6.52	5.72	3.79	5.89	4.72	5.65
$CD_{0.05}$	1.03	1.52	0.96	0.04	1.47	1.24	1.75

Means were separated by critical difference (CD) values at 5% level of significance. T_1 = 100% mungbean in rows (30 cm × 5 cm) + 50% sesame as broadcast, T_2 = 100% mungbean in rows (30 cm × 5 cm) + 25% sesame as broadcast, T_3 = Sole crop of mungbean in row (30 cm × 5 cm) (100% mungbean), T_4 = Sole crop of sesame in row (30 cm x 5 cm) (100% sesame)

Table 3. *Yield of mungbean and sesame as influenced by intercropping at different locations (average of two years)*

Treatment	Seed yield (t ha^{-1})						Seed yield (t ha^{-1})	
	Kuakata, Patuakhali			Amtali, Barguna			Over the location	
	Mungbean	Sesame	Total intercrop yield	Mungbean	Sesame	Total intercrop yield	Mungbean	Sesame
T_1	1.25	0.73	2.42	1.24	0.67	2.32	1.24	0.70
T_2	1.69	0.42	1.67	1.65	0.45	1.69	1.67	0.43
T_3	1.73	-	1.73	1.76	-	1.76	1.74	-
T_4	-	1.18	1.18	-	1.15	1.15	-	1.16
CV (%)	4.15	1.94	-	5.49	3.85	-	-	-
$CD_{0.05}$	0.15	0.03	-	0.19	0.08	-	-	-

Means were separated by critical difference (CD) values at 5% level of significance. T_1 = 100% mungbean in rows (30 cm × 5 cm) + 50% sesame as broadcast, T_2 = 100% mungbean in rows (30 cm × 5 cm) + 25% sesame as broadcast, T_3 = Sole crop of mungbean in row (30 cm × 5 cm) (100% mungbean), T_4 = Sole crop of sesame in row (30 cm x 5 cm) (100% sesame)

Economic return and cost benefit ratio of mungbean-sesame intercropping system

Mungbean equivalent yield (MEY) was higher (2.17 and 2.33 t ha^{-1}) in all the intercropping systems over sole crop of mungbean (1.73 and 1.76 t ha^{-1}) at both Kuakata and Amtali, respectively. This confirms the more efficient use of land and available resources under the mungbean-sesame intercropping than under sole cropping of each crop. Based on the mean of two years, highest gross margin and BCR were obtained (US$ 553.24 ha^{-1} and 1.75), respectively from the 100% mungbean in rows (30 cm × 5 cm) + 50% sesame combination at Kuakata, Patuakhali (Table 4). The lowest gross margin (US$ 155.60 ha^{-1}) and BCR (1.24) was obtained from the sole crop of sesame at Kuakata, Patuakhali.

At Amtali, Barguna, the highest gross margin and BCR were obtained (US$ 648.65 ha^{-1} and 1.88, respectively) were also from 100% mungbean in rows (30 cm × 5 cm) + 50% sesame intercropping (Table 4). The lowest gross margin of US$ 131.74 ha^{-1} was obtained from the sole crop of sesame while lowest BCR (1.20) was from thesole crop of mungbean.

LER, RVI and MAI of mungbean-sesame intercrop

The LER exceeded unity in allintercropping combinations (Table 5). However, the highest average total LER (1.71) was obtained in the 100% mungbean in rows (30 cm × 5 cm) + 50% sesame intercropping system. Replacement value of intercropping (RVI) is one of the better measures of the economic advantage of intercropping (Moseley, 1994; Vandermeer, 1989). The maximum value (4.28) of RVI was observed in the 100% mungbean in rows (30 cm × 5 cm) + 50% sesame intercropping system. The monetary advantage index (MAI) also indicates the economic advantage of the intercropping system. The values of MAI were positive in boththe intercropping combinations. The highest MAI (US$ 336.15 ha^{-1}) was obtained withthe 100% mungbean in rows (30 cm × 5 cm) + 50% sesame intercropping system. Similar to the present study, Dhima *et al.* (2007) also reported that higher LER ensured the economic benefit with the highest MAI.

Table 4. *Cost and return analysis of mungbean equivalent yield (MEY) as influenced by intercropping (average of two years) at Kuakata, Patuakhali and Amtali, Barguna during 2020-2022*

Treatments	Mean MEY (t ha^{-1})	Gross return (US$ ha^{-1})	TVC (US$ ha^{-1})	Gross margin (US$ ha^{-1})	BCR
Kuakata, Patuakhali					
T_1	2.17	1294.04	740.80	553.24	1.75
T_2	2.09	1246.33	742.27	504.06	1.68
T_3	1.73	1031.65	741.81	289.84	1.39
T_4	1.36	811.01	655.41	155.60	1.24
Amtali, Barguna					
T_1	2.33	1389.45	740.80	648.65	1.88
T_2	2.01	1198.62	742.27	456.36	1.61
T_3	1.76	1049.54	741.81	307.73	1.41
T_4	1.32	787.15	655.41	131.74	1.20

Selling Price: Mungbean = Tk. 65 kg^{-1}, Sesame = Tk. 75 kg^{-1}, 1 US$ = 109 Bangladeshi Taka

Table 5. *Land equivalent ratio (LER), replacement value of intercropping (RVI) and monetary advantage index (MAI) of mungbean-sesame intercropping at Kuakata, Patuakhali and Amtali, Barguna during 2020-2022 (Average of two years)*

Treatments	LER		RVI	MAI
	Kuakata	Amtali		US$ ha^{-1}
T_1	2.09	1.33	4.28	336.15
T_2	1.34	1.29	4.05	294.67
T_3	1.00	1.00	3.44	00
T_4	1.00	1.00	2.64	00

T_1= 100% mungbean in rows (30 cm × 5 cm) + 50% sesame as broadcast, T_2 = 100% mungbean in rows (30 cm × 5 cm) + 25% sesame as broadcast, T_3= Sole crop of mungbean in row (30 cm × 5 cm) (100% mungbean), T_4 = Sole crop of sesame in row (30 cm x 5 cm) (100% sesame), 1 US$ = 109 Bangladeshi Taka

CONCLUSION

The intercropping of sesame with mungbean gave maximum productivity and greater economic returns than the sole crops of sesame or mungbean. The intercropping of mungbean at 100% of the recommended seed rate sown in rows (30 cm × 5 cm) and broadcasting of sesame at 50% of the recommended seed rate would be suitable for obtaining maximum total productivity as well as economic return in the coastal zone of southern Bangladesh. We conclude that intercropping is a feasible option for coastal farmers to increase their productivity from small land holdings. Moreover, it will help to increase the area under sesame cultivation and will reduce the gap between production and the demand for cooking oil in Bangladesh.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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