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ABSTRACT

Sugarcane is a long duration and highly exhaustive crop because of its huge nutrient uptake from soil. The fertility status of Bangladesh Soil is decreasing day by day due to intensive cultivation of high yielding crop varieties, little use of organic material and improper soil and crop management practices. (BARC, 2005) Farmers have tendency to use higher dose of fertilizer to get high yield. Intercropping with legume maybe an option of sugarcane production which will maintain soil fertility. An experiment was conducted at the Bangladesh Sugarcrop Research Institute (BSRI) farm, Ishurdi for consecutive two years starting from 2008-2009 to 2009-2010 to find out the effects of row spacing and fertilizer on performance of mungbean (BINA Mung 5) as second intercrop where onion, mustard and lentil was used as first intercrop in paired rows transplanted sugarcane. Isd 38 variety was used for this experiment. The experiment was laid out in RCBD with replications. Thirteen treatments were employed for the study. Results revealed that sequential intercropping practices did not affect sugarcane growth, yield and juice quality. All the sequential intercropping treatments obtained higher benefit cost ratio (BCR) than the sole cane. Mungbean (BINA Mung 5) seed should be planted in 3 rows with 50% of recommended fertilizer dose in different sequential intercropping systems in paired rows transplanted sugarcane. Mungbean based sequential intercropping with paired rows transplanted sugarcane could be considered an option for sustaining sugarcane production and maintaining soil fertility.

Key words : Productivity, Sugarcane, Paired rows, Intercropping, Mungbean

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). The major sugar producing countries of the world are Brazil, India, China, Thailand, Pakistan, Mexico,

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Colombia, Australia, Argentina and Philippines (FAO, 2011). Sugarcane occupies an area of 23.82 million hectares with a total production of 1685.44 million metric tons (FAO, 2012). In Bangladesh, on an average 4.5 million metric tons of sugarcane is produced annually from 0.12 million hectares of land (FAOSTAT, 2012).

Sugarcane cultivation fetches less benefit compared with other short duration fruit and vegetable crops like papaya, banana, tomato, carrot, cabbage and cauliflower. Because of this, sugarcane is being replaced by different profitable short duration crops. 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 recently been developed that unveils the potential of practicing intercropping with sugarcane with high profit. In paired rows system of sugarcane planting, two rows of cane are planted at 60 cm apart rows in a trench leaving 120-140 cm vacant space between two paired rows of cane (Alam *et al.,* 2008). 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. Many reports suggest that mungbean can be used as second intercrop (Hossain *et al*, 1995).

Among all the intercrops, potato, onion, mustard, lentil, cabbage, cauliflower, carrot etc are grown 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).

The yield of onion as intercrop could be increased under paired rows system of cane plantation by accommodating higher intercrop population compared to the single row system. It has been reported that the yield of onion under paired rows systems is 4.4 t ha^{-1} while it was 2.25 t ha^{-1} under single row system (Miah *et al.,* 1994). Compared to other crops, onion exerted least detrimental effect on the emergence, tiller, millable cane and yield of sugarcane (Hossain, 1984).

Due to shallow rooting depth, onion extract nutrient from an area on the ridges where the sugarcane shoot roots are not reached at that stage. This minimizes competition for nutrients and water. Moreover, a lower rate of pest incidence has been reported in intercropped cane with onion (Verma *et al.,*1981). It shows some beneficial effects on pest and diseases (Abdullah *et al.,*2006)

Mixed cultivation of lentil/sugarcane has long been practiced in the sub-continent. Systematic trials of lentil along with other pulses and legume have been stated over a decade back. Intercropping of leguminous crops has been found to increase or decrease or have no effect on yield of cane (Hossain, 1984).

Khan *et al.* (1985) have successfully grown summer mung with 13 t ha^{-1} fresh biomass weight after harvesting potato and incorporated the biomass of mungbean into the soil to improve soil fertility and productivity.

Hossain *et al.* (1995) also grew summer mung as second intercrop after harvesting mustard/soybean as first intercrop and harvested 0.2 t ha^{-1} of mungbean grain and the plant biomass was incorporated in between the cane rows for improving soil fertility. Growing of mungbean as second intercrop fixes atmospheric nitrogen and enriches soil organic matter contributing to improvement of soil fertility and productivity for sustainable sugarcane production.

A number of studies had been conducted on intercropping lentil with single row sugarcane planting system, a very little number of studies had been made on the lentil intercropping in paired rows system. Under paired rows system of sugarcane, the highest sugarcane yield (96 t ha^{-1}) was obtained when intercropped with lentil followed by kheshari, pea and soybean. The highest net return of Tk. 9,400 ha^{-1} was obtained from lentil intercropping while the lowest of Tk. 100 ha^{-1} only was from kheshari in paired rows system. It is further observed that the level of intercrop yield (lentil) was increased in paired rows system compared to the single row system (Hossain *et al.,* 1995). 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 the effects of row spacing and fertilizer on performance of mungbean as second intercrop where as onion, mustard and lentil as first intercrop in paired rows transplanted sugarcane.

MATERIALS AND METHODS

The experiment was conducted at the Bangladesh Sugarcane Research Institute (BSRI) farm, Ishurdi, pabna during the year of 2008-2009 and 2009-2010 cropping season. The site represents High Ganges River Floodplain under Agro-Ecological Zone 11 with medium high land of typical sandy loam soil. Onion (*Allium cepa* L.), mustard (*Brassica* spp.) and lentil (*Lens culinaris* L.) were used as first intercrop and mungbean (*Vigna radiata* L.) 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 are as follows:

T_1 : Paired rows cane (PRC) only
T_2 : PRC + onion - MB (S_1F_1)
T_3 : PRC + onion - MB (S_1F_2)
T_4 : PRC + onion - MB (S_2F_1)
T_5 : PRC + onion - MB (S_2F_2)
T_6 : PRC + mustard - MB (S_1F_1)
T_7 : PRC + mustard - MB (S_1F_2)
T_8 : PRC + mustard - MB (S_2F_1)
T_9 : PRC + mustard - MB (S_2F_2)
T_{10} : PRC + lentil - MB (S_1F_1)
T_{11} : PRC + lentil - MB (S_1F_2)
T_{12} : PRC + lentil - MB (S_2F_2)
T_{13} : PRC + lentil - MB (S_2F_2)

S_1 : 2 rows of mungbean; S_2 : 3 rows of mungbean;

F_1 : Recommended Fertilizer Dose (RFD); F_2 : 50 % of RFD

Sowing/Planting

Forty five days old sugarcane settlings were transplanted on 26 November 2008 in 2008-09 and 23 November 2009 in 2009-10 on well prepared tranches at 60 cm apart paired rows maintaining 45 cm interplant spacing. The intercrops were grown within vacant wide space of 140 cm between two paired rows of cane. The spacing and seed rate of onion, mustard and lentil were similar to that of experiment 1. The first intercrops (onion, mustard and lentil,) were sown on 26 November 2008 and 23 November 2009 for 2008-09 and 2009-10 seasons respectively. The second intercrop BINA Mung 5 was planted on 22 March 2008 and 15 March 2010 in 2008-09 and 2009-10 cropping seasons, respectively. The tranches were made by paired rows trenchers at 140 cm distance. Before trenching, the land was prepared thoroughly by disc ploughing and harrowing followed by leveling. Sole crop of all first intercrops were grown in one side of the field and the second intercrop was also grown by sowing then at the same day of their sowing in the main field.

Fertilizer application

For sugarcane and other 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 and @ 50, 11, 20, 10, 0.3 and 0.6 kg ha^{-1} for mustard and @ 10, 12, 8, 3, 0.6 and 0.3 kg ha^{-1} for lentil. 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. For sugarcane, whole amount of TSP, gypsum, zinc sulphate and one third of MoP were placed 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, respectively. 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 lentil intercrops, all fertilizers were applied at the time of sowing. For mustard intercrop, all fertilizers and one - half urea were applied at the time of sowing. After harvesting of first intercrops (onion, mustard and lentil), mungbean variety BINA Mung 5 was sown as second intercrop. Three lines of mungbean were sown at 30 cm apart rows between two paired rows of cane.

Pest management

Furadan 5G was applied at the rate of 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). In addition to this, Regent 3G was applied in trenches at the rate 33 kg ha^{-1} before cane transplanting to control termites. Apart from chemical control, mechanical control was also done as and when required. No disease infestation was found in the field. The crop field was infested by 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.

Irrigation and other management practices

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% depletion of field capacity. Earthing up was done manually three times at 120, 150 and 180 DAT. This operation converted the furrows into ridges and ridges into furrows. 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.

Data record

Number of tiller, number of millable cane, plant height (of cane), diameter of cane, number of internodes cane^{-1}, unit stalk weight, cane dry matter m^{-2}, and cane yield (t ha^{-1}), were recorded. The plant height, weight of 1000 grain, grain yield, straw yield and days to maturity were recorded for onion, mustard, lentil and mungbean. The plant height and bulb yield were recorded for onion. Brix (%), Pol (%) cane, Purity (%), Recoverable sucrose (%) and Sugar yield (t ha^{-1}) were also recorded. pH, organic matter content, total nitrogen, available phosphorus, exchangeable potassium, available sulphur and available zinc content of 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 detailed procedure of data recording for sugarcane and intercrops are described below:

Sugarcane

Total number of tillers (shoot of cane) and millable cane (economic shoot or stalks) of sugarcane of each unit plot were recorded at 150 days after transplanting (DAT) and at harvest. For recording cane biomass, three hills were randomly selected unit^{-1} plot and were cut at ground level at 240 DAT. The sample plants were separated into leaves and stalks. The samples were dried in oven at 70^{0} C (until attaining a constant weight) and the weight was expressed in g m^{-2}. The plant height was recorded from randomly selected five canes by measuring the length from ground level to collar band of cane. The individual stalk weight was obtained by dividing the total weight of cane stalk of a plot with the number of millable cane stalks the plot. The stalk girth was measured with slide calipers by taking reading on diameter of top, middle and bottom and from average of these readings. The total number of internodes of five cane stalks were counted and the average number of internodes cane^{-1} was recorded.

Intercrops

Plant height was measured with meter scale for the base of the plant to the tip of the tallest leaf of the plant. Total plants of each plot were harvested and the biomass was recorded. The biomass yield was expressed as t ha^{-1}. Yield of first and second intercrops (onion, mustard, lentil and mungbean) were measured by the top loading balance on whole plot basis. Then the yield was expressed in t ha^{-1}. The total period from days after emergence (DAE) to maturity of the crop was counted and expressed in days. Straw was sun dried and weighed. Then a sub-sample of 200 g was oven dried for each crop. The straw yield was expressed in t ha^{-1}. For grain crops, one thousand seeds were counted from seed lot of each plot (for grain crop) and weighed to obtain 1000 grain weight.

Harvesting

The first intercrops were harvested during 17 February to 12 March 2009 in 2008-2009 and 22 February to 09 March 2010 in 2009-10 cropping seasons when they reached their maturity. In 2008-09, mustard (tori 7) was harvested on 17 February 2009 while onion and lentil were harvested on 05 and 12 March 2009, respectively. In 2009-10, mustard (tori 7) was harvested on 22 February 2010 while onion and lentil were harvested on 03 and 09 March 2010, respectively. Second intercrop BINA Mung 5 was harvested on 02 June 2009 and 14 June 2010 in 2008-2009 and 2009-10 cropping season, respectively. Sugarcane was harvested on 22 December 2009 in 2008-2009 (392 days after transplanting) and on 21 December 2010 in 2009-2010 (394 days after transplanting).

PRC + Onion-MB

PRC + Musterd-MB

: PRC + Lentil-MB

PRC +Lentil-MB (2 rows)

PRC + Lentil-MB (3 rows)

Fig 1: Field View of Sequential intercropping with Sugarcane

Chemical analysis of cane juice

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 brix hydrometer. 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 (Anon., 1970). Recoverable sucrose was determined by using the following formula:

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

Where, juice factor was 0.73.

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

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

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, cane diameter and number of internode $cane^{-1}$ did not differ significantly by different row spacing and fertilizer dose on mungbean productivity in onion, mustard, lentil - mungbean sequential intercropping under paired rows system of planting 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 (2931 g m^{-2}) was observed with T_{13} {PRC + lentil - MB (S_2F_2)} and the lowest cane biomass yield of 2055 g m^{-2} was found with T_1 (Paired rows cane only) treatments in 2008-09 season. In 2009-10, the highest cane biomass yield (3140 g m^{-2}) was found with T_{12} {PRC + lentil - MB (S_2F_1)} and the lowest (2140 g m^{-2}) was recorded with T_1 (Paired rows cane only) treatment (Table 1).

Table 1. Effects of first intercrop, row spacing and fertilizer dose on growth parameters of sugarcane in mungbean sequential intercropping with paired rows system in 2008-09 and 2009-10

Treatments	Cane height (m)		Cane diameter (cm)		No. of internodes cane^{-1}		Dry matter yield (g m^{-2})	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	2.43	2.17	1.90	2.09	23	21	2055 i	2140 i
T_2	2.58	2.80	2.08	2.18	23	25	2580 e	2815 d
T_3	5.53	2.80	1.98	2.20	23	24	2630 d	2715 e
T_4	2.80	2.67	2.12	2.19	24	25	2650 d	2775 d
T_5	2.37	2.63	1.93	2.12	23	26	2610 de	2690 e
T_6	2.32	2.33	1.97	2.11	22	23	2210 g	2210 h
T_7	2.33	2.20	1.88	2.22	22	22	2115 h	2450 g
T_8	2.67	2.40	1.92	2.20	22	24	2110 h	2152 i
T_9	2.47	2.50	1.82	2.10	21	23	2278 f	2525 f
T_{10}	2.37	2.90	2.03	2.20	24	23	2840 bc	3050 b
T_{11}	2.37	2.93	2.08	2.31	24	25	2810 c	2962 c
T_{12}	2.53	3.13	2.12	2.18	25	28	2871 b	3140 a
T_{13}	2.60	2.98	2.07	2.24	25	26	2931 a	3022 b
CV (%)	6.16	6.83	4.19	4.13	8.52	6.45	1.10	0.96
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

Tiller population, number of millable cane and cane yield were not significantly affected by different row spacing and fertilizer dose in mungbean in onion/mustard/lentil - mungbean sequential intercropping with paired rows transplanted sugarcane in 2008-09 and 2009-10 but unit cane weight diffferd significantly. The highest unit cane weight of 0.99 kg was found with T_6 {PRC + mustard - MB (S_1F_1)} and 0.84 kg was obtained from T_{12} {PRC + lentil - MB (S_2F_1)} in 2008-2009 and 2000-10 seasons, respectively. The lowest unit cane weight of 0.80 kg was obtained from T_{10} {PRC + lentil - MB (S_1F_1)} and T_{11} {PRC + lentil - MB (S_1F_2)} in 2008-09 and 0.69 kg with T_3 {PRC + onion - MB (S_1F_2)} in 2009-10 season (Table 2). The highest cane yield of 88.85 t ha^{-1} in T_{13} in 2008-09 and 89.23 t ha^{-1} was obtained from T_{12} treatment in 2009-10 season, respectively due to intercropping leguminous crop with sugarcane (Hossain *et al.*,1995).

Table 2. Effects of first intercrop, row spacing and fertilizer dose in mungbean in a sequential intercropping on yield and yield attributes of sugarcane in 2008-09 and 2009-10

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})	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	195	203	87	100	0.93 ab	0.81 ab	80.55	81.33
T_2	220	226	89	112	0.92 bc	0.78 abc	81.48	87.60
T_3	231	223	93	121	0.87 cd	0.69 c	80.65	83.87
T_4	238	244	95	116	0.86 d	0.73 bc	81.25	85.13
T_5	225	234	90	115	0.90 bcd	0.72 bc	81.40	82.60
T_6	210	209	83	106	0.99 a	0.77 abc	81.79	82.00
T_7	200	219	90	101	0.91 bc	0.82 ab	81.48	82.73
T_8	197	204	89	107	0.91 bc	0.77 abc	81.27	82.53
T_9	198	209	89	103	0.92 bc	0.80 ab	81.50	82.00
T_{10}	250	226	105	117	0.80 e	0.79 abc	84.25	92.60
T_{11}	245	228	104	118	0.80 e	0.76 abc	83.00	89.60
T_{12}	240	241	98	114	0.88 bcd	0.84 a	86.50	95.93
T_{13}	238	245	97	120	0.92 bc	0.76 abc	88.85	91.40
CV (%)	4.51	3.71	8.63	6.66	4.08	8.25	7.24	5.30
LSD (0.05)	NS	NS	NS	NS	**	**	NS	NS

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

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 90.00 cm was found with the treatment T_8 {PRC + mustard - MB (S_2F_1)} in 2008-09 season and 87.00 cm was found with the treatment T_9 {PRC + mustard - MB (S_2F_2)} in 2009-10 season. The lowest plant height of 34.00 cm was recorded with T_{12} {PRC + lentil - MB (S_2F_1)} tereatment in 2008-09 season and 33.00 cm was was found with the treatment T_{10} {PRC + lentil - MB (S_1F_1)} in 2009-10 season. The highest biomass yield of 2.12 t ha^{-1} and 2.15 t ha^{-1} were observed with the treatment T_{12} {PRC + lentil - MB (S_2F_1)} in both the years. The lowest biomass yield of 0.68 t ha^{-1} was produced by T_2 {PRC + onion - MB (S_1F_1)} in 2008-09 and 0.75 t ha^{-1} were observed with the treatment T_2 {PRC + onion - MB (S_1F_1)} and T_4 {PRC + onion - MB (S_2F_1)} treatments in 2009-10 seaon. The highest straw yield of 2.59 t ha^{-1} and 2.69 t ha^{-1} were observed with the treatment T_{12} {PRC + lentil - MB (S_2F_1)} in both the years. The lowest biomass yield of 0.83 t ha^{-1} was produced by T_2 {PRC + onion - MB (S_1F_1)} in 2008-09 and 0.94 t ha^{-1} were observed with the treatment T_2 {PRC + onion - MB (S_1F_1)} and T_4 {PRC + onion - MB (S_2F_1)} treatments in 2009-10 seaon. The highest 1000-grain weight of 17.60 g was recorded in treatment T_{12} {PRC + lentil - MB (S_2F_1)}

in 2008-09 season and 18.15 g was observed in treatment T_{13} {PRC + lentil - MB (S_2F_2)} in 2009-10 season. The lowest 1000-grain weight of 1.52 g was observed in T_6 {PRC + mustard - MB (S_1F_1)} treatment and 1.55 g was found with T_8 {PRC + mustard - MB (S_2F_1)} treatment in 2009-10 seson. The crop duration was lowest of 80 days and 78 days with treatment T_6 {PRC + mustard - MB (S_1F_1)} to T_9 {PRC + mustard - MB (S_2F_2)} and the highest duration of 114 days and 107 days were found with T_{10} {PRC + lentil - MB (S_1F_1)} to T_{13} {PRC + lentil - MB (S_2F_2)} treatment in both the years (Singh, 1983) (Table 3).

Table 3. Effects of first intercrop, row spacing and fertilizer dose in mungbean in a sequential intercropping on growth attributes of first intercrops 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	50.00 cd	41.00 e	0.68 f	0.75 c	0.83 d	0.94 e	-	-	101 b	99 b
T_3	52.00 c	40.00 ef	0.71 f	0.77 c	0.85 d	0.96 e	-	-	101 b	99 b
T_4	47.00 de	45.00 d	0.72 f	0.75 c	0.89 d	0.94 e	-	-	101 b	99 b
T_5	45.00 e	38.00 fg	0.77 e	0.78 c	0.86 d	0.97 e	-	-	101 b	99 b
T_6	87.00 ab	75.00 c	1.90 d	2.05 b	2.33 c	2.54 cd	1.52 b	1.60 c	80 c	78 c
T_7	85.00 b	80.00 b	1.91 d	2.06 b	2.38 bc	2.57 bcd	1.55 b	1.57 c	80 c	78 c
T_8	90.00 a	82.00 b	1.93 d	2.02 b	2.34 c	2.52 d	1.58 b	1.55 c	80 c	78 c
T_9	88.00 ab	87.00 a	1.89 d	2.11 a	2.36 c	2.59 abcd	1.60 b	1.58 c	80 c	78 c
T_{10}	37.00 fg	33.00 h	2.05 c	2.14 a	2.55 a	2.67 ab	17.50 a	18.00 a	114 a	107 a
T_{11}	38.00f	37.00 g	2.10 ab	2.12 a	2.53 a	2.64 abc	17.55 a	17.52 a	114 a	107 a
T_{12}	34.00 g	39.00dfg	2.12 a	2.15 a	2.59 a	2.69 a	17.60 a	17.57 a	114 a	107 a
T_{13}	37.00 fg	34.00 h	2.06 bc	2.14	2.51 ab	2.66 ab	17.00 a	18.15 a	114 a	107 a
CV (%)	3.94	3.27	1.91	1.91	4.35	3.61	6.84	1.91	3.02	4.09
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 due to different first intercrop, row spacing and fertilizer dose in mungbean in onion/mustard/lentil - mungbean sequential intercropping with paired rows transplanted sugarcane system. The mungbean crop duration was not affected significantly (Table 4). The crop duration was 73 days in 2008-09 and 62 days in 2009-10 from sowing to harvesting.

Intercrop yield and adjusted cane yield

The yield of the first intercrops (onion, mustard and lentil) under paired rows system were found satisfactory. The yield of mungbean as second intercrop were significantly different among the different treatment combinations. The highest yield of 0.66 t ha^{-1} and 0.67 t ha^{-1} were obtained with T_{13} {PRC + lentil - MB (S_2F_2)}. The lowest yield of 0.45 t ha^{-1} was recorded in T_2 {PRC + onion - MB (S_1F_1)} and T_6 {PRC + mustard - MB (S_1F_1)} treatment in 2008-09 and that of 0.56 t ha^{-1} was recorded with T_2 {PRC + onion - MB (S_1F_1)} treatment in 2009-10 season. Adjusted cane yield was affected significantly by different row spacing and fertilizer combinations. Significantly highest adjusted cane yield of 217.59 t ha^{-1} was found with T_5 {PRC + onion - MB (S_2F_2)} treatment in 2008-09 season (Khan *at el,*. 1995) and that of 147.38 t ha^{-1} was obtained from T_4 {PRC + onion - MB (S_2F_1)} treatment in 2009-10 season while the lowest of 80.55 t ha^{-1} and 81.33 t ha^{-1} were found with T_1 treatment (sole cane only) in both the years (Table 5).

Table 4. Effects of first intercrop, row spacing and fertilizer dose in mungbean under 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	-	-	-	-	80.55	81.33	80.55 f	81.33 e
T_2	6.15	6.66	0.45 d	0.56 d	124.60	59.21	206.08 b	146.81 a
T_3	6.50	6.13	0.55 bc	0.60 abcd	133.81	56.46	214.46 a	140.33 ab
T_4	6.40	6.93	0.50 bcd	0.61 abcd	130.57	62.25	211.82 a	147.38 a
T_5	6.60	6.86	0.57 abc	0.66 ab	136.19	62.92	217.59 a	145.52 a
T_6	0.45	0.58	0.45 d	0.58 cd	23.01	24.17	104.80 e	106.17 d
T_7	0.41	0.54	0.48 cd	0.62 abcd	22.95	24.35	104.43 e	107.08 d
T_8	0.39	0.60	0.51 bcd	0.61 abcd	23.35	25.23	104.62 e	107.76 d
T_9	0.43	0.66	0.59 ab	0.65 abc	26.53	27.27	108.03 d	109.27 c
T_{10}	0.62	0.80	0.48 cd	0.59 bcd	34.77	35.88	119.02 d	128.48 c
T_{11}	0.65	0.87	0.53 bcd	0.63 abcd	37.22	38.75	120.22 d	128.35 c
T_{12}	0.61	0.89	0.57 abc	0.60 abcd	36.99	38.61	123.49 cd	134.54 bc
T_{13}	0.67	0.87	0.66 a	0.67 a	41.59	39.68	130.44 c	131.08 c
CV (%)	-	-	11.03	7.16	-	-	4.32	3.81
LSD (0.05)	-	-	**	**	-	-	**	**

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

Price of crops (2008-09) Sugarcane : 1760 Tk. t^{-1}, Onion : 32 Tk. kg^{-1}, Mustard: 40 Tk. kg^{-1}, Lentil : 60 Tk. kg^{-1} and Mungbean : 50 Tk. kg^{-1}

Price of crops (2009-10) Sugarcane : 2160 Tk. t^{-1}, Onion : 15 Tk. kg^{-1}, Mustard: 40 Tk. kg^{-1}, Lentil : 60 Tk. kg^{-1} and Mungbean : 50 Tk. kg^{-1}

Cane juice quality and sugar yield

Sugarcane juice quality parameters such as brix (%), pol (%) cane, purity (%), recoverable sucrose (%) and sugar yield (t ha^{-1}) did not differ significantly by different row spacing (Rathi and Singh, 1979) and fertilizer dose in mungbean in onion/mustard/lentil - mungbean sequential intercropping combination in 2008-09 and 2009-10 (Table 5). The brix (%) ranged from 22.83 to 24.57 and 16.60 to 19.77 in 2008-09 and 2009-10 seasons. In case of pol (%) cane ranged from 15.75 to 16.71 and 11.08 to 13.49 in 2008-09 and 2009-10 seasons. The purity (%). ranged from 85.22 to 89.28 and 83.50 to 88.82 in 2008-09 and 2009-10 seasons. The recoverable sucrose (%) ranged from 13.66 to 14.21 and 9.10 to 10.99 in 2008-09 and 2009-10 seasons. Sugar yield (t ha^{-1}) ranged from 8.75 to 12.29 and 7.23 to 9.69 in 2008-09 and 2009-10 seasons.

Table 5. Effects of first intercrop, row spacing and fertilizer dose in mungbean sequential intercropping on cane juice 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	23.93	20.27	16.71	13.49	88.96	88.82	14.21	10.99	8.75	7.40
T_2	24.13	18.87	16.16	12.71	85.38	85.33	13.66	10.21	10.45	8.96
T_3	23.43	16.60	16.16	11.08	87.84	84.40	13.66	8.58	11.01	7.23
T_4	23.83	18.07	16.58	11.91	89.28	83.50	14.08	9.41	11.45	8.00
T_5	22.83	17.67	15.75	12.20	87.36	87.03	13.25	9.10	10.51	7.99
T_6	23.90	18.97	16.31	13.05	87.05	86.96	13.81	10.55	9.69	7.41
T_7	24.23	18.93	16.47	13.10	86.61	87.51	13.97	10.60	9.69	7.68
T_8	24.23	19.10	16.54	13.19	87.03	87.37	14.04	10.69	9.73	7.40
T_9	23.73	18.97	16.32	13.25	87.60	88.45	13.82	10.75	9.76	7.97
T_{10}	23.63	18.37	16.19	12.60	87.28	86.79	13.69	10.10	11.53	8.67
T_{11}	23.50	19.77	16.28	13.29	88.28	88.59	13.78	10.79	11.44	9.65
T_{12}	24.57	18.30	16.42	12.62	85.22	87.11	13.92	10.12	12.03	9.69
T_{13}	23.47	17.63	16.27	12.00	88.34	86.29	13.77	9.50	12.29	8.66
CV (%)	3.65	7.15	1.86	8.36	2.38	3.13	2.19	10.42	7.81	12.75
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

It was found that the maximum cost of cultivaion from T_2 {PRC + onion - MB (S_1F_1)}, T_3 {PRC + onion - MB (S_1F_2)}, T_4 {PRC + onion - MB (S_2F_1)} and T_5 {PRC + onion - MB (S_2F_2)} treatment were 1,62,000 Tk.ha^{-1} and 1,45,000 Tk.ha^{-1} in 2008-09 and 2009-10, seasons respectively. The sole cane required 80,000 Tk.ha^{-1} in both the years (Table 6). T_6 to T_9 treatments required 1,06,000 Tk.ha^{-1} and T_{10} to T_{13} required 107000 Tk.ha^{-1} in 2008-09 and 2009-10 seasons while T_6-T_9 treatments required 110000 Tk.ha^{-1} and T_{10}-T_{13} treatments required 116000 Tk.ha^{-1} in 2008-09 and 2009-10 seasons respectively.

Gross income and net return

The highest gross income of Tk. 3,82,964 ha^{-1} was obtained with T_5 {PRC + onion - MB (S_2F_2)} in 2008-09 and Tk. 3,63,419 ha^{-1} with T_4 {PRC + onion - MB (S_2F_1)} in 2009-10. The lowest gross income of Tk. 1,41,768 ha^{-1} and Tk. 1,75,673 ha^{-1} was obtained from T_1 (sole cane only) plot in 2008-09 and 2009-10 respectively. The highest net return of Tk. 2,20,964.00 with T_5 {PRC + onion - MB (S_2F_2)} and Tk. 1,73,330.80 were obtained with T_4 {PRC + onion - MB (S_2F_1)} in 2008-09 and 2009-10 seasons, respectively. The lowest net return of Tk. 61,768.00 and Tk. 95,672.80 were found with T_1 (sole cane only) in 2008-09 and 2009-10 seasons respectively (Table 6).

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

The benefit cost ratio (BCR) was maximum in T_5 {PRC + onion - MB (S_2F_2)} treatment which were 2.36 in 2008-09 and of 2.51 with T_{12} {PRC + lentil - MB (S_2F_1)} in 2009-10. The next highest BCR was found with 2.33 T_3 {PRC + onion - MB (S_1F_2)} in 2008-09 and 2.44 with T_{13} {PRC + lentil - MB (S_2F_2)} treatment in 2009-10. The minimum benefit cost ration were 1.77 with T_1 (sole cane only) in 2008-09 and 2.08 in 2009-10 under the treatment T_6 {PRC + mustard - MB (S_1F_1)}. Data on the LER value of different sugarcane + intercrop combination showed that the treatment T_{13} {PRC + lentil - MB (S_2F_2)} had the highest LER of 2.97 in 2008-09 and 2.47 in 2009-10 T_{13} {PRC + lentil - MB (S_2F_2)} while the lowest LER of 2.18 was in 2008-09 and 2.03 was in 2009-10 with T_7 {PRC + mustard - MB (S_1F_2)}and T_6 {PRC + mustard - MB (S_1F_1)}, respectively (Table 6).

Table 6. Effect of row spacing and fertilizer dose on mungbean productivity in onion, mustard, lentil - mungbean 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	141768	175673	61768	95672	1.77	2.20	1.00	1.0
T_2	162000	145000	362705	317116	200704	172116	2.24	2.19	2.45	2.29
T_3	162000	145000	377444	303109	215444	158109	2.33	2.09	2.67	2.23
T_4	162000	145000	372800	318331	210800	173330	2.30	2.20	2.62	2.31
T_5	162000	145000	382964	314316	220964	169316	2.36	2.17	2.68	2.32
T_6	106000	110000	184450	229320	78450	119320	1.74	2.08	2.22	2.03
T_7	106000	110000	183805	231297	77804	121296	1.73	2.10	2.18	2.08
T_8	106000	110000	184135	232765	78135	122764	1.74	2.12	2.20	2.06
T_9	106000	110000	190140	236020	84140	126020	1.79	2.15	2.35	2.22
T_{10}	107000	116000	209480	277516	102480	161516	1.96	2.39	2.64	2.36
T_{11}	107000	116000	211580	277236	104580	161236	1.98	2.39	2.71	2.39
T_{12}	107000	116000	217340	290609	110340	174608	2.03	2.51	2.76	2.45
T_{13}	107000	116000	229576	283124	122576	167124	2.15	2.44	2.97	2.47

Price of crops (2008-09) Sugarcane : 1760 Tk. t^{-1}, Onion : 32 Tk. kg^{-1}, Mustard: 40 Tk. kg^{-1}, Lentil : 60 Tk. kg^{-1} and Mungbean : 50 Tk. kg^{-1}

Price of crops (2009-10) Sugarcane : 2160 Tk. t^{-1}, Onion : 15 Tk. kg^{-1}, Mustard: 40 Tk. kg^{-1}, Lentil : 60 Tk. kg^{-1} and Mungbean : 50 Tk. kg^{-1}

Soil characteristics

Effects of first intercrop, row spacing and fertilizer dose on mungbean in a sequential intercropping in paired rows transplanted sugarcane on post harvest soil pH, 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. The highest Available P was the highest with T_2 (26.60 mg kg^{-1}) in 2008-09 and in T_8 (29.70 mg kg^{-1}) in 2009-10 while the lowest was in treatment T_{11} (13.50 and 19.70 mg kg^{-1}) in both the years. Available S was the highest with treatment T_7 (28.00 mg kg^{-1}) in 2008-09 and in T_2 (28.70 mg kg^{-1}) and in 2009-10 while the lowest was in treatment T_1 (17.70 and 21.00 mg kg^{-1}) in both the years (Table 7 and 8).

Table 7. Effects of first intercrop, row spacing and fertilizer dose on mungbean in a sequential intercropping on soil pH, organic matter (%), total N content (%) and available P (mg kg^{-1}) content 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	7.6	7.7	0.98	1.00	0.04	0.04	21.30	24.40
T_2	7.6	7.6	1.02	1.05	0.05	0.06	26.60	28.50
T_3	7.6	7.6	1.04	1.06	0.05	0.06	15.30	24.80
T_4	7.6	7.6	1.07	1.08	0.05	0.06	21.00	27.10
T_5	7.6	7.6	1.04	1.03	0.06	0.06	19.60	21.90
T_6	7.6	7.7	1.01	1.06	0.06	0.06	18.10	27.70
T_7	7.6	7.6	1.07	1.05	0.05	0.06	14.40	28.70
T_8	7.7	7.7	1.06	1.02	0.05	0.05	18.60	29.70
T_9	7.6	7.6	1.03	1.05	0.05	0.06	19.30	21.30
T_{10}	7.6	7.6	1.05	1.06	0.05	0.06	22.40	27.00
T_{11}	7.7	7.6	1.02	1.05	0.06	0.06	13.50	19.70
T_{12}	7.5	7.6	1.04	1.05	0.05	0.06	18.50	23.70
T_{13}	7.7	7.6	1.05	1.05	0.06	0.06	21.00	27.70
CV (%)	2.76	1.74	4.70	7.11	28.03	23.13	0.67	3.59
LSD (0.05)	NS	NS	NS	NS	NS	NS	**	**

Table 8. Effects of first intercrop, row spacing and fertilizer dose on mungbean in a sequential intercropping on exchangable K (cmol kg^{-1}), available S (mg kg^{-1}) and available Zn (mg kg^{-1}) content 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	0.14	0.16	17.70	21.00	0.56	0.54
T_2	0.16	0.19	18.30	28.70	0.58	0.57
T_3	0.15	0.18	20.50	22.50	0.63	0.59
T_4	0.15	0.16	17.80	24.70	0.58	0.57
T_5	0.15	0.19	18.70	25.70	0.60	0.56
T_6	0.17	0.16	19.00	24.80	0.64	0.58
T_7	0.15	0.17	28.00	25.20	0.62	0.56
T_8	0.16	0.18	19.80	24.70	0.63	0.58
T_9	0.16	0.20	21.00	22.10	0.60	0.55
T_{10}	0.15	0.18	19.60	21.80	0.61	0.50
T_{11}	0.15	0.19	22.50	23.30	0.64	0.52
T_{12}	0.16	0.19	18.60	21.10	0.67	0.57
T_{13}	0.15	0.19	20.80	20.50	0.63	0.57
CV (%)	19.50	24.53	3.62	3.12	14.77	8.69
LSD (0.05)	NS	NS	**	**	NS	NS

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

CONCLUSION

Mungbean (BINA Mung 5) seed should be planted in 3 rows with 50% of recommended fertilizer dose in different sequential intercropping systems in paired rows transplanted sugarcane. Mungbean based sequential intercropping with paired rows transplanted sugarcane could be considered as an option for sustainable sugarcane production maintaining soil health.

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