Economic assessment of maize (*Zea mays* L.) – Spinach (*Basella alba* L.) intercropping system for improving the livelihood of smallholders' in South-Asia

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The study was undertaken at Regional Agricultural Research Station of Bangladesh Agricultural Research Institute, Ishurdi, Pabna, Bangladesh in consecutive two years of 2015 and 2016 for evaluating the performance of maize and Indian spinach intercropping (MIS) under different row spacing for higher profitability through economic assessment. Five different cropping systems viz., T_1: hybrid maize normal row along with one row of spinach, T_2: hybrid maize paired row along with one row of spinach, T_3: hybrid maize paired row along with two rows of spinach, T_4: hybrid maize paired row along with three rows of spinach and T_5: sole maize were included in this experiment. The performance of the component crops was evaluated regarding total grain and vegetable yield, competitive functions, and economic returns. The results indicate that yield and yield contributing characters of maize were not significantly affected by the intercrop of spinach at different ratios. Maize paired row along with three rows of spinach (IS) (T_4) combination had higher maize equivalent yield (11.06 t ha^{-1}), gross return (US\$ 1,499 ha^{-1}), gross margin (US\$ 564 ha^{-1}) and benefit-cost ratio (*BCR*) (2.07) than others treatments. This intercropping system also recorded higher land equivalent ratio, monetary advantage index, land equivalent coefficient, income equivalent ratio and area time equivalent ratio of 1.24, US\$ 2,434 ha^{-1}, 0.30, 1.24 and 1.18, respectively. Hence, this cropping system may adopt in the smallholders' for getting maximum benefits in prevailing climate change.

Keywords: competitive functions, economics, intercropping, spinach, maize

1   Introduction

Intercropping is a common practice in small-scale farming systems in many parts of the world. The benefits of intercropping are to increase the cropping intensity and productivity of various plants constituents, yield stability, economic return, social benefits, pest control and effective fertilizer use. It also reduces the economic risk and market fluctuation resulting from growing a single crop that is more prone to natural hazards and helps the farmers efficient land utilization having more than one crop produced per unit area.

Besides, it ensures the utilization of sunlight both tall and short plant components for their potential complementarity for crop production (Gebru, 2015). The world's population in 2050 will reach 9.1 billion, about 34% higher than today mainly in developing countries. To feed this larger, more urban and richer population, food production must increase by 70%, and it can be achieved if the necessary investment and policies are undertaken to agricultural production (FAO, 2009). In that case, adopting the intercropping system could be increased food production in limited land, and

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though all intercrops produced higher productivity, the farmers could better use the appropriate population of component crops in intercropping systems to maximize the yield of both crops and total productivity benefits in prevailing climate change (Islam et al., 2018; Islam et al., 2016).

Indian spinach (*Basella alba* L.) is one of the important summer vegetables in the sub-tropical region. It is a popular leafy vegetable and can be commercially cultivated for fulfilling the nutritional requirements of the growing human population. Since the plant is hardy and does not require many agronomic practices, it can be easily cultivated than any other leafy vegetable and will be an ideal substitute for resource-poor farmers in the developing region. It can grow magnificently in diverse soil conditions (i.e., from acid to alkaline conditions and in degraded and nutrient-poor soils). The fresh leaves and stems of Basella species are rich in protein, vitamin A, vitamin C, Ca, Fe, Mg, P, K, Na, Zn, Cu, Mn and Se and also have essential amino acids and flavones (Sing et al., 2018).

On the other hand, maize (*Zea mays* L.) is considered as an economically important cereal crop, a major ingredient for food, feed, and other products. It is considered an important role after rice and wheat in the agriculture sector and macro-economy of the agrarian countries. In the globe, approximately total 1,115 million metric tons maize is produced per year (FAO, 2019) while Bangladesh has been grown about 3.89 million tons occupying around 0.44 million hectares land during 2017–2018, growing both in winter (Rabi) and summer (Kharif-1) season (Krishi Diary, 2019). The area and production of this crop have been expanding rapidly due to introduce of high yielding varieties. It is one such an unbranched and erect cereal crop that provides the opportunity for inclusion of intercrops because of the wide row spacing (Sravan & Murthy, 2014). So, maize-based intercropping is found profitable and suitable in many countries due to high economic returns. Indian spinach, which can be grown in the intermediate period of maize without hampering the main yield, can be cultivated with maize because it grows well in partial shading and absorbs nutrients from the upper layer of the soil that leads to less competition with deep-rooted maize. There is an ample research scope to determine the profitability of maize-indian spinach intercropping (MIS) through different competition functions. In view of this, an experiment was conducted to evaluate the performance of MSI combinations under different row spacing for higher profitability through economic assessment.

2 Material and methods

2.1 Experimental site and Season

The experiment was conducted at Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Ishurdi, Pabna during two consecutive years, 2014 and 2015 (Kharif-1 season). The experimental site was situated at approximately 24° 07' N and 89° 04' E with an altitude of 13.72 m above mean sea level and it belongs to the Agro-ecological Zone 11 (High Ganges River Flood plain) in Bangladesh (FRG, 2012). The initial soil sample (0–15 cm depth) was analyzed at the Soil Resources Development Institute (SRDI), Rajshahi, Bangladesh. The soil of the experimental site was medium-high and clay loam texture having 1.22% organic matter, pH 7.40, 0.07% total nitrogen (N), 0.36 meq 100 g^{-1} soil potassium (K), 10.6 ppm phosphorus (P), 7.2 ppm sulfur (S) and 1.13 ppm zinc (Zn).

The meteorological data were collected from Bangladesh Sugar Crops Research Institute (BSCRI) far away 400 m from our experimental field. The climate of the experimental site was subtropical. Daily rainfall, maximum temperature and minimum temperature during the study period (March–July 2015 and 2016) are presented in Figure 1. The weather of the experimental site is hot sub-humid with total rainfall of 886 mm in 2015 and 636 mm in 2016 during crop season, frequent rainfall occurred from June to July in both years. The average daily minimum and maximum temperatures were 25 °C and 30 °C in the first year and 25 °C and 31 °C in the second year during the growing period. However, the differences in minimum
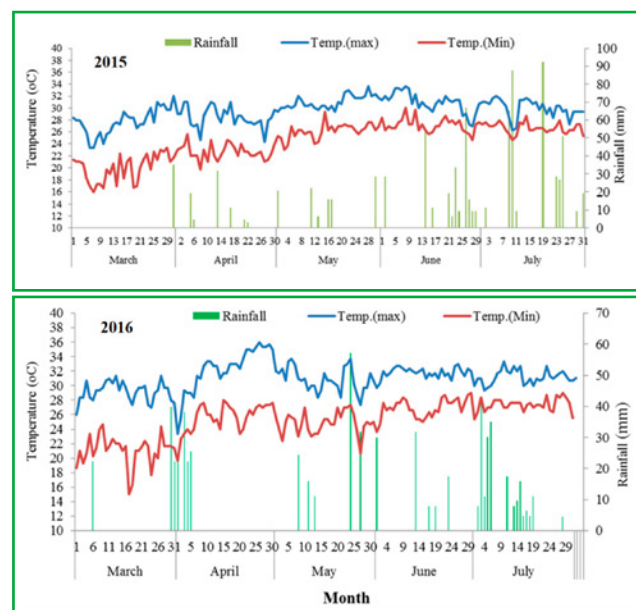
Figure 1 Daily total rainfall and average maximum and minimum temperatures during the cropping season in both years of experimentation
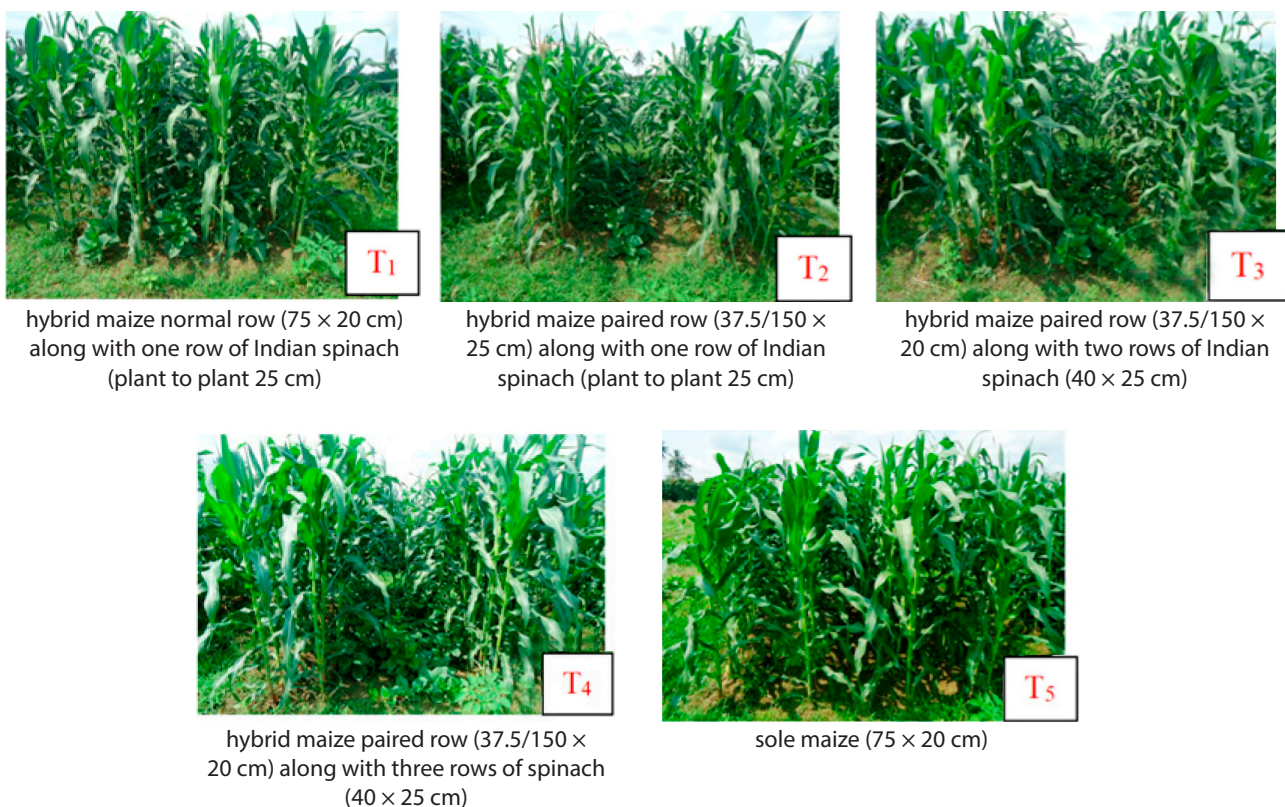
and maximum temperatures were slightly less in the first season than the second season.

2.2 Experimental design and treatments

The experiment was laid out in a randomized complete block design with three replications to evaluate the performance of maize and spinach intercropping under different row spacing for higher profitability through economic assessment and competition functions. The unit plot size was 12 m² (3 × 4 m). In the study, maize was the main crop and Indian spinach was intercrop. The experiment consisted of five treatments viz., T_1: hybrid maize normal row (75 × 20 cm) along with one row of IS (plant to plant 25 cm), T_2: hybrid maize paired row (37.5/150 × 25 cm) along with one row of Indian spinach (plant to plant 25 cm), T_3: hybrid maize paired row (37.5/150 × 20 cm) along with two rows of Indian spinach (40 × 25 cm), T_4: hybrid maize paired row (37.5/150 × 20 cm) along with three rows of spinach (40 × 25 cm) and T_5: sole maize (75 × 20 cm). Indian spinach was intercropped between single and paired row of maize. It is mentioned that between the maize paired kept 37.5 cm space, and space between the two pair maize were kept 75 cm space. Field appeance of all treatments is showing in Figure 2.

2.3 Crop management

Maize (BARI Hybrid Bhutta-9) and Indian spinach (BARI Puishak-2) were selected as test crops. The variety of both crops are chosen as they are suitable and high yielding for growing in the summer season. Seeds were collected from Bangladesh Agricultural Research Institute, Bangladesh. The crops (both maize and Indian spinach) were sown on 20 March during 2015 and 2016 with North-South row orientation. The seed rate was used @ 25 kg ha⁻¹ and 1 kg ha⁻¹, respectively in maize and Indial spenich. Fertilizers were applied at the rate of 250–75–110–40–4–1 kg ha⁻¹ of N, P, K, S, Zn and B, respectively for sole maize, and extra 40 kg ha⁻¹ N for intercrop as urea, triple superphosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid (FRG, 2012). One-third of urea and all other fertilizers were applied as basal and the remaining of two-thirds of urea was top-dressed in two equal splits at 20 and 40 days after emergence. Two hand weeding was done before top-dressed urea. A post sowing irrigation was done for proper germination and seedling establishment, and thereafter, three irrigations were applied at 20, 40 and 60 days after emergence. The infestation of insects and disease was less in maize, so no pesticides were applied, but rovral 50 WP @ 2 g liter⁻¹ of water was sprayed at 50 DAE to control Cercospora leaf spot in spinach. The vine of spinach was harvested for

hybrid maize normal row (75 × 20 cm) along with one row of Indian spinach (plant to plant 25 cm)

hybrid maize paired row (37.5/150 × 25 cm) along with one row of Indian spinach (plant to plant 25 cm)

hybrid maize paired row (37.5/150 × 20 cm) along with two rows of Indian spinach (40 × 25 cm)

hybrid maize paired row (37.5/150 × 20 cm) along with three rows of spinach (40 × 25 cm)

sole maize (75 × 20 cm)

Figure 2   Crop performance of different treatments at vegetative stage

vegetable four times from 25 May to 05 July in both years. Maize was harvested on 8 July and 10 July 2015 and 2016 respectively.

2.4 Assesment of economic indices

The economic analysis was done considering total variable costs (TVC) and gross returns (GR). The variable costs included human labour, machinery rent and production inputs (seed, fertilizer, pesticides). Gross returns were calculated by multiplying the economic yield of crops by the price at harvest time. Gross margin (GM) was calculated as the difference between GR and TVC (GM = GR - TVC). Various competition functions such as maize equivalent yield (*MEY*), land equivalent ratio (*LER*), land equivalent co-efficient (*LEC*), monetary advantage (*MA*), area-time equivalent ratio (*ATER*), income equivalent ratio (*IER*) and per day return (*PDR*) were worked out to find out the benefit and the effect of competition between the treatments. The competition functions were calculated by using the following formula:

2.4.1 Maize equivalent yield

Maize equivalent yield was calculated by converting the yield of spinach into the yield of maize-based on prevailing market price using the formula of Anjaneyulu et al. (1982):

$$MEY = yield\ of\ maize\ (\text{t ha}^{-1}) + $$
$$+ \frac{yield\ of\ intercrop\ indian\ spinach\ (\text{US \$ ha}^{-1}) \times price\ of\ Indian\ spinach\ (\text{US\$ kg}^{-1})}{price\ of\ maize\ (\text{US\$ kg}^{-1})}$$

2.4.2 Land equivalent ratio

LER indicates the efficiency of intercropping for using the resources of the environment compared with mono-cropping (Mead & Willey, 1980). When the *LER* is greater than one that indicates the advantages of intercropping which favours the growth and yield of the species. On the other hand, when *LER* is lower than one that indicates the opposite view of intercropping performance (Ofori & Stern, 1987). Land equivalent ratio (*LER*) was computed according to Shaner et al. (1982) as follows:

$$LER = \frac{yield\ of\ sole\ maize}{yield\ of\ intercrop\ maize} + $$
$$+ \frac{yield\ of\ sole\ indian\ spinach}{yield\ of\ intercrop\ indian\ spinach}$$

2.4.3 Land equivalent coefficient

The land equivalent coefficient was described by Adetiloye and Ezedinma (1983):

$$LEC = \frac{yield\ of\ sole\ maize}{yield\ of\ intercrop\ maize} \times $$
$$\times \frac{yield\ of\ sole\ Indian\ spinach}{yield\ of\ intercrop\ Indian\ spinach}$$

2.4.4 Monetary advantage index

It is also calculated to evaluate some economics of intercropping as compared to sole cropping. The monetary advantage index was calculated as described by Gosh (2004):

$$MAI = \frac{value\ of\ combined\ intercrops \times (LER-1)}{LER}$$

2.4.5 Area time equivalent ratio

ATER provides a more realistic comparison of the yield advantage of intercropping over mono-cropping in terms of time taken by component crops in the intercropping systems than *LER*. Area-time equivalent ratio was computed according to Hiebsch (1980):

$$ATER = \frac{(RY_a \times t_a) + (RY_b \times t_b)}{T}$$

where:
RY – refers to the relative yield of the main crop or intercrop; *RYa* – intercrop yield of maize with associated crop/pure stand yield of maize; *RYb* – intercrop yield of associated crop/pure stand yield of the associated crop; *t* – refers to duration (days) for main crop or intercrop; *T* – refers to the duration of intercropping system (days); <u>a</u> refers to main crop and *b* – refers to intercrops

2.4.6 Income equivalent ratio

IER is similar to *LER* but the yield is measured in terms of net income rather than plant product productivity. *IER* for intercrops may vary in different years due to the fluctuation of crop prices. A market price or gross incomes (GI) obtained from intercropping a hectare of land was used to calculate the *IER*. It was calculated by the following formula developed by Ghaffarzadeh (1997):

$$IER = \frac{I_{ab}}{I_{aa}} + \frac{I_{ba}}{I_{bb}}$$

where:
I_{aa} – gross income of component *a* in pure stand; I_{bb} – gross income of component *b* in pure stand; I_{ab} – gross

income of component a in mixed stand with b; I_{ba} – gross income of component b in mixed stand with a

2.4.7 Benefit-cost ratio

The benefit-cost analysis was performed considering the prevailing price of maize and spinach at the harvesting period in the local market. Benefit-cost ratio (BCR) was computed by the following formula (Hossain et al., 2015):

$$BCR = \frac{gross\ return}{total\ variable\ \cos t}$$

2.4.8 Per day return

Per day return (PDR) were calculated by using the following formula (Debasenapathy et al., 2008):

$$PDR = \frac{net\ return\ (US\$\ ha^{-1})}{cropping\ period\ (days)}$$

2.5 Data processing and analysis

Data on yield and other parameters of both the crops were recorded at the time of harvest in manually. For maize, ten plants were randomly selected in each plot and tagged for the data collection on plant height, number of cobs per plant, number of grains per cob, cob length, grain yield and straw yield. The cobs were cleaned, dried and then it was shelled by a maize hand sheller for separation of grains. The threshed grains of maize were dried under sun and maintained 12% moisture content using frequent observation. In case of spinach, fresh weight (vegetable) was taken for calculating yield. Yields of both the crops were taken from the whole plot basis and converted into ton per hectare. Collected data were analyzed (combined analysis) statistically using 'R' software (R Core Team, 2016) and mean separation was

done as per least significant difference (LSD) at 5% level of significance. M&M should be: Accurate, Brief, Clear to allow reproduction of experiment.

3 Results and discussion

3.1 Yield and yield contributing characters of maize

Yield and yield attributes of maize in MIS system were presented in Table 1. A result has obtained that yield and yield contributing traits of maize under different treatment combinations intercropped were not statistically significant. However, the agronomic performance of the sole maize was a little bit better than that of other treatments. Plant height ranged from 211–221 cm, cobs length fluctuated from 17.67–18.33 cm, and grains cob-1 vacillated from 403–429, 100-grain weight ranged from 29–31 g in different treatments. Stover yield in different treatments ranged from 6.53–7.08 t ha^{-1} (Table 1). The grain yield of maize in intercropped combinations varied from 5.26–5.72 t ha^{-1}. From pooled data, it was clear that grain yield was decreased 1.38%, 4.48%, 9.31% and 8.79% in T_1, T_2, T_3 and T_4, respectively over the sole stand (Figure 2 and 3). Similar results were found by Sarker et al. (2013) who observed that the yield of hybrid maize was not influenced by intercropping of hybrid maize with short duration vegetables.

3.2 Performance of Indian spinach

Vegetable yield was significantly influenced by MIS system (Figure 2 and 3). The vegetable yield was higher at hybrid maize paired row along with three rows of spinach (8.65 t ha^{-1}) followed by hybrid maize paired row along with two rows of spinach (8.13 t ha^{-1}) and the lowest vegetable yield (4.09 t ha^{-1}) were obtained in maize paired row along with one row of spinach (T_2). The vegetable

Table 1 Stover yield and yield contributing characters of maize as affected by intercropping of hybrid maize and Indian spinach (Pooled analysis of both years)

Treatment	Plant height (cm)	Cobs plant^{-1} (no.)	Cob length (cm)	Cob diameter (cm)	Grains cob^{-1} (no.)	100-grain weight (g)	Stover yield (t ha^{-1})
T_1	215 ±7.97*	1.17 ±0.07	17.83 ±0.58	4.43 ±0.06	429 ±22.09	30 ±0.53	6.64 ±0.05
T_2	221 ±8.81	1.17 ±0.07	18.33 ±0.62	4.33 ±0.06	429 ±27.19	30 ±0.58	6.69 ±0.17
T_3	211 ±7.61	1.17 ±07	18.17 ±0.40	4.19 ±0.04	420 ±22.54	29 ±0.49	6.94 ±0.01
T_4	219 ±8.74	1.17 ±0.07	18.00 ±0.58	4.42 ±0.08	403 ±24.23	31 ±0.49	6.53 ±0.06
T_5	216 ±7.28	1.17 ±0.07	17.67 ±0.31	4.21 ±0.08	422 ±24.32	30 ±0.36	7.08 ±0.25
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS
CV (%)	3.48	0.61	4.30	8.30	6.44	3.19	9.87

LSD – least significant difference; CV – coefficient of variation; NS – not significant; * – indicate SE (±); T_1 – hybrid maize normal row (MNR) (75 × 20 cm) along with one row Indian spinach (ISP) (plant to plant 25 cm); T_2 – hybrid maize paired row (MPR) (37.5 cm/150 × 25 cm) along with one row Indian spinach (plant to plant 25 cm); T_3 – hybrid maize paired row (37.5 cm/150 × 20 cm) along with two row Indian spinach (40 × 25 cm); T_4 – hybrid maize paired row (37.5 cm/150 × 20 cm) along with three rows Indian spinach (40 × 25 cm); T_5 – sole maize (75 × 20 cm)
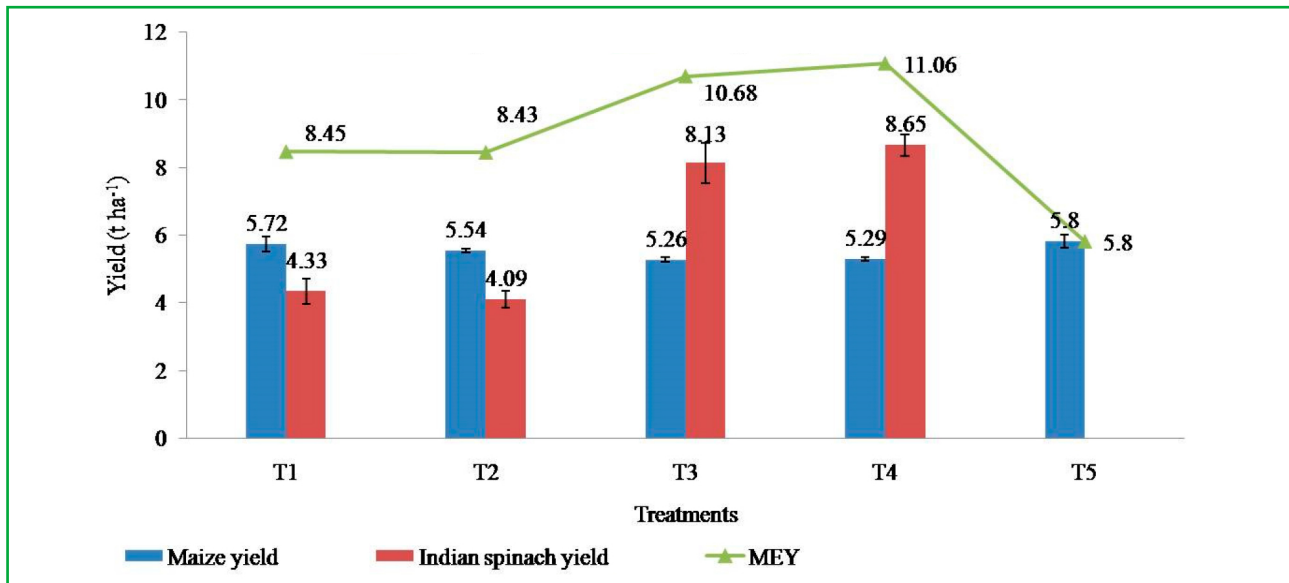
Figure 3 Comparison yield of maize and Indian spinach with maize equivalent yield in MIS system
treatments detailed in Table 1

yield was declined 100%, 112% and 6.44% in T_1, T_2 and T_3 respectively over T_4 treatment. Begum et al. (2017) were found the same results. Mian et al. (2011) showed that the yield of spinach is declined in intercropping of maize and spinach over the sole spinach.

3.3 Maize equivalent yield

Hybrid maize paired row along with three rows of spinach (T_4) gave the highest maize equivalent yield (11.06 t ha^{-1}), which was 90% higher than the sole crop of maize, followed by hybrid maize paired row along with two rows of spinach (T_3). Among the intercropping treatments, hybrid maize paired row along with a single row of spinach (T_2) gave the lowest *MEY* (8.43) that was 31% higher than the sole crop of maize (Figure 2 and 3). The maize equivalent yield differed significantly in order to high vegetable yield of spinach and less competition with maize. Kheroar and Patra (2013) reported that intercropping of maize and legume crops had increased the maize equivalent yield compared to sole maize. This

result agrees with the findings of Mian et al. (2011) and Rahaman et al. (2015) where they obtained maximum maize equivalent yield in maize paired row with spinach intercropping combination. Similar results are also reported by Rana et al. (2006).

3.4 Land equivalent ratio

The land equivalent ratio (*LER*) was used to evaluate the performance of an intercrop relative to the responding sole crop (Mead and Willey, 1980). All the intercropping combinations showed greater land equivalent ratio than monoculture due to high land-use efficiency of intercropping over the sole crop (Table 2). In intercropping, the maximum *LER* value (1.24) was obtained from hybrid maize paired row along with three rows spinach and the minimum *LER* value (1.12) in hybrid maize paired row along with one row Indian spinach. The results corroborate the findings of Alom et al. (2009). Islam et al. (2018) found that the combination of turmeric (100%) with 3 rows mung bean

Table 2 Land equivalent ratio (*LER*), monetary advantage index (MAI), land equivalent coefficient (*LEC*), income equivalent ratio (*IER*) and area time equivalent ratio (*ATER*) as affected by intercropping of hybrid maize and Indian spinach (average data of both years)

Treatments	*LER*	MAI	*LEC*	*IER*	*ATER*
T_1	1.14	1,678	0.16	1.15	1.11
T_2	1.12	1,706	0.15	1.11	1.09
T_3	1.22	2,304	0.28	1.22	1.16
T_4	1.24	2,434	0.30	1.24	1.18
T_5	1.00	–	–	1.00	–

treatments detailed in Table 1

(100%) in between turmeric lines intercropping gave the maximum *LER* value (2.12) that indicated 48–112% yield advantages.

3.5 Land equivalent coefficient

LEC was used for assessing the interaction and production potential of crop mixture. The highest land equivalent coefficient value (0.30) was recorded from hybrid maize paired row along with three rows of spinach and the lowest *LEC* value (0.16) was calculated in hybrid maize paired row along with one row of spinach (Table 2). Land equivalent co-efficient values are greater than 0.25 indicated yield advantages of intercropping reported by Kheroar and Patra (2013) or Parimaladevi (2019). The positive value of *LEC* indicates the intercropping system had the highest economic advantages whereas negative values showed an economic disadvantage (Parimaladevi, 2019). However, in the present study, all the treatments gave the positive values of *LEC* ranged from 0.15 to 0.30. This means that all the intercropping systems have economic advantages than sole stand.

3.6 Monetary advantage index

The higher MAI value indicated the more profitable cropping system (Dhima et al., 2007). The highest monetary advantage index (2,434) was calculated from hybrid maize paired row along with three rows of spinach which indicated that this intercropping system was highly beneficial as compared to other combinations. This result is line with the findings of Aasim et al. (2008) who reported that MAI is an indicator of the economic feasibility of intercropping systems as compared to sole cropping. The lowest monetary advantage index (1,678) was accounted for in hybrid maize normal row along with one row of spinach (Table 2). In this study, the positive monetary advantage values obtained from different cropping systems indicating a definite gain from intercropping over sole cropping (Muhammad et al., 1997). Higher MAI values were also found by Islam

et al. (2016) in turmeric sesame intercropping systems compared to their monoculture system.

3.7 Area time equivalent ratio

The area time equivalent ratio comprised the duration of the intercrops in intercropping systems in the field and assessed the crop yield per day basis. Hybrid maize paired row along with three rows of spinach recorded the highest area time equivalent ratio (1.18) followed by hybrid maize paired row along with two rows of spinach (1.16) indicating higher yield per day (Table 2). Kheroar and Patra (2013) obtained a similar trend towards increasing *ATER* with the increase in population density in the intercropping system. Mohan et al. (2005) also reported that the *ATER* was higher in maize + legume in 1 : 2 proportion than in 1 : 1 proportion. Khan et al. (2018) found similar results with garden pea and maize intercropping systems.

3.8 Income equivalent ratio

The highest *IER* (1.24) was obtained from hybrid maize paired row along with three rows of spinach which was followed by hybrid maize paired row along with two rows of spinach (1.22) that indicated an advantage from those intercropping system over pure stands in MIS combinations in terms of the use of natural resources for plant growth (Mead & Willey, 1980). The lowest *IER* (1.00) was accounted in sole hybrid maize. The *IER* of the system is 1.24 that meant 24% more income would be required as sole crops to produce the same income as intercropping. Income equivalent ratio of hybrid maize normal row along with one row of spinach and hybrid maize paired row along with two rows of spinach had 1.15, 1.22, respectively (Table 2). This result was similar to the findings of Bantie (2014).

3.9 Economic performance

The highest gross return (US$ 1,962 ha⁻¹) was obtained from hybrid maize paired row along with three rows of

Table 3   Economics of intercropping of hybrid maize and spinach (Mean data of both years)

Treatments	Gross return (US$ ha⁻¹)	Total cost (US$ ha⁻¹)	Gross margin (US$ ha⁻¹)	*BCR*	*PDR* (US$)
T₁	1,499	935	564	1.60	5.13
T₂	1,495	946	549	1.58	4.99
T₃	1,895	940	955	2.02	8.68
T₄	1,962	946	1016	2.07	9.23
T₅	1,029	887	142	1.16	1.29

treatments detailed in Table 1
rate: US$ 1 – BD Tk. 84 (28 September 2019); price, Urea – US$ 0.19 kg⁻¹, TSP – US$ 0.26 kg⁻¹, MoP – US$ 0.18 kg⁻¹, labour – US$ 4.73 eight hour⁻¹ head-1, maize – US$0.18 kg⁻¹ (non-seed) and seed– US$ 5.32 kg⁻¹, vegetable of Indian spinach – US$ 0.12 kg⁻¹

spinach (T_4) due to the higher vegetable yield of spinach and the lowest gross return (US$ 1,029 ha^{-1}) attained from sole maize (T_5). The gross margin was obtained from different intercropping treatments were appreciably higher than from sole maize. The gross margin followed a similar trend of gross return. The highest gross margin (US$ 1,016 ha^{-1}) was calculated from hybrid maize paired row along with three rows of spinach and the lowest in sole maize (US$ 142 ha^{-1}) (Table 3). Bharati et al. (2007) opined that maize-based intercropping created a higher net return than the sole crop of maize. The cost of production differed among the treatments. The lowest cost of production (US$ 887 ha^{-1}) was recorded from sole maize, and the cost of production of other treatments varied from US$ 935 ha^{-1} to US$ 946 ha^{-1}. It might be due to additional inputs and management requirements in the intercropping treatments. Cost and benefit analysis are an important tool for evaluating the economic feasibility of intercropping systems. The benefit-cost ratio was higher at hybrid maize paired row along with three rows of spinach (2.07) than other treatments. Similarly, the highest *PDR* (US$ 9.23) was gained from hybrid maize paired row along with three rows of spinach and the lowest *PDR* (US$ 1.29) was recorded from sole maize (Table 3). Rahaman et al. (2015) showed that maize paired row with spinach intercrop combination increased the benefit-cost ratio compared to the combination of other vegetables with paired row maize. Chaudhari (2018) and Hossain et al. (2015) also reported that maize with spinach intercropping gave higher monetary return and benefit: cost ratio than sole maize cropping.

4   Conclusions

Intercropping system could be improved the livelihood smallholder farmers through increase productivity with certain land area, and it contributes the national food security. In the present study, yield and yield contributing characters of maize were not affected by intercropping of Indian spinach with maize. Maize paired row along with three rows of Indian spinach intercropping combination had higher maize equivalent yield, land equivalent ratio, land equivalent coefficient, monetary advantage index, area time equivalent ratio, income equivalent ratio and economic return than other combination as well as their sole stand. So, this intercropping system might be recommended as a suitable cropping system for the smallholders' farmers to get maximum benefits.

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