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Productivity of Mustard-Mung Bean Sequential Intercropping in Paired Row Sugarcane

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted at Bangladesh Sugarcane Research Institute (BSRI) farm, Ishurdi for consecutive two years starting from 2008-2009 to 2009-2010 to find out the suitable mustard variety for mustard-mungbean sequential intercropping with paired row transplanted sugarcane. Tori 7, BARI Sarisha 9, BARI Sarisha 11, BARI Sarisha 15, BINA Sarisha 3 and BINA Sarisha 4 were used as mustard varieties. In this trial, PRC + onion - mungbean treatment combination was used as standard check. Results revealed that sequential intercropping practices did not affect sugarcane yield and juice quality. All the sequential intercropping treatments showed higher BCR than the sole cane crop. Among the treatment combinations, PRC + BARI Sarisha 9 - Mungbean performed better in respect of yield and yield contributing characters of sugarcane, yield of mungbean, net return, BCR and LER. Therefore, mustard (BARI Sarisha 9) - mungbean sequential intercropping with paired row transplanted sugarcane could be considered as a profitable combination for sustainable sugarcane farming with maintaining soil health.

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Keywords: Productivity; sugarcane; Paired Row Cane (PRC); intercropping; mustard.

1. INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the major food-cum-industrial cash crops in Bangladesh. It is cultivated in more than 90 countries of the tropical and sub-tropical regions of the world producing about 1685.44 million metric tons sugarcane from an area of 23.82 million hectares [1]. In Bangladesh, about 4.5 million metric tons of sugarcane is produced annually from 0.12 million hectares of land [2]. The yield of sugarcane in Bangladesh is around 44 t ha^{-1} against world average of 70.76 t ha^{-1}. This low yield of sugarcane in Bangladesh is mainly due cultivation of the crop in the marginal land with poor management practices under rainfed condition. There are 30 Agro-ecological zones (AEZs) in Bangladesh but sugarcane production is mainly confined to 12 AEZs in the north-west and south-west regions of the country especially in the greater districts of Jessore, Kushtia, Pabna, Rajshahi, Bogra, Rangpur, Dinajpur and Faridpur and in some pockets of greater districts of Mymensingh, Dhaka, Noakhali, Sylhet, Comilla, Chittagong, Khulna and Barisal. Therefore, adoption of improved technology would help to increase the yield level of sugarcane to a greater extent as the yield of the crop under research level is about 100-150 t ha^{-1}.

Sugarcane is being replaced by many short duration and high value profitable fruit and vegetable crops like papaya, banana, tomato, carrot, cabbage and cauliflower. Sugarcane cultivation could again be made highly profitable if intercropping could be practiced using suitable crops following modern techniques. Conventionally, sugarcane setts are planted in the trench at 90-100 cm distances where establishment of expected plant population is rarely achieved. Settling transplanting system has been developed to ensure optimum plant stand establishment which increases the yield of sugarcane. In addition, paired row planting system has been developed which helps growing two or more intercropping with sugarcane without impairing the yield of sugarcane. The growth of cane at the early stage is very slow and thus inter row spaces is not covered by sugarcane leaf canopy for the first 120-150 days. Many short duration crops *viz.* vegetables, pulses, oil seeds and spices can be grown as intercrop with sugarcane. The intercropping with single row sugarcane is less remunerative than the paired row system. In paired row system, two rows of cane are planted at 60 cm spacing (paired rows) in the trench leaving 120-140 cm vacant space between two paired rows where more than one crop can easily be grown sequentially as intercrop with more profit [3] Under paired row system, potato, onion, garlic and cabbage are profitable as first intercrops [4] and some short duration crops such as leafy vegetables, mungbean and dhaincha are suitable as second intercrop [5]. Thus, sequential intercropping is feasible with paired row sugarcane but not with single row cane [6].

Sugarcane is a long duration (12-14 months) and highly exhaustive crop. The fertility status of Bangladesh soil is decreasing day by day due to intensive cultivation with little use of organic manure [7]. Conventional method of sugarcane cultivation causes degradation of soil fertility [8] while intercropping legumes with sugarcane could be an option to maintain soil fertility. [9] found that summer mung could be grown as second intercrop after harvesting mustard/soybean and the plant biomass could be incorporated in between the cane rows for improving soil fertility. Intercropping also improves nutritional quality of diet for the farm family [10], allows better control of weeds, increases land equivalent ratio [11] and has some beneficial effects on pest and disease control [12].

Farmers usually grow intercrops with sugarcane under single row system. A number of vegetable crops are proved to be profitable as intercrop with sugarcane but farmers are interested to grow mustard because of low initial investment. Mustard ranks the first covering about 40-50% of the total intercropped area of sugarcane in Bangladesh. [13-15], reported that mustard intercropping gave the net return of Tk. 12,000 to 20,000 next to potato intercropping with net return of Tk. 26,000 to 35,000. Intercropping provides insurance against crop failure and/or better avenue of employment for the rural people [16]. [17] stated that mustard intercropping with sugarcane could be an alternative choice if investment is limited. [18] found that out of 17 places intercropping of mustard was found profitable at 13 places and net profit ranged from 2 to 66 percent. On the contrary, a reduction of 1.0 to 23% net profit was noticed by [19].

Growing mustard as intercrop exerts significant adverse effect on the emergence, tillering,

millable cane and yield of cane in the single row system [19-21,17,22]. A minimum reduction of 2-3% in cane yield has been reported by [20] while the maximum reduction of 64.40% was observed by [23]. The reduction might be due to the profused branching habit of mustard and greater competition for moisture and nutrients with cane at young stage. The degree of adverse effect of mustard on sugarcane has been shown to be less under paired row system of cane [24]. The decreases in millable cane and cane yield were 7.08 and 4.91% in single row system while it was only 0.94 and 0.73%, respectively under paired row system for mustard intercropping. The juice quality of cane was also reported to be badly affected by mustard intercropping. [17] obtained a considerable decrease in sucrose (%) and sugar yield (t ha^{-1}) under mustard intercropping under single row system compared to the sole cane.

Among the different varieties of mustard, tori 7, a local variety showed minimum adverse effect on cane yield in single row system [25]. The recently developed paired row system could allow growing a number of modern mustard varieties as intercrop without significant adverse effect on sugarcane. The effect of mustard on sugarcane growth, yield and quality has been extensively studied under single row system but the reports in this regard for paired row system is highly scarce. The present study was, therefore, undertaken to find out the suitable mustard variety for successful mustard-mungbean sequential intercropping under Paired row transplanted sugarcane.

2. MATERIALS AND METHODS

2.1 Site and Soil

The experiment was conducted at the Bangladesh Sugarcane Research Institute (BSRI) farm, Ishurdi, Pabna during 2008-2009 and 2009-2010 cropping seasons. The site represents High Ganges River Floodplain under Agro-Ecological Zone 11 with medium high land of typical sandy loam soil.

2.2 Experimental Treatment and Design

Tori 7, BARI Sarisha 9, BARI Sarisha 11, BARI Sarisha 15, BINA Sarisha 3 and BINA Sarisha 4 were used as mustard (*Brassica* spp.) varieties. The experiment was set up in a randomized complete block design with three replications. The unit plot size was 8 m × 8 m. The treatments are as follows:

T_1 - Sole paired row cane (PRC)
T_2 - PRC + onion - BINA Mung 5 (Control, farmers' practice)
T_3 - PRC + tori 7- BINA Mung 5
T_4 - PRC + BARI Sarisha 9 - BINA Mung 5
T_5 - PRC + BARI Sarisha 11- BINA Mung 5
T_6 - PRC + BARI Sarisha 15 - BINA Mung 5
T_7 - PRC + BINA Sarisha 3 - BINA Mung 5
T_8 - PRC + BINA Sarisha 4 - BINA Mung 5

2.3 Crop Management

Forty five days old sugarcane settlings were transplanted at 45 cm inter-plant spaces on well prepared trenches in paired row on 20 November 2008 and 08 November 2009 in 2008-09 and 2009-10, respectively. The trenches were made by paired row trenchers at 140 cm distance. The intercrops were planted in the space between two trenches. Onion bulb was planted in 6 rows (20 cm apart) with 15 cm space. Mustard, rapeseed and mungbean seeds were sown in 3 rows (30 cm apart) continuously. The first intercrops (onion, tori 7, BARI Sarisha 9, BARI Sarisha 11, BARI Sarisha 15, BINA Sarisha 3 and BINA Sarisha 4) were sown on 22 November 2008 and 10 November 2009 in 2008-09 and 2009-10, respectively. The second intercrop (mungbean variety BINA Mung 5) was planted on 16 March 2008 and 14 March 2010 in 2008-09 and 2009-10, respectively. Sole crop of all first intercrops and second intercrop were grown in one side of the field with three replications. The seed rates of onion were 400 kg and 750 kg ha^{-1} for intercrop and sole crop, respectively. The seed rates of mustard and rapeseed were 3.0 kg and 5.0 kg ha^{-1} for intercrop and sole crop, respectively. The seed rate of mung bean was 10 kg ha^{-1} for intercrop and 15 kg ha^{-1} for sole crop.

Fertilizer was applied following the recommended rates for each crop [8]. 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 and @ 50, 11, 20, 10, 0.3 and 0.6 kg ha^{-1} for mustard. Only N, P and K were applied in mung bean @ 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 (MoP), gypsum, zinc sulphate and boric acid, respectively. For sugarcane,

whole amount of TSP, gypsum, zinc sulphate and one-third of MoP were applied in trenches and mixed with soil prior to transplanting of settlings. Urea was applied in three equal splits as side dressing at 21, 90 and 150 days after transplanting (DAT). The rest MoP were applied in two equal splits at 90 and 150 DAT. In case of onion, one- half of urea and MoP and whole dose of TSP, gypsum, $ZnSO_4$ and boric acid were applied at final land preparation. The rest of urea and MoP were applied in two equal splits at 25 and 50 DAT. For mustard and rapeseed intercrops, all fertilizers and one-half of urea were applied at the time of sowing. Remaining one-half of urea was applied at 20 days after sowing.

Irrigation (10 cm) was given to the furrow of the sugarcane field after two days of settling placement. Subsequent four irrigations were done following furrow irrigation method at 30, 60, 90 and 120 DAT when the soil moisture reached to 60% of field capacity. Furadan 5G was applied at 40 kg ha^{-1} in three splits (8, 16 and 16 kg ha^{-1}) at transplanting, 90 DAT and 150 DAT, respectively to control early shoot borer (ESB) and top shoot borer (TSB). Regent 3G was also applied in trenches at 33 kg ha^{-1} before cane transplanting to control termites. Mechanical control was also done as and when required. No disease infestation was found in the field. The crop field was infested with some weed species such as *Cyperus rotundus* L., *Cynodon dactylon* L. *Chenopodium album* L. *Nicotiana plumbaginfolia*, *Argemone mexicana* and *Hydrocotyle asiatica*. Among them, *Cyperus rotundus* L. and *Cynodon dactylon* L. were the most dominating weed species in both sugarcane and intercrop plots. Spading and hand weeding were done at 30 and 60 DAT, respectively to control the weeds. Earthing up was done manually three times at 120, 150 and 180 DAT. Tying was done two times in July and September to keep the cane clump straight to avoid lodging. The dried leaves were removed from the plants and the green leaves on plants were tied together by taking all the canes in one bundle. Cross tying was done by binding two clumps of adjacent rows together.

2.4 Harvesting

The first intercrops were harvested during 07 February to 01 March 2009 in 2008-2009 and during 10 February to 08 March 2010 in 2009-10 seasons at their maturity. In 2008-09, onion, BARI Sarisha 11, BINA Sarisha 3 and BINA Sarisha 4 were harvested on 01 March 2009 while tori 7, BARI Sarisha 9 and BARI Sarisha 15 were harvested on 07, 12 and 17 February 2009, respectively. In 2009-10, BARI Sarisha 11, BINA Sarisha 3 and BINA Sarisha 4 were harvested on 08 March 2010 while BARI Sarisha 9 and BARI Sarisha 15 were harvested on 17 February 2010. Tori 7 and onion were harvested on 17 February and 02 March 2010, respectively. Second intercrop (BINA Mung 5) was harvested on 29 May 2009 (75 days) and 01 June 2010 (80 days) in 2008-2009 and 2009-10 seasons, respectively. Sugarcane was harvested on 14 December 2009 in 2008-2009 (390 days after transplanting) and on 12 December 2010 in 2009-2010 (400 days after transplanting).

2.5 Data Recorded

Number of tillers, millable canes, plant height, diameter of cane, number of internodes $cane^{-1}$, unit stalk weight, cane dry matter m^{-2}, cane yield (t ha^{-1}), brix (%), pol (%) cane, purity (%), recoverable sucrose (%) and sugar yield (t ha^{-1}) were recorded for sugarcane. The plant height, weight of 1000 grains, grain yield, straw yield and days to maturity were recorded for mustard, rapeseed and mungbean. The plant height and bulb yield were recorded for onion. Organic matter content, pH, total nitrogen, available phosphorus, exchangeable potassium, available sulphur and available zinc content of post-harvest soil were estimated. Brix (%), pol (%), purity (%) and recoverable sucrose (%) in sugarcane juice were recorded at harvest. Brix (%) refers to the total soluble solids while pol (%) refers to percentage of sucrose content in cane juice. Purity (%) refers to ratio of sucrose content (pol %) to the total soluble solids (brix %) in juice. Five cane stalks were selected from each plot at random and was crushed with a mini power crusher for juice extraction. The collected juice was poured in to a glass cylinder and the brix (%) was determined by hand refractometer. The same juice was clarified with basic lead sub-acetate and after filtration it was poured in 200 mm polarimeter tube for determination of pol (%) of cane [26].

Recoverable sucrose was determined by using the following formula:

$$\text{Recoverable sucrose (\%)} = \{\text{Pol} - (\frac{\text{Brix-Pol}}{2})\} \times \text{Juice factor (J.F.)}$$

Where, juice factor was 0.73.

Sugar yield was determined by multiplying with the recoverable sucrose (%) content with cane yield ha^{-1}.

$$\text{Sugar yield (t ha}^{-1}\text{)} = \frac{\text{Cane yield (t ha-1)} \times \text{recoverable sucrose (\%)}}{100}$$

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 of different sequential intercropping with sugarcane.

Statistical analysis for data was done using MSTAT-C package program and means were adjudged by DMRT.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters of Sugarcane

Cane height, cane diameter and number of internode per stalk did not differ significantly due to different mustard varieties in mustard-mungbean sequential intercropping both in 2008-09 and 2009-10 cropping seasons while the total dry matter yield of sugarcane differed significantly in both the years. The highest dry matter yield of 2523 g m^{-2} was found with T_4 (PRC + BARI Sarisha 9 - BINA Mung 5) treatment and the lowest dry matter yield of 2360 g m^{-2} was observed with T_1 (Sole paired row cane) treatment in 2008-09 season. In 2009-10, the highest dry matter yield of 2617 g m^{-2} was found with T_2 (PRC + onion - BINA Mung 5) and the lowest 2123 g m^{-2} was recorded with T_1 treatment (Table 1).

3.2 Yield and Yield Attributes of Sugarcane

Tiller population, number of millable cane and cane yield were not significantly affected by different mustard varieties in mustard-mungbean sequential intercropping with paired row transplanted sugarcane in 2008-09 and 2009-10 but unit cane weight diffferd significantly. The highest unit cane weight of 1.12 kg was found in T_7 (PRC + BINA Sarisha 3 - BINA Mung 5) in 2008-2009 and that of 0.94 kg was obtained from T_5 (PRC + BARI Sarisha 11 - BINA Mung 5) in 2009-10 seasons. The lowest unit cane weight of 0.95 kg was obtained from T_3 (PRC + tori 7 - BINA Mung 5) in 2008-09 and those of 0.86 kg were obtained in T_3, T_7 and T_8 in 2009-10 seasons (Table 2).

3.3 Growth Attributes of Intercrops

Plant height, biomass yield, straw yield, 1000-grain weight and crop duration of first intercrops differed significantly among the different mustard-mungbean sequential intercrop treatment combinations. The highest plant height of 138 cm and 139 cm were found in T_5 (PRC + BARI Sarisha 11 - BINA Mung 5), respectively in 2008-09 and 2009-10. The lowest plant height of 50 cm and 46 cm were recorded in T_2 (tereatment in both the years. The highest biomass yield of 3.06 t ha^{-1} and 3.05 t ha^{-1} were observed with the treatment T_7 (PRC + BINA Sarisha 3 - BINA Mung 5) while the lowest biomass yield of 0.65 t ha^{-1} and 0.72 t ha^{-1} were produced by the first intercrop in T_2 in both the years. The highest straw yield of 3.83 t ha^{-1} and 3.95 t ha^{-1} were observed in the first intercrop in treatment T_7 while the lowest straw yield of 0.81 t ha^{-1} and 0.90 t ha^{-1} were produced in T_2 (PRC + onion - BINA Mung 5) in both the years (Table 3). The highest 1000-grain weight of 3.4 g and 3.5 g were recorded in treatment T_5 and the lowest 1000-grain weight of 1.50 g and 1.61 g were observed in T_3 (PRC + tori 7 - BINA Mung 5) in both the years. The duration of first crop was the lowest (78 days and 80 days) in T_3 in both the years. The highest durations of 100 and 119 days were found with T_5, T_7 and T_8 in 2008-09 and 2009-10, respectively. Biomass yield and crop duration of second intercrop (mung bean) was not significantly affected by mustard-mung bean sequential intercropping treatment in paired row transplanted sugarcane system both the year (Table 3). The crop duration of mung bean was 75 days in 2008-09 and 80 days in 2009-10.

3.4 Intercrop Yield and Adjusted Cane Yield

The yields of the first intercrops (onion and mustard) and the second intercrop (mung bean) under paired row system were found satisfactory. The onion bulb yields were 7.43 t ha^{-1} and 8.67 t ha^{-1}, respectively in 2008-09 and 2009-10 seasons. The yield of rapeseed and mustard ranged from 0.51 and 0.73 t ha^{-1} in 2008-09 and from 0.71 to 0.90 t ha^{-1} in 2009-10 seasons. In 2008-09, the highest yield of 0.73 t ha^{-1} was found with BARI Sarisha 11 and the next highest (0.64 t ha^{-1}) with BARI Sarisha 9. In 2009-10, the

highest yield was found with BARI Sarisha 11 (0.94 t ha^{-1}) and the next highest yield (0.90 t ha^{-1}) was found in BINA Sarisha 4 followed by BINA Sarisha 3 (0.81 t ha^{-1}). The yield of second intercrop (mung bean) ranged from 0.37 to 0.43 t ha^{-1} and 0.60 to 0.66 t ha^{-1} in 2008-09 and 2009-10 seasons, respectively. Statistically the differences were not significant in both the seasons.

Adjusted cane yield is an important parameter for determining the total yield potentials of the intercropped plot (cane + intercrop) over the sole cane plot. The adjusted cane yield was significantly influenced by different sequential intercropping treatment. The highest adjusted cane yields of 241.54 t ha^{-1} and 168.83 t ha^{-1} were obtained in T_2 treatment (PRC + onion - BINA Mung 5) both in 2008-09 and 2009-10 seasons while the lowest one of 96.67 t ha^{-1} and 80.46 t ha^{-1} were obtained in T_1 (Sole paired row cane) in 2008-09 and 2009-10 seasons (Table 4). Among the intercropping treatments, T_2 gave the highest adjusted cane yield because of the highest yield and market price of onion

Table 1. Effect of mustard-mung bean sequential intercropping in paired row transplanted sugarcane on growth parameters of sugarcane in 2008-09 and 2009-10

Treatments	Cane height (m)		Cane diameter (cm)		Internodes $cane^{-1}$ (no.)		Dry matter yield (g m^{-2})	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	2.90	2.45	2.10	2.10	27	20	2360 d	2123 g
T_2	2.80	2.54	2.15	2.25	24	23	2423 cd	2617 a
T_3	2.93	2.87	2.10	2.13	25	21	2427 c	2442 c
T_4	3.07	2.61	2.13	2.15	27	20	2523 a	2297 e
T_5	3.05	2.48	2.17	2.18	26	22	2433 bc	2225 f
T_6	3.00	2.47	2.25	2.12	24	21	2427 c	2338 d
T_7	3.17	2.50	2.30	2.11	27	21	2403 cd	2327 d
T_8	2.80	2.49	2.15	2.20	26	20	2393 d	2483 b
$S\bar{x}$	0.12	0.12	0.06	0.06	0.54	0.54	7.71	3.38
CV (%)	11.42	11.42	6.12	6.12	6.22	6.22	0.78	0.35
Level of significance	NS	NS	NS	NS	NS	NS	**	**

*In a column, figures with similar or without letters do not differ significantly and those with dissimilar letters differ significantly as per DMRT. ** = significant at 1% level, NS = not significant*

Table 2. Effect of mustard-mung bean sequential intercropping in paired row transplanted sugarcane on yield and yield attributes of sugarcane in 2008-09 and 2009-10

Treatments	No. of tillers (×10^3 ha^{-1})		No. of millable canes (×10^3 ha^{-1})		Unit cane weight (kg)		Cane yield (t ha^{-1})	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	238	200	98	91	0.99 d	0.88 b	96.67	80.46
T_2	246	220	97	106	0.99 d	0.88 b	95.94	93.18
T_3	245	218	96	100	0.95 f	0.86 c	91.20	85.86
T_4	243	216	103	107	1.02 c	0.89 b	105.40	95.46
T_5	232	203	96	95	0.97 e	0.94 a	93.65	88.94
T_6	239	206	96	98	1.04 b	0.89 b	99.84	86.75
T_7	244	208	90	98	1.12 a	0.86 c	100.20	84.75
T_8	234	209	99	96	1.02 c	0.86 c	96.82	82.50
$S\bar{x}$	9.00	5.04	2.09	3.91	0.01	0.01	3.29	3.25
CV (%)	9.17	5.86	5.31	9.81	1.28	0.13	8.26	9.19
Level of significance	NS	NS	NS	NS	**	**	NS	NS

*In a column, figures with similar or without letters do not differ significantly and those with dissimilar letters differ significantly as per DMRT. ** = significant at 1% level, NS = not significant*

Table 3. Effect of mustard-mungbean sequential intercropping in paired row transplanted sugarcane on growth attributes of first intercrop in 2008-09 and 2009-10

Treatments	Plant height (cm)		Biomass yield (t ha^{-1})		Straw yield (t ha^{-1})		1000-grain wt. (g)		Crop duration (days)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	-	-	-	-	-	-	-	-	-	-
T_2	50 g	46 g	0.65 f	0.72 g	0.81 d	0.90 d	-	-	96 a	100 b
T_3	75 f	81 f	1.86 e	2.00 e	2.33 c	2.50 c	1.50 e	1.61 f	78 d	80 c
T_4	85 e	88 e	2.14 d	2.30 d	2.67 b	2.85 b	1.60 d	1.67 e	83 c	86 c
T_5	138 a	139 a	1.86 e	1.97 f	2.33 c	2.40 c	3.40 a	3.50 a	100 a	119 a
T_6	107 b	110 b	2.67 b	2.70 b	3.34 a	3.60 a	2.00 c	2.20 d	88 b	86 c
T_7	99 d	102 d	3.06 a	3.05 a	3.83 a	3.95 a	3.10 b	3.40 b	100 a	119 a
T_8	105 c	109 c	2.53 c	2.83 c	3.16 a	3.56 a	3.10 b	3.30 c	100 a	119 a
$S\bar{x}$	0.43	0.28	0.05	0.01	0.01	0.05	0.01	0.01	1.07	1.74
CV (%)	1.28	0.95	1.25	0.43	0.59	4.96	0.40	0.54	3.13	5.02
Level of significance	**	**	**	**	**	**	**	**	**	**

*In a column, figures with similar or without letters do not differ significantly and those with dissimilar letters differ significantly as per DMRT. ** = significant at 1% level, NS = not significant*

3.5 Cane Juice Quality and Sugar Yield

Sugarcane juice quality parameters namely, brix (%), pol (%) cane, purity (%) and recoverable sucrose (%) and also sugar yield (t ha^{-1}) did not differ significantly in both 2008-09 and 2009-10 due to intercropping treatments (Table 5). The brix (%) ranged from 21.90 to 23.40 and 18.93 to 20.70 in 2008-09 and 2009-10 seasons, respectively. The pol (%) cane ranged from 15.33 to 16.60 and 13.18 to 14.75 in 2008-09 and 2009-10 seasons, respectively. The purity (%) ranged from 87.78 to 93.92 and 88.66 to 91.15 in 2008-09 and 2009-10 seasons, respectively. The recoverable sucrose (%) ranged from 12.83 to 14.10 and 10.68 to 12.25 in 2008-09 and 2009-10 seasons, respectively. Sugar yield (t ha^{-1}) ranged from 12.32 to 14.19 and 9.14 to 10.77 in 2008-09 and 2009-10 seasons, respectively.

3.6 Economic Analyses

The costs of cultivation for T_2 (PRC + onion - BINA Mung 5) were 1,62,000 Tk.ha^{-1} and 1,45,000 Tk.ha^{-1} in 2008-09 and 2009-10, respectively while the cost for sole cane cultivation was 80,000 Tk.ha^{-1} in both the years (Table 6). Other intercropping treatments incurred costs of 106000 Tk.ha^{-1} and 110000 Tk.ha^{-1}, respectively in 2008-09 and 2009-10 cropping seasons. The highest gross income of Tk. 4,25,114 ha^{-1} and Tk. 3,63,419 ha^{-1} were obtained from T_2 (PRC + onion - BINA Mung 5) treatment in 2008-09 and 2009-10, respectively. The lowest gross income of Tk. 1,44,320 and Tk. 1,74,096 ha^{-1} was obtained from T_1 (sole cane) plot in 2008-09 and 2009-10. The highest net return of Tk. 2,63,114.40 and Tk. 2,18,818.80 were obtained in T_2 (PRC + onion - BINA Mung 5) in 2008-09 and 2009-10 seasons, respectively. The lowest net return of Tk. 64,320 and Tk. 94,096 were found with T_1 (sole cane) in 2008-09 and 2009-10 cropping seasons, respectively (Table 6). The benefit cost ratio (BCR) was maximum in T_2 (PRC + onion - BINA Mung 5) treatment which were 2.62 in 2008-09 and were 2.51 in 2009-10. The next highest BCR of 2.18 and 2.41 found in T_4 (PRC + BARI Sarisha 9 - BINA Mung 5) treatment in 2008-09 and 2009-10, respectively. The lowest benefit cost ratio of 1.8 in 2008-09 and 2.18 in 2009-10 were found in treatment T_1 (sole cane). Among different intercrop combinations the highest LER was noted in treatment T_2 (PRC + onion - BINA Mung 5) which were 2.24 in 2008-09 and 2.42 in 2009-10. The lowest LER of 2.00 was found in 2008-09 and 2.16 was found in 2009-10 in T_5 (PRC + BARI Sarisha 11 - BINA Mung 5) and T_6 (PRC + BARI Sarisha 15 - BINA Mung 5), respectively (Table 6). LER greater than one indicates the profitability of intercropping over sole cropping. Thus all intercropping treatments were found more profitable than sole cropping of sugarcane.

Table 4. Effect of mustard-mung bean sequential intercropping on intercrops, cane equivalent yield of intercrops and total adjusted cane yield in 2008-09 and 2009-10

Treatments	Intercrop yield (t ha^{-1})				Cane equivalent yield of intercrop (t ha^{-1})		Adjusted cane yield (t ha^{-1})	
	First intercrop		Second intercrop					
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	-	-	-	-	-	-	96.67 d	80.46 c
T_2	7.43	8.67	0.37	0.65	145.60	75.25	241.54 a	168.83 a
T_3	0.59	0.71	0.42	0.66	25.34	28.43	116.54 c	114.29 b
T_4	0.64	0.73	0.41	0.60	26.19	27.41	131.59 b	122.87 b
T_5	0.73	0.94	0.42	0.62	28.52	31.76	122.17 bc	120.70 b
T_6	0.59	0.71	0.39	0.61	24.49	27.27	124.33 bc	114.02 b
T_7	0.56	0.72	0.43	0.62	24.94	29.35	125.14 bc	114.10 b
T_8	0.51	0.90	0.41	0.60	23.24	30.56	120.06 bc	113.06 b
$S\bar{x}$	-	-	8.48	8.22	-	-	3.29	3.63
CV (%)	-	-	0.02	0.04	-	-	5.97	3.49
Level of significance	-	-	NS	NS	-	-	**	**

*In a column, figures with similar or without letters do not differ significantly and those with dissimilar letters differ significantly as per DMRT. ** = significant at 1% level, NS = not significant*

Table 5. Effect of mustard-mung bean sequential intercropping on juice quality and sugar yield (t ha^{-1}) in 2008-09 and 2009-10

Treatments	Brix (%)		Pol (%) cane		Purity (%)		Recoverable sucrose (%)		Sugar yield (t ha^{-1})	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	22.10	20.70	15.96	14.75	92.61	90.73	13.46	12.25	12.99	9.85
T_2	22.00	19.13	15.79	13.40	92.00	89.10	13.29	10.90	12.74	10.16
T_3	22.30	18.93	16.04	13.18	92.24	88.66	13.54	10.68	12.32	9.14
T_4	22.40	19.77	15.33	13.95	87.78	89.92	12.83	11.45	12.85	10.20
T_5	23.40	20.27	16.60	14.51	90.95	91.15	14.10	12.01	13.18	10.77
T_6	22.50	18.97	15.52	13.26	88.28	88.98	13.02	10.76	13.00	9.43
T_7	22.50	19.80	15.98	14.13	91.02	90.87	13.48	11.63	14.19	9.86
T_8	21.90	20.57	16.05	14.58	93.92	90.18	13.55	12.08	13.08	9.93
$S_{\bar{x}}$	0.22	0.48	0.23	0.44	0.87	0.90	0.23	0.44	0.51	0.57
CV (%)	2.41	5.93	3.48	7.70	2.35	2.45	4.13	9.38	9.56	13.91
Level of significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = not significant

Table 6. Effect of mustard-mung bean sequential intercropping on cost of production, benefit cost ratio (BCR) and land equivalent ratio (LER) in 2008-09 and 2009-10

Treatments	Total production cost (Tk. ha^{-1})		Gross income (Tk. ha^{-1})		Net return (Tk. ha^{-1})		BCR		LER	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	80000	80000	144320	174096	64320	94096	1.80	2.18	1.00	1.00
T_2	162000	145000	425114	363819	263114	218818	2.62	2.51	2.24	2.42
T_3	106000	110000	205112	246858	99112	136857	1.94	2.24	2.11	2.31
T_4	106000	110000	231604	265394	125604	155393	2.18	2.41	2.22	2.21
T_5	106000	110000	215024	260710	109024	150710	2.03	2.37	2.00	2.35
T_6	106000	110000	218818	246280	112818	136280	2.06	2.24	2.20	2.16
T_7	106000	110000	220252	246460	114252	136460	2.08	2.24	2.13	2.25
T_8	106000	110000	211303	244200	105303	134200	1.99	2.22	2.01	2.30

Price of crops (2008-09) sugarcane : 1760 Tk.t^{-1}, Onion : 32 Tk.kg^{-1}, mustard : 40 Tk.kg^{-1}, mung bean : 50 Tk.kg^{-1}
Price of crops (2009-10) sugarcane : 2160 Tk.t^{-1}, Onion : 15 Tk.kg^{-1}, mustard : 40 Tk.kg^{-1}, mung bean : 50 Tk.kg^{-1}

3.7 Soil Characteristics

Effects of mustard-mung bean sequential intercropping in paired row transplanted sugarcane on post harvest soil pH, organic matter (%), exchangeable K (cmol kg^{-1}) and available S (mg kg^{-1}) were not significant while that on total N content (%), available P (mg kg^{-1}) and available Zn (mg kg^{-1}) were found significant in both the years. Total N content was the highest in T_8 (0.08 and 0.06 %) in both the years. The available P was highest with T_7 (35.6 mg kg^{-1}) and T_6 (28.7 mg kg^{-1}) in 2008-09 and 2009-10, respectively. In both the years, the highest available Zn was found with T_8 (0.74 and 0.71 mg kg^{-1}, respectively). The lowest values of all these soil related parameters were found in T_1 (Sole paired row cane) in both the years (Tables 7 and 8).

Table 7. Effect of mustard-mung bean sequential intercropping on post harvest soil pH, organic matter (%), total N content (%) and available P (mg kg^{-1}) in 2008-09 and 2009-10

Treatments	pH		Organic matter (%)		Total N content (%)		Available P (mg kg^{-1})	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
				Post harvest soil				
T_1	7.5	7.6	1.00	0.99	0.03 d	0.03 c	14.0 g	12.0 g
T_2	7.7	7.8	1.02	1.01	0.05 c	0.05 ab	17.0 f	17.5 d
T_3	7.6	7.6	1.04	1.00	0.06 bc	0.04 bc	25.4 e	19.6 c
T_4	7.5	7.5	1.06	1.02	0.07 ab	0.04 bc	29.7 c	23.8 b
T_5	7.6	7.7	1.03	1.00	0.06 bc	0.05 ab	32.8 b	17.4 d
T_6	7.6	7.6	1.02	1.05	0.06 bc	0.04 bc	15.6 f	28.7 a
T_7	7.6	7.6	1.07	1.06	0.05 c	0.05 ab	35.6 a	13.6 f
T_8	7.6	7.7	1.01	1.04	0.08 a	0.06 a	28.1 d	15.2 e
$S\bar{x}$	0.02	0.01	0.01	0.01	0.01	0.01	0.04	0.07
CV (%)	0.66	0.24	1.70	2.69	2.42	2.16	0.29	0.63
Level of significance	NS	NS	NS	NS	**	**	**	**

*In a column, figures with similar or without letters do not differ significantly and those with dissimilar letters differ significantly as per DMRT. ** = significant at 1% level, NS = not significant*

Table 8. Effect of mustard-mungbean sequential intercropping on post harvest soil exchangeable K (cmol kg^{-1}), available S (mg kg^{-1}) and available Zn (mg kg^{-1}) in 2008-09 and 2009-10

Treatments	Exchangeable K (cmol kg^{-1})		Available S (mg kg^{-1})		Available Zn (mg kg^{-1})	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
			Post harvest soil			
T_1	0.18	0.17	15.94	18.80	0.40 c	0.45 d
T_2	0.20	0.19	19.65	20.30	0.56 b	0.61 b
T_3	0.22	0.18	20.12	21.30	0.65 ab	0.54 c
T_4	0.22	0.21	21.22	20.80	0.73 a	0.63 b
T_5	0.21	0.20	22.65	19.80	0.60 b	0.65 b
T_6	0.21	0.20	21.80	20.50	0.59 b	0.53 c
T_7	0.19	0.21	20.98	23.00	0.57 b	0.62 b
T_8	0.20	0.21	20.18	21.30	0.74 a	0.71 a
$S\bar{x}$	0.01	0.01	0.01	0.02	0.03	0.01
CV (%)	0.99	1.47	0.20	0.30	11.02	4.71
Level of significance	NS	NS	NS	NS	**	**

*In a column, figures with similar or without letters do not differ significantly and those with dissimilar letters differ significantly as per DMRT. ** = significant at 1% level, NS = not significant*

4. CONCLUSION

Intercropping of mustard with sugarcane does not have any negative effect on growth, yield and juice quality of sugarcane rather it is economically profitable than sole cane. Among the mustard varieties BARI Sarisha 9 appeared as the best for intercropping with sugarcane for high economic return. This variety has short field duration and therefore, permits growing mungbean earlier. Thus, mustard variety BARI Sarisha 9 could be selected for mustard-mungbean sequential intercropping in paired row sugarcane for sustaining sugarcane production and maintaining soil fertility.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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