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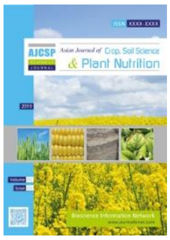

Intercropping of some winter vegetables with sweet gourd in Bandarban hill district of Bangladesh

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ABSTRACT

A field experiment was undertaken at a farmer's field located in the hill valleys of Bandarban Sadar Upazila during the winter season of 2020-21 and 2021-22 to find the most acceptable and economically viable short-duration winter vegetables that can be intercropped with sweet gourd. Five intercrop combinations viz. T_1: (sweet gourd + radish green), T_2: (sweet gourd + chinese cabbage), T_3: (sweet gourd + red amaranth), T_4: (sweet gourd + spinach) and T_5: (sweet gourd + bushbean) along with T_0: (sole sweet gourd as control) were put to the test. The yield of sweet gourd was not affected significantly in association with different intercrop vegetables. However, all the intercrop combinations were superior to sole sweet gourd in terms of sweet gourd equivalent yield, values of competition functions, and economic returns. However, sweet gourd + red amaranth produced significantly higher yield (41.95 t ha^{-1}), gross margin (Tk. 640200 ha^{-1}) and benefit-cost ratio (4.22) followed by sweet gourd + bushbean combination (38.91 t ha^{-1}, Tk. 585027 ha^{-1} and 4.03 respectively) in two successive years over sole sweet gourd (23.05 t ha^{-1}, Tk. 277200 ha^{-1} and 2.51 respectively). It indicates that the intercrop combination of the sweet gourd with red amaranth or bushbean was the more profitable and well-fitted system in the hill valleys of Bandarban.

Key Words: *Competition function, Cropping intensity, Cucurbita maxima, Intercropping, Rabi vegetables and Yield*

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I. Introduction

Intercropping is an ancient farming practice used by farmers to increase the productivity of the land. Compatible selection of intercrop is crucial in an overpopulated country like Bangladesh, which may increase farm yield significantly. Intercropping of short-duration vegetables ensures efficient resource and space utilization (Sing et al., 2018), along with high yield (Islam et al., 2014) and financial return (Begum et al., 2018). It is one of the vertical extension approaches where the overall production profitability of a unit area in a given time and input use may be boosted without compromising the productivity of the main crops (Islam et al., 2013). Food security is ensured by the intercropping method (Mahfuza et al., 2012) since it increases cropping intensity and decreases the likelihood of crop failure in developing countries like Bangladesh (Rusinamhodzi et al., 2012).

The sweet gourd is a widely cultivated vegetable highly favoured in regions characterized by tropical and subtropical climates. This particular crop has gained significant popularity due to its versatile nature since its fruits, fragile stems, leaves, and even blossoms may be used as edible vegetables. Moreover, the fruits of the sweet gourd are utilized as vegetables during both the green and ripe phases (Hossain et al., 2015). Although the people of Bangladesh could ensure food security to a large extent, they are experiencing a range of dietary inadequacies, including insufficient protein intake, calories, vitamins, and minerals. The sweet gourd is a highly nutritious vegetable with a significant amount of carbohydrates, minerals, pro-vitamin A and antioxidants, mainly when consumed during its ripening stage (Dutta et al., 2006). Intercropping different short-duration crops like radish green, Chinese cabbage, red amaranth, spinach, bushbean and sweet gourd can increase system productivity and act as a storehouse of nutrients. In the winter of 2020-21, 17768.36 hectares of sweet gourds have been cultivated in Bangladesh (BBS, 2021). Chittagong division is one of the largest producers of sweet gourd in Bangladesh, which is 18.60% of the total production, where 60% and 40% of areas have been cultivated for the winter and summer seasons, respectively (BBS, 2022).

The sweet gourd takes 95–120 days to mature with broader plant spacing (between 0.8 and 2.0 m, depending on plant growth and variety) and moderate growth at the initial stage (Napier, 2009). It was found that even after 40 days; the sweet gourd's canopy still did not cover the entire plot. Growing high-value vegetables as intercrops (radish green, chinese cabbage, red amaranth, spinach, and bush bean) during the early stages of development does not reduce the yield of sweet gourds. Unfortunately, a monoculture system was adopted in 58.45% of the pumpkin cultivation area in Bangladesh (BBS, 2014). In some studies, intercropping of winter vegetables with sweet gourd was evaluated, but most of them were long-duration vegetables such as Kakon et al. (2018) studied the suitability of intercropping cabbage, cauliflower, radish, lettuce and tomato with sweet gourd. Some other crops were also used as intercrop, for instance, the optimization of plant density of chilli (Alom et al. 2014) and plant population of brinjal (Rahman et al. 2016) with sweet gourd was also examined.
In our study, we intended to assess the performance of some short-season winter vegetables since they are ready for harvest in just 35–40 days, growers of these may get their produce to market faster than with other vegetable crops (Biswas, 2015). Therefore, this experiment was conducted to discover the optimum intercrop combination with a sweet gourd for improved production and the highest economic return to maximize land use efficiency.

II. Materials and Methods

Experimental site, soil and climate

The experiment was carried out in the Bikricchara hill valleys of Bandarban Sadar Upazila (22°13'29''N, 92.12'45"E and 78 m above sea) over two years, specifically during the winter seasons of 2020-21 and 2021-22. This location is a stand-in for AEZ-29. The soil of the experimental site contains low organic matter (1.50% to 2.80%), low pH (5.5), and minimal nitrogen and phosphorus (Ahmed, 2003). The region has a tropical monsoon climate. The dry and cool seasons run during the rabi season. The district experiences an annual mean temperature range of 37º C to 12.5º C, with an average annual precipitation of 3031 mm (CEGIS, 2013).

Treatments and design

The experiment was set out in a randomized complete block design with plots of 2m×2m and replicated thrice. Five different intercrop combinations and sole sweet gourd (for a total of six treatments) were tested: T_1: sweet gourd + radish leaf (*Raphanus sativus*), T_2: sweet gourd + chinese cabbage (*Brassica rapa* var. *parachinensis*) named as Batisak, T_3: sweet gourd + red amaranth (*Amaranthus gangeticus*), T_4: sweet gourd + spinach (*Spinacia oleracea*) and T_5: sweet gourd + bushbean (*Phaseolus vulgaris*). Sole sweet gourd (*Cucurbita maxima*) was cultivated as a control (T_0).

Crop management

Land preparation for all crops began two weeks before seeding in November. This required ploughing, cross-ploughing, and laddering. Before sowing, all seeds were treated with 2 g/L Bavistin to reduce disease-causing organisms on the seed surface.

Urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum, zinc sulfate, boric acid, and cow dung were applied at 175, 175, 150, 100, 12.5 and 10000 kg ha^{-1}, respectively. All cow dung, TSP, gypsum, zinc sulfate, boric acid, and one-third of MOP were applied during pit preparation (5 days before sowing). The total volume of Urea and the remaining MOP were applied in four equal instalments at 15, 35, 55, and 75 days after seed sowing in the pit following the ring method. At the early vegetative stage, 15 days after sowing, leafy vegetables were top-dressed with 46 kg ha^{-1} of N. The commercial variety used for this experiment were BARI mistikumra-2, BARI Mula-1, Thai green, Altapeti (Ispahani seeds), Sathi (Ispahani), and BARI Bushbean-2 for sweet gourd, radish, red amaranth, chinese spinach and bushbean respectively. All seeds were sown on the same day, i.e., 03 December 2020 and 15 November 2021 (rabi/winter season). For sweet gourd, pits of 50 cm x 50 cm x 45 cm were prepared at a distance of 2 m x 2 m apart. Two seeds were planted in each pit, only one plant was allowed to grow, and seeds for leafy vegetables were sown following the line sowing method. Line-to-line distance for radish, chinese cabbage, red amaranth and spinach was 30 cm, 25 cm, 20 cm, and 30 cm, respectively, with continuous sowing in line. Seeds were sown at a 1.5-2 cm depth by drawing a line. Bushbean seeds were sown, maintaining 30 cm × 20 cm spacing. Samih (2008) and Mureithi et al. (2012) observed the highest bushbean pod yield at this spacing. Pit areas were excluded for intercrop seeding, which gave approximate intercropped areas about 95%. After a week of seedling emergence in each line, leafy vegetable thinning was carried out while maintaining a 3-5 cm plant-to-plant distance for healthy growth. Weeds were hand-pulled before top dress and split fertilizer applications. Two irrigations were provided in all crops at 15 and 20 days after sowing (DAS), and an additional irrigation on only sweet gourd at 55 DAS. Chemical protection measures were taken to check different insect pests and disease infestations. Thiovit 80 WP at 2 g /L was sprayed against powdery mildew diseases, and cypermethrin 10 EC at 1ml/L was used to check red pumpkin beetle at seedling, vegetative, and flowering stages. The shoot and fruit borers were managed with a sex pheromone trap (Cuelure). Radish (leaf), chinese cabbage, red amaranth, and spinach were harvested at 25-33 DAS, and bushbean at 64-66 DAS in both years. The sweet gourd was harvested at 113-120 DAS in March 2021 & 2022. Plot-wise data on yield and yield-contributing characters were recorded and converted to tons per hectare.

Specification of System productivity and profitability

Attributes		Definition	Source
Sweet Gourd Equivalent Yield (SEY)	=	Yb (Pb/Pa) + Ya	Biswas et al. (2006)
Land Equivalent Ratio (LER)	=	Yab/Yaa + Yba/Ybb	Hiebsch (1978)
Area Time Equivalent Ratio (ATER)	=	[(Ya/Sa) × Ta + (Yb/Sb) × Tb]/T	Hiebsch (1978)
System Productivity Index (SPI)	=	Ya + Yb (Sa/Sb)	Khan et al. (2018)
Replacement Value of Intercropping (RVI)	=	[(Ya × Pa + Yb × Pb)/(Sa × Pa – Csa)]	Khan et al. (2018)
Monetary Advantage Index (MAI)	=	Value of combined intercrop yield × (LER-1)/LER	Khan et al. (2018)

Where,

a= Main crop or sweet gourd,
b= Respective intercrops,
Csa= Input cost of the crop 'a' in sole cropping
Pa and Pb= Price of the crop 'a' and crop 'b'
Pa= price of crop 'a' or main crop or sweet gourd
Pb= price of crop 'b', and
Sa and Sb= Yield of the crop 'a' and crop 'b' in sole cropping,
T= Total duration of intercropping system,
Ta and Tb= Duration of the crop 'a' and crop 'b',
Ya and Yb = Yield of crop 'a' and 'b' (ton ha^{-1}),
Ya and Yb= Yield of the crop 'a' and crop 'b' in intercropping,
Yaa and Ybb= Sole yield of crops 'a' and crop 'b' respectively,
Yab and Yba= Yield of the crop 'a' and crop 'b' respectively in intercropping.

Finally, A cost-return analysis was conducted to estimate the economic efficiency of the intercropping systems, utilizing the prevailing local market price.

Data analysis

STATISTIX 10 was used for all statistical analyses. ANOVA and Duncan's multiple range (DMRT) tests at a 5% level were used to compare mean crop yields, yield characteristics, and sweet gourd equivalent yield. Pooled analysis was done since yield and yield characteristics did not vary between years.

III. Results and Discussion

Yield components of sweet gourd influenced by intercrops

Fruit plant^{-1}, fruit length and average fruit weight were not significantly influenced by the intercropping system (Table 01). The number of fruits plant^{-1} ranged from 2.56-4.50, where the highest was obtained from the sweet gourd + spinach combination (4.50), and the lowest result was found from sweet gourd + radish leaf (2.56). Fruit length and breadth ranged from 13.46-14.70 and 20.07-21.44 cm, respectively. Sole sweet gourd showed the highest fruit length (14.70 cm), breadth (21.44 cm), and average fruit weight (2.92 kg) over all other treatments but at a very low margin. The intercropping system did not affect sweet gourd fruit characteristics notably. Begum et al. (2018) reported similar outcomes when leafy vegetables were intercropped with pumpkin and Islam et al. (2014) found the same in the brinjal-leafy vegetables intercropping system. Although, significant yield reduction was observed in plant density variation of different winter vegetables with pumpkin; for instance, a 12.34 to 20.71% yield reduction of pumpkin with cauliflower (Khanum et al., 2022) and a 7 to 31% yield reduction with chilli at Joydebpur and 2 to 22% at Jamalpur (Alom et al., 2014),

Table 01. Fruit characteristics of sweet gourd as influenced by companion crops for the crop year 2020-21 and 2021-22 (Pooled).

Treatments	Fruits plant^{-1}	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (kg)
T_0	3.89	14.70	21.44	2.92
T_1	2.56	13.46	20.07	2.29
T_2	3.92	13.90	20.83	2.40
T_3	4.00	14.65	20.99	2. 74
T_4	4.50	14.20	20.72	2.48
T_5	3.61	13.95	20.62	2.44
CV(%)	12.23	2.43	2.50	13.44
LSD $_{(0.05)}$	1.30	0.97	1.47	0.32

T_0: sole sweet gourd, T_1: sweet gourd + radish, T_2: sweet gourd + chinese cabbage, T_3: sweet gourd + red amaranth, T_4: sweet gourd + spinach and T_5: sweet gourd + bushbean

Yield of companion crops

The highest vegetable yield was observed from radish (10.26 kg/plot and 21.72 t/ha), followed by red amaranth (9.52 kg/plot and 20.67 t/ha), chinese cabbage (7.87 kg/plot and 15.78 t/ha) and bushbean (6.32 kg/plot and 13.10 t/ha) whereas lowest yield was observed from spinach (5.70 kg/plot and 11.97 t/ha) (Table 02).

Sweet gourd equivalent yield (SEY)

The sole sweet gourd recorded the highest fruit yield plot^{-1} and ha^{-1} (11.14 kg and 23.05 t). However, in terms of SEY, the sweet gourd + red amaranth combination showed the highest yield (41.95 t ha^{-1}), which was 82% increased productivity over the sole, followed by sweet gourd + bushbean (38.91 t ha^{-1}), and sweet gourd + spinach (33.89 t ha^{-1}). This result differs from Begum et al. (2018) where the highest system productivity was obtained from the pumpkin + spinach intercropping system, followed by the pumpkin + red amaranth intercropping system. On the other hand, the combination of radish and sweet gourd did not go well as radish hampered the fruit yield of sweet gourd (11.77 t ha^{-1} only), which lowered overall productivity in both years. Monocropping of sweet gourd exhibited the least system productivity in terms of SEY (23.05 t ha^{-1}). All intercropping combinations increased total productivity, ranging from 24.82 to 82 percent (Figure 01). Akhter et al. (2019) also found similar findings where all vegetables and spices intercrops increased the productivity of the pointed gourd intercropping system over sole cropping.

Table 02. Yield and sweet gourd equivalent yield (SEY) in sweet gourd-vegetables intercropping system for the crop year 2020-21 and 2021-22 (Pooled)

Treatments	Fruit yield (Kg $plot^{-1}$)	Fruit yield (t ha^{-1})	Vegetable yield (Kg $plot^{-1}$)	Vegetable yield (t ha^{-1})	SEY (t ha^{-1})
T_0	11.14	23.05	-	-	23.05
T_1	5.79	11.77	10.26	21.72	28.77
T_2	9.30	18.66	7.87	15.78	32.36
T_3	10.81	22.42	9.52	20.67	41.95
T_4	10.52	21.92	5.70	11.97	33.89
T_5	6.63	17.56	6.32	13.10	38.91
CV(%)	13.44	16.27	6.85	5.54	8.69
LSD $_{(0.05)}$	3.56	8.86	1.28	2.18	8.16

average selling price (tk. kg^{-1}): sweet gourd: 20, radish leaf: 16, chinese cabbage: 16.5, red amaranth: 21, spinach: 20, and bushbean: 32.5.

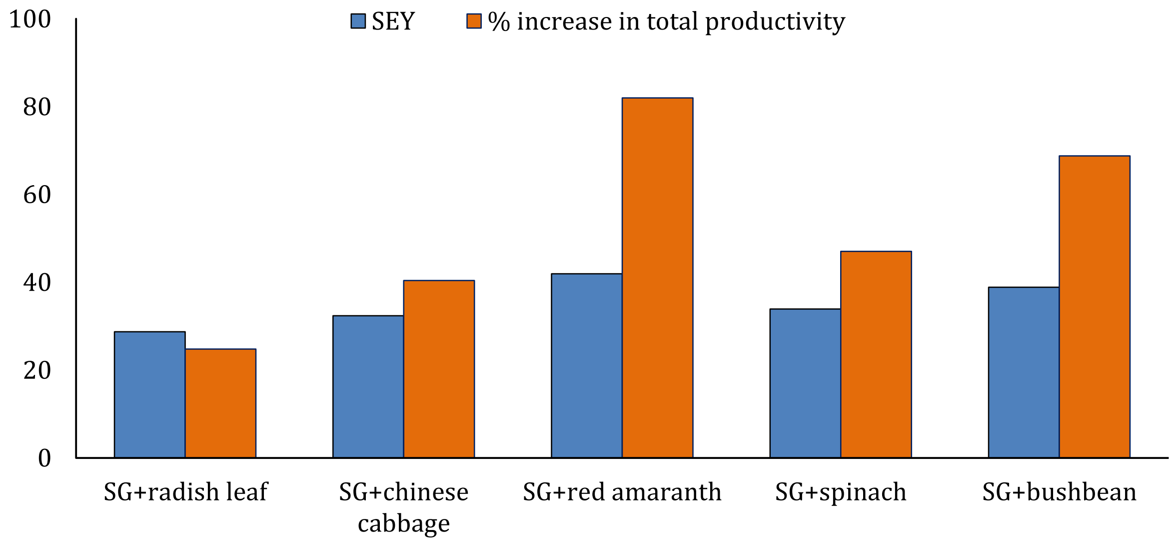

Figure 01. Productivity increment (%) over sole sweet gourd at different intercrop combinations (average of both years)

Economic Performance

According to the findings of the cost-return analysis, it was found that the combination of sweet gourd and red amaranth yielded the highest gross return (Tk. 839000 ha^{-1}) and gross margin (Tk. 640200 ha^{-1}) and BCR (4.22). Other successful intercropping combinations were sweet gourd+bushbean (Tk. 778200 ha^{-1}, Tk. 585027 ha^{-1} and 4.03) and sweet gourd+spinach (Tk. 677800 ha^{-1}, Tk. 480615 ha^{-1}, and 3.44). The intercropping of sweet gourd and radish (leaf) resulted in the lowest gross return of Tk. 575400 ha^{-1}, the gross margin of Tk. 377685 ha^{-1} and the benefit-cost ratio (BCR) of 2.91 among the various vegetable intercropping systems studied. Profitability (Tk. 461000 ha^{-1}, Tk. 277200 ha^{-1}, and 2.51 respectively) was lowest for sole sweet gourd (Table 03). Akhtar et al. (2015), Begum et al. (2015), Hossain et al. (2015) and Islam et al. (2014) also reported that intercropping resulted in increased production and economic benefits when compared to monoculture.

Table 03. Cost and return analysis of sweet gourd-vegetables intercropping system in Bandarban (average of 2020-21 & 2021-22)

Treatments	Gross return (Tk. ha^{-1})	TVC (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
T_0	461000.00	183800.00	277200.00	2.51
T_1	575400.00	197715.00	377685.00	2.91
T_2	647200.00	197200.00	450000.00	3.28
T_3	839000.00	198800.00	640200.00	4.22
T_4	677800.00	197185.00	480615.00	3.44
T_5	778200.00	193173.00	585027.00	4.03

Note: input price (tk. kg^{-1}): urea = 16, tsp = 22, mop = 15, gypsum = 10, zinc sulphate = 180, boric acid = 200.

Land equivalent ratio (LER)

LER was used to estimate the resource use efficiency of the intercropping system compared to monoculture. LER value in all the intercropping systems was more than 1.0 and ranged from (1.45-1.96), indicating efficient crop combination with higher yield advantage. The highest LER value (1.96) was obtained from the sweet gourd + red amaranth intercropping system, which increased 82% of total system productivity (Table 04). Begum et al. (2018) also found higher LER in pumpkin-leafy vegetable intercropping system, Hauggaard-Neilsen et al. (2001b) in pea-bearly intercropping and Shanmugam et al. (2021) in faba bean-cabbage intercropping system.

Area time equivalent ratio (ATER)

ATER is a better index of yield advantage assessment in intercropping systems, as suggested by Hiebsch (1978). In the current research, the intercrops were of different maturity periods, and the range of ATER values was 0.74 to 1.28, which indicates varied utilization time and space in those intercropping systems (Table 04). The highest ATER value was found from sweet gourd + bushbean (1.28), followed by sweet gourd + red amaranth (1.25), which showed a 28% and 25% yield advantage over the sole. The lowest value (0.74) from sweet gourd + radish showed the opposite scenario. Soybean-pigeon pea intercropping system in the semi-arid tropics of India exhibited higher ATER value over sole soybean (Ghosh et al., 2006).

System Productivity Index (SPI)

SPI standardized the secondary intercrop yield of the main crop (sweet gourd) and also identified the best intercrop combinations in terms of stable yield performance (Tajudeen, 2010). The results showed that SPI value ranged from 33.31-44.73, and the highest value was given by the sweet gourd + red amaranth intercropping system, which indicates that all intercrops have higher yield potentiality and red amaranth was the best among them (Table 04). The results agree with Khan *et al.* (2018), who reported higher SPI from maize + two rows of garden pea intercropping system than other intercropping systems in Mymensingh during 2015-2017.

Replacement Value of Intercropping (RVI)

RVI is widely regarded as a robust metric for assessing the economic benefits associated with intercropping practices. The result revealed that RVI value ranged from 2.10-3.18, and sweet gourd + red amaranth intercropping system exhibited the highest RVI (3.18) among all treatments. This combo can earn 218% more than sweet gourd monoculture (Table 04).

Monetary Advantage Index (MAI)

Table 04 shows positive MAI values in all intercropping systems. The study shows the yield and economic benefits of intercropping short-duration vegetables. Sweet gourd + red amaranth had the highest MAI value (Tk. 4,10,939 ha^{-1}), indicating that this intercropping was profitable. Islam *et al.* (2016) found greater MAI values in turmeric-sesame intercropping systems than in mono-cropping.

Table 04. Competition dynamics as influenced by sweet gourd-vegetables intercropping system in Bandarban (averaged over 2020-21 & 2021-22)

Treatments	LER	ATER	SPI	RVI	MAI (Tk. ha^{-1})
T_0	1.00	1.00	-	-	-
T_1	1.45	0.74	33.31	2.10	178572.00
T_2	1.76	1.05	40.17	2.29	279473.00
T_3	1.96	1.25	44.73	3.18	410939.00
T_4	1.91	1.23	43.66	2.45	322931.00
T_5	1.70	1.28	39.21	2.80	320435.00

IV. Conclusion

Intercropping red amaranth with sweet gourd will be the best combination in terms of profitability in hill valleys. This intercrop combination provided the highest SEY (41.95 t ha^{-1}) with 82% increased productivity over the sole and exhibited the highest gross margin (Tk. 640200.00 ha^{-1}) and BCR (4.22) than all other combinations. Farmers can also grow bushbean, spinach and chinese cabbage as intercrop rather than sweet gourd monocropping.

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