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Productivity and economic efficiency of sugarcane cultivation under intercropping system with potato and mungbean

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Abstract

Sugarcane is an important cash-cum-industrial crop of Bangladesh and mainly cultivated in north-western part of the country where different intercropping systems are available. The experiment was carried out at the Bangladesh Sugarcane Research Institute (BSRI) farm, Ishurdi, Pabna, Bangladesh in two successive years viz. 2008–2009 and 2009–2010 to investigate the profitability of sugarcane (cv. Isd 37) with potato (cv. Cardinal) and mungbean (cv. BINA mung5) as successive intercrops. Two factors included in the experiment viz. Factor A: Row to row distance of sugarcane such as 80 cm (S_1), 100 cm (S_2) and 120 cm (S_3) where potato and Mungbean were intercropped. Factor B: Cutting of sugarcane leaf such as cutting of leaves (C_1) and No cutting of leaves (C_2). The experiment was laid out following randomize complete block design. For sugarcane cultivation BSRI technique and for intercropping the cultivation systems indicated by Bangladesh Agricultural Research Institute were followed. The cane yield and sugar yield were the highest at 100 cm row to row spacing (RRS) of sugarcane (non-leaf cutting = C_0) intercropped with 2 rows (2R) of potato followed by 2R of mungbean (S_2C_0). The lowest yield of sugarcane was found at 80 RRS (C_0) with one row (1R) of potato and 1R of mungbean (S_1C_0). The effect of light interception on growth and yield of first intercrop (potato) was insignificant but significant for second intercrop. The highest yield of potato tuber was 15.28 t ha^{-1} in S_5 (sole potato) followed by 10.85 t ha^{-1} in S_3C_1 (sugarcane under leaf cutting at RRS 120 cm with 3R of potato followed by 3R of mungbean). For the yield of mungbean (2nd intercrop), light interception ratio (%) was significantly lowest in (S_3C_1) where sugarcane RRS was 120 cm with 3R of potato followed by 3R of mungbean under leaf non-cutting (C_0) of sugarcane. The highest adjusted cane yield (170.66 t ha^{-1}), benefit cost ratio (3.49) and LER (2.33) were observed in sugarcane at RRS 120 cm with 3R of potato followed by 3R of mungbean (S_3C_1). Results of both years indicated that intercrops gave higher land equivalent ratio and net return over sole sugarcane planted while sole sugarcane gave maximum benefit cost ratio compared with other intercrops. Finally, on the basis of results it may be concluded that sugarcane transplanted at RRS at 120 cm with 3R potato followed by 3R of mungbean can be grown as intercrops for higher economic return.

Introduction

Sugarcane (*Saccharum officinarum* L.) is the second cash-cum-industrial crop. It is a long duration crop for cultivation which needs about 12-13 months from transplanting to harvest. Sugarcane is a wide spacing crop usually planted at 80 to 120 cm row to row spacing (RRS). For full canopy development it needs 3-5 months and therefore, allows selective short duration intercrops (Hossain, 2003). Intercropping in sugarcane has long been practiced to get interim monetary return. It is an excellent technique to increase total yield, higher monetary return, greater resource utilization and fulfill the diversified need of farmers (Chowdhury, 2015). Different intercrops such as potato, mustard, onion, lentil, tomato, garlic, chickpea, coriander etc. has long been intercropping in sugarcane. Generally single intercrop in sugarcane is well practiced in cane growing regions. Inter-cropping in sugarcane generally requires more labor, thereby creating productive employment opportunities and generating higher income. Many studies indicated that inter-cropping with sugarcane increase the grower's net income, create the employment opportunities for landless and owner household families. Intercropping also improves nutritional quality of diet for the farm family (Khan *et at*., 2005), allows better control of weeds, increases land equivalent ratio (Imran *et al.*, 2011) and has some beneficial effects on pest and disease control (Abdullah *et al*., 2006). However, very little research effort has been made pertaining to input use, seasonal pattern of production and other practices which to be followed by farmers. Very little is known about the cost and return of successive intercrops and its profitability in sugarcane. The factors affecting yield and profitability of sugarcane with different successive intercrops have not been well documented. Wider RRS of sugarcane may be preferred as it reduces the chance of intercrop competition with least effect on cane growth and tillering. Recent report stated that RRS of 120 cm is best for higher growth and yield of sugarcane in AEZ 11 of Bangladesh (Islam and Islam, 2016). Hence sugarcane need 5-6 months for full canopy growth, two successive selective intercrops cultivation is possible within this period, if judicially managed. Planting of intercrops

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should be done in between RRS critically to avoid undue competition. When different crops are grown together, the productivity of sugarcane enhances ultimately due to better use of resources and complementary effect of different crops. Following an experiment, Verma *et al*. (1986) reported that sugarcane cultivation with potato as intercrop at different row spacing neither affected yield of cane nor of potato. Sugarcane+potato+vegetable (amaranth) was profitable followed by sugarcane+onion (Imam *et al.*, 1982). In respect of land use efficiency sugarcane+potato+onion was found to be the best combination (Rahman *et al.*, 1994). In intercropping, each crop must have adequate space to maximize cooperation and minimize competition between them. Thus four things such as spatial arrangement, density, maturity date of the crops being grown and plant architecture should be considered.

Sugarcane is a C_4 plant and can utilize higher solar energy for photosynthesis than C_3 plant. Higher light intensity and long duration promote the number of tiller production in sugarcane while cloudy and shorter day-length affects it adversely. Narrow vacant spaces in between two sugarcane rows affects light interception resulting higher level of shading on intercrop especially on second intercrop and affect photosynthesis. To get proper lighting for growth and yield of second intercrop it is needed to maintain wider row spacing to pass required solar radiation for proper photosynthesis (Miah *et al*., 2002). Therefore, selection of successive intercrop is an important factor for a sugarcane variety. Very less effort was given to select the most suitable intercrop combination(s) for higher production and economic return from sugarcane and two successive intercrops which may be reproducible in an agro-ecological zone. Considering the gap the present research was planned.

Materials and Methods

The experiment was conducted at Bangladesh Sugarcane Research Institute (BSRI) farm, Ishurdi, Pabna, Bangladesh in 2008-2009 and repeated in 2009-2010 cropping season. During sugarcane (cv. Isd 37) transplanting potato (cv. Cardinal) was intercropped and mungbean (cv. BINAmung5) cultivated as successive intercrop after harvesting potato. The site is located at $24^0 8'$north latitude and $89^0 04'$east longitude and situated about 15.5 m above the mean sea level. The experimental site represents the High Ganges River Flood Plain soils under the Agro ecological zone-11 (AEZ 11). The experiments were laid out in farm field soil having good internal drainage. The land category was medium high. It belongs to 'Sara series' of calcareous soil. The soil was sandy loam in texture having pH 7.58, contained organic carbon 0.88%, total N (0.05%), available phosphorus 17.00 $\mu g\ g^{-1}$, available sulphur 21.0 $\mu g\ g^{-1}$, exchangeable potassium 0.20 meq 100 g^{-1}, available Zinc 0.77 $\mu g\ g^{-1}$ and having cation exchange capacity (CEC) 12.25 meq 100 g^{-1}.

In 2008-2009 cropping season, the experiment was conducted with two factorial treatments. As treatment RRS of sugarcane were 80 cm, 100 cm and 120 cm with 1, 2 and 3 rows (R) of potato, respectively (in first intercrop) and followed by mungbean (2^{nd} intercrop) after harvesting potato. Another treatment was bended leaf cutting at middle and leaf non-cutting (control) of sugarcane. All experiments conducted in the first year were repeated in the second year (2009–2010) with same treatments and cultivation methods.

Experimental design

The two-factorial experiment was laid out in a Randomized Complete Block Design (RCBD), where each treatment replicated thrice. The unit plot size was 8 m × 6 mwhich separated by 1.0 m border. Total number of unit plot was 24 in the experiment.

Factors A (Row to row spacing of sugarcane and number of row of intercrops)

S_1 = Sugarcane RRS 80 cm + 1R of 1^{st} intercrop followed by 1R of 2^{nd} intercrop.

S_2 = Sugarcane RRS 100 cm + 2R of 1^{st} intercrop followed by 2R of 2^{nd} intercrop

S_3 = Sugarcane RRS 120 cm + 3R of 1^{st} intercrop followed by 3R of 2^{nd} intercrop

S_4 = Sole sugarcane RRS 100 cm (farmers practice).

Factors B (Bended leaves of sugarcane cutting)

C_0 = Non leaf cutting (NLC)

C_1 = Leaf cutting (LC)

Cultivation and management of crops

The land plough and tranches preparation were done by tractor plough and harrow. The following fertilizers were applied in kg/ha.

Crop's name	Urea	TSP	MoP	Gypsum	$ZnSo_4$
Sugarcane (main crop)	325	250	180	190	09
Potato (1^{st} intercrop)	120	60	100	45	00
Mungbean (2^{nd} intercrop)	20	40	25	00	00
Sugarcane (sole crop)	325	250	180	190	09
Potato sole (sole crop)	220	120	220	100	08
Mungbean (sole crop)	30	80	50	50	03

For sugarcane full doses of TSP, Gypsum, $ZnSo_4$ and one-third of MoP were mixed with soil in trench during land preparation. Urea was top dressed at 21, 90 and 150 DAT @ of $1/3^{rd}$ of total dose. For potato total amount of TSP, Gypsum and half urea and half MoP were mixed to furrow soil as basal dose. The remaining 50% urea and MoP were side dressed in two equal splits at 25 and 45 DAT during first and second earthing-up (Rahman *et al.* 2005). For mungbean all fertilizers were applied at basal dose at time of sowing (Rahman *et al.* 2008).

Sugarcane settlings of 45 days old earlier grown in polybag were transplanted in trenches at 45 cm plant to plant spacing (PPS) in second week of November in both the year. Potato seed tubers were sown at same day between RRS. The second intercrop mungbean seeds were sown in first week of March following harvest of potato. The seed rate of potato tubers and mungbean were 0.75 t ha^{-1} and 10 kg ha^{-1}, respectively. While these were 1.5 t ha^{-1} and 25 kg ha^{-1} as sole crop. After transplanting of the settlings irrigation (about 10 cm) was given in trenches. Supplementary irrigation was done at 30, 60, 90 and 120 DAT. Dead settling were replaced by healthy settlings within 15 days after transplanting. Following each irrigation surface soil of tranches were mulches manually with a *khupri*. The plots were kept weed free from up to 135 DAT. Earthen-up and tying of sugarcane were done after 140 days of plantation to protect the cane stalks from lodging or damage by wind during the period from July to September. Pest management and disease controls were done on following the recommend of Alam*et al.*, 1990. During trench preparing Chlorpyrifos (Regent 3 GR) was applied in the trenches @ 33 kg ha^{-1} to control termite and Carbofuran (Furadan 5G) was applied as a preventive measure against borers at 90 and 150 days (two time) after planting @ 40 kg ha^{-1} for each time. No disease infestation was observed in sugarcane and intercrop during cultivation.

Leaf cutting

Only bending leaves at bending position (middle) of sugarcane were cut (about 20% leaf) to minimize light interception. Leaves cutting of sugarcane were done 3 times with 21 day interval of seed sowing of second intercrop.

Data collection

For sugarcane data on cane yield, brix (%), pol (%) cane, purity (%) of juice, recovery (%) and sugar yield were collected in different days were collected and presented in respective Tables under results and discussion. Similarly data on yield of intercrops and % light interception (measured by a 660/730. Red: Far red measuring system; SKR 110/100 Skys Instruments Ltd. Powys, U.K.) were collected, analyzed and presented in respective Tables.

Light interception

Light interception was calculated according to the following formula:

$$\% \text{ light interception} = (1.0 - \frac{I}{I_0}) \times 100 \quad \text{(Szeicz } et\ al., 1964)$$

Where,

I = Light intensity received at the ground level

I_0= Light intensity received just above the crop canopy

Equivalent cane yield of intercrops (ECY):

Yield of intercrops was converted into equivalent cane yield on the basis of prevailing market price and calculated following formula of Bandyopadhyay (1984).

Adjusted cane yield (ACY):

Adjusted cane yield was calculated by adding equivalent cane yield of intercrops with the yield of sole sugarcane crop.

Adjusted cane yield (ACY) = ECY + SY

where, ECY = Equivalent cane yield of intercrops, and SY = Sugarcane yield

Benefit cost ratio (BCR)

It was calculated by following formula (CIMMYT, 1988)

$$BCR = \frac{\text{Gross return (Tk.)}}{\text{Total production cost (Tk.)}}$$

Land equivalent ratio

Land equivalent ratio (LER) was calculated following formula (Mead and Willey, 1980)

$$LER = \frac{Yis}{Ys} + \frac{Yix}{Yx} + \frac{Yix_1}{Yx_1}$$

Where,

Yis = Yield of sugarcane with intercrop

Ys = Yield of sole sugarcane

Yix = Yield of 1st intercrop (potato)

Yx = Yield of sole 1st intercrop (potato)

Yix_1 = Yield of 2nd intercrop (mungbean)

Yx_1 = Yield of sole 2nd intercrop (mungbean)

Statistical analysis

The analysis of variance for different parameters was performed and means differences were compared by Duncan's Multiple Range Test (DMRT) using program MSTAT-C (Russel, 1986).

Results

Cane yield

Cane yield varied significantly with varied RRS of sugarcane under successive intercropping. The highest cane yield was in S_2 (Table 1) and in S_2C_0 (sugarcane RRS 100 cm + 2R potato-2R mungbean with non-cutting leaf of sugarcane), which was statistically at par with S_3C_0 (sugarcane RRS 120 cm + 3R potato-3R mungbean), S_3C_1 (sugarcane RRS 120 cm + 3R potato-3R mungbean with leaf cutting of sugarcane), S_4C_1 and S_4C_0. The lowest one was in S_1C_1(sugarcane RRS 80 cm + 1R potato - 1R mungbean) in both the seasons (Table 3).The data also indicate that leaf non-cutting and cutting had no significant effect on yield of sugarcane (Table 2). The highest cane yield (97.62 t ha^{-1}) was obtained in S_2C_0 and the lowest one was (86.47 t ha^{-1}) in S_1C_1.

Yield of first intercrop potato

Yield of potato (first intercrop) varied significantly due to different RRS of sugarcane compared to sole potato. Data on interaction of RRS and leaf non-cutting (C_0) and leaf cutting (C_1) of sugarcane revealed that the highest potato tuber yield was 15.28 t ha^{-1} in S_5 (sole potato) followed by 10.85 in S_3C_1 (sugarcane RRS 120 cm + 3R potato-3R mungbean with C_1) and the lowest one was 7.79 t ha^{-1} in S_1C_1 (sugarcane RRS 80 cm + 1R potato-1R mungbean with C_1) in first year (Table 3). Similar production was obtained in second year. Light interception (%) was insignificant in all spacing treatment on growth of potato in both the years (Table 4). It indicates that sugarcane canopy did not compete to intercrop for light and therefore, yield of both crop remained unaffected at least for light. At 75 DAS light interception was 1.29 -1.89.

Table 1. Effects of row to row spacing (RRS) on cane yield of sugarcane with potato-mungbean as intercrop

Treatments	Cane yield (t ha^{-1})	
	2008-2009	2009-2010
S_1	87.20b	84.01c
S_2	96.89a	93.76a
S_3	91.06ab	87.69bc
S_4	95.20a	91.87ab
LSD (0.05)	6.303	5.272

Table 2. Effects of leaf cutting (LC) or non leaf cutting (NLC) on cane yield of sugarcane with potato-mungbean as intercrop

Cutting (C)	Cane yield (t ha^{-1})	
	2008-2009	2009-2010
C_0	93.02	89.78
C_1	91.96	88.89
LSD (0.05)	NS	NS

Yield of second intercrop mungbean

Yield of mungbean as second intercrop with sugarcane varied significantly due to RRS and C_0 or C_1 of main crop sugarcane. The highest yield of mungbean was at S_3C_1 where 3R of mungbean was produced in 120 cm rows spacing of sugarcane. The yield of mungbean was significantly lower to that of yield in sole crop. The lowest yield of mungbean was observed in S_1C_0 (Table 3). The highest light interception (%) was obtained in S_1C_0 and the lowest was at S_3C_1 in both the years (Fig. 1, 2). The light interception affected mungbean yield significantly. The interception of light gradually increased with increase of days after sowing of mungbean in both the years (Fig. 1, 2). A negative correlation between light interception (%) and grain yield of mungbean at 75 DAS was observed. Mungbean yield and light interception (%) is presented in Figure 3 by the equation, Y= -0.017x + 1.351 (R^2=0.80), which indicate that mungbean yield can be increased at the rate of 0.80 (t ha^{-1}) with the decrease in light interception (%) from 75 DAS. Similar relationship was observed in 2009-2010 (Fig.4).

Brix (%), pol % cane, purity (%) and recovery (%)

Brix %, the measurement of the ratio of the mass of dissolved sugar was not affected by RRS and leaf-cutting and non-cutting in sugarcane cultivated with potato and mungbean as successive intercrops (Table 5). The interaction table shows that the range of brix (%) was 20.2 –20.8% in 2008–2009 and almost similar was in next year. As brix is important for sugar yield, it indicates that spacing variation and intercropping did not affect sugar content in juice of sugarcane. Similarly pol % cane, purity % and recovery %, the important factors of total sugar yield of sugarcane were remained unaffected with various RRS of sugarcane cultivated with potato and mungbean as intercrops (Table 5). In 2008-2009, range of pole % cane, purity %, and recovery % were ranged from 14.34-14.91, 89.89-90.73 and 11.14-11.64%, respectively and were almost similar in 2009-2010.

Sugar yield

Sugar yield was significantly affected by RRS under successive intercropping of potato and mungbean. The highest sugar yield (11.15 t ha^{-1}) was observed in S_2C_0 (sugarcane RRS 100 cm + 2R potato-2 R mungbean under non-cutting leaf) and the lowest one (9.63 t ha^{-1}) was in S_1C_1 (sugarcane RRS 80 cm + 1R potato-1R mungbean under leaf-cutting). Similar yield of sugar was obtained in S_4C_0, the sole sugarcane under leaf non-cutting. Higher sugar yield in S_2C_0 might be due to higher cane yield under double row of intercrops (Table 6). Similar sugar yield was observed in next season.

Equivalent and adjusted cane yield of intercrops

The highest equivalent cane yield of intercrops was 86.41 t ha^{-1} in S_5 (sole potato) followed by 79.68 t ha^{-1} in S_3C_1 (sugarcane RRS 120 cm + 3R potato-3R mungbean with LC) and the lowest 29.01 t ha^{-1} in S_6 (sole mungbean) during 2008–2009 (Table 7). Almost similar result was observed in next year. The highest adjusted cane yield (where sugarcane yield + equivalent cane yield of two intercrops were considered) was 170.66 t ha^{-1} recorded from S_3C_1 and the lowest was 29.01 t ha^{-1} obtained in S_6 (sole mungbean) in both the years (Table 6).

Cultivation cost and return

Total cultivation cost of sugarcane and successive two intercrops was the highest Tk. 93925.46 ha^{-1} in S_1C_1 and the lowest one Tk. 72532.25 $ha^{-1}$was in S_4C_0 (sole sugarcane) during 2008-2009 (Table 7). The highest and lowest gross return were Tk. 288509.67 ha^{-1} and Tk. 51296.93 ha^{-1}, respectively in S_3C_1 and S_6 (sole mungbean), in the same year (Table 5). However, the highest gross margin income was Tk. 215521.73 ha^{-1} obtained from the S_3C_1 and the lowest one Tk. 148572.34 $ha^{-1}$was in S_1C_0. Almost similar trend was observed in the next year for cost, return and margin (Table 7).

Benefit cost ratio

The interactions of RRS and LC or NLC on benefit cost ratio (BCR) shows (Table 7) that the highest benefit cost ratio (BCR) was 3.49 in S_3C_1, followed by S_3C_0 and the lowest one (2.16) in S_4C_1. Similar trend was observed in the next year except in lowest BCR in S_5 (sole potato), where market price was lower.

Land equivalent ratio

Land equivalent ratio (LER), an important parameter for determining the adoption or rejection of intercrop or mixed cropby farmers is revealed (Table 7) that the highest value 2.33 was in S_3C_1 and the lowest one 1.62 in S_1C_0. Similar trend was observed in 2009–2010. The LER value greater than 1.0 indicated the yield advantages of the component crops in intercropping system compared to their sole cropping.

Table 3. Interaction effects of RRS and LC or NLC on yield of sugarcane with successive intercrop of potato-mungbean

Treatments	Cane yield ($t\ ha^{-1}$)	Yield of intercrops ($t\ ha^{-1}$)		Cane yield ($t\ ha^{-1}$)	Yield of intercrops ($t\ ha^{-1}$)	
		Potato (1st)	Mungbean (2nd)		Potato (1st)	Mungbean (2nd)
	2008-2009			2009-2010		
S_1C_0	87.93ab	7.84c	0.23e	84.05b	6.92c	0.19d
S_1C_1	86.47b	7.79c	0.26e	83.98b	6.81c	0.23d
S_2C_0	97.62a	9.67b	0.32de	94.39a	9.37b	0.24d
S_2C_1	96.15ab	9.94b	0.38cd	93.13a	9.54b	0.43c
S_3C_0	91.14ab	10.62b	0.47c	88.23ab	10.16b	0.36c
S_3C_1	90.98ab	10.85b	0.72b	87.15ab	10.25b	0.74b
S_4C_0	96.13ab	-	-	92.45a	-	-
S_4C_1	94.27ab	-	-	91.29ab	-	-
S_5	-	15.28a	-	-	14.75a	-
S_6	-	-	1.14a	-	-	1.16a
LSD (0.05)	8.914	1.776	0.112	7.456	1.973	0.097

Figures with similar letter (s) of a column don't differ significantly at 5.0% probability by DMRT
Price (2008-2009): Sugarcane: 1,768.25 Tk t^{-1}, Potato: 10,000.00 Tk t^{-1}, Mungbean: 45,000.00 Tk t^{-1}
Price (2009-2010): Sugarcane: 2150.00 Tk t^{-1}, Potato: 8,000.00 Tk t^{-1}, Mungbean: 50,000.00 Tk t^{-1}

S_1 = Sugarcane RRS 80 cm + 1R potato - 1R mungbean
S_2 = Sugarcane RRS 100 cm + 2R potato - 2R mungbean
S_3 = Sugarcane RRS 120 cm + 3R potato - 3R mungbean
S_4 = Sole sugarcane RRS 100 cm
S_5 = Sole potato (cv. Cardinal)
S_6 = Sole summer mungbean (cv. BINAmoog5)

C_0 = Non leaf cutting (NLC)
C_1 = Leaf cutting (LC)

Table 4. Interaction effect of RRS to light interception on potato under successive intercropping of potato-mungbean with sugarcane

Treatment (S)	Light interception (%) of potato at different days after sowing									
	15	30	45	60	75	15	30	45	60	75
	2008–2009					2009–2010				
S_1C_0	0.86	0.89	0.94	1.76	1.87	0.75	0.84	0.91	1.54	1.76
S_1C_1	0.79	0.85	0.92	1.74	1.85	0.68	0.79	0.88	1.47	1.71
S_2C_0	0.73	0.79	0.88	1.65	1.79	0.65	0.74	0.83	1.42	1.68
S_2C_1	0.59	0.65	0.82	1.59	1.76	0.55	0.68	0.79	1.37	1.55
S_3C_0	0.44	0.52	0.8	1.42	1.65	0.41	0.54	0.70	1.30	1.51
S_3C_1	0.41	0.51	0.76	1.37	1.62	0.39	0.42	0.63	1.24	1.47
S_5	0.26	0.31	0.62	1.06	1.29	0.19	0.22	0.58	1.14	1.43
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5. Interaction effects of RRS to LC or NLC on Brix, pol % cane, purity and sugar yield of sugarcane with successive intercropping of potato-mungbean

Interaction (S×C)	Brix (%)	Pol % cane	Purity (%)	Recovery (%)	Brix (%)	Pol % Cane	Purity (%)	Recovery (%)
	2008-2009				2009-2010			
S_1C_0	20.4	14.60	90.58	11.39	20.3	14.47	90.20	11.26
S_1C_1	20.2	14.34	89.89	11.14	20.1	14.27	89.90	11.08
S_2C_0	20.5	14.66	90.54	11.43	20.5	14.64	90.42	11.41
S_2C_1	20.3	14.46	90.19	11.25	20.3	14.45	90.12	11.24
S_3C_0	20.8	14.91	90.73	11.64	20.7	14.88	90.98	11.64
S_3C_1	20.6	14.75	90.65	11.51	20.4	14.57	90.43	11.36
S_4C_0	20.5	14.64	90.42	11.41	20.5	14.64	90.39	11.40
S_4C_1	20.4	14.52	90.09	11.29	20.4	14.55	90.25	11.32
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 6. Interaction effects of RRS to LC or NLC on sugar yield, equivalent cane yield and adjusted cane yield of sugarcane with successive intercropping of potato-mungbean

Interaction (S×C)	Sugar yield (t ha^{-1})	Equivalent cane yield	Adjusted cane yield (t ha^{-1})	Sugar yield (t ha^{-1})	Equivalent cane yield	Adjusted cane yield (t ha^{-1})
	2008-2009			2009-2010		
S_1C_0	10.01e	50.19	138.12	9.46d	30.16	114.20
S_1C_1	9.63f	50.67	137.14	9.30d	30.68	114.66
S_2C_0	11.15a	62.83	160.45	10.76a	40.44	134.83
S_2C_1	10.81bc	65.88	162.03	10.46ab	45.89	139.02
S_3C_0	10.61cd	72.02	163.16	10.26bc	46.17	137.32
S_3C_1	10.47d	79.68	170.66	9.90c	55.34	147.57
S_4C_0	10.96ab	-	96.13	10.53ab	-	92.45
S_4C_1	10.64cd	-	94.27	10.33b	-	91.29
S_5		86.41	86.41		-	54.88
S_6		29.01	29.01		-	26.98
LSD (0.05)	0.247	-	-	0.391	-	

Figures with similar letter (s) of a column don't differ significantly at 5.0% probability by DMRT

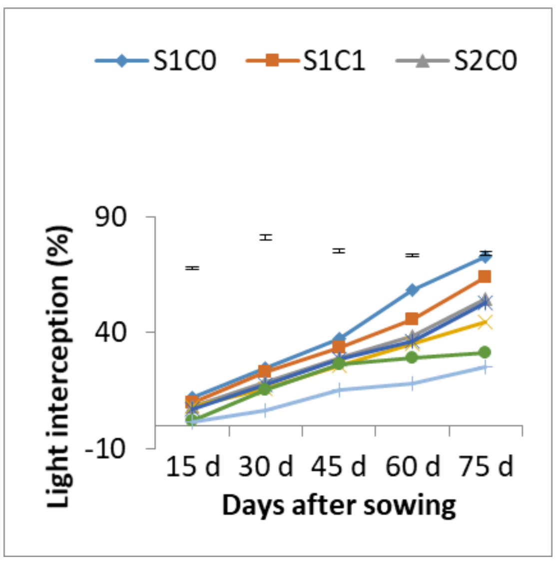

Fig. 1. Light interception (%) of mungbean at DAS in 2008–2009. Narrow vertical bars indicate LSD values

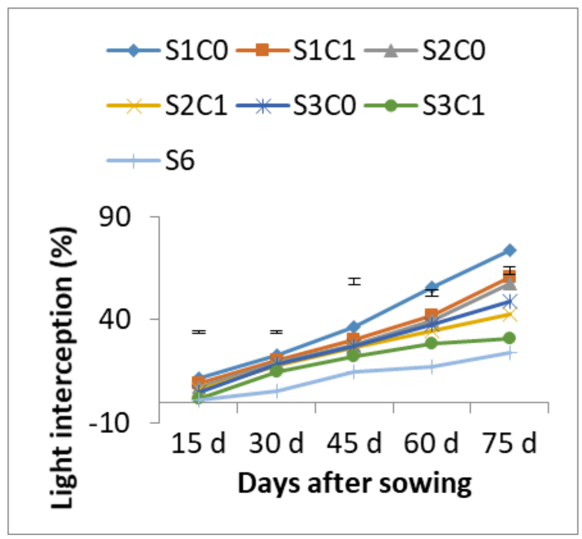

Fig. 2. Light interception (%) of mungbean at DAS in 2009-2010. Narrow vertical bars indicate LSD values

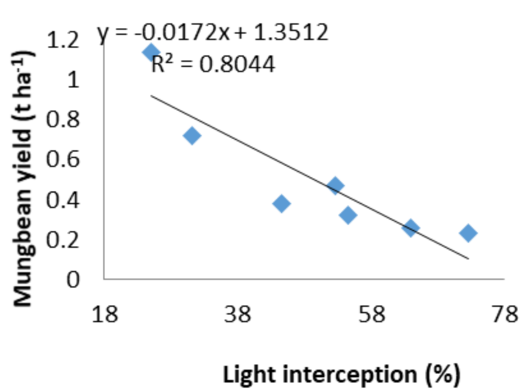

Fig. 3. Relationship between light interception (%) and yield of mungbean at 75 DAS in 2008–2009

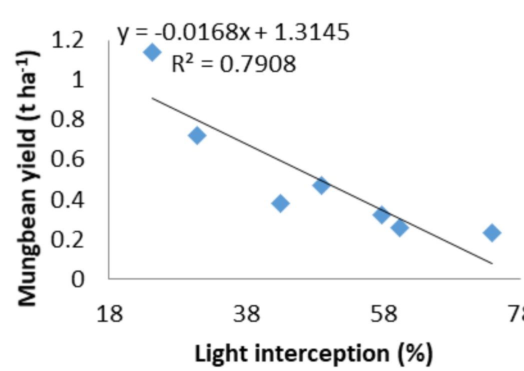

Fig. 4. Relationship between light interception (%) and yield of mungbean at 75 DAS in 2009–2010

Table 7. Interaction effects of RRS to LC or NLC on gross return, total production cost, gross margin, BCR and LER of sugarcane with successive intercropping of potato-mungbean

Treatments	Gross return (Tk. ha^{-1})	Total production cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	Benefit cost ratio (BCR)	Land equivalent ratio (LER)
			2008–2009		
S_1C_0	244230.69	88375.65	155855.04	2.76	1.62
S_1C_1	242497.80	93925.46	148572.34	2.58	1.63
S_2C_0	283715.71	84287.52	199428.19	3.36	1.92
S_2C_1	286509.54	89708.74	196800.80	3.19	1.98
S_3C_0	288509.67	83012.45	204595.22	3.43	2.05
S_3C_1	301769.54	86247.81	215521.73	3.49	2.33
S_4C_0	169981.87	72523.25	97458.62	2.34	1.00
S_4C_1	166692.92	77073.06	89619.86	2.16	1.00
S_5	152794.48	59845.85	92948.63	2.55	1.00
S_6	51296.93	21896.45	29400.48	2.34	1.00
			2009–2010		
S_1C_0	245530.00	90480.00	155050.00	2.71	1.54
S_1C_1	246519.00	96240.00	150279.00	2.56	1.56
S_2C_0	289884.50	87225.00	202659.50	3.32	1.86
S_2C_1	298893.00	92985.00	205900.00	3.21	2.02
S_3C_0	288960.00	85312.00	203648.00	3.38	1.95
S_3C_1	306353.50	89812.00	216541.50	3.41	2.27
S_4C_0	198767.50	75287.29	123480.21	2.64	1.00
S_4C_1	196273.50	79025.45	117248.05	2.48	1.00
S_5	117992.00	60138.27	57853.73	1.96	1.00
S_6	58007.00	23583.25	30423.75	2.29	1.00

Price (2008-2009): Sugarcane: 1,768.25 Tk t^{-1} and price (2009-2010): Sugarcane: 2,150.00 Tk t^{-1}

Discussion

Sugarcane is a long duration crop which gives net economic return after one year. Farmers cultivating sugarcane in Bangladesh are almost small and marginal. Without interim return it is difficult to sustain sugarcane cultivation in Bangladesh. Intercrop cultivation with sugarcane is only way to get interim return. The present research indicate that two successive short duration intercrops can be grown with sugarcane for getting interim and higher economic return. Selection of intercrop with sugarcane, spacing adjustment and management practices of crops are important issues in getting higher return. In different sugarcane producing areas different intercrops were reported profitable. Although intercrop with sugarcane of an area depends on farmer knowhow (traditional), available facilities, local market demand, environmental factors etc., research result based intercrop selection, suitable spacing adjustment to sugarcane and cost saving but effective management practices are key determinant for intercropping in an AEZ, which might ensure higher return income and profitability of farmers. It was reported that khira (*Cucumis sativus*) as intercrop with sugarcane in AEZ3 enhanced return income of farmers distinctly (Kashem *et al.*, 2009). Other reports showed different intercrops with sugarcane were profitable (Alam, *et al*., 1915, Ganapati, 2015). Most of those reports were on paired row sugarcane intercropped with different short duration crops. Almost all reports indicated that the selection of suitable intercrop and their spacing with sugarcane was the important factor for interim return as well as profitable sugarcane cultivation. In present experiment the yield of sugarcane and intercrops varied differently depending on spacing without changing cane qualities. The profitable intercropping with sugarcane is calculated by depending on gross return, gross margin, benefit cost ratio (BCR) as well as land equivalent ratio (LER). Land equivalent ratio (LER), benefit cost ratio (BCR) and monetary advantage index (MAI) are used to assess the productivity and its economic benefits (Matusso, *et al.* 2012). BCR and LER are two important determining factors in crop production (Mead and Willey, 1980). Higher LER provide higher economic return to growers (Razzaque *et al.* 2007). Although the sugar yield of main crop sugarcane was significantly highest at S_2C_0 in present experiment (Table 6),the highest gross return, gross margin and BCR were obtained at S_3C_1 where RRS of sugarcane was 120 cm with 3 rows of potato (as first intercrop) and followed by 3 rows of mungbean (as second intercrop) under leaf cutting of sugarcane. The most important factor LER was distinctly higher under 120 cm RRS of sugarcane both in leaf cutting and non-leaf cutting of sugarcane, where 3 rows of potato was cultivated as first intercrop and followed by 3 rows of mungbean as second intercrop with sugarcane.

Being long duration exhaustive crop sugarcane caused soil fertility decrease (Tiwana *et al.*, 1999).Intercropping protect soil from fertility decrease of soil and also improve soil health (Alam *et al*., 2015). Therefore, it is also a profit to be considered, where next crop will be benefited economically with intercrops compared to sole crop. Intercropping legumes with sugarcane could be an option to maintain soil fertility. In consequential intercropping with sugarcane it will be better to consider a leguminous crop for better soil health. Summer mungbean 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 (Hossain *et al*., 1995). Furthermore, intercropping is helpful to control weed infestation, reduces pest disease infestation, gives yield advantage and there is stable yield over time and improves nutritional quality of diet for the farm family (Ibeawuchi, 2007). Intercropping provides insurance against crop failure and/or better avenue of employment for the rural people (Bandyopadhyay, *et al*., 1984). Introducing this double intercropping might play a wonderful role in providing interim return. Thus it is a sustainable way of sugarcane popularization in AEZ 11 of Bangladesh.

Conclusion

In light of above discussion, it may be concluded that there is a scope to increase potato and mungbean production by adapting as first and second intercrop with sugarcane. Sugarcane cultivation at row to row spacing of 120 cm by leaf cutting with 3 row potato as first intercrop and followed by 3 rows of mungbean may be recommended for higher net return and profitability in AEZ 11 of Bangladesh. Quality of cane remained similar to that of sugarcane sole cultivation.

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