

Effect of integrated plant nutrient management on soil fertility and crop productivity under Cauliflower-Amaranth-T. Aman Rice Cropping Pattern in Tista Meander Floodplain Soils of Bangladesh

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Abstract

A field experiment on Cauliflower-Amaranth-T. aman rice cropping pattern was conducted in Tista Meander Floodplain Soils (AEZ-3) at Sherpur, Bogura during the year of 2014 to 2016 with the objectives to enhance soil fertility through a balanced use of mineral fertilizers combined with organic sources of plant nutrients, to improve the efficiency of plant nutrients thus limiting losses to the environment and to increase sustainable crop yield. Eight treatments were tested. Treatment T₅ (3 t ha⁻¹ PM + IPNS) achieved the highest yields for all crops: cauliflower (43.0 and 51.33 t ha⁻¹), amaranth (63.33 and 65.0 t ha⁻¹), and T. aman yield (5.10 and 5.46 t ha⁻¹). T₅ also had the highest gross margin (582,882/- Tk ha⁻¹ yr.⁻¹) and benefit-cost ratio (2.78). Soil quality improved in order to incorporation of organic manures through integrated plant nutrition system. The native nutrient treatment produced the lowest yields.

Keywords: Organic Manures; Yield; Vegetables; Economics; Improvement; Nutrients

1. Introduction

Integrated Plant Nutrition Systems (IPNS) enhance soil productivity through a balanced use of organic and inorganic sources of plant nutrients in a way that maintains or improves soil fertility and is environmentally-friendly. Soil test based (STB) fertilizer management is deemed great significance for improvement of soil health and sustainable yield. An integrated plant nutrition system (IPNS) enables the adaptation of the plant nutrition and soil fertility management in farming systems to site characteristics, taking advantage of the combined and harmonious use of organic, mineral and biofertilizer nutrient resources to serve the concurrent needs of food production and economic, environmental and social viability. Almost every cropping pattern is rice based in Bangladesh. Out of the total land area of 13.01 million ha, a little over 8.2 million ha is suitable for crop cultivation situated in the highlands and medium highlands, where the farmer's grow 2-3 crops. A crop production system with high yield target will not be sustainable unless nutrients inputs to soil are least balanced against nutrient removal of crops. However, application of imbalanced and/or excessive nutrients led to declining nutrient-use efficiency making fertilizer consumption uneconomical and producing adverse effects on atmosphere (Aulakh and Adhya 2005 and Aulakh, M.S. 2010) and groundwater quality (Aulakh *et al.* 2009) causing health hazards and climate change. INM, which entails the maintenance/adjustment of soil fertility to an optimum level for crop productivity to obtain the maximum benefit from all possible sources of plant nutrients organics as well as inorganics – in an integrated manner (Aulakh and Grant 2008).

Cauliflower is nutritious, tasteful and popular winter vegetable in our country. In Bangladesh, about 10,000 ha land is cultivated for cauliflower and its production is about 76,000 t which is too much low for our over populated country. It

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can be grown all over the country so there is ample scope of extending the cultivated area. Amaranth is a vegetable crop which grown in Bangladesh during summer and rainy season. It is a quick growing crop characterized by its short duration and large yield of edible matter per unit area. The fresh tender leaves and stem of amaranths are rich in protein, minerals and vitamin. Amaranth can be grown in a wide range of soils preferably cauliflower-amaranth cropping pattern is suitable to cultivate at AEZ-3 (FRG 2012). Rice-fallow-Rice cropping pattern is still a major pattern in many parts of the country. But most of the farmers do not know about crop diversification in the same land for improvement of soil health. In that case, inclusion of vegetable in rice-based cropping pattern following IPNS will sustain production which enhances nutritive quality of the produce, improving soil health, and minimizing environmental pollution. Therefore, the study was undertaken to increase economically-viable sustainable production of Cauliflower-Amaranth-T. aman cropping systems.

Objectives

The main objectives are

- To enhance soil fertility through a balanced use of mineral fertilizers combined with organic sources of plant nutrients
- To improve the efficiency of plant nutrients, thus limiting losses to the environment
- To increase sustainable crop yield

2. Material and methods

A Field experiment was conducted in the Tista Meander Floodplain Soils (AEZ-3) at Sherpur, Bogura during 2014-2015 and 2015-2016. The initial soil samples collected from depth of 0-15 cm were analyzed in the laboratory following standard methods. Initial values of some important chemical parameters of soil of the experimental field are presented in Table 1. Nutrient status of the cowdung (CD) and poultry manure (PM) used in the experiment are shown in Table 2.

The experiment was laid out in a randomized complete block design with three replications. Eight different treatments viz. T₁: Native Nutrient, T₂: 75% STB from chemical fertilizers T₃: 100% STB from chemical fertilizers, T₄: 75% STB chemical fertilizer + 3 t ha⁻¹ PM, T₅: 3 t ha⁻¹ PM + IPNS, T₆: 75% STB chemical fertilizer + 5 t ha⁻¹ CD, T₇: 5 t ha⁻¹ CD + IPNS and T₈: 125% STB chemical fertilizer were selected for different plots randomly. IPNS means releasing amount of nutrients of cowdung and poultry manure were subtracted from STB basis chemical fertilizers. The unit plot size was 3m × 3m. The tested crop was cauliflower and the hybrid variety was Snow white. Thirty-one days seedlings of cauliflower were transplanted in line with 60 cm row to row and 50 cm seedlings spacing on 24 November in 2015 and 22 November in 2016. The BARI danta-1 was sown on 19 March 2015 and 12 March 2016 in line with 30 cm. Seeds were treated with vitavex prior to seeding. The T. aman variety BRRIdhan 57 were transplanted in line with 20 cm row to row and 15 cm seedlings spacing in 1 August 2015 and 4 August 2016.

Fertilizer N-P-K-S-Zn-B were supplied from urea, TSP, MP, gypsum, zinc sulphate and boric acid, respectively. All PKSZnB and 1/3 of N were applied at the time of final land preparation. The remaining two third of N were applied as top dress at 15 and 40 days after transplanting cauliflower. In case of T. aman, 2nd and 3rd top dress of N was applied at early tillering stage and 5-7 days before panicle initiation stage, respectively. Irrigation and other intercultural operations were done as and when required. The crops were harvested i.e. cauliflower on 25 February in 2015 and 24 February in 2016, BARI danta-1 on 28 April to 6 May 2015 and 25 April to 4 May 2016 and T. aman on 25 October 2015 and 4 November 2016. Data on yield and yield contributing characters were recorded and analyzed statistically using MSTATC, Statistical Analysis System version 9.3 (SAS Institute Inc. NC, USDA) and Statistics 10. DMRT, LSD and Tukey's test was used to determine the significant differences between treatments (Steel and Torrie, 1980). Plant samples and post-harvest soil samples were collected from each plot for chemical analysis.

Table 1 Chemical properties of experimental soil (initial) at Sherpur, Bogura during 2014-2015

Location	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	B	Zn
			meq 100g ⁻¹				µg g ⁻¹			
Bogura	6.5	1.06	4.5	2.1	0.15	0.06	14.4	18.0	0.10	2.12
Critical Level	-	-	2.0	0.5	0.12	0.12	7	10	0.20	0.6

Table 2 Nutrient status of poultry manure and cow dung used in the experimental field

Name of the manure	pH	OM	Ca	Mg	K	Total N	P	S	B	Zn
		%								
Poultry manure	8.1	18.7	13.0	2.8	0.87	2.13	2.55	0.90	0.011	0.11
Cow dung	7.5	12.4	1.50	0.44	0.53	1.15	1.32	0.38	0.013	0.15

Moisture content of CD = 20.46, PM = 18.25.

3. Results and discussion

3.1. Cauliflower

There was a significant effect of different nutrient management treatments on the yield and yield contributing characters of cauliflower in both the year (Table 3 and Table 4). The plant height of cauliflower varied significantly among the treatments. Highest plant height of 62.23 and 65.33 cm was obtained from T₅ treatment (3 t PM + IPNS) during the year 2014-2015 and 2015-2016 respectively. Curd length and curd circumference significantly influenced by different treatments. Highest curd length of 21.30 and 17.57 cm were obtained from T₅ treatment during the year 2014-2015 and 2015-2016, respectively. These curd lengths were statistically similar with T₃, T₄, T₆, T₇ and T₈ treatments in the year 2014-2015. Lowest curd length of 7.90 and 7.97 cm was obtained from T₁ treatment (control) during the year 2014-2015 and 2015-2016, respectively. Highest curd circumference of 55.53 and 55.60 cm was obtained from T₅ treatment during the year 2014-2015 and 2015-2016, respectively which was statistically similar to all treatment except T₂ and control treatment in 2014-15 and statistically similar to T₃, T₄, T₆ and T₇ treatments in 2015-16. Significantly lowest curd circumference of 44.07 and 37.57 cm was found in the native nutrient treatment (T₁) in both the years. This might be due to the greater efficiency of poultry manure that releasing different available nutrients by mineralization. Mehla *et al.* (2006) found that the higher photosynthetic efficiency of plants estimated in terms of biomass accumulation seems to be one of the potential factors for improving various yield components. Hence, plants are able to get nutrients for higher yield (Al-Nasir, 2002) upon application of organic manures.

This trend of influence of the treatments were observed with marketable wt. of single curd and the curd yield per hectare (Tables 3). Marketable wt. of single curd and yield of cauliflower significantly influenced by different treatments. Highest marketable wt. of single curd was found in T₅ treatment (1.31 g in 2014-2015 and 1.53 g in 2015-2016) which were statistically similar to T₄, T₆ and T₇ treatments. Lowest marketable wt. of single curd 0.68 g in 2014-2015 and 0.90 g in 2015-2016 were attained in control treatment. Highest curd yield 43.00 and 51.33 t ha⁻¹ were obtained from T₅ treatment during the year 2014-2015 and 2015-2016, respectively. These curd yields are statistically similar with T₄ and T₇ treatment. Lowest curd yield 22.77 t ha⁻¹ in 2014-2015 and 22.40 t ha⁻¹ in 2015-2016 were found from T₁ (control) treatment. Reza *et al.* (2016) reported that curd diameter and cauliflower yield were higher in vermicompost 5 t ha⁻¹ + IPNS treatment. This result is supported by Farahzety and Aishah (2013) and Sanjida *et al.* (2019).

Table 3 Effect of different treatments on the yield and yield attributes of cauliflower under Cauliflower-Amaranth-T. aman cropping pattern at Sherpur, Bogura during 2014-2015

Treatments	Plant height (cm)		Curd length (cm)		Curd circumference (cm)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
T ₁ = Control	49.10b	42.00d	7.90c	7.97d	44.07b	37.57c
T ₂ = 75% STB	56.67ab	56.67c	18.60b	15.60c	46.15b	53.03b
T ₃ = 100% STB	61.50a	61.33abc	18.93ab	16.27bc	51.07a	54.30ab
T ₄ = 75% STB + 3 t PM	60.73a	59.67abc	20.40ab	16.17bc	51.20a	54.17ab
T ₅ 3 t PM + IPNS	62.23a	65.33a	21.30a	17.57a	55.53a	55.60a
T ₆ = 75% STB + 5 t CD	59.33ab	63.33abc	20.10ab	16.57b	54.20a	54.33ab
T ₇ = 5 t CD + IPNS	60.40a	64.00ab	20.53ab	16.23bc	52.10a	54.67ab
T ₈ = 125% STB	55.57ab	57.67bc	20.43ab	16.63b	50.37a	53.63b
CV (%)	6.44	6.12	7.53	6.59	8.05	7.89

Means followed by the same letter in a column are not statistically significant at 5% level.

Table 4 Effect of different treatments on the yield and yield attributes of cauliflower under Cauliflower-Amaranth-T. aman rice cropping pattern at Sherpur, Bogura during 2014-2015 to 2015-2016

Treatments	Marketable wt. of single curd (g)		Curd Yield (t ha ⁻¹)	
	2014-15	2015-16	2014-15	2015-16
T ₁ = Control	0.68c	0.90b	22.77c	22.40c
T ₂ = 75% STB	1.03b	1.33a	33.45b	32.66b
T ₃ = 100% STB	1.07b	1.40a	35.78b	47.46a
T ₄ = 75% STB + 3 t PM	1.27a	1.38a	42.33a	50.33a
T ₅ = 3 t PM + IPNS	1.31a	1.53a	43.00a	51.33a
T ₆ = 75% STB + 5 t CD	1.27a	1.50a	36.63b	50.00a
T ₇ = 5 t CD + IPNS	1.15ab	1.37a	38.22ab	49.87a
T ₈ = 125% STB	1.10b	1.53a	34.00b	48.26a
CV (%)	5.27	7.88	5.49	9.33

Means followed by the same letter in a column are not statistically significant at 5% level.

3.2. Amaranth

Yield and yield contributing characters of amaranth were significantly influenced by different treatments at Sherpur, Bogura (Table 5 and Table 6). Maximum plant height (82.67 cm in 2014-15 and 83.67 cm in 2015-16) was found in T₅ treatment. The highest leaf yield (33.83 t ha⁻¹ in 2014-15 and 37.83 t ha⁻¹ in 2015-16) was noted in T₅ treatment which was statistically similar to all treatments except control treatment in the year of 2014-15. The highest stem length (62.47 cm in 2014-15 and 62.80 cm in 2015-16) and highest stem circumference (10.23 cm in 2014-15 and 10.28 cm in 2015-16) were found in T₅ treatment. The highest yield of amaranth 63.33 t ha⁻¹ and 65.0 t ha⁻¹ were obtained in T₅ treatment in the year of 2014-15 and 2015-16, respectively. This amaranth yield was statistically similar to the all-integrated nutrient treatment except control treatment. Organic sources might play the key role in enhancing efficient utilization of the native as well as added fertilizer nutrients which maintain a balance between growth and this yield attribute. Pramanik *et al.* (2021) investigated that; stem yield of amaranth was higher due to N based organic compost treated plots under all the previous vegetable crops. They also reported that, yield and yield parameters of stem amaranth were performed better when the pre-crop was cauliflower under Cauliflower - Amaranth - T. Aman cropping system due to soil test based inorganic fertilizer with N based organic compost.

Table 5 Effect of different treatments on the yield and yield attributes of amaranth under Cauliflower-Amaranth-T. aman rice cropping pattern at Sherpur, Bogura during 2014-15 to 2015-16

Treatments	Plant height (cm)		Leaf yield (t ha ⁻¹)		Stem length (cm)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
T ₁ = Control	63.33c	56.67d	19.50b	19.50c	49.00c	40.67d
T ₂ = 75% STB	69.73bc	61.67d	30.11a	20.50c	50.60c	49.67c
T ₃ = 100% STB	81.20a	73.07c	32.66a	30.00b	59.85ab	51.27bc
T ₄ = 75% STB + 3 t PM	73.20abc	74.87bc	32.00a	33.00ab	60.20ab	61.20a
T ₅ = 3 t PM + IPNS	82.67a	83.67a	33.83a	37.83a	62.47a	62.80a
T ₆ = 75% STB + 5 t CD	78.50ab	76.60abc	29.66a	33.00ab	54.47bc	54.80bc
T ₇ = 5 t CD + IPNS	70.20bc	82.53ab	30.33a	33.50ab	56.27abc	61.40a
T ₈ = 125% STB	79.93ab	73.53c	35.83a	33.33ab	60.73ab	57.27ab
CV (%)	6.82	6.08	7.13	9.58	6.94	6.29

Means followed by the same letter in a column are not statistically significant at 5% level.

Table 6 Effect of different treatments on the yield and yield attributes of amaranth under Cauliflower-Amaranth-T. aman rice cropping pattern at OFRD, Bogura during 2014-15 to 2015-2016

Treatments	Stem circumference (cm)		Amaranth Yield (t ha ⁻¹)	
	2014-15	2015-16	2014-15	2015-16
T ₁ = Control	5.70c	5.70c	43.33b	38.00b
T ₂ = 75% STB	8.00b	7.87b	55.86ab	45.00b
T ₃ = 100% STB	9.50a	9.73a	58.33a	59.67a
T ₄ = 75% STB + 3 t PM	9.90a	9.87a	63.33a	64.67a
T ₅ = 3 t PM + IPNS	10.23a	10.28a	63.33a	65.00a
T ₆ = 75% STB + 5 t CD	9.47a	9.63a	61.66a	64.00a
T ₇ = 5 t CD + IPNS	9.53a	10.14a	62.33a	64.33a
T ₈ = 125% STB	9.95a	10.00a	63.00a	63.67a
CV (%)	8.23	10.01	5.73	7.33

Means followed by the same letter in a column are not statistically significant at 5% level

3.3. T. Aman

Yield contributing characters and yield of T. aman were significantly influenced by different treatments in both of the year 2014-2015 and 2015-2016 at Sherpur, Bogura (Table 7 and Table 8). Plant height of T. aman significantly varied among the treatments and it ranged from 97.67 to 103.3 cm and 96.20 to 106.0 cm in the year of 2014-2015 and 2015-2016, respectively. Highest plant height was obtained from 3 t PM with IPNS treatment and lowest plant height was recorded in control (T₁) treatment.

Highest number of tiller hill⁻¹ (16.23) was found in T₅ (3 t PM + IPNS) treatment which was statistically similar to T₄, T₆, T₇ and T₈ treatment in the year of 2014-2015 but in the year of 2015-16, there was no significance differences. Lowest number of tillers hill⁻¹ 11.87 in the year 2014-2015 and 14.37 in the year 2015-2016 were found in control (T₁) treatment. Panicle length of T. aman significantly varied among the treatments and it ranged from 23.87 to 28.87 cm and 17.67 to 21.33 cm in 2014-2015 and 2015-2016, respectively. The highest panicle length was obtained from T₅ treatment and lowest panicle length was recorded in control (T₁) treatment in both the years. Rahman *et al.*, (2009) reported that, poultry manure at the rate of 3 t ha⁻¹ applied with 80 kg ha⁻¹ nitrogen in rice crop produced the longest panicle. The number of filled grains panicle⁻¹ significantly influenced by the treatments in both the years. Highest number of filled grains panicle⁻¹ 98.27 and 120.0 were obtained from T₅ treatment in the year 2014-2015 and 2015-2016, respectively. These number of filled grains panicle⁻¹ were statistically similar with T₃, T₄, T₆ and T₇ treatments. These results are in agreement with those of study as well as the findings reported by Chettri *et al.* (2002). Lowest number of filled grains panicle⁻¹ 80.43 and 97.67 were obtained from native nutrient treatment (T₁) during the year 2014-2015 and 2015-2016, respectively. 1000-grain weight of T. aman significantly varied among the treatments 19.33 to 20.67 cm and 16.97 to 19.89 cm in 2014-2015 and 2015-2016, respectively. Straw yield of T. aman significantly differed among the treatments and it ranged from 6.82 to 7.46 and 5.23 to 7.00 t ha⁻¹ in 2014-2015 and 2015-2016, respectively. The highest straw yield was obtained from T₅ treatment and the lowest straw yield was recorded in control (T₁) treatment. Similarly, grain yield of T. aman significantly influenced by different treatments. Highest grain yield of 5.10 and 5.46 t ha⁻¹ were obtained from T₅ treatment during the year 2014-2015 and 2015-2016, respectively. These grain yields were statistically similar with T₄, T₆ and T₇ treatments. Lowest grain yield of 3.36 t ha⁻¹ in 2014-2015 and 3.03 t ha⁻¹ in 2015-2016 were obtained from T₁ treatment (control). Saha *et al.* (2016) observed that grain and straw yield of T. aman rice was significantly increased by 3 t ha⁻¹ PM with IPNS basis chemical fertilizers which supports the result of present study.

Table 7 Effect of different treatments on the yield and yield attributes of T. Aman under Cauliflower-Amaranth-T. aman rice cropping pattern at Sherpur, Bogura during 2014-2015 to 2015-2016

Treatments	Plant height (cm)		Tiller hill ⁻¹ (no.)		Panicle length (cm)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
T ₁ = Control	97.67b	96.20b	11.87d	14.37	23.87c	17.67b
T ₂ = 75% STB	103.0a	103.0ab	14.17c	15.63	24.67bc	20.67ab
T ₃ = 100% STB	102.1a	102.1ab	14.50bc	15.97	26.17b	20.67ab
T ₄ = 75% STB + 3 t PM	101.7a	103.8a	15.97ab	16.07	28.83a	20.33ab
T ₅ = 3 t PM + IPNS	103.3a	106.0a	16.23a	16.47	28.87a	21.33a
T ₆ = 75% STB + 5 t CD	102.6a	103.1ab	15.30abc	16.17	26.37b	20.67ab
T ₇ = 5 t CD + IPNS	102.2a	103.5ab	15.77ab	16.17	26.60b	20.67ab
T ₈ = 125% STB	102.3a	103.1ab	14.93abc	16.57	28.17a	21.33a
CV (%)	8.16	4.36	5.29	8.08	6.99	8.04

Means followed by the same letter in a column are not statistically significant at 5% level in DMRT test.

Table 8 Effect of different treatments on the yield and yield attributes of T. Aman under Cauliflower-Amaranth-T. aman rice cropping pattern at Sherpur, Bogura during 2014-2015 to 2015-2016

Treatments	Filled grain panicle ⁻¹ (no.)		1000 grain wt. (g)		Straw yield (t ha ⁻¹)		Grain yield (t ha ⁻¹)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
T ₁ = Control	80.43c	97.67d	19.33b	16.97cd	6.82b	5.23c	3.36b	3.03c
T ₂ = 75% STB	90.15b	113.0bc	20.00ab	15.63d	7.26a	6.23b	4.86a	4.86b
T ₃ = 100% STB	96.27a	114.0abc	20.33ab	19.49a	7.35a	6.45ab	4.97a	5.08ab
T ₄ = 75% STB + 3 t PM	96.53a	119.0ab	20.00ab	19.83a	7.26a	6.98a	5.07a	5.34a
T ₅ = 3 t PM + IPNS	98.27a	120.0a	20.67a	19.89a	7.46a	7.00a	5.10a	5.46a
T ₆ = 75% STB + 5 t CD	97.97a	114.3abc	20.00ab	18.99ab	7.41a	6.45ab	5.01a	5.11ab
T ₇ = 5 t CD + IPNS	97.97a	115.3abc	20.00ab	19.00ab	7.42a	6.88ab	5.04a	5.08ab
T ₈ = 125% STB	88.50b	112.0bc	20.00ab	17.63bc	7.44a	6.80ab	5.06a	4.89b
CV (%)	8.05	7.76	9.13	5.02	8.43	7.24	7.33	8.16

Means followed by the same letter in a column are not statistically significant at 5% level in DMRT test.

3.4. Chemical properties of post-harvest soil

Effect of different nutrient treatment on post-harvest soil is presented in Table 9. Data presented in Table 9 showed that the pH of the post-harvest soil ranged from 6.4 to 6.8 whereas the initial soil pH was 6.5. There was no change on soil pH in post-harvest soil. Organic matter content increased in post soil than initial soil in integrated nutrient treated plot and decreased in control plot. Highest organic matter content 1.48% was recorded in T₄ (75% STB + 3 t PM) and T₅ (3 t PM + IPNS) treatments. Similarly, nitrogen content increased in integrated nutrient treated plot and decreased in control plot than initial soil. N content in post-harvest soils ranged from 0.05% to 0.08%. Highest nitrogen content 0.08% was obtained in T₄, T₅, T₆, and T₇ treatments. Inorganic nitrogen along with poultry manure and cowdung increased total N content in soil. This might have happened due to the N accumulation in soil either by the application of N-fertilizer or organic manure which built up OM in soil. The lowest total N content in soil (0.05%) was obtained from T₁ (control) treatment at harvest time. After T. aman rice harvest, the exchangeable K content in post-harvest soils was not increased than initial soil. The range of exchangeable K content in post-harvest soils of 0.13-0.17 meq100g⁻¹ soil. The lowest value was observed in T₁ (control) treatment. It was reported that the FYM application could increase total N, available P and

exchangeable K content in soil (Bharadwaj and Omanwar, 1994; Kaushik *et al.*, 1994). This results also supported by Saha *et al.* (2016)

Maximum P content in soil ($16.37 \mu\text{g g}^{-1}$) was recorded in T₅ treatment (3 t PM + IPNS) followed by T₄ (75% STB + 3 t PM) treatment. The minimum P content in soil was found in T₁ (control) treatment. The available S and B content in the post-harvest soil increased than initial soil and it's ranged from 14.40 to $24.43 \mu\text{g g}^{-1}$ and 0.08 to $0.15 \mu\text{g g}^{-1}$, respectively. The maximum available S content $24.43 \mu\text{g g}^{-1}$ in post-harvest soil was recorded in T₅ treatment which was superior to the rest of the treatments. The highest available B content $0.15 \mu\text{g g}^{-1}$ in post-harvest soil was observed in T₅ treatment at Sherpur, Bogura. Available B content in post-harvest soil was increased due to combined application of chemical and inorganic fertilizers.

Organic carbon, total N, exchangeable K, Ca and Mg, available P, S, B and Zn were increased due to application of organic manure compared to that of initial soil. The highest NPKSBZnCaMg content and OC% in post-harvest soil received from poultry manure @ 3 t ha⁻¹ with IPNS basis chemical fertilizer which was supported by Sabina Devkota *et al.*, (2021).

Table 9 Chemical properties of post-harvest soil after completion of Cauliflower-Amaranth-T. aman rice cropping pattern during 2015-2016

Treatment	Soil pH	OM	Total N	K meq 100g ⁻¹	P	S	B
		%			$\mu\text{g g}^{-1}$		
T ₁ = Control	6.5	1.01	0.05	0.13	8.30	14.40	0.08
T ₂ = 75% STB	6.5	1.15	0.07	0.16	12.77	20.43	0.11
T ₃ = 100% STB	6.5	1.34	0.06	0.16	14.57	23.37	0.13
T ₄ = 75% STB + 3 t PM	6.7	1.48	0.08	0.17	16.23	23.27	0.14
T ₅ = 3 t PM + IPNS	6.8	1.48	0.08	0.17	16.37	24.43	0.15
T ₆ = 75% STB + 5 t CD	6.8	1.47	0.08	0.17	15.20	23.20	0.14
T ₇ = 5 t CD + IPNS	6.7	1.47	0.08	0.16	15.97	24.30	0.14
T ₈ = 125% STB	6.4	1.32	0.08	0.16	14.93	21.93	0.13

3.5. Benefit cost analysis

Table 10 Benefit cost ratio analysis for Cauliflower-Amaranth-T. aman rice cropping pattern at Sherpur, Bogura during 2014-2015 and 2015-2016

Treatments	Av. yield (t ha ⁻¹)			Total gross return	Total variable cost	Gross margin	BCR
	Curd	Amaranth	Aman				
T ₁ = Control	22.59	40.67	3.20	493250	144350	348900	2.42
T ₂ = 75% STB	33.06	50.43	4.86	582847	181774	401073	2.21
T ₃ = 100% STB	41.62	59.67	5.03	714651	197800	516851	2.61
T ₄ = 75% STB + 3 t PM	46.33	64.00	5.21	783404	217774	565630	2.60
T ₅ = 3 t PM + IPNS	47.17	64.17	5.28	792656	209774	582882	2.78
T ₆ = 75% STB + 5 t CD	43.32	62.83	5.06	747451	210774	536677	2.55
T ₇ = 5 t CD + IPNS	44.05	63.33	5.06	757251	207774	549477	2.64
T ₈ = 125% STB	41.13	63.34	4.98	728100	205580	522520	2.54

Urea= Tk. 17 kg⁻¹, TSP= Tk. 28 kg⁻¹, MoP= Tk. 16 kg⁻¹, Gypsum= Tk. 10 kg⁻¹, Boric Acid= Tk.170 kg⁻¹, Cowdung = Tk. 3 kg⁻¹, Poultry manure= Tk. 5 kg⁻¹, Cauliflower = Tk. 10 kg⁻¹, Amaranth = 5 kg⁻¹, Aman rice grain= Tk. 20 kg⁻¹.

Benefit cost analysis of the Cauliflower-Amaranth-T. aman rice cropping pattern is given in Table 10. Highest gross return 792656 Tk. ha⁻¹ yr.⁻¹ was obtained from T₅ treatment and the highest gross margin 582882 Tk. ha⁻¹ yr.⁻¹ was also

noted in T₅ treatment. The highest benefit cost ratio (2.78) was found in T₅ (PM + IPNS) treatment which was followed by T₇ (CD + IPNS) treatment.

4. Conclusion

Combined application of organic manures and inorganic fertilizers produced higher crop yields in cauliflower-amaranth-T. aman rice cropping pattern than inorganic fertilizers. Poultry manure and cowdung had significant positive effect on the yield and yield contributing characters of the crops in the pattern. Soil Test Basis (STB) IPNS treatment through poultry manure recorded higher yield of the crops in cauliflower-amaranth-T. aman rice cropping pattern. IPNS treatments through cowdung or poultry manures showed almost similar performance and it improved chemical properties of post-harvest soil thus sustained soil fertility. Economic analysis showed that, the highest gross margin and highest BCR were noted with T₅ (PM + IPNS) treatment. So, it could be used in cauliflower-amaranth-T. aman rice cropping pattern for crop productivity and soil health improvement at AEZ-3 of Bangladesh. The farmers may preferably choose any of the two treatments which can give a higher gross margin with relatively a lower variable cost and which can sustain soil fertility.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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