Screening of Rabi Crops for Rabi-Mungbean Sequential Intercropping in Paired Rows Transplanted Sugarcane

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ABSTRACT

Sugarcane is a T_4, long duration and exhaustive crop because of its high nutrient uptake from soil. Farmers have tendency to use higher dose of fertilizer. Conventional method of sugarcane cultivation for increasing yield causes degradation of soil fertility. Intercropping with legumes maybe an option which will help to maintain soil fertility. An experiment was conducted at the Bangladesh Sugarcrop Research Institute (BSRI) farm, Ishurdi, Pabna, Bangladesh for consecutive two years from 2009-2010 to 2010-2011 to find out suitable rabi crops for Rabi-mungbean sequential intercropping with paired rows transplanted sugarcane. The site represents High Ganges River Floodplain under Agro-Ecological Zone 11 with medium high land of typical sandy loam soil. Onion bulb, onion seed, potato, tomato, cabbage, mustard, lentil and soybean were used as first intercrop and mungbean as second intercrop.Variety Isd 38 was used in the experiment. The experiment was set up in randomized complete block design with three replications. Eleven treatments combination were employed for the study. Results revealed that sequential intercropping practices did not affect sugarcane, growth and yield and juice quality. All the sequential intercropping treatments showed higher benefit cost ration (BCR) and land equivalent ration (LER) than the sole cane crop. The mungbean based sequential intercropping systems in paired rows sugarcane gave higher economic benefit compared with sole cane. The selection of first intercrops could be in the order of onion seed crop > cabbage > tomato > potato > lentil > onion (bulb) > mustard > soybean.

Key words: Productivity, Sugarcane, Paired rows cane (PRC), Intercropping

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the major food-cum-industrial cash crops in Bangladesh and cultivated in more than 90 countries of the tropical and sub-tropical regions of the world (FAO, 2011). In Bangladesh, on an average 4.5 million metric tons of sugarcane is produced annually from 0.12 million hectares of land (FAOSTAT, 2012). There are 30 Agro-ecological zones (AEZs) in Bangladesh but sugarcane production is mainly confined to only 12 AEZs.

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Sugarcane is mainly grown in high and medium high land under rainfed conditions in the north-west and south-west regions of the country. Though the soil and climate of Bangladesh is very much congenial for sugarcane production but the average yield is around 44 t ha^{-1} (BBS, 2011) while the world average is 70.76 t ha^{-1} (FAOSTAT, 2012). In Bangladesh sugarcane cultivation is gradually being pushed into low lying marginal and char lands that are not suitable for its cultivation. This crop fetches less benefit compared to other high value short duration fruits and vegetables and using crop lands for housing and industrialization. On the other hand sugar or *goor* require is increasing for the growing population. In this situation, there is a little scope of expanding sugarcane area to fulfill the increased sugar or *goor* requirement.

Since, horizontal expansion of sugarcane production is not possible it is essential to increased sugarcane production using modern technologies to meet the increased demand. In addition, intercropping of high value crops with sugarcane using modern technology will help making sugarcane cultivation more profitable.

Conventionally sugarcane setts are planted in trench made at 90-100 cm distances. In many cases, plant population establishment is hampered in this system. To overcome this situation and ensure plant establishment the system of settling planting at specified distances in the trenches has been developed. The transplanting of cane ensures optimum plant establishment. The initial crop growth of the crop is slow and thus inter row spaces is not covered by sugarcane leaf canopy for the first 120-150 days. The vacant space can be used for intercrop cultivation. In early stage of growth, some short duration crops *viz.* vegetables, pulses, oil seeds and spices can be grown as intercrop in the vacant spaces between two rows of sugarcane. The intercropping offers an opportunity of increasing land utilization. The traditional intercropping with single row sugarcane is less remunerative as the growth and yield of both the component crops are not satisfactory. Under this situation, paired rows system of cane cultivation has been developed that unveils the potential of practicing intercropping with sugarcane with high profit. More than one intercrops in sequence can be easily cultivated with paired rows system to make sugarcane cultivation more profitable (Alam *et. al.,* 2007). Successful intercropping of various crops with sugarcane has been reported by many researchers (Islam *et. al.,* 2009; Alam *et al.,* 2007, Alam *et. al.,* 2008). It has been reported that potato, onion, garlic and cabbage could be cultivated profitably as first intercrops with sugarcane (Matin *et. al.,* 2001). Besides, after harvesting of first intercrop, the possibility of growing some short duration crops such as leafy vegetables, mungbean and dhaincha. successfully as second intercrop with sugarcane has been explored. The possibility of growing a second intercrop under single row system of cane plantation is restricted due to canopy development of cane after the harvest of first intercrop. On the other hand, sequential intercropping in paired rows sugarcane is feasible (De and Singh, 1979). Among winter crops, potato, onion, mustard, lentil, cabbage, cauliflower, carrot etc are grown as intercrop with sugarcane. Mustard ranks the first covering about 40-50% of the total intercropped area in Bangladesh (Hossain, 1984). In another study, potato yield was increased by 80-100% in paired rows system compared to the single row system.

The adverse effects of mustard intercrop on tiller, millabe cane and cane yield under paired rows system increased by 80% compared to the single row intercrop (Ahmed *et. al.*, 2007).

Rathi and Singh (1979) and Parashar *et. al.* (1979) reported that juice quality parameters of sugarcane (brix, purity and sucrose percentages) were not affected by onion intercropping. Sinha *et. al.* (1990) obtained higher net return (54.3-76.2%) from intercropping potato under paired rows system compared to the single row system. It is further reported that sugarcane in paired rows system showed less tiller mortality than in single row system (Jayabal and Sankaran, 1991). Khan et al. (1995) obtained the highest adjusted cane yield (140.8 t ha^{-1}) under paired rows system from sugarcane + potato - kangkong intercropping compared with the other intercropping system (65.2-125.6 t ha^{-1}) where potato was followed by dhaincha/ indigo/ mungbean. They also obtained the highest adjusted cane yield (201.23 t ha^{-1}) and gross income. Moreover, maximum benefit cost ratio (BCR) of 4.09 was found from PRC + tomato (3 lines) - mungbean combination. On the other hand, growing mungbean as second intercrop increased soil fertility due to addition of atmospheric inert nitrogen in available form and also add organic matter in soil. Yadav (1987) observed soil fertility improvement through legumes intercropping with sugarcane. In India, a large quantity of N fertilizer (150 kg ha^{-1}) is required to produce cane yield. Legume is a companion intercropping system that improves soil fertility by fixing atmospheric N to benefit sugarcane grown in association or in succession. Intercropping/mixed cropping makes the better use of sunlight and water. It shows some beneficial effects on pest and diseases (Abdullah *et. al.*, 2006). In many cases it gives higher total production, monetary returns and greater resource use efficiently and increases the land productivity by almost 60 percent. Intercropping also increases nutritional quality of diet for the farm family (Khan *et. al.*, 2005), allows better control of weeds, increases land equivalent ratio (Imran et al., 2011). In an intercrop community, the individual plant of one crop exposed to both intra and inter-specific competition although causing a reduction in individual yield but total productivity per unit area increases (Gani and Paul, 2005). Therefore, the present study was undertaken to find out suitable crops for sequential intercropping with paired rows transplanted sugarcane.

MATERIALS AND METHODS

The experiment was conducted at the Bangladesh Sugarcrop Research Institute (BSRI) farm, Ishurdi, pabna during the year of 2009-2010 and 2010-2011 cropping season. Onion bulb, onion seed, potato, tomato, cabbage, mustard, lentil and soybean were used as first intercrop and mungbean was as second intercrop. The experiment was set up in randomized complete block design with three replications. The unit plot size was 8m 8m. The treatments were as follows:

T_1 - Single row cane (SRC) only
T_2 - Paired rows cane(PRC) only
T_3 - SRC + onion (bulb) - mungbean
T_4 - PRC + onion (bulb) - mungbean
T_5 - PRC + onion (seed) - mungbean
T_6 - PRC + potato - mungbean
T_7 - PRC + tomato - mungbean
T_8 - PRC + cabbage - mungbean
T_9 - PRC + mustard - mungbean
T_{10} - PRC + lentil - mungbean
T_{11} - PRC + soybean - mungbean

Forty five days old sugarcane settlings of variety Isd 38 were transplanted on 20 November 2008 in 2008-09 and 08 November 2009 in 2009-10 in 60 cm apart paired rows trenches maintaining 45 cm interplant spacing. The intercrops were grown within vacant wide space of 140 cm between two paired rows of cane. The seed rates of onion, mustard, potato, lentil, soybean and mungbean as intercrop were 400, 3, 750, 15, 15 and 10 kg ha^{-1}, respectively. For tomato and cabbage seedling to seedling distance was 50 cm and number of line 3 in paired rows system where 27,500 seedlings ha^{-1} for both the crops were transplanted. The first intercrops (onion bulb, onion seed, potato, tomato, cabbage, mustard, lentil and soybean) were sown on 12 November 2008 and 24 November 2009 for 2008-09 and 2009-10 seasons, respectively. The second intercrop BINA Mung 5 was planted on 15 March 2008 and 13 March 2010 in 2008-09 and 2009-10 cropping seasons respectively. All intercrops were grown as sole crop in one side of the main field.

For sugarcane and intercrops, fertilizers were applied following the recommended rates (BARC, 2005). N, P, K, S and Zn were applied in sugarcane @ 150, 50, 90, 34 and 3.5 kg ha^{-1}, respectively while N, P, K, S, Zn and B were applied @ 75, 30, 75, 30, 3 and 0.6 kg ha^{-1} for onion, @ 70, 15, 60, 10, 0.3 and 0.6 kg ha^{-1} for potato, @ 50,12,16,5, 0.6 and 0.6 kg ha^{-1} for tomato, @ 24, 22, 9, 7, 1.0 and 0.3 kg ha^{-1} for cabbage, @ 50, 11, 20, 10, 0.3 and 0.6 kg ha^{-1} for mustard, 10, 12, 8, 3, 0.6 and 0.3 kg ha^{-1} for lentil and @ 12, 15, 21, 6, 0.6 and 0.3 kg ha^{-1} for soybean. Only N, P and K were applied in mungbean @ 15, 18 and 14 kg ha^{-1}, respectively. Sole crops received 100% of the recommended doses of fertilizers. while 60% of the recommended rate was applied in intercrops. N, P, K, S, Zn and B were applied in the form of urea, triple super phosphate (TSP), muriate of potash (PoM), gypsum, zinc sulphate ($ZnSO_4$) and boric acid, respectively. Pest management and necessary intercultural operations like weeding, mulching, gap filling, irrigation, earthing up, tying etc were done according to the recommendation. Data on number of tiller, millable cane, plant height (of cane), diameter of cane, number of internodes $stalk^{-1}$, unit stalk weight, cane dry matter m^{-2}, and cane yield (t ha^{-1}), were recorded. The plant height, weight of 1000 grains, grain yield, straw yield and days to maturity were recorded for onion bulb, onion (seed), potato, tomato, cabbage,mustard, lentil, soybean and mungbean. Brix (%), pol (%) cane, purity (%), recoverable sucrose (%) and sugar yield (t ha^{-1}) were also recorded.

Organic matter content, pH, total nitrogen, available phosphorus, exchangeable potassium, available sulphur and available zinc content of initial and post-harvest soil were measured. Cane equivalent yield of intercrops and the adjusted cane yield were also calculated. Total production cost, gross income, net return, benefit cost ratio and land equivalent ratio were calculated for economic analysis. The economics and statistical analyses on different treatments for sugarcane and intercrops were done using statistical package programme MSTATC.

RESULTS AND DISCUSSION

Growth parameters of sugarcane

Cane height, diameter and number of internodes cane^{-1} did not differ significantly by some selected crops - mungbean sequential intercropping under paired rows system in 2008-09 and 2009-10 cropping seasons. The total cane biomass yield significantly differed due to these treatment combinations in both the seasons. The highest biomass yield of sugarcane (3023 g m^{-2}) was found from T_7 (PRC + tomato - BINA Mung 5) and the lowest cane biomass yield of sugarcane (2350g m^{-2}) from recorded with T_1 (Paired row cane only) treatments in 2009-10 season. In 2010-11, the highest cane biomass yield (3231g m^{-2}) was found from T_{11} (PRC + soyben - BINA Mung 5) and the lowest (2400 g m^{-2}) was observed from T_1 (Paired row cane only) treatment (Table1).

Table 1. Effect of some selected Rabi crops - mungbean sequential intercropping in paired rows transplanted sugarcane on growth parameters of sugarcane in 2009-10 and 2010-11.

Treatments	Cane height (m)		Cane diameter (cm)		No. of internodes cane^{-1}		Dry matter yield (g m^{-2})	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	2.00	2.71	2.02	2.04	20	26	2350 d	2400 f
T_2	2.26	2.80	2.14	2.08	22	27	2435 bcd	2870 d
T_3	2.17	2.77	2.12	2.10	22	26	2407 cd	2460 e
T_4	2.27	2.78	2.14	2.08	24	27	2430 bcd	2860 d
T_5	2.29	2.71	2.19	2.06	22	26	2990 a	2438 ef
T_6	2.30	2.90	2.19	2.13	24	29	2995 a	3170 b
T_7	2.47	2.88	2.29	2.11	26	28	3023 a	3050 c
T_8	2.27	2.79	2.16	2.09	22	27	2488 bc	2888 d
T_9	2.10	2.72	2.08	2.05	21	26	2378 d	2430 ef
T_{10}	2.27	2.84	2.18	2.12	23	28	2516 b	3078c
T_{11}	2.39	2.91	2.19	2.17	25	29	2999 a	3231 a
CV (%)	13.95	2.17	1.76	1.46	9.08	9.18	2.08	1.02
LSD (0.05)	NS	NS	NS	NS	NS	NS	**	**

In a column, figures with similar letters do not differ significantly at 5% level

Yield and yield attributes of sugarcane

Number of millable cane and cane yield were not significantly different among the different intercrops of some selected crops - mungbean sequential intercropping with paired rows transplanted sugarcane but number of tiller population and unit cane weight were significantly different among the different treatment combinations. The highest number of tillers of 215.00 10^{-3} ha^{-1} and 235.00 x 10^{-3} ha^{-1} were found from T_{11} (PRC + soybean - BINA Mung 5) in both the year. Significantly the highest unit cane weight of 0.99 kg was found from T_3 (SRC + onion - BINA Mung 5) and T_9 (PRC + mustard - BINA Mung 5) treatments in 2009-2010 season and 0.97 kg from T_7 (PRC + tomato - BINA Mung 5) and T_{11} (PRC + soyben - BINA Mung 5) treatments in 2010-11 season. The highest cane yield of 88.85 t ha^{-1} and 98.66 t ha^{-1} were obtained from T_{11} treatment in both the years (Table 2).

Table 2. Effect of different sequential intercropping on yield and yield attributes of sugarcane in 2009-10 and 2010-11.

Treatments	No. of tiller (10^3 ha^{-1})		No. of millable cane (10^3 ha^{-1})		Unit cane weight (kg)		Cane yield (t ha^{-1})	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	198 bcd	200 cd	86	92	0.94 ab	0.89 c	81.01	82.16
T_2	205 abc	210 abcd	90	96	0.94 ab	0.92 abc	84.16	88.54
T_3	203 abc	205 bcd	84	94	0.99 a	0.90 bc	83.08	84.70
T_4	206 abc	220 abcd	93	96	0.90 b	0.92 abc	84.16	88.37
T_5	214 a	230 ab	94	95	0.85 c	0.88 c	80.15	83.39
T_6	207 abc	212 abcd	89	101	0.90 b	0.95 ab	80.31	96.41
T_7	210 ab	208 bcd	94	95	0.87 c	0.97 a	81.66	92.45
T_8	204 abc	215 abcd	90	98	0.91 b	0.91 bc	82.29	89.20
T_9	187 d	195 d	83	88	0.99 a	0.95 ab	82.20	83.87
T_{10}	212 a	225 abc	93	100	0.88 c	0.93 abc	82.18	93.12
T_{11}	215 a	235 a	95	102	0.96 ab	0.97 a	90.91	98.66
CV (%)	3.81	7.16	7.99	7.65	5.41	3.28	7.55	8.27
LSD (0.05)	**	**	NS	NS	**	**	NS	NS

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Growth attributes of intercrops

Plant height, biomass yield, straw yield, 1000 - grain weight and crop duration of first intercrops differed significantly among the different treatment combinations. The highest plant height of 85.59 cm and 86.24 cm were found from the treatment T_5 (PRC + onion (seed) - BINA Mung 5) while the lowest plant height of 25.12 cm and 27.23 were recorded from T_8 (PRC + cabbage - BINA Mung 5) treatment in both the years. The highest biomass yield of 2.01 t ha^{-1} and 2.06 t ha^{-1} were observed with the treatment T_{10} (PRC + lentil - BINA Mung 5) while the lowest biomass yield of 0.70 t ha^{-1} and 0.68 t ha^{-1} were observed with the treatment T_3 (SRC + onion - BINA Mung 5) treatments in both the years. The highest straw yield of 2.51 t ha^{-1} and 2.58 t ha^{-1} were observed with the treatment T_{10} (PRC + lentil - BINA Mung 5) while the lowest biomass yield of 0.87 t ha^{-1} and 0.85 t ha^{-1} were observed with the treatment T_3 (SRC + onion - BINA Mung 5) treatment in both the years. The highest 1000-grain weight of 80.12 g and 84.46 were observed with T_{11} (PRC + soyben - BINA Mung 5) treatment while the lowest 1000-grain weight of 1.61 g and 1.65 g was found with T_9 (PRC + mustard - BINA Mung 5) treatment in both the years. The crop duration was lowest of 80 days and 86 days with the treatment T_9 (PRC + mustard - BINA Mung 5) while the highest duration of 140 days and 144 days were found with T_5 (PRC + onion (seed) - BINA Mung 5) treatment in both the years (Table 3).

Table 3. Effect of some selected Rabi crops - mungbean sequential intercropping on growth attributes of first intercrops in 2009-10 and 2010-11.

Treatments	Plant height (cm)		Biomass yield (t ha^{-1})		Straw yield (t ha^{-1})		1000-grain wt. (g)		Crop duration (days)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	-	-	-	-	-	-	-	-	-	-
T_2	-	-	-	-	-	-	-	-	-	-
T_3	51.00 c	49.50 g	0.70	0.68	0.87 f	0.85 g	-	-	98 e	100 e
T_4	51.08 d	50.98 f	0.78	0.77	0.98 e	0.96 f	-	-	100 d	105 d
T_5	85.59 a	86.24 a	0.91	0.95	1.14 d	1.19 e	3.26 c	3.29 c	140 a	144 a
T_6	49.67 d	57.67 d	0.96	1.00	1.20 d	1.25 d	-	-	95 f	102 de
T_7	48.76 e	51.99 e	1.23	1.26	1.54 c	1.58 c	-	-	101 d	105 d
T_8	25.12 h	27.23 i	-	-	-	-	-	-	98 e	100 e
T_9	76.49 b	78.51 b	0.90	0.92	1.12 d	1.15 e	1.61 d	1.65 d	80 g	86 f
T_{10}	32.64 g	33.58 h	2.01	2.06	2.51 a	2.58 a	17.88 b	18.13 b	110 c	112 c
T_{11}	35.99 f	67.82 c	1.38	1.34	1.72 b	1.68 b	80.12 a	84.46 a	125 b	128 b
CV (%)	0.58	0.64	8.14	3.42	5.40	2.45	3.31	3.21	2.03	2.45
LSD (0.05)	**	**	**	**	**	**	**	**	**	**

In a column, figures with similar letters do not differ significantly at 5% level

Biomass yield of second intercrops was not affected significantly by the selected crops - mungbean sequential intercropping with paired rows transplanted sugarcane system but crop duration was not affected significantly. The crop duration was 80 days in 2009-10 and 79 days in 2010-11 from sowing to harvesting.

Intercrop yield and adjusted cane yield

The overall yield performance of the first intercrops (onion, potato, tomato, cabbage, onion seed, mustard, lentil and soybean) and second intercrop of mungbean under paired rows system was found satisfactory. Adjusted cane yield is an important parameter for determining the total yield potentials of the intercropped plot (cane + intercrop) over the sole cane plot. In the present experiment significantly the highest adjusted cane yield of 263.07 t ha^{-1} and 218.83 t ha^{-1} were obtained with T_5 treatment (PRC + onion seed - BINA Mung 5) in both the years while the lowest yield of 81.01 t ha^{-1} and 82.16 t ha^{-1} were found with T_1 treatment (single row cane) in 2009-10 and 2010-11 seasons (Table 4).

Table 4. Effect of some selected Rabi crops - mungbean sequential intercropping on intercrops, cane equivalent yield of intercrops and total adjusted cane in 2009-10 and 2010-11

Treatments	Intercrop yield (t ha^{-1})				Cane equivalent yield of intercrop (t ha^{-1})		Total adjusted cane yield (t ha^{-1})	
	First intercrop		Second intercrop					
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	-	-	-	-	81.01	82.16	81.01 h	82.16 h
T_2	-	-	-	-	84.16	88.54	84.16 h	88.54 h
T_3	6.36	5.21	0.44	0.43	66.70	46.13	149.78 e	130.83 e
T_4	10.62	7.15	0.66	0.68	109.26	65.39	193.42 b	153.76 d
T_5	0.25	0.24	-	-	172.92	135.44	263.07 a	218.83 a
T_6	9.79	12.06	0.65	0.68	74.09	54.82	164.40 c	151.23 d
T_7	26.0	24.01	0.61	0.62	91.31	103.28	182.97 b	195.73 b
T_8	68.7	57.71	0.63	0.64	135.09	121.69	221.38 b	210.89 b
T_9	0.79	0.68	0.67	0.69	36.99	28.56	119.09 f	112.43 f
T_{10}	0.86	0.79	0.63	0.68	47.22	37.69	134.40 e	130.81 e
T_{11}	0.89	0.81	-	-	23.09	17.64	114.00 f	116.30 f
CV (%)	-	-	-	-	-	-	4.41	4.38
LSD (0.05)	-	-	**	**	-	-	**	**

In a column, figures with similar letters do not differ significantly at 5% level

Price of crops (2009-10) Sugarcane : 2160 Tk.t^{-1}, Onion : 15 Tk.kg^{-1}, Potato: 10 Tk.kg^{-1}, Tomato: 5 Tk.$kg.^{-1}$, Cabbage: 3 Tk.kg^{-1}, Onion (seed): 1,200 Tk.kg^{-1}, Mustard: 40 Tk.kg^{-1}, Letil: 60 Tk.kg^{-1} Soybean: 40 Tk.kg^{-1} Mungbean : 50 Tk.kg^{-1} and Mungbean (GM) : 600 Tk.t^{-1}

Price of crops (2010-11) Sugarcane : 2500 Tk.t^{-1}, Onion: 15 Tk.kg^{-1}, Potato: 7Tk.kg^{-1}, Tomato: 8 Tk.$kg.^{-1}$, Cabbage: 4 Tk.kg^{-1}, Onion (seed): 1,200 Tk.kg^{-1}, Mustard: 40 Tk.kg^{-1}, Letil: 60Tk.kg^{-1}. Soybean: 40 Tk.kg^{-1}. Mungbean : 50 Tk.kg^{-1} and Mungbean (GM) : 600 Tk.t^{-1}

Cane juice quality and sugar yield

Sugarcane juice quality parameters like brix (%), pol (%) cane, purity (%), recoverable sucrose (%) and sugar yield (t ha^{-1}) did not differ significantly by different selected crops - mungbean sequential intercropping combination in 2009-10 and 2010-11 (Table 5). The brix (%) ranged from 19.10 to 20.43 and 19.23 to 20.97 in 2008-09 and 2009-10 seasons. In case of pol (%) cane ranged from 13.44 to 14.44 and 13.47 to 14.95 in 2008-09 and 2009-10 seasons. The purity (%) ranged from 88.10 to 92.36 and 89.21 to 91.42 in 2008-09 and 2009-10 seasons. The recoverable sucrose (%) ranged from 10.94 to 11.94 and 10.97 to 12.45 in 2008-09 and 2009-10 seasons. Sugar yield (t ha^{-1}) ranged from 8.92 to 9.96 and 8.78 to 11.60 in 2008-09 and 2009-10 seasons.

Table 5. Effect of some selected Rabi crops - mungbean sequential intercrops on cane juice quality and sugar yield (t ha^{-1}) in 2009-10 and 2010-11.

Treatments	Brix (%)		Pol (%) cane		Purity (%)		Recoverable sucrose (%)		Sugar yield (t ha^{-1})	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	19.23	19.23	13.73	13.47	91.54	89.72	11.23	10.97	8.99	8.78
T_2	19.73	20.00	13.83	14.04	89.87	89.88	11.33	11.54	9.53	9.66
T_3	19.60	19.87	13.47	13.92	88.10	89.81	10.97	11.42	9.11	9.61
T_4	20.17	20.40	14.33	14.26	91.13	89.54	11.83	11.76	9.96	10.39
T_5	20.43	20.53	14.57	14.34	91.38	89.49	12.07	11.84	9.67	10.23
T_6	19.53	19.77	14.16	13.98	92.36	90.65	11.66	11.48	9.34	11.03
T_7	19.90	20.87	14.02	14.66	90.33	90.05	11.52	12.16	9.41	10.24
T_8	19.97	20.00	14.17	14.07	90.99	90.15	11.67	11.57	9.61	10.38
T_9	20.27	20.13	14.38	14.01	90.98	89.21	11.88	11.51	8.92	9.17
T_{10}	19.10	20.97	13.44	14.95	90.13	91.42	10.94	12.45	8.97	11.60
T_{11}	20.33	20.33	14.44	14.18	91.03	89.37	11.94	11.68	10.84	10.20
CV (%)	3.03	4.60	3.07	5.83	1.51	1.64	4.50	7.08	8.21	12.37
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

In a column, figures with similar letters do not differ significantly at 5% level

Economic analyses

Cost of cultivation

The cost of cultivation was estimated for different sequential intercropping treatment. It was found that the maximum cost of cultivation in T_4 (PRC + onion (bulb) - BINA Mung 5) and T_5 (PRC + onion (seed) - BINA Mung 5) treatments were 1,45,000 Tk.ha^{-1} in 2009-10 and 2010-11, seasons respectively. The sole cane required 80,000 Tk.ha^{-1} both the years (Table 6). T_6 required 1,25,000 Tk.ha^{-1}; T_7 required 1,30,000 Tk.ha^{-1}; T_8 required 1,40,000 Tk.ha^{-1}; T_9 required 1,10,000 Tk.ha^{-1}; T_{10} required 1,06,000 Tk.ha^{-1} and T_{11} required 1,11,000 Tk.ha^{-1} in 2009-10 and 2010-11, seasons respectively.

Table 6. Effect of some selected Rabi crops - mungbean sequential intercropping on cost of production, benefit cost ratio (BCR) and land equivalent ratio (LER) in 2009-10 and 2010-11.

Treatments	Total production cos (Tk. ha^{-1})		Gross income (Tk. ha^{-1})		Net return (Tk. ha^{-1})		BCR		LER	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	80000	80000	142578	177466	62577	97465	1.78	2.22	1.00	1.00
T_2	80000	80000	148122	191246	68121	111246	1.85	2.39	1.00	1.00
T_3	125000	125000	263621	282602	138620	157602	2.11	2.26	1.94	2.10
T_4	145000	145000	340422	332129	195421	187129	2.35	2.29	2.50	2.23
T_5	145000	145000	463008	472682	318008	327682	3.19	3.26	2.06	2.03
T_6	125000	125000	289346	326666	164345	201665	2.31	2.61	2.30	2.17
T_7	130000	130000	322022	422772	192021	292772	2.48	3.25	2.39	2.10
T_8	140000	140000	389620	455512	249620	315512	2.78	3.25	2.29	2.16
T_9	110000	110000	209596	242859	99596	132859	1.91	2.21	2.13	2.09
T_{10}	106000	106000	236537	282539	130536	176539	2.23	2.67	2.16	2.13
T_{11}	111000	111000	200642	251206	89641	140205	1.81	2.26	2.20	2.00

Price of crops (2009-10) Sugarcane : 2160 Tk.t^{-1}, Onion : 15 Tk.kg^{-1}, Potato: 10 Tk.kg^{-1}, Tomato: 5 Tk.kg.$^{-1}$, Cabbage: 3 Tk.kg^{-1}, Onion (seed): 1,200 Tk.kg^{-1},

Mustard: 40 Tk.kg^{-1}, Letil: 60 Tk.kg^{-1}. Soybean: 40 Tk.kg^{-1}. Mungbean : 50 Tk.kg^{-1} and Mungbean (GM) : 600 Tk.t^{-1}

Price of crops (2010-2011) Sugarcane : 2500 Tk.t^{-1}, Onion : 15 Tk.kg^{-1}, Potato:7Tk.kg^{-1}, Tomato: 8 Tk.kg.$^{-1}$, Cabbage: 4 Tk.kg^{-1}, Onion (seed): 1,200 Tk.kg^{-1} , Mustard: 40 Tk.kg^{-1}, Letil: 60 Tk.kg^{-1}. Soybean: 40 Tk.kg^{-1},. Mungbean : 50 Tk.kg^{-1} and Mungbean (GM) : 600 Tk.t^{-1}

Gross income and net return

The highest gross income of Tk. 4,63,008 ha^{-1} and Tk. 4,72,682 ha^{-1} were obtained from T_8 (PRC + cabbage - BINA Mung 5) treatment in 2009-10 and 2010-11. The lowest gross income of Tk. 1,42,578 ha^{-1} and Tk. 1,77,466 ha^{-1} was obtained from T_1 (sole cane only) plot in 2008-09 and 2009-10. The highest net return of Tk. 3,18008.00 and Tk. 3,27,682.40 were obtained with T_8 (PRC + cabbage - BINA Mung 5) in 2008-09 and 2009-10 seasons, respectively. The lowest net return of Tk. 62,577.60 and Tk. 97,465.60 were found with T_1 (sole cane only) in 2008-09 and 2009-10 seasons (Table 6).

Benefit cost ratio (BCR) and land equivalent ratio (LER)

The benefit cost ratio (BCR) was maximum in T_8 (PRC + cabbage - BINA Mung 5) treatment which were 3.19 in 2008-09 and of 3.26 in 2009-10. The next highest BCR was found with 2.78 and 3.25 with T_6 (PRC + potato - BINA Mung 5) treatment in both the years. The minimum benefit cost ration were 1.78 in 2008-09 and 2.22 in 2009-10 under the treatment T_1 (sole cane only). Data on the LER value of different sugarcane + intercrop combination showed that the treatment T_7 (PRC + tomato - BINA Mung 5) had the highest LER of 2.50 in 2008-09 and 2.23 in 2009-10 while the lowest LER of 1.94 was in 2008-09 and 2.00 was in 2009-10 with T_3 (SRC + onion - BINA Mung 5) and T_{11} (PRC + soyben - BINA Mung 5), respectively (Table 6).

Soil characteristics

Effect of some selected crops - mungbean sequential intercropping in paired rows transplanted sugarcane on post harvest soil p^H, organic matter (%), total N content (%), exchangeable K (cmol kg^{-1}) and available Zn (mg kg^{-1}) were not significant while that on available P (mg kg^{-1}) and available S (mg kg^{-1}) were significant in both the years. Available P was the highest with T_7 (28.40 mg kg^{-1}) in 2009-10 and in T_4 (28.20 mg kg^{-1}) in 2010-11 while the lowest was in treatment T_2 (18.50 mg kg^{-1}) in 2009-10 and in T_1 (22.50 mg kg^{-1}) in 2010-11. Available S was the highest with treatment T_5 (24.70 mg kg^{-1}) in 2009-10 and in T_3 (22.50 mg kg^{-1}) and in 2010-11 while the lowest was in treatment T_1 (14.30 and 12.26 mg kg^{-1}) in both the years (Table 7 and 8). Before experimentation the p^H value, organic matter content, total

nitrogen, available status of calcium, magnesium, potassium, phosphorus, sulphur, boron, iron and zinc in the soil were 7.62, 1%, 0.05%, 11.51cmol kg^{-1}, 0.83 cmol kg^{-1}, 0.15 cmol kg^{-1},12.0 mg kg^{-1}, 20 mg kg^{-1}, 0.20 mg kg^{-1}, 3.40 mg kg^{-1} and 0.56 mg kg^{-1} soil, respectively.

Table 7. Effect of some selected Rabi crops - mungbean sequential intercropping on harvest soil soil p^H, organic matter (%), total N content (%) and available P (mg kg^{-1}) content in 2009-10 and 2010-11.

Treatments	p^H		Organic matter (%)		Total N content (%)		Available P (mg kg^{-1})	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Post harvest soil								
T_1	7.6	7.6	1.00	0.98	0.04	0.05	18.90	22.50
T_2	7.5	7.7	1.02	1.02	0.05	0.05	18.50	23.10
T_3	7.6	7.7	1.01	1.02	0.05	0.05	27.00	24.00
T_4	7.6	7.6	1.01	1.01	0.05	0.06	28.10	28.20
T_5	7.5	7.6	1.04	1.01	0.05	0.05	20.10	26.10
T_6	7.6	7.6	1.02	1.03	0.05	0.05	21.00	24.00
T_7	7.6	7.6	1.03	1.03	0.05	0.05	28.40	23.30
T_8	7.5	7.6	1.01	1.03	0.05	0.05	22.20	24.10
T_9	7.6	7.6	1.03	1.01	0.06	0.05	22.50	25.30
T_{10}	7.6	7.7	1.01	1.01	0.06	0.06	25.20	24.10
T_{11}	7.6	7.7	1.05	1.04	0.05	0.05	19.40	24.40
CV (%)	1.89	2.06	6.21	20.01	26.30	23.95	2.00	3.53
LSD (0.05)	NS	NS	NS	NS	NS	NS	**	**

In a column, figures with similar letters do not differ significantly at 5% level

Table 8. Effect of some selected Rabi crops - mungbean sequential intercropping on harvest soil exchangeable K (cmol kg^{-1}), available S (mg kg^{-1}) and available Zn (mg kg^{-1}) content in 2009-10 and 2010-11.

Treatments	Exchangeable K (cmol kg^{-1})		Available S (mg kg^{-1})		Available Zn (mg kg^{-1})	
	2009-10	2010-2011	2009-10	2010-2011	2009-10	2010-2011
Post harvest soil						
T_1	0.17	0.16	14.30	12.26	0.50	0.55
T_2	0.16	0.14	16.10	18.10	0.51	0.56
T_3	0.14	0.13	19.50	22.50	0.54	0.60
T_4	0.12	0.15	23.20	20.16	0.55	0.62
T_5	0.14	0.15	24.70	21.17	0.54	0.63
T_6	0.15	0.14	20.30	21.15	0.61	0.67
T_7	0.13	0.15	23.00	20.10	0.54	0.60
T_8	0.11	0.14	22.80	22.18	0.55	0.60
T_9	0.17	0.16	23.00	20.19	0.60	0.60
T_{10}	0.16	0.15	23.30	20.10	0.60	0.61
T_{11}	0.15	0.16	21.40	21.75	0.60	0.60
CV (%)	9.64	17.70	2.19	0.74	6.47	5.68
LSD (0.05)	NS	NS	**	**	NS	NS

In a column, figures with similar letters do not differ significantly at 5% level


Single Row Cane (SRC), sole plot


Paired Rows Cane (PRC), sole plot


SRC + Onion - MB


PRC + Onion - MB


PRC + Potato - MB


PRC + Tomato - MB


PRC + Cabbege - MB


PRC + Onion seed – MB


PRC + Mustard - MB


PRC + Lentil - MB


PRC + Soybean - MB


PRC + 1st Intercrop - MB

Fig 1: Rabi-Mungbean Sequential Intercropping in Paired Rows Transplanted Sugarcane

CONCLUSION

The mungbean based sequential intercropping systems in paired rows sugarcane gave higher economic benefit compared to sole sugarcane. The selection of first intercrops could be in the order of onion seed crop > cabbage > tomato > potato > lentil > onion (bulb) > mustard > soybean.

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