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Productivity and profitability of sugarcane with lentil-sesame sequential intercropping under High Ganges River Flood Plain soils of Bangladesh

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ABSTRACT

An experiment was conducted at Bangladesh Sugarcrop Research Institute farm, Pabna, Bangladesh to find out productivity and profitability of sugarcane with lentil-sesame sequential intercropping. The experiment was laid out in two factor Randomized Complete Block Design (RCBD) with three replication. One factor consisted of four spacing of sugarcane along with row number of intercrops. They were- S_1 (Sugarcane row to row spacing (RRS) 80 cm + 1 row of lentil - 1 row of sesame), S_2 (Sugarcane RRS 100 cm + 2 rows of lentil -2 rows of sesame), S_3 (Sugarcane RRS 120 cm + 3 rows of lentil - 3 rows of sesame) and S_4 (Sole sugarcane with RRS 100 cm). Another factor consisted of C_0 (non leaf cutting and C_1 (leaf cutting) of sugarcane. The highest plant height was observed in S_3C_0 treatment. The highest LAI, TDM and cane yield were found in S_2C_0 treatment. The number of tiller and millable cane were the highest S_1C_0 treatment. Brix (%), pol per cent cane, purity (%) and recovery (%) were insignificant of lentil-sesame sequential intercropping of sugarcane. The highest BCR and LER were obtained 2.73 and 2.06, respectively, in S_3C_1treatment. Finally, on the basis of results it may be concluded that sugarcane transplanted at RRS at 120 cm under leaf cutting with 3R lentil-3R of sesame can be grown as intercrops for higher economic return and might be recommended for farmers practice in High Ganges River Flood Plain soils under AEZ 11 of Bangladesh.
Keywords: Intercropping, lentil, LAI, sesame, sugarcane

INTRODUCTION

Sugarcane is the most important cash-cum-industrial crops in Bangladesh. It is a long duration crop for cultivation which needs about 12-13 months from transplanting to harvest. Due to a rapid increase in the global population, the demand for food is also increasing. Several strategies have been followed around the world to improve land use efficiency (Dhaliwal 2018). Intercropping can be a viable option to boost up crop productivity in farming systems. It is an efficient and eco-friendly method which enhances crop production. Intercropping ensures best utilization of natural assets and harmonizes the effect of two or more crops grown simultaneously on same unit of land; thus, it is an excellent option in the development of sustainable crop production systems (Nadeem et al. 2020). Intercropping is an important aspect to combat the crop failure in rainfed agriculture under the situation of climate change and helps in improving productivity and profitability through efficient utilization of natural resources (Thimmegowda et al. 2016). This system gives spatial and temporal crop intensification of both time and space. Apart from its advantages like diversification, labour distribution, maintenance of soil fertility, suppression of weeds; two major advantages of intercropping are: higher productivity and greater stability through utilization of solar energy, moisture and nutrients (Kapse 2017). In addition to high productivity of the intercropping system, selection of suitable intercrops also assure greater importance in minimizing the adverse effects on cane yield by utilizing the inter row space thereby reducing the weed infestation (Singh and Uppal 2015).

Intercropping sugarcane with short duration crops

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enables the small and marginal farmers to get more economic returns on account of better utilization of land, labour, nutrients and irrigation water (Singh and Uppal 2017). In the intercropping, two or more crops are planted together in one place, during their growing season or at least in a timeframe. It is possible that the plants are different in terms of planting time, and a plant is planted after the first plant (Mazaheri et al. 2006). Solar radiation is a major resource determining growth and yield of crops in intercropping, particularly when other resources like water and nutrients are not severely limiting the crop growth. During growth and development, plants intercept and absorb growth factors like light, energy, water and nutrients and use them to produce biomass. Since these growth factors are distributed variously in space and time, crop complementary and supplementary relations determine the magnitude of intercrop (Ponnaiyan et al. 2015). Row intercropping system, involves two or more crops grown in the same field simultaneously with one or more of the crops grown in a distinct row arrangement (Mousavi 2011). The rows make weeding and harvesting easier than with mixed intercropping (Sam and Ghannay 2018). Wider row to row spacing 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 row to row spacing of 120 cm is the best for higher growth and yield of sugarcane in AEZ 11 of Bangladesh (Islam and Islam 2016). Planting of intercrops in between row to row spacing critically need 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. It has been reported that sugarcane intercropped with potato and vegetable (amaranth) was profitable followed by sugarcane with onion (Imam et al. 1982). In respect of land use efficiency sugarcane intercropped with potato and 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. Nadeem et al. (2020) concluded that 120 cm trench planting pattern of sugarcane along with lentil intercropping outperformed in improving the LER and gave maximum economic return as compared to other intercropping patterns and sole planting of sugarcane.

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 solar radiation for proper photosynthesis (Miah et al. 2002, Islam and Islam 2018). Therefore, the present study was undertaken to examine productivity and profitability of sugarcane with lentil-sesame sequential intercropping.

MATERIALS AND METHODS

A field study was conducted at the research field of the Bangladesh Sugarcrop Research Institute farm, Pabna, Bangladesh. 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. Sugarcane variety Isd 37, lentil (*Lens culinaris* L.) BARI Masur-5 as first intercrop and sesame (*Sesamumindicum* L.) BARI till-3 as second intercrop were used as test crop. For polybag settlings, the cane stalks were cut into small pieces (5 cm) containing one bud each with at least 1.5 cm stalk on above the node and about 3 cm at below. All setts were treated with Bavistin solution (1:1000) for 30 minutes to prevent fungal infection. The soil for filling polybag (12.5 cm × 10.0 cm) was mixed with cowdung (1:1) and then treated with Chlorpyrifos (Regent 3 GR) @ 0.04 g bag^{-1} and Carbofuran (Furadan 5G) @ 0.05 g bag^{-1} to control insect pest in the nursery. About two third of polybag were filled with the mixed soil and a previously treated sett was placed vertically in the centre of soil of the bag keeping the bud in upward direction. Then the polybag was completely filled with the soil so that about 1.5-2.0 cm soil covered the setts. The polybags were kept in a sunny place and thinly covered with rice straw to preserve soil moisture, and also protect soil loss from heavy rain (Ali et al. 1989). Watering was done at 2 days interval to the nursery beds throughout the period before transplantation of the settlings to the main field. Other cultural operations like weeding, rouging of diseased and pest infected settlings were done to maintain healthy settlings. Watering was done on days of transplanting of settlings into the main field.

Experimental design: The experiment was laid out in Randomized Complete Block Design (RCBD) in where each treatment replicated thrice under 2 factors. The unit plot size was 8 m × 6 m. Each plot was separated by 1.0 m border. Total number of unit plots was 24 in the experiment.

Factors A (Spacing of sugarcane and row number of intercrops)

S_1 = Sugarcane row to row spacing (RRS) 80 cm + 1 row of lentil followed by 1 row of sesame
S_2 = Sugarcane RRS 100 cm + 2 rows of lentil followed by 2 rows of sesame
S_3 = Sugarcane RRS 120 cm + 3 rows of lentil followed by 3 rows of sesame
S_4 = Sole sugarcane with RRS 100 cm

Factors B (Leaf cutting of sugarcane)
C_0 = Non leaf cutting (NLC)
C_1 = Leaf cutting (LC)

Cultivation and management of crops: The land was prepared by using tractor plough and harrow. To achieve good tilth, about 20 cm deep trenches were made. Row to row distances was maintained 80 cm, 100 cm and 120 cm. For sugarcane Urea, TSP, MOP, Gypsum and $ZnSO_4$ were applied @ 325, 250, 180, 190 and 9kg ha^{-1}, respectively. Full quantity of TSP, Gypsum, $ZnSO_4$ and one-third of MOP were applied in trench and mixed with soil prior to transplanting of settlings. One-third of urea was applied at 21 days after transplanting (DAT). The second dose of (1/3rd) Urea and 1/3rd MOP were applied as first top dressing at 90 DAT. Similarly final dose of Urea and MOP were applied as top dressing at 150 DAT (Anon 2005). For lentil intercrop Urea, TSP and MOP, Gypsum and $ZnSO_4$ were applied @ 20, 50, 20, 30 and 2.5 kg ha^{-1}, respectively. Total amount of Urea, TSP, MOP, Gypsum and $ZnSO_4$ were applied at basal dose at time of sowing (Rahman et al. 2005). For sole lentil Urea, TSP, MOP, Gypsum and $ZnSO_4$ were applied @ 40, 80, 30, 50 and 4.5 kg ha^{-1}, respectively. Total amount of Urea, TSP, MOP, Gypsum and $ZnSO_4$ were applied at basal dose at time of sowing (Rahman et al. 2008). For sesame intercrop Urea, TSP, MOP, Gypsum and $ZnSO_4$ were applied @ 50, 70, 25, 50 and 2 kg ha^{-1}, respectively. Total amount of Urea, TSP and MOP were applied at basal dose at time of sowing. For sole sesame Urea, TSP, MOP, Gypsum and $ZnSO_4$ were applied @ 100, 130, 40, 100 and 3 kg ha^{-1}, respectively. Total amount of Urea, TSP, MOP, Gypsum and $ZnSO_4$ were applied at basal dose at time of sowing (Satter et al. 2005).

Transplanting/Sowing: Previously raised 45 days old polybag sugarcane settlings were transplanted in each plot within 14 November, maintaining 45 cm plant to plant spacing. Lentil was sown as first intercrop sesame was sown as second intercrop. Lentil was shown on 14 November and harvested on 23 February. Sesame was shown on 4 March and harvested on 13 June. The seed rate of lentil and sesame were 15 kg ha^{-1} and 4 kg ha^{-1} respectively as intercrops while these were 35 kg ha^{-1} and 9 kg ha^{-1} as sole crop. In the main field, irrigation (10 cm) was given in trenches just after transplanting of the settlings for easy establishment. Supplementary irrigation was done at 30, 60, 90 and 120 DAT considering dryness of surface soil. Dead settling were replaced by healthy settlings within 15 days after transplanting. The mulching of the top soil was done after each irrigation. The plots were kept weed free 15 to 135 DAT, as the period is considered to be the critical period for crop-weed competition in sugarcane. Earthing-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 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.

Sugarcane leaf cutting: Only bending leaves at bending position of sugarcane were cut to minimize light interception. Leaves cutting of sugarcane were done 3 times at 21 days interval of seeds sowing of 2nd intercrops (sesame).

Data collection: For sugarcane data onplant height, number of tiller, leaf area index, total dry matter, millable cane, cane height, cane diameter, Brix (%), pol (%) cane, purity (%) of juice and recovery (%) were collected in different days presented in respective tables in results section. For intercrops data were collected on plant height, LAI, total dry matter, 1000 grain weight and yield and were analyzed and presented in tables in results section.

Plant height: Plant height was measured with a measuring tape from bottom to the tip of leaf.

Number of tillers: Number of tillers was recorded in each plot at 30 days interval starting from 90 DAT to 180 DAT. Number of tillers was expressed in 1000 ha^{-1}. Number of tillers for all types of settlings were used to compare the potentiality of millable cane stalks production and the trend of tillers establishment across the season.

Leaf Area Index (LAI)**:** Leaf area of green lamine was rescored on leaf area meter (ΔT Area meter MK2). Leaf area index was calculated from unit area. LAI was calculated as the ratio of leaf area to land area (Watson 1952).

Total dry matter production: For total dry matter production, canes of one m^{-2} were collected at 90, 180, 270 and 360 DATs cutting to the ground level. The samples including leaf and stalk were cut into small pieces and oven dried at 70°C for seven days up to constant weight (for 7 days and expressed in kg m^2).

Millable cane, cane height and cane diameter: When sugarcane washarvest, the total number of cane stalks from a sample area of 48 m^2 was counted and expressed in number per hectare. The boarder rows of each plot were not included during data collection. For cane height, 20 canes wereselected randomly and the length of individual cane was measured (m) from the bottom to the top using a measuring tape. Similarly diameter (cm) of sample cane was determined the average value of bottom, middle and top measurement by slide calipers.

Yield of cane: The yield of sugarcane stalks was recorded at final harvest from the same sample used for millable cane count. For collection of yield data, the cane stalks were cut to the ground level by spade. Sickle was used to remove the dried old trashes and cut green top of the cane stalks. The weight of clean cane stalks was taken by a balance and expressed in t ha^{-1}.

Brix (%): Sugarcane juice for Brix (%) was done at the harvest time of sugarcane. Randomly selected 15 sample cane stalks were crushed with a mini power crusher to get juice. The juice was collected in glass jars. The reading of brix (%) was recorded with Brix hydrometer (Cole-Parmer 0/35 Degree Brix Sugar Scale Hydrometer). Temperature of the juice was noted. These brix reading were corrected with the help of Schmitz,s table (Spancer and Meade 1963).

Pol % cane: With the help of automatic Polarimeter (AP-300, ATAGO ® Company limited, Japan) pol reading of extracted juice of every treatment was recorded by Horne's dry lead method. Sucrose contents of cane juice were calculated with the help of Schmitz,s table (Spancer and Meade 1963).

Purity (%): Percentage of pure sucrose in dry matter =

$$\frac{\text{Pol}}{\text{Brix}} \times 100$$

Recoverable sucrose: The recoverable sucrose (%) was calculated by using the following formula: Recoverable sucrose % =

$$\left[\text{Pol} - \left(\frac{\text{Brix} - \text{pol}}{2}\right) \times \text{Juice factor}\right]$$

Where, juice factor was 0.65 (extraction percentage)

Economic analysis: To determine the cost of production, the cost of land preparation, prices of all inputs including seed cane, fertilizers, pesticides, herbicide, irrigation etc., and labour cost at current wage rates were considered. For return, the market price of cane at the time of harvest was considered. Gross return was calculated by multiplying the total volume of output of an enterprise by the average price in the harvesting period. Net return was calculated by deducting all costs (variable and fixed) from gross return. Benefit cost ratio (BCR) was calculated by following formula (CIMMYT 1988)

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

Land equivalent ratio (LER): Land equivalent ratio (LER) was calculated with the following formula (Mead and Willey 1980)

$$\text{LER} = \frac{\text{Yis}}{\text{Ys}} + \frac{\text{Yix}}{\text{Yx}} + \frac{\text{Yix}_1}{\text{Yx}_1}$$

Where,
Yis = Yield of sugarcane with intercrop
Ys = Yield of sole sugarcane
Yix = Yield of 1st intercrop (lentil)
Yx = Yield of sole 1st intercrop (lentil)
Yix_1 = Yield of 2nd intercrop (sesame)
Yx_1 = Yield of sole 2nd intercrop (sesame)

Statistical analysis: The data were analyzed following standard statistical procedures (Gomez and Gomez 1984) by the Microsoft excel where applicable. The analyses of variance for different parameters was performed and mean differences were compared by Duncan's Multiple Range Test (DMRT) using a computer operated program named MSTAT-C (Russel 1986).

RESULTS AND DISCUSSION

Effect of different row spacing, intercropped, leaf clipping of sugarcane and their interaction on the plant height, tiller production, leaf area index and total dry matter of sugarcane: Plant height of sugarcane was affected significantly by RRS under sequential intercropping of lentil-sesame. The average highest plant heights 0.45 m, 1.82 m, 3.76 m and 4.23 m were recorded from RRS 120 cm with 3 rows of lentil followed by 3 rows of sesame (S_3) at 90, 180, 270 and 360 DATs, respectively (Table 1). The lowest plant height (0.41 m, 1.58 m, 3.39 m and 4.04 m) was observed in S_1 treatment (RRS spacing 80 cm with 1 R lentil - 1 R sesame) at 90, 180, 270 and 360 DATs, respectively. Leaf cutting and non leaf cutting of sugarcane did not show any significant effect on plant height. The interaction of spacing and LC or NLC on plant height was found significant during growth periods and the highest plant heights 0.46 m, 1.85 m, 3.78 m and 4.25 m were in S_3C_0 (sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with NLC) at 90, 180, 270 and 360 DATs, respectively (Table 1). The lowest plant height was observed in S_1C_1 (sugarcane RRS 80 cm+1 R lentil-1 R sesame with LC) (Table 1). The present result was well agreed with those of earlier report by Rahman et al.(2012) who stated that highest plant height (4.24 m) was recorded in paired row sugarcaneintercropped with potato-mungbean.

Table 1. Effect of row spacing along with number of row of intercrops, leaf clipping of sugarcane and their interaction on the plant height of sugarcane

Treatment (S)	Plant height (m) at different DATs			
	90	180	270	360
S_1	0.41c	1.58c	3.39c	4.04c
S_2	0.44ab	1.69b	3.56b	4.15ab
S_3	0.45a	1.82a	3.76a	4.23a
S_4	0.43b	1.71b	3.56b	4.13b
LSD (0.05)	0.018	0.058	0.082	0.082
Cutting (C)	-	-	-	-
C_0	0.46	1.72	3.59	4.16
C_1	0.42	1.69	3.55	4.13
LSD (0.05)	NS	NS	NS	NS
Interaction (S×C)	-	-	-	-
S_1C_0	0.41cd	1.59d	3.41c	4.06cd
S_1C_1	0.40d	1.57d	3.38c	4.03d
S_2C_0	0.44ab	1.71bc	3.59b	4.17a-c
S_2C_1	0.43bc	1.68c	3.54b	4.14a-d
S_3C_0	0.46a	1.85a	3.78a	4.25a
S_3C_1	0.44ab	1.79ab	3.74a	4.21ab
S_4C_0	0.43bc	1.72bc	3.57b	4.15a-c
S_4C_1	0.42b-d	1.70c	3.55b	4.12b-d
LSD (0.05)	0.025	0.082	0.116	0.116

Figures with similar letter (s) of a column don't differ significantly at 5.0% probability by DMRT, NS = Non significant, DAT= Days after transplanting , S_1 = Sugarcane row to row spacing (RRS) 80 cm + 1 row (1R) of lentil followed by 1 row (1R) of sesame , S_2 = Sugarcane RRS 100 cm + 2 R lentil - 2 R sesame, S_3 = Sugarcane RRS 120 cm + 3 R lentil - 3 R sesame , S_4 = Sole sugarcane RRS 100 cm, C_0 = Non leaf cutting (NLC), C_1 = Leaf cutting (LC)

Table 2. Effect of row spacing along with number of row of intercrops, leaf clipping of sugarcane and their interaction on the tiller production of sugarcane

Treatment (S)	Number of tiller (10^3ha^{-1}) at different DATs			
	90	120	150	180
S_1	114.12a	185.22a	226.59a	175.85a
S_2	97.36b	146.72b	165.48b	143.63b
S_3	88.65c	119.89c	145.13b	117.69c
S_4	96.93b	147.01b	165.44b	143.12b
LSD (0.05)	6.23	14.64	23.06	21.70
Cutting (C)	-	-	-	-
C_0	100.25	151.51	177.96	146.64
C_1	98.27	147.91	173.36	143.50
LSD (0.05)	NS	NS	NS	NS
Interaction (S×C)	-	-	-	-
S_1C_0	115.49a	187.64a	229.61a	178.26a
S_1C_1	112.75a	182.81a	223.58a	173.44ab
S_2C_0	98.29b	148.68b	168.29b	145.67bc
S_2C_1	96.43b	144.76b	162.67b	141.59c
S_3C_0	89.72bc	122.53c	147.54b	119.12c
S_3C_1	87.58c	117.26c	142.73b	116.26c
S_4C_0	97.51b	147.19b	166.40b	143.52bc
S_4C_1	96.35bc	146.83b	164.48b	142.73bc
LSD (0.05)	8.820	20.71	32.62	30.69

Table 3. Effect of row spacing along with number of row of intercrops, leaf clipping of sugarcane and their interaction on the leaf area index of sugarcane

Treatment	Leaf area index at different DATs			
(S)	90	180	270	360
S_1	0.33c	2.02c	7.39c	5.19c
S_2	0.40a	2.25a	7.66a	5.78a
S_3	0.38b	2.08b	7.50b	5.60b
S_4	0.38b	2.25a	7.65a	5.72a
LSD (0.05)	0.018	0.058	0.101	0.082
Cutting (C)	-	-	-	-
C_0	0.38	2.19	7.60	5.61
C_1	0.37	2.11	7.51	5.54
LSD (0.05)	NS	NS	NS	NS
Interaction (S×C)	-	-	-	-
S_1C_0	0.34d	2.03de	7.41b	5.21e
S_1C_1	0.33d	2.01e	7.38b	5.17e
S_2C_0	0.41a	2.32a	7.71a	5.81a
S_2C_1	0.40ab	2.19bc	7.62a	5.75a-c
S_3C_0	0.39a-c	2.11cd	7.59a	5.64cd
S_3C_1	0.38bc	2.06de	7.42a	5.56d
S_4C_0	0.39a-c	2.31a	7.69a	5.77ab
S_4C_1	0.37c	2.20b	7.61a	5.68bc
LSD (0.05)	0.026	0.082	0.142	0.116

Table 4. Effect of row spacing along with number of row of intercrops, leaf clipping of sugarcane and their interaction on the total dry matter of sugarcane

Treatment	Total dry matter (kg m^{-2}) at different days after transplanting			
(S)	90	180	270	360
S_1	0.15c	1.33c	3.20b	4.05c
S_2	0.19a	1.78a	3.90a	4.91a
S_3	0.17b	1.55b	3.84a	4.77b
S_4	0.18ab	1.77a	3.87a	3.85d
LSD (0.05)	0.018	0.082	0.082	0.116
Cutting (C)	-	-	-	-
C_0	0.18	1.65	3.75	4.44
C_1	0.17	1.57	3.66	4.35
LSD (0.05)	NS	NS	NS	NS
Interaction (S×C)	-	-	-	-
S_1C_0	0.16cd	1.37c	3.24d	4.09c
S_1C_1	0.15d	1.29c	3.17d	4.02c
S_2C_0	0.20a	1.83a	3.96a	4.96a
S_2C_1	0.19ab	1.74a	3.84bc	4.87ab
S_3C_0	0.18a-c	1.59b	3.87a-c	4.78b
S_3C_1	0.17b-d	1.52b	3.82c	4.76
S_4C_0	0.19ab	1.81a	3.94ab	3.93cd
S_4C_1	0.18a-c	1.73a	3.81c	3.78d
LSD (0.05)	0.025	0.116	0.1162	0.164

Table 5. Effect of row spacing along with number of row of intercrops, leaf clipping of sugarcane and their interaction on the millable cane, stalk height and stalk diameter of sugarcane

Treatment (S)	Number of millable cane ($10^3 ha^{-1}$)	Stalk height (m)	Stalk diameter (cm)	Cane yield (t ha^{-1})
S_1	98.31a	2.44c	2.35c	80.60b
S_2	90.39ab	2.54b	2.41b	88.14a
S_3	85.29b	2.65a	2.48a	84.17ab
S_4	89.95ab	2.54 b	2.42b	87.67a
LSD (0.05)	11.82	0.018	0.058	6.03
Cutting (C)	-	-	-	-
C_0	91.83	2.57	2.43	85.91
C_1	90.13	2.51	2.40	84.37
LSD (0.05)	NS	NS	NS	NS
Interaction (S×C)	-	-	-	-
S_1C_0	99.37	2.47 e	2.37cd	81.37ab
S_1C_1	97.25	2.42f	2.34d	79.82b
S_2C_0	91.46	2.58c	2.43a-c	89.06a
S_2C_1	89.31	2.51d	2.40b-d	87.21ab
S_3C_0	85.74	2.68a	2.51a	84.96ab
S_3C_1	84.83	2.62b	2.46ab	83.38ab
S_4C_0	90.76	2.57c	2.43a-c	88.26ab
S_4C_1	89.14	2.52d	2.41b-d	87.08ab
LSD (0.05)	-	0.025	0.082	8.52

Similar result was found by Islam and Islam (2016) in where thehighest plant height 4.29 m was in RRS of 120 cm with 3 rows of potato followed by 3 rows of mungbean cultivation with sugarcane non leaf cutting.

The number of tiller was affected significantly by RRS under sequential intercropping of lentil-sesame. Tiller number in sugarcane increased gradually up to 150 DAT and then decreased in all treatments (Table 2). The highest number of tiller was observed under lower spacing. In S_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame) the number of tillers were found 114.12 × 10^3ha^{-1}, 185.22 × 10^3ha^{-1}, 226.59 × 10^3ha^{-1} and 175.85 × 10^3ha^{-1} at 90, 120, 150 and 180 DATs, respectively (Table 2). With increased spacing, the tiller production was decreased. The lowest number of tillers were observed 88.65 × 10^3, 119.89 × 10^3, 145.13 × 10^3 and 117.69 × 10^3ha^{-1} at 90, 120, 150 and 180 DATs respectively in S_3 (sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame) treatment.The effect of leaf cutting of sugarcane on number of tiller production was statistically insignificant. The interaction effects of RRS and LC or NLC of sugarcane on tiller production was significant. The highest number of tiller was produced in S_1C_0 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame with NLC) and the lowest tiller production was observed in S_3C_1 (sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with LC) (Table 2). The present results are more or less similar with Islam and Islam (2016) who reported that the highest tiller 247.75 × 10^3ha^{-1} in RRS of 80 cm with 1 rows of potato followed by 1 rows of mungbean with NLC cultivation. Hossain et al. (2003) reported that intercropping of sugarcane potato followed by sesame and tillers were found 182.5× 10^3ha^{-1} in paired row system.

The leaf area index was affected significantly by RRS under sequential intercropping of lentil-sesame and LAI of sugarcane increased gradually up to 270 DAT and then decreased in all treatments (Table 3). The highest LAI (0.40, 2.25, 7.66 and 5.78) was observed in S_2 (sugarcane RRS 100 cm + 2 rows of lentil-2 rows of sesame), at 90, 180, 270 and 360 DATs, respectively but the lowest were 0.33, 2.02, 7.39 and 5.19 at 90, 180, 270 and 360 DATs, respectively but the lowest were 0.33, 2.02, 7.39 and 5.19 at 90, 180, 270 and 360 DATs respectively in S_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame) (Table 3).The effect of leaf cutting of sugarcane on LAI was statistically insignificant (Table 3). The interaction effects of RRS and LC or NLC of sugarcane on LAI showed the significantly highest LAI was produced in S_2C_0 (sugarcane RRS 100 cm + 2 rows of lentil-2 rows of sesame with NLC) and the lowest one was observed in S_1C_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame with LC) treatment (Table 3). The present result agrees to earlier report by Islam and Islam (2016). They stated that the highest LAI 7.88 was found in RRS of 80 cm with 1 rows of potato followed by 1 rows of mungbean cultivation with non leaf cutting.

Effects of RRS on total dry matter were significantly with sequential intercropping of lentil-sesame (Table 4). The highest total dry matters 0.19 kg m^{-2}, 1.78 kg m^{-2}, 3.90 kg m^{-2} and 4.91 kg m^{-2} were found in S_2 (RRS 100 cm with 2 rows of lentil followed by 2 rows of sesame) at 90, 180, 270 and 360 DATs, respectively but the lowest was observed in S_1 (RRS spacing 80 cm with 1 R lentil-1 R sesame) treatment. Leaf cutting and non leaf cutting of sugarcane showed insignificant effect on total dry matter production. The interaction effects of RRS to LC or NLC of sugarcane on total dry matter was significantly the highest was produced in S_2C_0 (sugarcane RRS 100 cm + 2 rows of lentil-2 rows of sesame with NLC) and the lowest was observed in S_1C_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame with LC) (Table 4). Islam and Islam 2016 reported that the highest total dry matter 5.19 kg m^{-2} was found in RRS of 100 cm with 2 rows of potato followed by 2 rows of mungbean cultivation with non leaf cutting.

Effect of different row spacing, intercropped, leaf clipping of sugarcane and their interaction on the number of millable cane, stalk height stalk diameter and cane yield of sugarcane: The number of millable cane production varied significantly with varying RRS in sugarcane. Data revealed that the highest number of millable cane was (91.31×10^3 ha^{-1}) recorded in S_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame) followed by S_2 (sugarcane RRS 100 cm + 2 rows of lentil-2 rows of sesame) treatment. The lowest number of millable cane was observed (85.29×10^3 ha^{-1}) in S_3 (sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame) treatment. The effect of leaf cutting of sugarcane on number of millable cane was statistically insignificant. The interaction effects of RRS and LC or NLC of sugarcane on millable cane production was not significantly different among the treatments. The number of millable cane ranged in 84.83 to 99.37 (Table 5). Similar result was found by Islamet al. (2017). They found that millable cane higher in sole sugarcane than sugarbeet intercropping. Islam and Islam (2016) reported that the highest millable cane 105.3010^3 ha^{-1} observed in RRS of 100 cm with 1 rows of potato followed by 1 rows of mungbean cultivation with non leaf cutting.

The data on stalk height varied significantly with varying RRS in sugarcane and. revealed the highest stalk height 2.65 m in S_3 (sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame) treatment (Table 5). The lowest stalk height was observed in 2.44 m in S_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame) treatment. The effect of leaf cutting of sugarcane on stalk height was statistically insignificant. The interaction effects of RRS and LC or NLC of sugarcane on stalk height was significant and the highest stalk height (2.68 m) was obtained in S_3C_0(sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with NLC) treatment. The lowest stalk height (2.42 m) was observed in S_1C_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame with LC) treatment (Table 5). Rahman et al. (2012) reported that paired row cane with potato followed by mungbean produced 2.72 m stalk height.

The stalk diameter of the cane is another important yield component of sugarcane. Stalk diameter in sugarcane was affected significantly by RRS under sequential intercropping of lentil-sesame (Table 5). The highest stalk diameter was observed under higher spacing with the treatment S_3 (sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame). The lowest stalk diameter was 2.35 cm in S_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame.The effect of leaf cutting of sugarcane on stalk diameter was statistically insignificant. The interaction effects of RRS and LC or NLC of sugarcane on stalk diameter was significantly the highest (2.51 cm) was obtained in S_3C_0(sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with NLC) and the lowest (2.34 cm) was observed in S_1C_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame with LC) treatment (Table 5). The stalk diameter was increased with increased spacing. Similar result was found by Islam and Islam (2016). They found that highest stalk diameter 2.56 cm in RRS of 120 cm with 3 rows of potato followed by 3 rows of mungbean cultivation with non leaf cutting.

The data on cane yield in sugarcane was affected significantly by RRS under successive intercropping of lentil-sesame (Table 5). The highest cane yield 88.14 t ha^{-1} was observed in S_2 (sugarcane RRS 100 cm + 2 rows of lentil-2 rows of sesame) treatment but the lowest was 80.60 t ha^{-1} in S_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame) treatment (Table 5). The interaction effects of RRS and LC or NLC of sugarcane on cane yield was significant and the highest (89.06 t ha^{-1}) and the lowest (83.38 t ha^{-1}) cane yield was obtained in S_2C_0(sugarcane RRS 100 cm + 2 rows of lentil-2 rows of sesame with NLC) and S_1C_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame with LC) treatments (Table 5). Similar result was reported by Hossain et al. (2003) who reported intercropping of sugarcane with onion and potato followed by sesame in paired row system.

Effect of different row spacing, intercropped, leaf clipping of sugarcane and their interaction on the brix (%), pol % cane, purity (%) and Recovery (%) of sugarcane: Brix (%), pol % cane, purity (%) and recovery (%) were not affected by RRS under sequential intercropping of lentil-sesame in the season. Similarly leaf cutting and non cutting had no significant effect on sugarcane on Brix (%), pol % cane, purity (%) and recovery (%) were also insignificant. Al-Azad et al. (2009) reported that paired row cane with five winter vegetables crops and oil seed namely potato, onion, garlic, mustard and sesame followed by mungbean did not significantly affect Brix (%). Similar reports are given by Islam et al. (2008) and Rasool et al. (2011). The present results are agreed to these reports.

First intercrop of Lentil yield: Yield of first intercrop lentil was found significant effects in all the treatment combination. It is observed in Table 7 that significantly highest lentil yield was obtained (1.25 t ha^{-1}) in S_5 (sole lentil). The lowest lentil yield (0.45 t ha^{-1}) was in S_1C_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame with LC) treatment (Table 7).

Table 7. Interaction effects of RRS and LC or NLC on cane yield, intercrop yield, equivalent cane yield of intercrops and adjusted cane yield of sugarcane under sequential intercropping of lentil-sesame

Treatment	Cane yield (t ha^{-1})	Yield of intercrops (t ha^{-1})		Equivalent cane yield of intercrops (t ha^{-1})	Adjusted cane yield (t ha^{-1})
		lentil (1st)	Sesame (2nd)		
S_1C_0	81.37ab	0.47d	0.12f	18.01	99.38
S_1C_1	79.82b	0.45d	0.17ef	18.80	98.62
S_2C_0	89.06a	0.58c	0.21de	23.97	113.03
S_2C_1	87.21ab	0.56c	0.35c	27.31	114.52
S_3C_0	84.96ab	0.69b	0.29cd	29.66	114.62
S_3C_1	83.38ab	0.68b	0.65b	39.53	122.91
S_4C_0	88.26ab	-	-	-	88.26
S_4C_1	87.08ab	-	-	-	87.08
S_5	-	1.25a	-	38.88	38.88
S_6	-	-	1.13a	31.95	31.95
LSD (0.05)	8.52	0.082	0.08	-	-

Second intercrop of sesame yield: Sesame yield was significantly influenced by RRS with LC or NLC under sequential intercropping of lentil-sesame. The results on sesame grain yield have been presented in Table 7. The highest sesame yield (1.13 t ha^{-1}) was obtained in S_6 (sole sesame) followed by the 2nd intercropping sesame grain yield (0.65 t ha^{-1}) obtained in S_3C_1(sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with LC) during the season (Table 7).

Equivalent cane yield of intercrops: The highest equivalent cane yield of intercrops was obtained in S_3C_1(sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with LC) (39.53 t ha^{-1}) followed by (38.88 t ha^{-1}) S_5 (sole lentil) treatment (Table 7).

Adjusted cane yield: Adjusted cane yield of 122.91 t ha^{-1} was recorded from S_3C_1(sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with LC). The lowest total adjusted cane yield was obtained in 31.95 t ha^{-1} in S_6 (sole sesame) treatment (Table 7).

Gross return: The economic analysis of the experiment has been shown in the Table 8. Under intercropping condition it is seen that the S_3C_1(sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with LC) was the highest gross return (Tk. 217333.60 ha^{-1}) and the lowest gross return was obtained in S_6 (sole sesame) (Tk. 56495.58 ha^{-1}) in the cropping year (Table 8).

Total production cost: Under intercropping condition, among the different treatments the highest total production cost of cultivation (Tk. 86237.12 ha^{-1}) was found in S_1C_1 (sugarcane RRS 80 cm + 1 R lentil-1 R sesame with LC). The lowest total production cost (Tk. 23765.65 ha^{-1}) was obtained in S_6 (sole sesame) treatment (Table 8).

Gross margin: Under intercropped condition, the highest gross margin income of Tk. 138008.77 ha^{-1} was obtained from the S_3C_1(sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with LC). The lowest gross margin income (Tk. 32729.93 ha^{-1}) was obtained in S_6 (sole sesame) during the year (Table 8).

Benefit cost ratio: Interaction effects of RRS to LC or NLC on benefit cost ratio (BCR) were presented in

Table 8. Interaction effects of RRS and LC or NLC on gross return, total production cost, gross margin, BCR and LER of sugarcane under sequential intercropping of lentil - sesame

Treatment	Gross return (Tk. ha^{-1})	Total production cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	Benefit cost ratio (BCR)	Land equivalent ratio (LER)
S_1C_0	175728.68	81085.54	94643.14	2.16	1.40
S_1C_1	174384.81	86237.12	88147.69	2.02	1.41
S_2C_0	199865.29	77001.29	122864.00	2.59	1.64
S_2C_1	202499.99	81328.57	121171.42	2.48	1.74
S_3C_0	202676.81	76215.64	126461.17	2.65	1.77
S_3C_1	217335.60	79326.83	138008.77	2.73	2.06
S_4C_0	155606.00	72523.25	83082.75	2.14	1.00
S_4C_1	153979.21	75726.35	78252.86	2.03	1.00
S_5	68749.56	26835.27	41914.29	2.56	1.00
S_6	56495.58	23765.65	32729.93	2.37	1.00

Table 8, the highest BCR was obtained (2.73) in S_3C_1(sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with LC) treatment (Table 8). Alam et al. (2000) reported that paired row cane with potato followed by mungbean had the highest BCR of 2.68. Al-Azad et al.(2009) reported that paired row cane with potato followed bymungbean had 2.41 BCR. Islam and Islam (2018) reported that the highest benefit cost ratio (BCR) was 3.49 in sugarcane RRS 120 cm + 3 R potatofollowed by 3 R mungbeanwith sugarcane leaf cutting.

Land equivalent ratio (LER): LER value of different combinations (sugarcane with intercrop) indicated that the treatment S_3C_1(sugarcane RRS 120 cm + 3 rows of lentil-3 rows of sesame with LC) showed the highest LER of 2.06 and the lowest LER of 1.40 was from the S_1C_0(sugarcane RRS 80 cm + 1 R lentil-1 R sesame with NLC) (Table 8). The LER value greater than 1.0 indicated the yield advantages of the component crops in intercropping system compared to their sole cropping. Therefore, in the present experiment, sugarcane RRS 120 cm + 3 R lentil - 3 R sesame with LC were proved to be highly profitable over other intercrop combinations. Islam and Islam (2018) reported that the highest LER was 2.33 in sugarcane RRS 120 cm + 3 R potatofollowed by 3 R mungbeanwith sugarcane leaf cutting.

CONCLUSION

Finally, on the basis of results it may be concluded that sugarcane transplanted at row to row spacing 120 cm under leaf cutting with 3 rows of lentil followed by 3 rows of sesame can be grown as intercrops for higher economic return and might be recommended for the farmers' level in High Ganges River Flood Plain soils under AEZ 11 of Bangladesh.

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