

# Intercropping Short Duration Leafy Vegetables with Pumpkin in Subtropical Alluvial Soils of Bangladesh

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## Abstract

*Intercropping may allow increasing both the productivity and diversity of crop through efficient utilization of land in densely populated countries like Bangladesh where fertility of agricultural land is declining gradually. A field experiment was conducted at a recently developed alluvial soil in Bangladesh during 2015-16 and 2016-17 winter seasons to select suitable leafy vegetables intercropping with pumpkin for higher productivity, better land and time utilization and maximum economic return. Six leafy vegetables viz., coriander green, red amaranth, radish green, mustard green, jute green, and spinach were intercropped with pumpkin and compared with sole pumpkin using a randomised complete block design. Intercropping leafy vegetables with pumpkin did not reduce pumpkin yield but increased system productivity by 39-120% over sole cropped pumpkin. All the intercropping combinations performed better than sole pumpkin. However, the highest system yield (72.7 & 75.6 t ha<sup>-1</sup>), land equivalent ratio (1.74 & 1.75), area time equivalent ratio (1.20 & 1.16), net return (8001 & 8350 USD ha<sup>-1</sup>) and benefit cost ratio (10.3 & 10.7) were obtained in 2015-16 & 2016-17, respectively from pumpkin + spinach system indicating that this system might be suitable for higher crop productivity, better land and time utilization as well as economic return for the selected area.*

**Keywords:** *Intercropping, Pumpkin, Leafy vegetables.*

## 1. Introduction

Intercropping is a cropping system which involves the intensification and diversification of cropping in time and space dimensions (Francis 1986). The intensification of land and resource use in the space dimension is an important aspect of multiple cropping in efforts to develop energy-efficient and sustainable agriculture. It is a traditional but important approach of cropping system for increasing total productivity as well as farmer's income particularly in densely populated countries like Bangladesh which has limited per capita land for crop production. Intercropping has been long practiced in many parts of the world for the production of food and feed crops (Dasbak and Asiegbu 2009) and it is common in Indonesia, India, Niger, Mali, Central America and western Europe (Zomer *et al.* 2009). Therefore, a wide range of intercropping has been developed in the world as it significantly increases land productivity compared to monocultures (Li *et al.* 2007).

Intercropping increases total productivity through efficient utilization of land, labour and growth resources such as increasing utilization of solar radiation and different inputs including fertilizer and water (Ahmed *et al.* 2006). Apart from its higher yields, intercropping also maintains the stability of most of the soil chemical properties and enzyme activities relative to rotations and

monocropping in the relatively fertile soil studied in the North West China (Wang *et al.* 2015). Moreover, the system reduces environmental pollution (Stuelpnagel 1992), controls weed (Videnović *et al.* 2013), increases LER (Land Equivalent Ratio, the relative land area required as sole crops to produce the same yields as intercropping) (Keating and Carberry 1993; Islam *et al.* 2014; Hossain *et al.* 2015), reduces the risk of crop failure and increases food security (Rusinamhodzi *et al.* 2012). Greater productivity in intercropping systems is commonly achieved by minimizing inter-specific competition and maximizing complementary use of growth resources (Islam *et al.* 2006). Inter-specific competition may be minimized through judicious choice of crops (Santalla *et al.* 2001). Usually plants differing in growth duration, height, rooting systems and nutrient requirements are considered to grow together in intercropping systems (Reddy and Willey, 1981). The system becomes more productive and profitable by selecting appropriate crops, population density and planting geometry of component crops (Alom *et al.* 2014; Begum *et al.* 2015).

Pumpkin is a popular vegetable grown extensively throughout the tropical and subtropical countries (Hossain *et al.* 2015). This crop is appreciated by

consumers because their fruits, tender stems, leaves and even flowers can be used as vegetables. Further, fruits of pumpkin are used as vegetables both at immature (green) and mature (ripe) stage (Hossain *et al.* 2015). It is rich in carbohydrate and minerals and a cheaper source of vitamins, especially carotenoid pigments, which play a major role in nutrition in the form of pro vitamin A, antioxidants, when used at ripening stage (Dutta *et al.* 2006). Pumpkins are a vigorous, prostrate, annual vine with an extensive root system but roots can penetrate up to a meter deep (Bhattacharai *et al.* 2008; Napier 2009). It is a long duration (typically takes 95 to 120 days to mature, depending on variety and climate) and wider spacing crop (generally sown in rows on 1.8-3.0 m wider bed with wider plant spacing varying from 0.8-2.0 m depending on the vigour of the variety of pumpkin grown) (Napier 2009). Leafy vegetables on the other hand are an important constituent of fresh vegetables which can be grown with minimum investment and by growing leafy vegetables a grower can market his product more quickly than other types of vegetables as these vegetables can be harvested within 35-40 days (Biswas 2015). These nutritious vegetables are actually a source of minerals, vitamins and fibers and have nutraceutical properties as well.

The use of early maturing crop varieties, row arrangement, spacing and plant population are some important aspects that help to increase the yield of intercrops (Craufard 2000). As pumpkin is a long duration and wider spacing crop, there is a great scope to cultivate short duration leafy vegetables in the inter-row space of pumpkin to utilize the land and other resources to the maximum extent. Furthermore, pumpkin is deep rooted and leafy vegetables are shallow rooted crops, so they can use soil moisture and nutrients from different level of soil depths. It is also observed that up to 40 days, the canopy of the pumpkin cannot cover the whole plot although it depends on variety and soil fertility. In a bitter gourd-leafy vegetable intercropping experiment on peat in Malaysia, Leong (1992) reported that bitter gourd (*Momordica charantia*) needs 7-8 weeks to achieve complete ground cover and this period can be utilized by growing a short-term leafy vegetable as intercrop. Therefore, crop productivity may be increased by cultivating leafy vegetables like coriander (*Coriandrum sativum*), red amaranth (*Amaranthus gangeticus*), radish (*Raphanus sativus*), mustard (*Brassica campestris*), jute (*Corchorus capsularis*) and spinach (*Spinacia oleracea*) between two rows of pumpkin at early growth stage as they are short and quick growing crops. Intercropping pumpkin with field crops were studied by numerous authors (Bhattacharai *et al.* 2008; Zang *et al.* 2009; Alom *et al.* 2014; Momirović *et al.* 2015; Hossain *et al.* 2015). However, very few studies have been conducted on leafy vegetables-pumpkin intercropping system. The

reported study was undertaken to determine suitable intercrop combination with pumpkin for higher productivity and maximum economic return.

## 2. Materials and Methods

### 2.1. Experimental site and soil

The experiment was conducted on recently developed alluvial soil popularly known as 'char land' (Typic Endoaquents as per USDA Soil Taxonomy) of Dori Bhabkhali, Mymensingh sadar upazilla (240 43.407' N, 90026.22' E and 18 m above sea level) for two consecutive years 2015-16 and 2016-17 during the winter season. The experimental site is classed as medium low land on a Brahmaputra alluvial soil (Active Brahmaputra-Jamuna Floodplain soil) (FAO/UNDP 1988). The soil (0-15 cm) was sandy textured with very low organic matter content (0.98%) having a pH (water) 6.8, total N (Kjeldahl N), 0.05%, exchangeable K 0.14 meq 100 g<sup>-1</sup> soil, available P (Bray) 6.72 µg g<sup>-1</sup>, available S 27.45 µg g<sup>-1</sup>, available Zn 0.44 and available B 0.33 µg g<sup>-1</sup> soil. The experimental area has sub-tropical humid climate and is characterized by hot and humid summers and cool winters with an annual mean temperature of 25.8°C and rainfall of 2427 mm, 80% of which falls between May to September (Fig. 1) (BMD 2017).

### 2.2. Treatments and design

The experiment was laid out in a randomised complete block design with 4 m × 4 m plots replicated thrice (at 3 farmers' field). Six crop combinations along with sole pumpkin (i.e., seven treatments all together) were evaluated: pumpkin + coriander green, pumpkin + red amaranth, pumpkin + radish green, pumpkin + mustard green, pumpkin + jute green and pumpkin + spinach. Sole crops of coriander green, red amaranth, radish green, mustard green, jute green and spinach were also cultivated for standard yield in this soil condition with 3 dispersed replications only in 2015-16 following the cultivation procedure by Mondal *et al.* (2014).

### 2.3. Crop management

Land preparation for all crops was started in the third week of October by ploughing with a power tiller and kept exposed to the natural elements for four days. Afterwards, the experimental plot was prepared by several ploughing and cross ploughing followed by laddering. High yielding modern varieties of vegetables developed by Bangladesh Agricultural Research Institute (BARI), were used as test crops here. Seeds of pumpkin (*Cucurbita maxima* var. BARI mistikumra 1), coriander (*Coriandrum sativum* var. BARI Dhania 1), red amaranth (*Amaranthus gangeticus* var. BARI Lalshak 1), radish (*Raphanus sativus* var. BARI Mula 1), mustard (*Brassica campestris* var. BARI Sarisha 14), jute (*Corchorus capsularis* var. BINA patshak-1)

and spinach (*Spinacia oleracea* var. BARI palong shak 1) were sown on same day i.e. 6 November, 2015 and 28 October, 2016 (Robi/winter season). For pumpkin, pits of 50 cm × 50 cm × 45 cm size were dug at a spacing of 2 m × 2 m. Pumpkin seeds were directly sown in pits (3 seeds per pit) whereas leafy vegetables seeds were sown following broadcasting method. Seed rate of pumpkin, coriander, red amaranth, radish, mustard, jute and spinach were 5, 24, 3, 5, 8, 15 and 40 kg ha<sup>-1</sup>, respectively. Intercrop seeds were sown in the whole plot excluding pit areas and therefore the approximate intercropped areas were 95%. Pumpkin, coriander and spinach seeds were soaked in water overnight for quick germination. Seeds of all crops were treated with a recommended fungicide, Bavistin at 2 g L<sup>-1</sup> before sowing to control disease organisms, such as bacterial spot, fusarium root rot and damping-off disease, which may be on the seed surface. The crop was fertilized with N, P, K, S, Zn, B and cowdung at 69, 35, 75, 18, 3, 2 kg ha<sup>-1</sup> and 10 t ha<sup>-1</sup>, respectively as per recommendation of Mondal *et al.* (2014). The sources of N, P, K, S, Zn and B were urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum, zinc sulphate and boric acid, respectively. Entire amount of cowdung, TSP, gypsum, zinc sulphate, boric acid and one third (1/3) of MOP were applied during pit making (5 days prior to seed sowing of pumpkin). Total amount of Urea and rest of MoP were applied in four equal instalments at 15, 35, 55, and 75 days after seed sowing in pit at ring method. An additional 46 kg ha<sup>-1</sup> N was top dressed only on leafy vegetables at their early vegetative stage at 15 days after sowing. Hand weeding was done for all plots as per requirement to control weed infestation especially before top dress and split application of fertilizer. Three irrigations were provided in the experimental field with ground water at 15, 35 and 55 days after sowing (DAS). Insect pest and disease infestations were generally low for most of the seasons during the experimental years. However, sex pheromone trap (Cuelure) was used in both years to control shoot and fruit borers. Chemical protection measures were also taken against powdery and downy mildew diseases by spraying sulphur fungicide, Thiovit 80 WP at 2 g L<sup>-1</sup>. The experimental plots were kept separated from each other by using a nylon net. Coriander green, red amaranth, radish green, mustard green, jute green and spinach were harvested manually at 40, 30, 25, 26, 28 and 44 DAS respectively in both years. First harvest of sweet gourd (green) was done at 77 and 80 DAS and harvesting was continued up to 130

DAS in 2016 and 2017, respectively. Data on yield and yield contributing characters were recorded plot wise accept fruit size and average fruit weight (5 fruits from each treatment were sampled). Plot yields were then converted to tons per hectare.

#### 2.4. Productivity and profitability

To compare system productivity, yield of individual crop was converted to Pumpkin equivalent yield (PEY) considering prevailing market price of the crops which was calculated following the formula of Biswas *et al.* (2006):

$$\text{PEY (of crop } x) = Y_x (P_x/P_r)$$

Where  $Y_x$  is the yield of crop  $x$  (tons harvest product ha<sup>-1</sup>),  $P_x$  is the price of crop  $x$ , and  $P_r$  is the price of pumpkin. Prices of individual inputs and outputs were assumed to be stable during the experimental period.

However, the PEY does not indicate the net gain obtained from the cropping system and also does not explain the land use pattern on the cropping systems. As yield is a function of duration of land use utilization, Hiebsch (1978) suggested that area time equivalent ratio (ATER) is a better index for assessing yield advantage in intercropping systems. In the present study, the companion crops were of different maturity periods, thus, it was computed from the following equation used by Haruna *et al.* (2013):

$$\text{ATER} = [(Y_a/S_a) \times T_a + (Y_b/S_b) \times T_b]/T$$

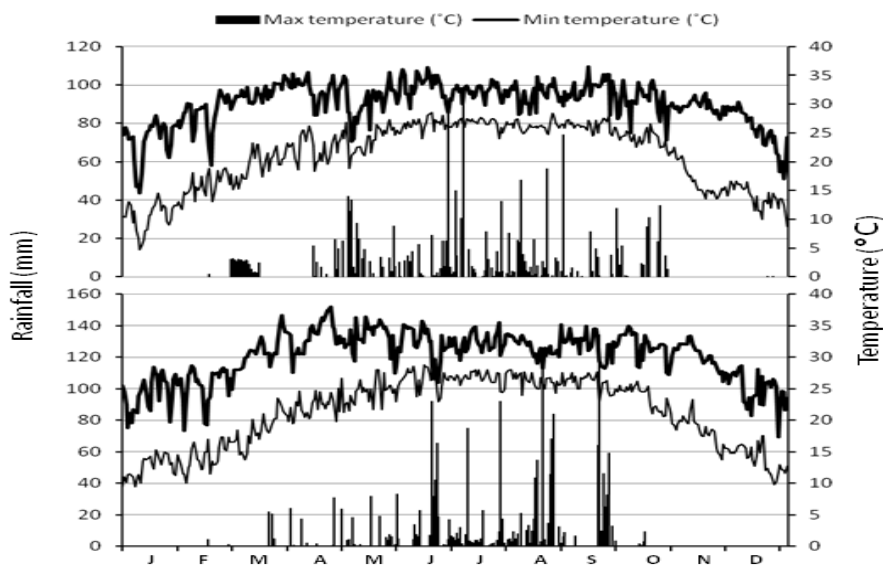
Where  $Y_a$ = Yield of crop 'a' in intercropping,  $S_a$ = Yield of crop 'a' in sole cropping,  $Y_b$ = Yield of crop 'b' in intercropping,  $S_b$ = Yield of crop 'b' in sole cropping,  $T_a$ = duration of crop 'a',  $T_b$ = duration of crop 'b',  $T$ = Total duration of intercropping system.

On the other hand, land equivalent ratio (LER, the relative land area required as sole crops to produce the same yields as under intercropping) was used as the criteria for measuring the efficiency of intercropping advantages using the resources of environment compared to monoculture and it was calculated by the following formula adapted by Haruna *et al.* (2013):

$$\text{LER} = Y_{ab}/Y_{aa} + Y_{ba}/Y_{bb}$$

Where,  $Y_{aa}$  and  $Y_{bb}$ = Sole yield of crops 'a' and 'b' respectively,  $Y_{ab}$  and  $Y_{ba}$ = Mixture yield of crops 'a' and 'b' respectively.

Economic analyses were carried out to assess the economic productivity of the intercropping systems. Net return or profit was calculated by subtracting production cost from the gross return. Prices used for harvest products were the average prices observed in the market during the experimental period.



**Figure 1.** Weather at the experimental site during the growing period (horizontal line represents air temperature and vertical bar represents total rainfall)

**Table 1.** Vine length, fruit length and fruit circumference of sweet gourd in pumpkin-leafy vegetables intercropping system for the crop years 2015-16 and 2016-17.

Intercrop combinations	Vine length (cm)		Fruit length (cm)		Fruit circumference (cm)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Pumpkin(sole)	637.9	638.2	21.8	21.9	61.4	59.3
Pumpkin + coriander green	637.0	637.7	21.2	21.0	59.2	58.2
Pumpkin + red amaranth	636.9	637.2	21.3	21.9	61.0	57.9
Pumpkin + radish green	637.1	637.5	20.6	21.6	57.9	57.0
Pumpkin + mustard green	637.4	637.9	21.4	21.8	58.2	60.2
Pumpkin + jute green	637.0	637.4	21.9	21.7	59.6	58.2
Pumpkin + spinach	637.0	637.3	21.6	21.3	56.6	58.1
F test	NS	NS	NS	NS	NS	NS
CV (%)	10.14	13.10	12.09	3.84	6.88	6.54

NS= Not significant

## 2.5. Data analysis

All statistical analyses were carried out using the MSTAT-C statistical software (Michigan State University, USA). ANOVA and Duncan's multiple range (DMRT) tests were performed to assess significant differences in the mean crop yields, yield attributes, PEY, LER and ATER.

## 3. Results and Discussion

### 3.1. Yield and yield parameters of pumpkin

The yield and yield components of pumpkin did not differ significantly as intercropping with different leafy vegetables in both years except fruits plant<sup>-1</sup> and average

fruit weight in 2015-16 (Tables 1 and 2). The number of fruits plant<sup>-1</sup> ranged from 3.00 to 3.48. The highest number of fruits plant<sup>-1</sup> was obtained from pumpkin + radish green (3.48) followed by pumpkin + coriander green (3.46) while the lowest number of fruits plant<sup>-1</sup> (3.00) was recorded in pumpkin + red amaranth intercropping combination in 2015-16 although it was insignificant in 2016-17. Significantly the highest average fruit weight was recorded in sole pumpkin (3.00 kg) while lowest was from pumpkin + coriander and pumpkin + radish combination (2.63 kg) in 2015-16 which was also found insignificant in 2016-17. The highest fruit yield of pumpkin in sole crop was recorded in 2015-16 and 2016-17 at 24.48 and 25.04 t ha<sup>-1</sup>,

respectively which was bit higher than intercropped yield of pumpkin in both years although yield difference was statistically at par. Under different intercropping treatments it varied from 21.58-24.48 and 21.58-24.48 t ha<sup>-1</sup> in 2015-16 and 2016-17, respectively. Statistically identical yield and yield attributes of pumpkin in different intercropping system indicate that leafy vegetables intercropped with pumpkin did not reduce or adversely affect pumpkin yield and yield components. It might be due to the fact that there was minimum inter-

specific competition for space and growth resources as they are short structured, shallow rooted and quick growing crops (harvested within 25-44 DAS when sweet gourd was vegetative stage and vine was just starting to spread). Similar results were also reported by Islam *et al.* (2014) where leafy vegetables (red amaranth, leaf amaranth & jute green) and legumes (Mungbean & blackgram) were intercropped with brinjal.

**Table 2.** Number of fruits plant<sup>-1</sup>, average fruit weight and fruit yield of sweet gourd in pumpkin-leafy vegetables intercropping system for the crop years 2015-16 and 2016-17.

Intercrop combinations	Fruits plant <sup>-1</sup> (no)		Average fruit weight (kg)		Fruit yield (t ha <sup>-1</sup> )	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Pumpkin(sole)	3.25ab	3.50	3.00a	2.86	24.48	25.04
Pumpkin + coriander green	3.46a	3.42	2.63b	2.58	22.77	22.07
Pumpkin + red amaranth	3.00b	3.33	2.88ab	2.63	21.58	21.77
Pumpkin + radish green	3.48a	3.40	2.75ab	2.61	23.93	23.03
Pumpkin + mustard green	3.14ab	3.25	2.90ab	2.75	22.79	22.71
Pumpkin + jute green	3.30ab	3.53	2.63b	2.67	21.73	21.83
Pumpkin + spinach	3.16ab	3.25	2.78ab	2.66	21.94	21.43
F test	*	NS	**	NS	NS	NS
CV (%)	7.86	11.45	7.24	17.63	7.29	23.74

NS= Not significant. Different letters e.g. a and b after the numerical values in each column indicate significant differences ( $p \leq 0.05$ ) according to Duncan's Multiple Range test.

### 3.2. Leafy vegetables yield

The green yield of coriander, red amaranth, radish, mustard, jute and spinach in different intercropping system was recorded 3.02, 9.73, 8.65, 9.52, 9.33 and 20.33 t ha<sup>-1</sup>, in 2015-16 while 2.98, 9.79, 9.06, 9.58, 9.56 and 21.67 t ha<sup>-1</sup> in 2016-17, respectively. However, the standard yield of these leafy vegetables when cultivated as a sole crop in the same soil condition were found to be 4.17, 13.33, 11.67, 12.50, 14.17 and 24.42 t ha<sup>-1</sup> for coriander, red amaranth, radish, mustard, jute and spinach, respectively (Figure 2). Among the intercrops, spinach yielded significantly higher while coriander yielded the lowest in both years. Significant yield differences of leafy vegetables in different intercropping systems might be attributed to the differences in yield potentials of different vegetables.

### 3.3. Yield advantages of pumpkin-leafy vegetables intercropping system

Yield advantages of intercropping systems were assessed in terms of system productivity, land equivalent ratio and area time equivalent ratio.

#### 3.3.1. System productivity

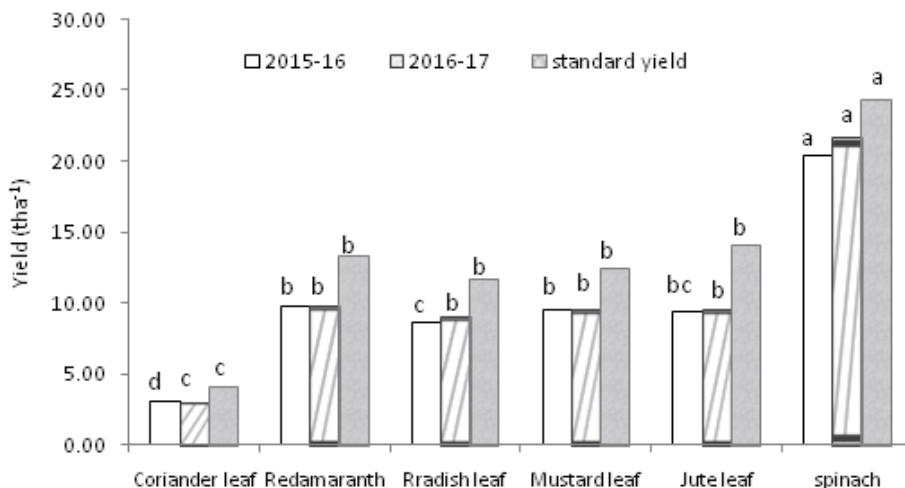
Total productivity of each system was expressed as its pumpkin equivalent yield (PEY) which was found to differ significantly among the various systems tested (Table 3). All the intercrop combinations produced

higher system yield over the sole pumpkin indicating higher productivity of intercropping systems. Greater productivity in intercropping system might be achieved by minimizing inter-specific competition and maximizing complementary use of growth resources (Islam 2004). Among the intercropping systems, pumpkin, including spinach recorded significantly greater production (72.7 t ha<sup>-1</sup>) followed by pumpkin + red amaranth (41.1 t ha<sup>-1</sup>) and pumpkin + jute green (40.5 t ha<sup>-1</sup>) combination, whereas the lowest (35.0 t ha<sup>-1</sup>) was recorded in the coriander system in 2015-16. In 2016-17, the highest production was from pumpkin + spinach (75.6 t ha<sup>-1</sup>) followed by pumpkin + red amaranth (41.4 t ha<sup>-1</sup>), pumpkin + jute green (41.0 t ha<sup>-1</sup>), pumpkin + mustard green (37.1 t ha<sup>-1</sup>) and pumpkin + radish green (36.6 t ha<sup>-1</sup>) combination while pumpkin + coriander system had the lowest productivity (34.0 t ha<sup>-1</sup>) like previous year. Greater productivity obtained from pumpkin including the spinach system in both years might be due to the highest yield of spinach as compared to other leafy vegetables. Uddin *et al.* (2009) also reported the greater system productivity in the maize + spinach intercropping system.

Intercropping increased system productivity (considering mean system yield of both the year) by 39 -120% over sole pumpkin (Figure 3). Among the

treatments, pumpkin including spinach combination was 120 % higher over the sole pumpkin followed by pumpkin+ red amaranth (66%), pumpkin+ mustard green (50%), pumpkin+ radish (49%), pumpkin+ jute green (46%) and pumpkin+ coriander (39%). Increased

system productivity was also reported by many authors when leafy vegetables were intercropped with maize (35- 63% by Akhtar *et al.* 2015), Brinjal (11-27% by Islam *et al.* 2014) and okra (28-45% by Ahmed *et al.* 2013).



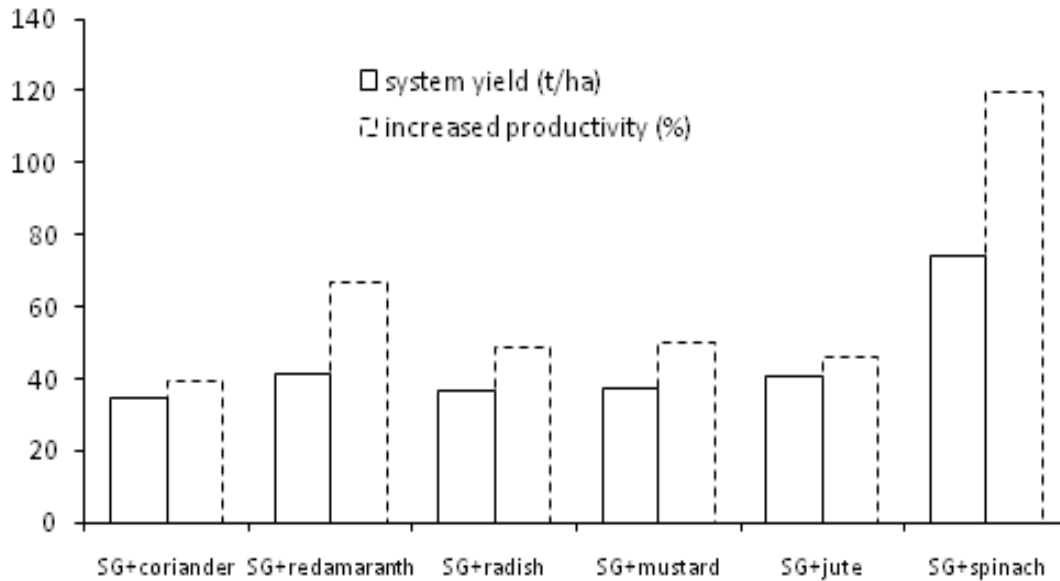
**Figure 2.** Yield of different leafy vegetables in sweet gourd-leafy vegetable intercropping system. Different letters after group means in top of the same coloured bars indicate significant differences ( $p \leq 0.05$ ) according to Duncan's Multiple Range test.

**Table 3.** System productivity (expressed in pumpkin equivalent yield), land equivalent ratio and area time equivalent ratio of the pumpkin-leafy vegetables intercropping system for the crop years 2015-16 and 2016-17.

Crop combinations	System productivity (PEY, t ha <sup>-1</sup> )		Land equivalent ratio (LER)		Area time equivalent ratio (ATER)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Pumpkin (sole)	24.5e	25.0c	1b	1b	1c	1c
Pumpkin + coriander green	35.0d	34.0bc	1.69a	1.63a	1.17a	1.13ab
Pumpkin + red amaranth	41.1b	41.4b	1.63a	1.65a	1.06bc	1.05bc
Pumpkin + radish green	37.2cd	36.6b	1.73a	1.68a	1.13ab	1.04bc
Pumpkin + mustard green	37.1cd	37.1b	1.71a	1.67a	1.09abc	1.04bc
Pumpkin + jute green	40.5bc	40.9b	1.56a	1.57a	1.04bc	1.03bc
Pumpkin + spinach	72.7a	75.6a	1.74a	1.75a	1.20a	1.16a
Ftest	**	**	**	**	*	*
CV (%)	4.74	13.51	7.61	10.33	5.80	17.68

Values having same lowercase letters in a column do not differ significantly at  $p < 0.05$  by Duncan's multiple range tests. Selling price (US \$ kg<sup>-1</sup>): pumpkin: 0.12, coriander leaf: 0.49, red amaranth: 0.24, radish leaf: 0.18, mustard leaf: 0.18, jute leaf: 0.24 and spinach: 0.30. Different letters e.g. a and b after the numerical values in each column indicate significant differences ( $p \leq 0.05$ ) according to Duncan's Multiple Range test.

1 US \$ = 82 BDT



**Figure 3.** Increased productivity (%) over sole pumpkin under different intercropping systems (means of both years).

### 3.3.2. Land equivalent ratio (LER)

Land equivalent ratio is another index of yield advantage of intercropping system over sole cropping. In both the growing season, all treatment combinations had significantly greater LER compared to monoculture in equal land area (Table 3). From the Table 3 it is observed that LER values in the intercrops ranged from 1.56 to 1.74 in 2015-16 and 1.57 to 1.75 in 2016-17 respectively which indicated 56-74% and 57-75% more area would be required by a sole crop to recover the yield of intercropping system in 2015-16 and 2016-17, respectively. Among the treatments, pumpkin including the spinach combination produced the highest LER (1.74 in 2015-16 and 1.75 in 2016-17) compared to other combinations. This might be due to the maximum complementary use of different growth resources in this combination which translated the higher yield from the two crops. These results indicate that there was a big advantage of land utilization in intercropping leafy vegetables with pumpkin over growing either of the crops as a sole. Mazaheri and Overysi (2004) stated that any value greater than 1.0 indicates yield advantage for intercropping than monoculture.

### 3.3.3. Area time equivalent ratio (ATER)

ATER values showed an advantage of 4 to 20 % in 2015-16 and 3 to 16% in 2016-17, respectively in all intercropping systems than sole cropping with

maximum advantage from pumpkin + spinach combination (1.20 in 2015-16 and 1.16 in 2016-17) (Table 3). This indicates that the maximum utilization of space and time was observed in this system. The better ATER was due to better combined intercropped yield and temporal difference which existed between the crops. Higher yield advantage in terms of ATER value was also observed in soybean/pigeonpea intercropping system as compared to sole soybean in semi-arid tropics of India (Ghosh *et al.* 2006).

### 3.4. Economic performances

Higher economic return was obtained in all intercropped treatments compared to sole pumpkin (Table 4). However, the pumpkin + spinach combination was found the most profitable with a higher net return of US\$ 8001 and 8350 ha<sup>-1</sup> over sole in 2015-16 and 2016-17, respectively. The benefit cost ratio of this treatment was also computed highest with a value of 10.3 & 10.7 in both years. Additional yield of companion crops having a good market price mainly contributed to increase the profitability of intercropping systems over sole pumpkin. Begum *et al.* (2015), Hossain *et al.* (2015), Akhtar *et al.* (2015), Islam *et al.* (2014) and Ahmed *et al.* (2013) also reported that intercropping gave higher productivity and economic returns compared to monoculture.

**Table 4.** Economic performances of various pumpkin-leafy vegetables intercropping systems.

Crop combinations	Gross return (US \$ ha <sup>-1</sup> )		Production cost (US \$ ha <sup>-1</sup> )		Net return (US \$ ha <sup>-1</sup> )		Benefit cost ratio	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Pumpkin(sole)	2985	3054	1567	1567	1418	1487	1.9	2.0
Pumpkin + coriander green	4262	4140	806	806	3456	3334	5.3	5.1
Pumpkin + red amaranth	5011	5450	776	776	4235	4674	6.5	7.0
Pumpkin + radish green	4530	4465	780	780	3751	3685	5.8	5.7
Pumpkin + mustard green	4527	4522	776	776	3751	3746	5.8	5.8
Pumpkin + jute green	4937	4993	805	805	4132	4189	6.1	6.2
Pumpkin + spinach	8866	9216	866	866	8001	8350	10.3	10.7

Price of input (US \$ kg<sup>-1</sup>): Urea: 0.24, TSP: 0.27, MOP: 0.21, Gypsum: 0.12, Zinc sulphate: 2.20 and Boric acid: 4.27, pumpkin seed: 3.66, radish seed: 2.44, red amaranth seed: 2.44, coriander seed: 159, mustard seed: 1.04, spinach seed: 2.44, labour: 3.66 US \$, land lease: US \$ 40.24 bigha<sup>-1</sup>

1 US \$ = 82 BDT

#### 4. Conclusions

All the intercropping systems tested performed better than sole cropping but the cultivation of spinach with pumpkin was found to be the best option with regards to its higher productivity, better land and time utilization as well as maximum economic return for the recently developed alluvial soils of Bangladesh. Excluding productivity, intercropping also increased crop diversity by intensifying the use of natural resources and reduced risk of complete crop failure as failure of one crop in the intercropping system does not mean a total system failure as one or more companion crop(s) may still yield harvestable produce.

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