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NUTRIENT REQUIREMENT FOR HIGHER SEED YIELD OF GYPSOPHILA (*Gypsophila paniculata*)

M. A. QUDDUS[1], F. NASRIN KHAN[2], M. M. MASUD[3]
M. A. SIDDIKY[4] AND M. ATAUR RAHMAN[5]

Abstract

A study was conducted at the research field of Bangladesh Agricultural Research Institute (BARI), Gazipur to determine the optimum dose of N, P, K and S for higher seed yield of Gypsophila (*Gypsophila paniculata*). The experiment was designed with 15 treatment combinations taking 4 doses each of N (0, 70, 100 & 130 kg ha^{-1}), P (0, 20, 40 & 60 kg ha^{-1}), K (0, 60, 90 & 120 kg ha^{-1}) and S (0, 10, 20 & 30 kg ha^{-1}) arranged in a randomized complete block design (RCBD) with three replications. A blanket dose of 3 kg Zn ha^{-1} and 1.5 kg B ha^{-1} along with cowdung at 5 t ha^{-1} was used. The results showed that the significantly highest seed yield (903 kg ha^{-1}) of gypsophila was recorded from combined application of 100 kg N, 40 kg P, 60 kg K and 20 kg S per ha which was 29% higher over control ($N_0P_0K_0S_0$).The maximum number of filled fruits per plant, seeds per fruit and 1000-seed weight were noted in the said treatment. The same treatment recorded the highest uptake of N, P, K and S. The apparent N, P and K recovery efficiency was also higher in the same treatment. The organic matter and total N in postharvest soil was also higher in the said treatment. The overall results suggest that combined application of N 100 kg, P 40 kg, K 60 kg and S 20 kg ha^{-1} including 3 kg Zn ha^{-1}, 1.5 kg B ha^{-1} and 5 t ha^{-1} cowdung would help to increase seed yield of Gypsophila.

Keywords: Gypsophila, seed yield, nutrient requirement, nutrient uptake.

Introduction

Globally Gypsophila (*Gypsophila paniculata L.*) is grown as a commercial filler cut flower, bedding or as potted plant (Wahome *et al.,* 2011). In Bangladesh it is a new flowering crop and its commercial value. Recently the researchers of BARI have released a new variety BARI Gypsophila-1. As a new crop, quality seed production is important (Rahman *et al*., 2017) for sustainable adaption and extension to the farmers.

Soils of Bangladesh are largely deficient in N, P, K and S due to intensive cropping, use of high yielding variety (HYV) crops and minimum use of manure which necessitate application of fertilizers to supply those nutrients in order to achieve higher crop yield. Preliminary studies on fertilizer management of gypsophila cut

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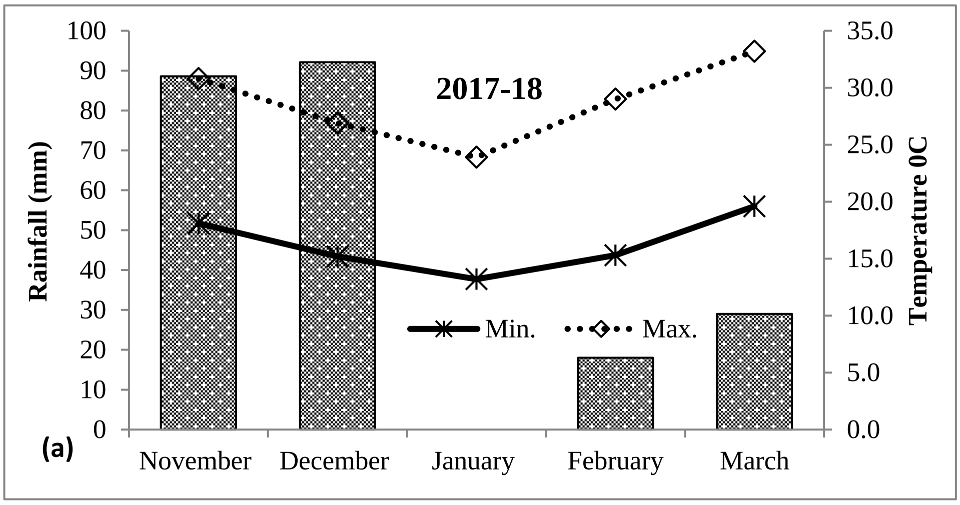
flower in Bangladesh have been published (Quddus *et al.*, 2021). But the information regarding the optimum requirement of N, P, K and S for seed production of gypsophila flower is lacking in Bangladesh. Considering the above perspectives, the present study was undertaken to ascertain the requirement of specific macro nutrients such as N, P, K and S for obtaining better seed yield of Gypsophila. This result would be used to update the national Fertilizer Recommendation Guide as well as fertilizer recommendation for Gypsophila cultivation.

Materials and Methods

Site description

The field trial was carried out at the research field of Floriculture Division of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur during *Rabi* season of 2017-18 and 2018-19. The experimental field was high land and the soil was terrace of *Chhiata* series under the AEZ Madhupur Tract (AEZ-28) (Shil *et al.*, 2016). Texturally the soil was clay loam having 6.5 pH, 1.20% organic matter, 0.061% total N, 12.2 ppm P, 0.13 meq./100 g soil K, 12.5 ppm S, 0.73 ppm Zn and 0.17 ppm B. Analyses of initial and postharvest soils were done following the standard methods (Page *et al*., 1982). Information on weather conditions (temperature and rainfall) during the cultivation period at the experimental site are presented in Figure 1a and Figure 1b.



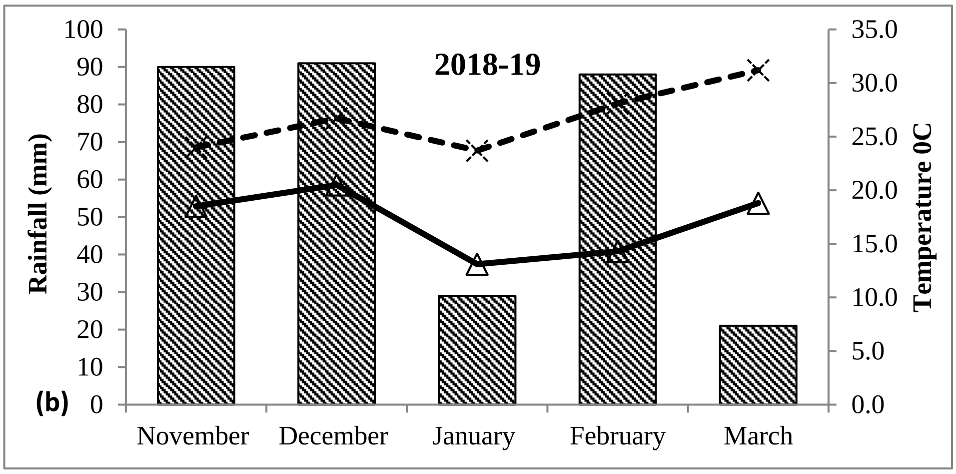


Fig. 1. Monthly mean minimum and maximum temperature ^{0}C and rainfall (a, b) during the experiment period of 2017-18 and 2018-19.

Land preparation, treatments and design

The experimental land was ready for the test crop by 4 passes with a tractor driven plough and leveled with a tractor driven rotavator. Weeds and stubbles were removed and cleaned manually. The experiment was designed with 15 treatment combinations taking 4 doses each of N (0, 70, 100 & 130 kg ha^{-1}), P (0, 20, 40 & 60 kg ha^{-1}), K (0, 60, 90 & 120 kg ha^{-1}) and S (0, 10, 20 & 30 kg ha^{-1}). The 15 treatment combinations were T_1 ($N_0P_0K_0S_0$), T_2 ($N_0P_{40}K_{90}S_{20}$), T_3 ($N_{70}P_{40}K_{90}S_{20}$), T_4 ($N_{100}P_{40}K_{90}S_{20}$), T_5 ($N_{130}P_{40}K_{90}S_{20}$), T_6 ($N_{100}P_0K_{90}S_{20}$), T_7 ($N_{100}P_{20}K_{90}S_{20}$), T_8($N_{100}P_{60}K_{90}S_{20}$), T_9 ($N_{100}P_{40}K_0S_{20}$), T_{10}($N_{100}P_{40}K_{60}S_{20}$), T_{11}($N_{100}P_{40}K_{120}S_{20}$), T_{12}($N_{100}P_{40}K_{90}S_0$), T_{14}($N_{100}P_{40}K_{90}S_{30}$) and T_{15} ($N_{130}P_{60}K_{120}S_{30}$). The blanket dose of Zn and B at 3 and 1.5 kg ha^{-1}, respectively including cowdung 5 t ha^{-1} were used in all treatments. The field trial was designed with randomized complete block design (RCBD) with three replications. The unit plot size was being 3.7 m × 1.5 m. 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. TSP, zinc sulphate, boric acid and decomposed cowdung were applied as basal during final land preparation. The 1/3rd of urea and ½ of MoP were applied basal as per above treatment plot. The healthy seeds of gypsophila (var. BARI Gypsophila-1) were sown continuously in rows at a rate of 2.5 kg ha^{-1} with the space of row to row 25 cm on 30 November 2017 and 28 November 2018.

Intercultural operations

Irrigation was done twice a week up to 40 days of seed sowing then it was applied single in a week before maturity. Hands weeding as well as thinning of seedlings were done at 20 days after sowing (DAS) keeping the distance of plant to plant as

10 cm. The rest 2/3rd of Urea and half of MoP were applied in two equal splits. The first split was applied at 20 days after sowing (DAS) and the second split at 35 DAS. The second hand weeding was done at 35 days after sowing. Seedlings were protected from disease (root rot) by using fungicide Dithane M-45 for two times at the rate of 2 g L^{-1} water at 25 and 35 days after sowing.

Data collection

The data on growth parameters of gypsophila were noted and cut flower yield was recorded from two rows of each treatment plot at 66 days after sowing (Quddus *et al*., 2021). The crop was harvested after maturity from the rest four rows of each treatment plot. Data on seed yield, straw yield and yield attributes viz. number of filled fruits and unfilled fruits per plant were recorded. The number of seeds per fruit was counted from randomly selected 10 fruits from each treatment plot and averaged. The 1000-seed weight (g) was determined from the composite seeds of each plot.

Plant samples analysis

Ground plant samples like ground straw and seed samples were digested with di-acid mixture (HNO3-HClO4) (5:1) by the procedure of Piper (1964) for estimation of N content by Micro-Kjeldahl method, P by using spectrophotometer, K by using atomic absorption spectrophotometer and S by turbidity method using $BaCl_2$ crystals and its determination by spectrophotometer).

Protein content estimation

The protein content in seed of gypsophila was calculated by using the constant food factor 6.25 that means (% N × 6.25) (Hiller *et al*., 1948).

Nutrient uptake determination

Nutrient (N, P, K and S) uptake by gypsophila was measured from the results of crop yields and nutrient content in seed and straw (Anon., 2018).

$$\text{Nutrient uptake} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg/ha)}}{100} \text{---------------(1)}$$

Nutrient use efficiency calculation

The apparent nutrient recovery efficiency (ANR) was calculated on dry weight basis according to Baligar *et al.* (2001). The equation as follows-

$$\text{ANR} = \frac{\text{Nutrient uptake(kg/ha)} - \text{control value}}{\text{Applied nutrient (kg/ha)}} \text{x } 100\text{------------- (2)}$$

Statistical analysis

Statistical analysis was done on the average data of two years. However, all data were subjected to statistical analysis of variance (ANOVA) according to Statistix 10 software (www.statistix.com). The means of each treatment were compared using the least significant difference (LSD) at significant level $p \leq 0.05$ (Statistix-10, 1985).

Results and Discussion

Seed yield attributes of Gypsophila

Seed yield contributing characters like number of filled fruits per plant, number of unfilled fruits per plant, number seeds per fruit and 1000-seed weight of gypsophila were significantly influenced by the application of N, P, K and S (Table 1). The maximum number of filled fruits per plant (87.2) was recorded with the treatment T_{10} but statistically identical with T_8. Adequate application of N, P, K and S stimulated higher flowering and fruit setting per plant leading to filled fruits. Similar report was corroborated by Nain *et al*. (2015) in African marigold and Samoon and Kirad (2013) in Calendula (*Calendula officinalis* L.) The lowest number of filled and unfilled fruits was observed in control (T_1) treatment. The highest number of seeds per fruit (18.9) was found in T_{10} treatment and the lowest from control treatment (Table 2). These results are in agreement with findings of Moon *et al*. (2018) in Gaillardia and Kumar and Moon (2014) in African marigold. The maximum 1000-seed weight was noted in T_{10} treatment which was statistically similar to T_3, T_4, T_5 and T_{14} treatments (Table 2). Similarly Samoon and Kirad (2013) reported that combined application of N and P recorded the maximum seed weight of Calendula.

Table 1. Effects of N, P, K and S application on seed yield attributes of Gypsophila (Pooled data of two years)

Treatments	No. of filled fruits plant^{-1}	No. of unfilled fruits plant^{-1}	No. of seeds fruit^{-1}	1000-seedwt. (g)
T_1 ($N_0P_0K_0S_0$)	43.7h	14.8d	10.5g	1.55c
T_2 ($N_0P_{40}K_{90}S_{20}$)	46.6h	15.4d	11.2g	1.70b
T_3 ($N_{70}P_{40}K_{90}S_{20}$)	65.1e-g	18.6a-d	14.1f	1.74ab
T_4 ($N_{100}P_{40}K_{90}S_{20}$)	72.4d	20.2a-d	16.3bc	1.78ab
T_5 ($N_{130}P_{40}K_{90}S_{20}$)	73.9cd	19.0a-d	16.6b	1.74ab
T_6 ($N_{100}P_0K_{90}S_{20}$)	68.4d-f	24.2abc	15.2c-e	1.25g
T_7 ($N_{100}P_{20}K_{90}S_{20}$)	63.0fg	19.3a-d	14.9d-f	1.70b
T_8 ($N_{100}P_{60}K_{90}S_{20}$)	81.4ab	26.3a	15.7b-d	1.51cd
T_9 ($N_{100}P_{40}K_0S_{20}$)	61.8fg	25.4ab	14.2ef	1.40ef
T_{10} ($N_{100}P_{40}K_{60}S_{20}$)	87.2a	18.2bcd	18.9a	1.81a
T_{11} ($N_{100}P_{40}K_{120}S_{20}$)	69.8de	21.9a-d	15.6b-d	1.44de
T_{12} ($N_{100}P_{40}K_{90}S_0$)	62.5fg	21.0a-d	16.0b-d	1.29g
T_{13} ($N_{100}P_{40}K_{90}S_{10}$)	79.5bc	18.3bcd	16.6b	1.71b
T_{14} ($N_{100}P_{40}K_{90}S_{30}$)	67.9def	16.3cd	15.0d-f	1.75ab
T_{15} ($N_{130}P_{60}K_{120}S_{30}$)	60.8g	18.7a-d	14.1f	1.32fg
CV (%)	6.01	13.4	4.55	3.50

Values within a column with common letter (s) do not differ significantly according to the least significant difference (LSD) test at $p \leq 0.05$.

Yield of Gypsophila

The seed and straw yields of gypsophila were significantly responded to the application of N, P, K and S fertilizers (Figures 2a, b). The maximum seed yield of 903 kg ha^{-1} was observed in the T_{10} ($N_{100}P_{40}K_{60}S_{20}$) treatment which was statistically similar with most of the treatments and the lowest seed yield was in control treatment (Figure 2a). The T_{10} treatment showed the maximum straw yield (1635 kg ha^{-1}) comparable with T_{13}, T_{14}, T_8, T_{11} and T_{12} treatments and the control treatment gave the lowest straw yield (Figure 2b). Addition of N, P, K and S fertilizer triggered the significant increase in seed and straw yields of gypsophila might be attributed to the healthy growth which may have more food reserves to be utilized during the growing period for more filled fruit of gypsophila ultimately increase the seed and straw yield. The result is in agreement with the findings of Sharma *et al.*, (2006) in African marigold who obtained significantly higher yield with balanced levels of nitrogen and phosphorus application. Similar result was also reported by Ravi Teja *et al.* (2017) in *Chrysanthemum coronarium* L. that combined application of N (200 kg ha^{-1}) and K (150 kg ha^{-1}) contributed to get higher yield. Among the treatments, the highest seed yield increment (29.0%) over control was obtained from the same T_{10} treatment (Figure 2c). Similar report was reported by Khan *et al.* (2012) in gladiolus and Senapati *et al*. (2020) in *Chrysanthemum*.

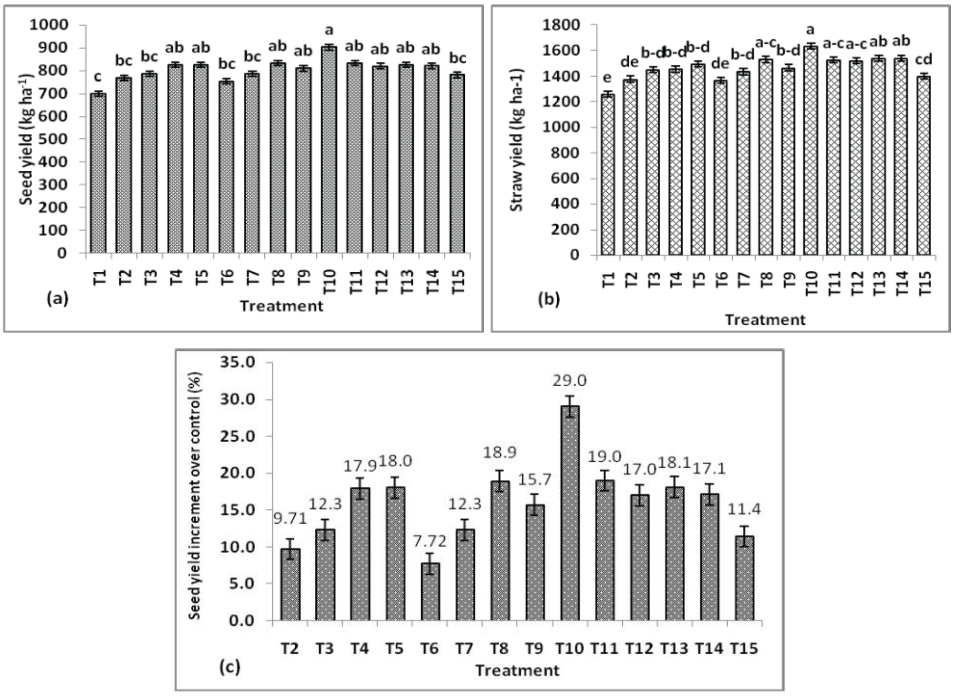


Fig. 2. Effects of nitrogen, phosphorus, potassium and sulphur on (a) seed yield, (b) straw yield and (c) seed yield increment over control of Gypsophila (pooled

data of two years). Mean values of above bars followed by the same letter are not significantly different according to the least significant difference (LSD) test at $p \leq 0.05$.

Note: $T_1(N_0P_0K_0S_0)$, $T_2(N_0P_{40}K_{90}S_{20})$, $T_3(N_{70}P_{40}K_{90}S_{20})$, T_4 $(N_{100}P_{40}K_{90}S_{20})$, $T_5(N_{130}P_{40}K_{90}S_{20})$, $T_6(N_{100}P_0K_{90}S_{20})$, $T_7(N_{100}P_{20}K_{90}S_{20})$, $T_8(N_{100}P_{60}K_{90}S_{20})$, $T_9(N_{100}P_{40}K_0S_{20})$, T_{10} $(N_{100}P_{40}K_{60}S_{20})$, $T_{11}(N_{100}P_{40}K_{120}S_{20})$, $T_{12}(N_{100}P_{40}K_{90}S_0)$, T_{13} $(N_{100}P_{40}K_{90}S_{10})$, $T_{14}(N_{100}P_{40}K_{90}S_{30})$and T_{15} $(N_{130}P_{60}K_{120}S_{30})$.

Effects of N, P, K and S addition on its content in seed of Gypsophila

The N, P, K and S contents in seed of gypsophila were influenced significantly by the application of N, P, K and S fertilizers (Table 3). The maximum N content in seed (35.8 g kg^{-1}) was recorded in T_5 which was statistically similar to T_{15} treatment. The maximum P content (4.91 g kg^{-1}) was noted in T_8 followed by T_{10} treatment. Higher K content (8.95 g kg^{-1}) was exhibited in T_{11} being statistically similar with T_{10}, T_8 and T_{14} treatment. Significantly the highest S content (2.32 g kg^{-1}) was found in T_{14} while control treatment showed the lowest N, P, K and S content values of 29.1, 3.39, 5.81 and 1.30 g kg^{-1}, respectively (Table 3).

Table 3. Effects of N, P, K and S addition on nutrient content in seed of Gypsophila (Pooled data of two years)

Treatment	N content	P content	K content	S content
	g kg^{-1}			
T_1 $(N_0P_0K_0S_0)$	29.1f	3.39g	5.81j	1.30e
T_2 $(N_0P_{40}K_{90}S_{20})$	29.8f	4.08ef	6.62i	1.72b-d
T_3 $(N_{70}P_{40}K_{90}S_{20})$	31.4d-f	4.38b-e	7.13gh	1.84bc
T_4 $(N_{100}P_{40}K_{90}S_{20})$	34.7a-c	4.46a-e	7.51e-g	1.90bc
T_5 $(N_{130}P_{40}K_{90}S_{20})$	35.8a	4.22d-f	7.33fg	1.81bc
T_6 $(N_{100}P_0K_{90}S_{20})$	32.9b-e	3.89f	7.72d-f	1.65cd
T_7 $(N_{100}P_{20}K_{90}S_{20})$	33.6a-d	4.23c-f	8.14b-d	1.73b-d
T_8 $(N_{100}P_{60}K_{90}S_{20})$	34.1a-c	4.91a	8.55ab	1.92bc
T_9 $(N_{100}P_{40}K_0S_{20})$	30.9ef	3.88f	6.16j	1.75b-d
T_{10} $(N_{100}P_{40}K_{60}S_{20})$	34.5a-c	4.90a	8.82a	1.92bc
T_{11} $(N_{100}P_{40}K_{120}S_{20})$	33.3a-e	4.26c-f	8.95a	1.88bc
T_{12} $(N_{100}P_{40}K_{90}S_0)$	32.4c-e	4.00ef	7.84c-e	1.47de
T_{13} $(N_{100}P_{40}K_{90}S_{10})$	34.0a-c	4.78ab	6.78hi	1.76bc
T_{14} $(N_{100}P_{40}K_{90}S_{30})$	35.4ab	4.69a-c	8.52ab	2.32a
T_{15} $(N_{130}P_{60}K_{120}S_{30})$	35.6a	4.57a-d	8.27bc	1.94b
CV (%)	4.55	6.47	3.40	9.58

Values in a column having common letter (s) do not differ significantly according to the least significant difference (LSD) test at $p \leq 0.05$.

Effects of N, P, K and S addition on protein content in seed of gypsophila

Gypsophila seed is a good source of food and it has medicinal value. The extracts of gypsophila are used as herbal cheese and ice cream with several uses (Korkmaz and Özçelik, 2011). However, application of N, P, K and S fertilizers contributed significantly to increase the protein content in seed of gypsophila (Figure 3).The protein content among the treatments varied from 18.2 to 22.4%. The maximum content of protein (22.4 %) was obtained from T_5 followed by T_{15} (22.3%) treatment while lowest content of protein (18.2%) from control (Figure 3). The maximum protein content in T_5 and T_{15} treatment might be related with increasing the level of N application up to 130 kg ha^{-1}. The augmenting effect of nitrogen on gypsophila seed protein content might be credited to the direct role of N in protein formation. Potassium might also involve in protein synthesis and nitrogen use efficiency which leads to increase the protein content in crop.

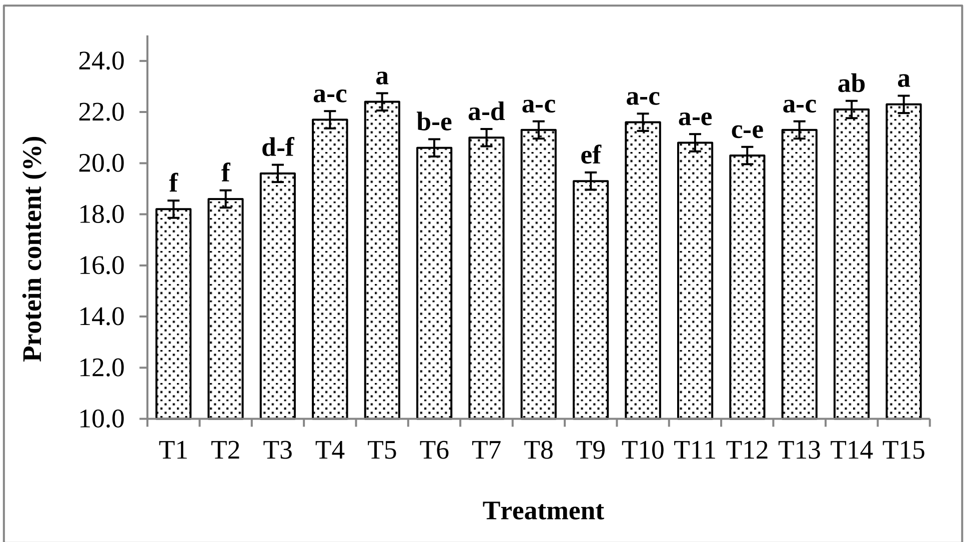


Fig. 3 Effect of N, P, K and S on protein content in seed of gypsophila (pooled data of two years). Mean values of above bars followed by the same letter are not significantly different according to the least significant difference (LSD) test at p≤0.05.

Note: $T_1(N_0P_0K_0S_0)$, $T_2(N_0P_{40}K_{90}S_{20})$, $T_3(N_{70}P_{40}K_{90}S_{20})$, T_4 $(N_{100}P_{40}K_{90}S_{20})$, $T_5(N_{130}P_{40}K_{90}S_{20})$, $T_6(N_{100}P_0K_{90}S_{20})$, $T_7(N_{100}P_{20}K_{90}S_{20})$, $T_8(N_{100}P_{60}K_{90}S_{20})$, $T_9(N_{100}P_{40}K_0S_{20})$, $T_{10}(N_{100}P_{40}K_{60}S_{20})$, $T_{11}(N_{100}P_{40}K_{120}S_{20})$, $T_{12}(N_{100}P_{40}K_{90}S_0)$, $T_{13}(N_{100}P_{40}K_{90}S_{10})$, $T_{14}(N_{100}P_{40}K_{90}S_{30})$ and T_{15} $(N_{130}P_{60}K_{120}S_{30})$.

Effects of N, P, K and S addition on its content in straw of Gypsophila

The application of N, P, K and S fertilizer affected their content in gypsophila straw (Tables 4). The increased N content in straw (33.1 g kg^{-1}) was recorded in T_5 which is statistically similar with T_4, T_{10}, T_{14} and T_{15} treatments. The maximum

P content (3.90 g kg^{-1}) was noted in T_8 treatment being close to T_{10} (Table 4). The maximum K content (24.2 g kg^{-1}) was exhibited in T_{11} treatment but similar to T_{12}, T_{12}, T_{13}, T_{14}, T_{15} and T_{10} treatments. The increased sulphur content in straw (1.99 g kg^{-1}) was found in T_{14} comparable to most of the treatments (Table 4). All nutrient content values in the study were shown inconsistent across the treatments. In the study, lesser content of N, P, K and S were recorded (24.0, 2.38, 12.2 and 1.20 g kg^{-1}, respectively) in T_1 (control) treatment (Table 4).

Table 4. Effects of N, P, K and S addition on nutrient content in straw of Gypsophila (Pooled data of two years)

Treatment	N content	P content	K content	S content
	g kg^{-1}			
T_1 ($N_0P_0K_0S_0$)	24.0g	2.38f	12.2f	1.20d
T_2 ($N_0P_{40}K_{90}S_{20}$)	24.7fg	3.02de	15.8e	1.62bc
T_3 ($N_{70}P_{40}K_{90}S_{20}$)	26.3f	3.34a-e	18.8d	1.73ab
T_4 ($N_{100}P_{40}K_{90}S_{20}$)	29.4de	3.40a-e	20.7c	1.81ab
T_5 ($N_{130}P_{40}K_{90}S_{20}$)	33.1a	3.12c-e	17.5d	1.76ab
T_6 ($N_{100}P_0K_{90}S_{20}$)	29.5de	2.88ef	17.9d	1.55b-d
T_7 ($N_{100}P_{20}K_{90}S_{20}$)	30.4b-e	3.21b-e	21.2c	1.66a-c
T_8 ($N_{100}P_{60}K_{90}S_{20}$)	30.0c-e	3.90a	21.7bc	1.87ab
T_9 ($N_{100}P_{40}K_0S_{20}$)	28.8e	2.87ef	12.4f	1.66a-c
T_{10} ($N_{100}P_{40}K_{60}S_{20}$)	32.0ab	3.89a	23.0ab	1.85ab
T_{11} ($N_{100}P_{40}K_{120}S_{20}$)	30.8b-d	3.25b-e	24.2a	1.79ab
T_{12} ($N_{100}P_{40}K_{90}S_0$)	29.5de	2.99de	23.0ab	1.35cd
T_{13} ($N_{100}P_{40}K_{90}S_{10}$)	30.6b-e	3.76ab	23.8a	1.63bc
T_{14} ($N_{100}P_{40}K_{90}S_{30}$)	31.5a-c	3.68a-c	24.0a	1.99a
T_{15} ($N_{130}P_{60}K_{120}S_{30}$)	31.7a-c	3.56a-d	24.1a	1.81ab
CV (%)	4.26	10.7	4.74	12.5

Values in a column having common letter (s) do not differ significantly according to the least significant difference (LSD) test at $p \leq 0.05$.

Effects of N, P, K and S addition on nutrient uptake (seed + straw) by Gypsophila

Application of N, P, K and S fertilizers influenced the uptake of N, P, K and S by Gypsophila (Tables 5). The maximum N uptake of 83.4 kg ha^{-1} was recorded in T_{10} which was statistically similar to T_8, T_3 and T_7 treatments. The maximum

Phosphorus uptake by Gypsophila (10.8 kg ha^{-1}) was noted in T_{10} which was comparable with T_8 and T_{13} treatments. The K uptake was also maximum (45.6 kg ha^{-1}) in T_{10} treatment which was statistically similar to T_{11} and T_{14} treatments. Concerning S uptake, T_{10} treatment showed the maximum (4.74 kg ha^{-1}) but not significantly different from T_{14}, T_8, T_{11}, T_{15}, T_{14}, T_3, T_4 and T_5 treatments. The minimum S uptake was exhibited in T_1 (control) treatment. Similar results have been reported in previous studies involving different crops, where added N, P, K and S had a significant positive influence on their uptake (Islam *et al*., 2018; Singh *et al*., 2013). It is noted that the control treatment exhibited the lowest N, P, K & S uptake recording the values of 50.8, 5.43, 19.7 & 2.44 kg ha^{-1}, respectively.

Table 5. Effects of N, P, K and S on nutrient uptake (seed + straw) by Gypsophila (Pooled data of two years)

Treatments	N uptake	P uptake	K uptake	S uptake
	kg ha^{-1}			
T_1 ($N_0P_0K_0S_0$)	50.8h	5.43h	19.7h	2.44f
T_2 ($N_0P_{40}K_{90}S_{20}$)	56.9gh	7.31fg	26.8f	3.58c-e
T_3 ($N_{70}P_{40}K_{90}S_{20}$)	62.8fg	8.21ef	32.7e	3.99a-d
T_4 ($N_{100}P_{40}K_{90}S_{20}$)	71.4c-e	8.67c-e	36.4d	4.22a-d
T_5 ($N_{130}P_{40}K_{90}S_{20}$)	79.0ab	8.14e-g	32.2e	4.13a-d
T_6 ($N_{100}P_0K_{90}S_{20}$)	66.0ef	6.96g	30.5e	3.42de
T_7 ($N_{100}P_{20}K_{90}S_{20}$)	70.0c-f	7.92e-g	36.8d	3.74b-d
T_8 ($N_{100}P_{60}K_{90}S_{20}$)	74.3b-d	10.1ab	40.3c	4.47ab
T_9 ($N_{100}P_{40}K_0S_{20}$)	67.3d-f	7.37fg	23.1g	3.84b-d
T_{10} ($N_{100}P_{40}K_{60}S_{20}$)	83.4a	10.8a	45.6a	4.74a
T_{11} ($N_{100}P_{40}K_{120}S_{20}$)	74.7b-d	8.50d-f	44.5ab	4.30a-c
T_{12} ($N_{100}P_{40}K_{90}S_0$)	71.4c-e	7.81e-g	41.4bc	2.84ef
T_{13} ($N_{100}P_{40}K_{90}S_{10}$)	75.3bc	9.76a-c	42.2bc	3.80b-d
T_{14} ($N_{100}P_{40}K_{90}S_{30}$)	77.4a-c	9.47b-d	44.0ab	4.51ab
T_{15} ($N_{130}P_{60}K_{120}S_{30}$)	72.1b-e	8.54c-f	40.2c	4.11a-d
CV (%)	6.36	8.87	5.30	13.3

Values in a column having common letter (s) do not differ significantly according to the least significant difference (LSD) test at $p \leq 0.05$.

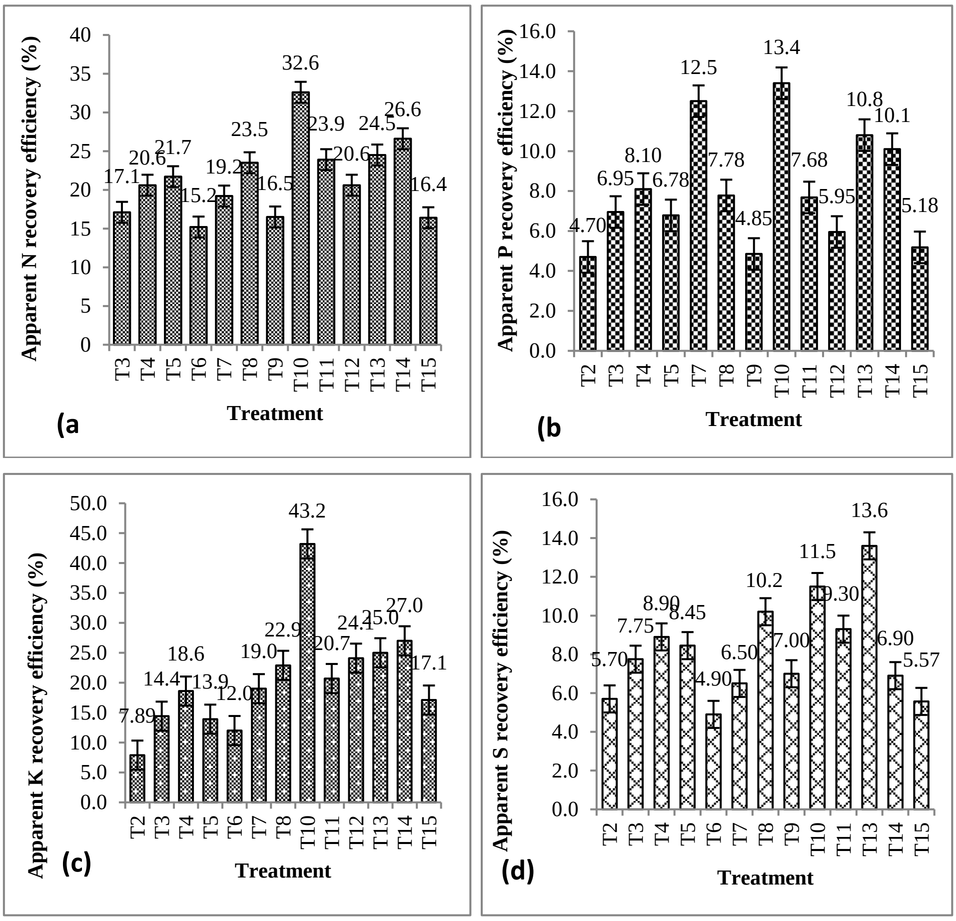


Fig. 4 Effect of nitrogen, phosphorus, potassium and sulphure on (a) apparent N recovery efficiency, (b) apparent P recovery efficiency, (c) apparent K recovery efficiency and (d) apparent S recovery efficiency of gypsophila.

Note: $T_1(N_0P_0K_0S_0)$, $T_2(N_0P_{40}K_{90}S_{20})$, $T_3(N_{70}P_{40}K_{90}S_{20})$, T_4 $(N_{100}P_{40}K_{90}S_{20})$, $T_5(N_{130}P_{40}K_{90}S_{20})$, $T_6(N_{100}P_0K_{90}S_{20})$, $T_7(N_{100}P_{20}K_{90}S_{20})$, $T_8(N_{100}P_{60}K_{90}S_{20})$, $T_9(N_{100}P_{40}K_0S_{20})$, $T_{10}(N_{100}P_{40}K_{60}S_{20})$, $T_{11}(N_{100}P_{40}K_{120}S_{20})$, $T_{12}(N_{100}P_{40}K_{90}S_0)$, T_{13} $(N_{100}P_{40}K_{90}S_{10})$, $T_{14}(N_{100}P_{40}K_{90}S_{30})$ and T_{15} $(N_{130}P_{60}K_{120}S_{30})$.

Effects of N, P, K and S addition on apparent nutrient recovery efficiency of gypsophila

The apparent N, P, K and S recovery efficiency of gypsophila was significantly influenced by the application of N, P, K and S fertilizers (Figure 4a, b, c, d). The highest apparent N recovery efficiency (32.6%) was recorded in T_{10} treatment while the lowest (15.2%) in T_6 treatment (Figure 4a). The apparent maximum P recovery efficiency (13.4%) was attained in T_{10} followed T_7 treatment and minimum value of P recovery efficiency in T_2 treatment (Figure 4b). The highest apparent K recovery efficiency (43.2%) was also recorded in the said T_{10} treatment while the lowest value in T_2 treatment (Figure 4c). In the study, the maximum apparent S recovery efficiency (13.6%) was found in T_{13} treatment and the minimum (4.90%) in T_6 treatment (Figure 4d). Nutrient absorption power of Gypsophila might be depended on the utilization of biological levels and varied recovery of the applied nutrients.

Table 6. Effect of N, P, K and S, on postharvest soil pH and the status of different nutrients (Pooled data of two years)

Treatment	pH	OM	Total N	K	P	S
		(%)	(%)	meq. 100 g^{-1}	µg g^{-1}	
Initial	6.5	1.20	0.061	0.13	12.2	12.5
T_1 ($N_0P_0K_0S_0$)	6.4	1.20	0.061	0.12	12.0	12.2
T_2 ($N_0P_{40}K_{90}S_{20}$)	6.5	1.23	0.062	0.13	13.1	13.8
T_3 ($N_{70}P_{40}K_{90}S_{20}$)	6.6	1.22	0.064	0.13	13.3	14.0
T_4 ($N_{100}P_{40}K_{90}S_{20}$)	6.4	1.24	0.065	0.12	13.1	14.3
T_5 ($N_{130}P_{40}K_{90}S_{20}$)	6.4	1.23	0.066	0.12	13.0	13.9
T_6 ($N_{100}P_0K_{90}S_{20}$)	6.4	1.23	0.066	0.12	12.0	13.2
T_7 ($N_{100}P_{20}K_{90}S_{20}$)	6.5	1.24	0.067	0.13	12.8	14.0
T_8 ($N_{100}P_{60}K_{90}S_{20}$)	6.4	1.24	0.066	0.12	14.0	14.1
T_9 ($N_{100}P_{40}K_0S_{20}$)	6.4	1.23	0.065	0.11	13.3	13.9
T_{10} ($N_{100}P_{40}K_{60}S_{20}$)	6.5	1.25	0.067	0.14	14.1	14.2
T_{11} ($N_{100}P_{40}K_{120}S_{20}$)	6.5	1.23	0.066	0.14	13.4	14.3
T_{12} ($N_{100}P_{40}K_{90}S_0$)	6.4	1.23	0.066	0.13	13.8	12.7
T_{13} ($N_{100}P_{40}K_{90}S_{10}$)	6.5	1.22	0.067	0.12	14.1	13.5
T_{14} ($N_{100}P_{40}K_{90}S_{30}$)	6.3	1.23	0.067	0.13	14.1	15.0
T_{15} ($N_{130}P_{60}K_{120}S_{30}$)	6.4	1.24	0.068	0.13	14.9	17.2

Effect of N, P, K and S on postharvest soil properties

Application of N, P, K and S fertilizers affected the postharvest soil properties after the completion of 2^{nd} year experiment (Table 6). The initial soil pH of the experimental field was 6.5, but the postharvest soil pH was slightly reduced after two years. The OM of postharvest soil improved marginally for all treatments, with the highest value being observed from the treatment of T_{10}. Comparable results were noted for total N. The exchangeable K concentration was slightly increased in T_{10} and T_{11} treatment. The available P and S concentrations were slightly increased in most of the treatments. However, most of the nutrient concentrations in the postharvest soil were slightly increased over the initial status. It has been reported that available nitrogen, phosphorus, potassium and sulphur in the postharvest soil were increased due to the application of N, P, K and S fertilizer. Similar kind of high residual nutrient values in postharvest soil was also reported by Ravi Teja *et al.* (2017) in Chrysanthemum, Chandana *et al.,* (2014) and Chouhan *et al.,* (2014) in Gladiolus.

Conclusion

Results of the experiment indicate that combination of $N_{100}P_{40}K_{60}S_{20}$ kg ha^{-1} along with 3 kg Zn ha^{-1} and 1.5 kg B ha^{-1} plus 5 t ha^{-1} cowdung contributed to higher number of Gypsophila fruits per plant as well as seeds per fruit. The same treatment gave the highest seed yield of Gypsophila showing 29% higher over control ($N_0P_0K_0S_0$). The highest uptake of N, P, K & S was also noted for T_{10} treatment. The apparent N, P and K recovery efficiency was higher in T_{10} treatment. The organic matter and total N in postharvest soil was also higher in same treatment. Hence, overall results reveal that nutrient recommendation at $N_{100}P_{40}K_{60}S_{20}$ kg ha^{-1} was the best treatment for obtaining satisfactory seed yield of Gypsophila at *Chhiata* soil series of Gazipur.

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PERFORMANCE OF FIELD PEA WITH MUSTARD AS A MIXED CROP FOR YIELD AND PROFITABILITY

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Q. M. AHMED[4] AND M. A. R. GAZI[5]

Abstract

Mixed cropping practices can help farmers meet their different types of daily needs because mustard can be used as edible oil, whereas field peas may be consumed as legume food. The field experiments were carried out at a farmer's field in South Lemua, MLT site, Feni (AEZ 19a), during the Rabi seasons of 2015-16 and 2017-18 to find out the performance of field pea as a mixed crop with mustard. The treatment combinations were T_1 = Sole field pea (100%) @ seed rate 50 kg ha^{-1}, T_2 = Sole mustard (100%) @ seed rate 7 kg ha^{-1}, T_3 = field pea (90%) + mustard (10%), T_4 = Field pea (80%) + mustard (20%), and T_5 = Field pea (70%) + mustard (30%). A field pea var. BARI Motor-1 and a mustard var. BARI Sarisha-14 were used . The trial was conducted in a randomized complete block design with 6 dispersed replications. . The seed yield of field pea decreased with the increase of mustard population and the yield of mustard decreased with the increase of field pea population in the mixed cropped situation. All the mixed cropping combinations showed superiority over sole cropping in terms of gross margin, benefit cost ratio (BCR), and field pea equivalent yield (FEY). The highest field pea equivalent yields were 1646 kg ha^{-1} in 2015-16 and 1576 kg ha^{-1} in 2017-18, respectivelyin the treatment combination of field pea (80%) and mustard (20%). The lowest FEYs were observed at 1326 kg ha^{-1} in T_2 during 2015–16 and 1296 kg ha^{-1} in T_1 during 2017–18. The highest gross margins (Tk. 49280 ha^{-1} in 2015-16 and Tk. 44854 ha^{-1} in 2017-18) as well as BCR (2.45 in 2015-16 and 2.32 in 2017-18) were obtained from T_4 treatment. In 2015–16, T_2 provided the lowest gross margin (Tk. 31980 ha^{-1}) and BCR (1.93), but in 2017–18, T_1 yielded the lowest gross margin (Tk. 32515 ha^{-1}) and BCR (2.00). More profitable mixed crops combinations should be explored in future research.

Keyword: Field Pea, Mustard, Mixed crop, Yield, Profitability.

Introduction

Practicing the mixed cropping technique always provides some benefits to the farmer. It decreases the chance of total crop failure and increases crop yield. Besides, this practice makes it possible to harvest multiple crops at the same time. Traditionally, farmers in char areas have liked to cultivate some crops as

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intercrops and others as mixed crops to minimize the input cost. Crop compatibility is the most important factor in determining the viability of a mixed cropping system. Only those crops that do not harm other crops by providing shade can be cultivated as a mixed crop. Mustard grows tall, whereas field pea grows short; as a result, mustard provides shade to field pea, which may escape the hot weather in coastal char areas of Bangladesh. Field peas as well as other legumes are known for their unpredictable yields and being unable to withstand changing weather circumstances, such as high temperatures during flowering (Watson et al., 2017; Jiang et al., 2019). Thus, the success of any mixed cropping system is dependent on the proper selection of crop species with the least amount of competition for light, space, moisture, and nutrients (Fukai and Trenbath, 1993). Competition in a mixed crop mixture can be significantly reduced by judicious crop selection as well as changing plant populations with the spatial orientation of either crop. A careful crop selection could significantly reduce competition (Ofori and Stern, 1986). On the other hand, choosing the right crop species for intercropping could increase the possibility of increasing overall production per unit of land and time (Midmore, 1993). Some farmers in the coastal charland areas of Bangladesh also practice mixed/ intercropping to fulfill their families' needs. The farmers of the said area do not maintain proper seeding ratios, planting times, and other management practices. Field pea is a dry-land winter pulse, and its cultivation area is increasing day by day in the coastal areas of Noakhali, Feni, and Laxmipur. On the other hand, mustard is the major oil seed crop and main source of edible oil in char areas of Bangladesh. Farmers usually use local varieties and obtained poor yields due to their low yield potential. The Bangladesh Agricultural Research Institute (BARI) has developed some high-yielding varieties of field pea and mustard, which need to be disseminated among the farmers. It is observed that some farmers in the char areas of Feni, Noakhali, and Laxmipur cultivate field pea as a mixed crop with mustard. Farmers obtained a higher yield and profit from field pea and mustard as mixed cropping than from sole cropping. Mixed cropping increases food production and income for small farmers by encouraging agricultural diversification, ensuring consistent returns throughout the season, and providing a safety net against climatic uncertainties. Mixed cropping has been shown to improve crop productivity and develop a more balanced, biodiverse, and richer ecosystem. The present study was, therefore, undertaken to find out the most profitable mixed crop combination for field pea with mustard.

Materials and Methods

The experiments were carried out at the MLT site in South Lemua, Feni, during the Rabi seasons of 2015–16 and 2017–18. The experiments were conducted at latitude 22° 56' 49" N and longitude 91° 26' 36" E. The experimental site's climate was hot, humid, and tropical monsoon-like.

Table 1. The average climatic condition of the site during the experimental periods of 2015-16 and 2017-18

Month	Temperature (°C)		Total Rainfall (mm)
	Low	High	
December,2015	17	25	11
January, 2016	14	24	2
February, 2016	19	29	14
March, 2016	22	33	106
December,2017	11	29	77
January, 2018	7	27	0
February, 2018	13	34	2
March, 2018	15	34	4

The soils of the experimental areas belong to the Old Young Meghna River Estuarine Flood Plain (AEZ 19a). The soils of the experimental plots were clay loam in texture. The experiment was laid out in a randomized complete block design with six dispersed replications. The treatments were T_1 = sole field pea (100%) @ seed rate 50 kg ha^{-1}, T_2 = sole mustard (100%) @ seed rate 7 kg ha^{-1}, T_3 = field pea (90%) + mustard (10%), T_4 = field pea (80%) + mustard (20%), and T_5 = field pea (70%) + mustard (30%). The unit plot size was 40 m^2 (10 m x 4 m). The fertilizer doses for sole mustard (60-20-25-7-2-1 kg N-P-K-S-Zn-B ha^{-1}) and sole field pea (18-17-20-7-2-1 kg N-P-K-S-Zn-B ha^{-1}) were given according to FRG-2012 in sole crop fields. The other mixed crop plots were fertilized with 21-17-25-7-2-1 kg N-P-K-S-Zn-B ha^{-1}, respectively. The entire amount of all fertilizers was applied during final land preparation in all treatment combinations. A field pea (var. BARI Motor-1) and a mustard (var. BARI Sarisha-14) were used. Seeds of both crops were treated with Provax 200 WP at the rate of 3 g/kg to protect the seeds from seed-borne and soil-borne diseases. Field pea and mustard seeds were mixed based on the treatments and sown by the broadcast method on December 7–11, 2015, and December 11–14, 2017. The crops were grown under a rain-fed condition because the soil moisture level was adequate for crop growth due to rainfall that occurred during the crop-growing period. Plant protection measures and all other management practices were done as and when necessary. Aphid infestation was observed in some parts of the plot, which was relatively low. Tafgor 40 EC was sprayed at the rate of 2 mL/L water to control this pest. Disease infestation was not observed during the experiment period. Mustard was harvested on February 22–28, 2016 and February 27–March 3, 2018, whereas field pea was harvested on March 20–25, 2016 and March 7–12, 2018. Data on the different crop parameters were analyzed by the computer program Crop Stat. Field pea equivalent yield (FEY) and economic analysis were calculated to ascertain the efficiency of intercropping. Field pea equivalent yield was calculated by converting the yield of mixed crops to the yield of field pea on the basis of prevailing market prices for individual crops. Based on the mustard crop's local market price, the yield of the crop was converted into field pea equivalent yield (Prasad and Srivastava, 1991).

$$\text{Field pea Equivalent Yield} = Y_{mFp} + \frac{\text{Yield of Mustard (kg ha}^{-1}\text{) x Price of Mustard (Tk. kg}^{-1}\text{)}}{\text{Price of Field pea (Tk. kg}^{-1}\text{)}}$$

Here, Y_{mFp} = Yield of the Field pea in the mixed crop combination

Results and Discussions

Yield and yield attributes of field pea

The result indicated that most of the yield attributes of field pea were influenced by mixed cropping with mustard (Tables 2 and 3). The results showed that plant populations of field pea varied depending on the percentage of seeds used in each treatment. Plant population increased when only field pea was used and decreased when mustard plants in the mixed cropping in the same plot. The treatment T_1 had the highest number of plants m^{-2} (106 in 2015-16 and 89.40 in 2017-18), while the T_5 plot had the lowest (59.00 in 2017-18 and 72 in 2015-16). The highest plant height was found in $T_{5,}$ which were 84.5 cm in 2015-16 and 88.34 cm in 2017-18. However, the lowest plant height resulted from the T_1 plot 69.6 cm in 2015-16 and 73.86 cm in 2017-18. This result has a similarity to Chongtham et al. (2018). Some researchers observed a similar result, suggesting that this type of result may happen because heat stress was higher in field peas than in mixed cropping with mustard, which provided some shade to reduce the heat stress of pea plants (Jiang et al. 2019). The maximum number of pods per plant were 14 and 13.20, which were recorded in 2015-16 and 2017-18, respectively, from the T_1 (sole field pea), followed by T_3 and $T_{4.}$ The lowest number of pods per plant (10 and 10.20) obtained from the T_5 combination in 2015-16 and 2017-18, respectively. The maximum numbers of seeds pod^{-1} (6.0 and 5.60 in 2015–16 and 2017–18, respectively) were obtained from T_1 but at par to T_2 treatment. Moreover, in 2015–16, t maximum numbers of seeds pod^{-1} showed a non-significant difference. The lowest seeds per pod were found in T_5, which was identical to T_4. This result has a similarity to Ahmed et al., 2020. The treatment T_1 had the maximum 1,000 - seed weight (80 and 89.32 g in 2015-16 and 2017-18, respectively), followed by T_3. The lowest 1,000 seed weight was found in T_5 (76 and 87.26 g) during 2015-16 and 2017-18, where field pea (70%) and mustard (30%) as broadcast. This is possible because nutrient availability is greater in sole cropping than in mixed cropping. The highest seed yield was recorded in the sole field pea, i.e., T_1 (1343 and 1295.80

kg ha^{-1}) while the lowest seed yield in the treatment T_5 (986 and 921.40 kg ha^{-1}) in 2015-16 and 2017-18, respectively. In a mixed crop situation, seed yield decreased as the mustard population increased. It could be due to nutrient competition and reduced light interception between the main and intercrops. Below-ground competition for water and nutrients may increase as crop species share similar areas of the soil profile (a similar resource pool), resulting in greater niche overlap (Bramley et al., 2007), limiting some intercropping benefits. It was observed that for mustard, the low (10%), medium (25%), and high (50%) seeding rates significantly reduced field pea yield compared with the field pea monoculture (Elkin et al., 2021).

Table 2. Seed yield and yield attributes of field pea as a mixed crop with mustard at Feni MLT site during 2015–16

Treatments	Plant population m^{-2} (no.)	Plant height (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000-seeds weight (g)	Seed yield (kg ha^{-1})
T_1 = Sole field pea (100%)	106	69.6	14	6.0	80	1343
T_3 = Field pea (90%) + mustard (10%)	94	79.2	13	6.0	78	1202
T_4 = Field pea (80%) + mustard (20%)	84	79.8	12	5.0	78	1134
T_5 = Field pea (70%) + mustard (30%)	72	84.5	10	5.0	76	986
LSD (0.05)	8.63	5.19	3.63	NS	0.10	59.01
CV (%)	6.72	4.25	4.50	3.78	2.54	9.63

Table 3. Seed yield and yield attributes of field pea as a mixed crop with mustard at Feni MLT site during 2017–18

Treatments	Plants m^{-2} (no.)	Plant height (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 - seeds weight (g)	Seed yield (kg ha^{-1})
T_1 = Sole field pea (100%)	89.40	73.86	13.20	5.60	89.32	1295.80
T_3 = Field pea (90%) + mustard (10%)	77.80	84.40	11.60	5.20	88.24	1151.20
T_4 = Field pea (80%) + mustard (20%)	68.40	85.82	11.50	4.60	87.83	1106.20
T_5 = Field pea (70%) + mustard (30%)	59.00	88.34	10.20	4.60	87.26	921.40
LSD (0.05)	3.53	2.17	0.94	0.84	0.58	61.25
CV (%)	2.00	3.60	6.10	12.60	0.50	4.00

Yield and yield attributes of mustard

The findings show that field pea mixed cropping had a significant effect t on the most of the yield parameters of mustard (Tables 4 and 5). The results showed that mustard plant populations varied depending on the percentage of seeds used in each treatment. The sole mustard plot had the highest number of plants per square meter (185.60 in 2017–18 and 168.2 in 2015–16, respectively). Plant populations increased as the amount of mustard seeds increased. The maximum plant height was observed in the mixed crop in T_4 (89.57 and 87.82 cm) during 2015-16 and 2017-18, whereas the shortest plant in sole mustard (79.62 cm in 2015-16 and 70.16 cm in 2017-18). The nitrogen-fixing ability of field peas could increase the amount of nitrogen in a mixed crop plot, which may increase plant height. Moreover, T_4 combination generated the highest number of pods on plant^{-1} (33 in 2015–16 and 37.20 in 2017–18). As compared to the other treatments, the sole mustard plot produced the lower plant^{-1} pods (27 and 29) of 2015–16 and 2017–18. The number of seeds in each pod was not significantly different in 2015-16 but during 2017-18, it showed a significant variation, and the maximum number of seeds pod^{-1} (21.40) was recorded in the T_3 treatment, which was similar to the T_4 combination, and the lowest number of seeds pod^{-1} (18.40) in the treatment T_2. Nitrogen accumulation by the pea nodule might provide more nutrients to the mustard plant, which promoted pod and seed production. This might also be due to the high plant density and the fact that competition for light and nutrients was higher in sole mustard than in mixed pea. Similar results were reported by Kumar *et al.* (2006). The treatment T_4 and T_3 combinations produced the highest (2.80 g) and lowest (2.75 g) seed weights in 2015–16. Besides, the lowest 1,000- seed weight was achieved in T_4 (2.97 g), while T_5 (3.05 g) recorded the highest 1,000 - seed weight during 2017–18. This result was in conformity with the result found from the chickpea and mustard mixed crop (Hasan et al., 2018). The highest seed yields (1105 and 1215 kg ha^{-1}) were recorded in T_2 (sole mustard) during 2015–16 and 2017–18, respectively. However, the minimum seed yields (212 and 200.60 kg ha^{-1}) were found from T_3 treatment, which was 70% field pea with 10% mustard. Because the population of mustard increased, the seed yield increased. The result of sole mustard is in conformity with Rahman et al. (2009). Similar findings were also reported by Maniruzzaman et al., 2020, where lentil and mustard were cultivated in mixed cropping.

Table 4. Seed yield and yield attributes of mustard as a mixed crop with field pea at Feni MLT site during 2015–16

Treatments	Plants m^{-2} (no.)	Plant height (cm)	Pods $plant^{-1}$ (no.)	Seeds pod^{-1} (no.)	1000-seeds weight (g)	Seed yield (kg ha^{-1})
T_2 = Sole mustard (100%)	168.2	79.62	27	19	2.77	1105
T_3 = Field pea (90%) + mustard (10%)	25.3	84.48	31	22	2.75	212
T_4 = Field pea (80%) + mustard (20%)	49.6	89.57	33	21	2.80	442
T_5 = Field pea (70%) + mustard (30%)	71.10	82.87	30	18	2.78	525
LSD (0.05)	9.39	1.79	0.54	NS	0.042	53.6
CV (%)	10.47	3.81	6.25	3.06	2.40	7.95

Table 5. Seed yield and yield attributes of mustard as a mixed crop with field pea at Feni MLT site during 2017–18

Treatments	Plants m^{-2} (no.)	Plant height (cm)	Pods $plant^{-1}$ (no.)	Seeds pod^{-1} (no.)	1000-seeds weight (g)	Seed yield (kg ha^{-1})
T_2 = Sole mustard (100%)	185.60	70.16	29.00	18.40	3.03	1205.00
T_3 = Field pea (90%) + Mustard (10%)	20.80	85.88	34.40	21.40	3.04	200.60
T_4 = Field pea (80%) + mustard (20%)	43.20	87.82	37.20	21.20	2.97	391.40
T_5 = Field pea (70%) + mustard (30%)	66.60	87.34	32.40	19.20	3.05	509. 60
LSD (0.05)	7.61	1.86	3.09	1.70	0.20	37.75
CV (%)	7.20	1.70	6.90	6.40	4.90	4.90

Field pea equivalent yield (FEY)

All the mixed crop treatments produced a higher field pea equivalent yield than their respective sole crops (Tables 6 and 7). The results showed that the field pea equivalent yield increased with increasing mustard seed percentage for mixed cultivation up to 20% with 80% field pea and then decreased with increasing mustard seed percentage. It might be due to excessive interplant competition for nutrients, light, water, and space. The field pea (80%) and mustard (20%) combination (T_4) produced the highest field pea equivalent yield of 1646.4 and 1576 kg ha1 during 2015–16 and 2017–18, respectively. The FEYs in T_4 were higher than the sole crops of field pea and mustard, respectively. The findings suggested that field pea-mustard mixed cropping could benefit farmers more than either field pea or mustard alone. Lauk and Lauk (2008) found similar result when growing peas and oats in mixed cropping systems, the higher yield of the mixed cropping system was more productive than that of monoculture crops. The increment in total production by intercropping rather than sole cropping was also reported by several authors (Rao and Willey, 1980; Umrani et al., 1984; Bandhyopadhyay, 1984; and Basak *et al., 2006*).

Cost and Return Analysis

The cost and return analysis is displayed in Tables 6 and 7. Gross returns as well as gross margins were found higher in mixed crop cultivation in comparison to sole cropping. From cost and return analysis, the combination of field pea (80%) and mustard (20%) (T_4) had the highest gross margin (Tk. 49280 ha^{-1} in 2015-16 and Tk. 44854 ha^{-1} in 2017-18), followed by T_5. In 2015–16, the sole mustard plot provided the lowest gross margin (Tk. 31980 ha^{-1}), but in 2017–18, the sole field pea plot yielded the lowest gross margin (Tk. 32515 ha^{-1}). In terms of benefit-cost ratio (BCR), the most profitable treatment combination was T_4 (2.45 and 2.32) during 2015-16 and 2017-18, respectively, followed by T_5. In 2015–16, the lowest BCR (1.93) was observed in sole mustard cultivation, whereas in 2017–18, the lowest BCR (2.00) was found in the sole field pea plot. Farhad et al. (2018) reported a similar type of outcome.

Table 6. Field pea equivalent yield (FEY) with cost benefit analysis at the MLT site, Feni during 2015-16

Treatment	Yield (kg ha^{-1})		FEY (kg ha^{-1})	Gross return (Tk. ha^{-1})	Total cultivation cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	Benefit cost ratio (BCR)
	Field Pea	Mustard					
T_1 = Sole field pea (100%)	1343	-	1343	67150	32275	34875	2.08
T_2 = Sole mustard(100%)	-	1105	1326	66300	34320	31980	1.93
T_3 = Field pea (90%) + Mustard(10%)	1202	212	1456.4	72820	34030	38790	2.13
T_4 = Field pea (80%) + mustard (20%)	1134	442	1646.4	83220	33940	49280	2.45
T_5 = Field pea (70%) + mustard(30%)	986	525	1616	80800	33750	47050	2.39

Table 7. Field pea equivalent yield (FEY) with cost benefit analysis at the MLT site, Feni during 2017–18.

Treatment	Yield (kg ha^{-1})		FEY (kg ha^{-1})	Gross return (Tk. ha^{-1})	Total cultivation cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	Benefit cost ratio (BCR)
	Field pea	Mustard					
T_1 = Sole field pea (100%)	1295.80	-	1295.80	64790	32275	32515	2.00
T_2 = Sole mustard (100%)	-	1205.00	1446.00	72300	34320	37980	2.10
T_3 = Field pea (90%) + mustard (10)	1151.20	200.60	1391.92	69596	34030	35566	2.04
T_4 = Field pea (80%) + mustard (20)	1106.20	391.40	1575.88	78794	33940	44854	2.32
T_5 = Field pea (70%) + mustard (30)	921.40	509. 60	1532.92	76646	33750	42896	2.27

FEY= Field pea Equivalent Yield,

Price of Field pea per kg =Tk. 50.00 and Mustard per kg = Tk. 60.00,

Price of Urea =Tk.16.00 kg^{-1}, TSP = Tk.22.00 kg^{-1}, and MoP = Tk.15.00 kg^{-1}

Conclusion

Considering the yield and return, it can be concluded that the combination of 80% (40 kg/ha) field pea and 20% (1.4 kg/ha) mustard is the most profitable as compared to other treatment combinations when grown as a mixed crop. From the result of this study, it is evident that mixed cropping is more profitable than sole cropping, and the risk of cultivation of one crop can be reduced by mixed cropping. Further study should be done to identify more relevant combinations for growing mixed crops.

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ENHANCEMENT OF CROP PRODUCTIVITY OF MUSTARD-MUNGBEAN-T. AMAN CROPPING PATTERN THROUGH NEW VARIETIES AND NUTRIENT MANAGEMENT

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Abstract

The experiment was conducted at the farmers' fields of Kalkini and sadar upazila of Madaripur, during two consecutive years 2019-20 and 2020-21 to evaluate the performance of yield, productivity and profitability of Mustard-Mungbean-T. *aman* cropping pattern through incorporating, short duration and high yielding crop varieties with integrated nutrient management. The experiment was laid out in a randomized complete block design with three dispersed replications. The cropping cycle was with three crops, nine varieties namely Mustard: var. BARI Sarisha-14, BARI Sarisha-17, BARI Sarisha-11; Mungbean: var. BARI Mungbean-6, BARI Mungbean-8, BINA Mungbean-8; T. *aman*: var. BRRI dhan 57, BRRI dhan 71 and BRRI dhan 75 and three fertilizer levels (F_1 = Recommended Fertilizer Dose, RFD from inorganic source as per soil test bases, STB; F_2 = RFD on STB + 5 t ha^{-1} cowdung, integrated plant nutrient system, IPNS approach; F_3 = Farmers practices). Highest yield as well as by-product yield, rice equivalent yield (REY) (16.12 t ha^{-1} yr^{-1}), gross return (3,86,880 Tk ha^{-1} yr^{-1}), total variable cost (1,36,621 Tk ha^{-1} yr^{-1}), gross margin (2,50,259 Tk ha^{-1} yr^{-1}) and marginal benefit cost ratio (2.83) were obtained from the treatment combination of mustard var. BARI Sarisha-14, mungbean var. BARI Mung-6 and rice var. BRRI dhan71 with integrated plant nutrient system (IPNS) and the lowest from farmers' practices. IPNS based fertilizer management in this cropping pattern performed better compared to other fertilizer management practices. Higher REY indicates that improved cropping pattern Mustard (var. BARI Sarisha-14/BARI Sarisha-17)-Mungbean (var. BARI Mung-6)-T. *aman* (var. BRRI dhan57/BRRI dhan71/BRRI dhan75) could be suitable in Madaripur for increasing crop productivity cropping intensity as well as profitability.

Keywords: Cropping pattern, Cropping intensity, Gross return, Integrated plant nutrient system, Rice equivalent yield, System productivity.

Introduction

Bangladesh is the most densely populated country of the world but surprisingly it has to feed 149 million people, which is increasing annually at the rate of about 1.42% (BBS, 2019). Besides, the cultivable land is in a decreasing trend and it is

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about 1% per year. Bangladesh covers about 14.84 M ha (million hectares) of total land and among this 3.74 M ha (25% of the total) is not appropriate for cultivation due to deployment for urban areas, commercial buildings, countryside homesteads, roads etc. Climate change, population expansion, food scarcity, poverty, starvation, accelerated land cover change and environmental degradation are the foremost challenges (Neamatollahi *et al.,* 2017). Therefore, to declare food security for increasing people in the future we need to produce huge food on a reduced amount of land (Islam *et al.,* 2015). So, increasing cropping intensity by producing more crops over the same piece of land in a year and to increase the production efficiency (productivity) of the individual crop by using optimum management practices (FAOSTAT, 2014; Dobermann *et al.,* 2013; Ladha *et al.,* 2016; Datta *et al.,* 2017; Islam *et al.,* 2017).

The cropping system of Bangladesh is usually rice-based as well as diversified, includes pulses, oilseeds, vegetables, tuber crops, and other winter cereals like maize and wheat. The productivity and sustainability of rice-based systems are threatened because of inefficient use of imputes (seed, fertilizer, scarcity of resources (water and labour), climate change, energy crisis and rising fuel prices and declining soil fertility (Alam *et al.,* 2017; Alam *et al.,* 2018). Oilseed and pulse are the important group of crops which are mostly grown in rabi season but area of those crops decreased due to increasing cultivation of irrigated (withdrawal of huge groundwater) Boro rice, caused the lowering of water tables (Shamsudduha *et al.,* 2009). Recently with the development of short duration varieties of rice, mustard, potato, pulse, vegetables and jute opportunities have been created to accommodate three more crops in same piece of land in a year. Rape-seed mustard production can be increased up to 20-25% only by replacing traditional variety (Tori-7) with high yielding short duration varieties like BARI Sarisha-14 and BARI Sarisha-17 in the existing rice based cropping system. Another potential way of achieving this is to switch short duration T. *aman* (var. BRRI dhan57/BRRI dhan71/BRRI dhan75) in place of long duration T. *aman* (var. BRRI dhan39/Gutisorna) variety and inclusion of high yielding mungbean varieties in Mustard-Mungbean-T. *aman* cropping system. It will increase the total system productivity, profitability and sustainability of the rice-based cropping system. Different cropping patterns are available in Bangladesh and these are well reported (Khan *et al.,* 2005; Anowar *et al.,* 2012; Nazrul *et al.,* 2013). Aziz *et al.* (2013) reported that multiple cropping system effects soil carbon and nitrogen status, and also improve soil functional properties. Nevertheless, continuous cropping cause's nutrient mining from soil while a blanket fertilizer dose for all regions without considering the soil nutrient status leads to tremendous damage to soil, environment and economy. Sultana *et al.,* (2015) also reported that actual recommended fertilizer dose is higher than actual need of fertilizer and this resulted soil nutrient imbalance. As soil fertility is a major determinant for the success and failure of a crop production system. Therefore, an improved cropping system is needed that will reduce the production cost, increase crop productivity and soil health.

Madaripur district is located under Low Ganges River Floodplain (AEZ-12) and the soil is silty clay. The cropping intensity of this area is 201% and about 66% and 15% land areas are under double and triple cropped (DAE, 2016). About 72% lands are under medium high to low land in which 20% lands remains fallow after harvesting of T. *aman* rice. Potential adoption of improved cropping patterns Mustard-Mungbean-T. *aman* instead of T. *aman*-Fallow-T. Boro cropping system would be more productive and profitable for the farmers'. Considering the above issues, the study was undertaken to increase cropping intensity, productivity and profitability in rice based cropping system.

Materials and Methods

Site Description

The experiment was conducted in farmer's field at Kalkini and Madaripur sadar upazila under Madaripur district during 2019-20 and 2020-21. The initial soil samples were collected from 0-15 cm depth and soil chemical and microbiological properties were analyzed by Soil Science Division and Central Laboratory, BARI before sowing of the experiment. The soil was silty clay soil and it belongs to Ganges soil series under the Low Ganges Floodplain Soils (AEZ-12). Most of the soils contain less than 1.71% soil organic matter (SOM), and some soils have even less than 1% SOM. The sub-tropical humid climate causes rapid breakdown of SOM by heterotrophic microbes; consequently, nutrients loss occurs through different processes, viz. leaching, volatilization, runoff etc. The low SOM is a cause of low productivity and is considered as a serious threat to the sustainability of agriculture in Bangladesh. Thus, with advancement of time, soil fertility has declined and chronologically the deficiency of nitrogen, phosphorus, potassium, sulphur, zinc and boron has arisen in the soils. The initial farmer's field soil results showed that pH ranged from 8.06-8.21, total N (0.085-0.095%), calcium (21.16-21.77 meq 100 g^{-1}), magnesium (3.85-3.96 meq 100 g^{-1}), potassium (0.16-0.23 meq 100 g^{-1}), phosphorus (12-52 μg g^{-1}), iron (97.54-99.43 μg g^{-1}), zinc (0.89-0.91 μg g^{-1}), boron (0.37-0.43 μg g^{-1}) and sulpher (15-28 μg g^{-1}). Besides, initial soil microbial properties of experimental plots results showed that *Rhizobium* ranged from ($3.8x10^3$-$4.1x10^3$ $cfug^{-1}$soil), PSB from ($2.5x10^5$-$3.5x10^5$ $cfug^{-1}$soil) and *Azotobacter* from ($3.6x10^5$– $4.4x10^5$ $cfug^{-1}$soil) in Madaripur sadar and Kalkini upazila, respectively. A description of initial nutrient status of experimental plots of Madaripur district soils prior to fertilization has been presented in Table 1.

Table 1. Initial soil physical, chemical and microbial population of experimental soil at Kalkini and sadar upazila of Madaripur during 2019-20 and 2020-21

Initial chemical status of the experimental plots											
Location	pH	OM %	Ca	Mg	K	Total N%	P	S	B	Fe	Zn
			meq 100 g^{-1}				µg g^{-1}				
Madaripur sadar	8.06	1.71	21.16	3.85	0.16	0.095	52	28	0.43	97.54	0.91
Kalkini upazilla	8.21	1.65	21.77	3.96	0.23	0.085	12	15	0.37	99.43	0.89
Critical level	-	-	2	0.50	0.12	-	10	10	0.20	4.0	0.60

Physical and microbial population status of experimental plots							
Location	Sand	Silt	Clay	Moisture	*Rhizobium*	PSB	*Azotobacter*
	%				cfug^{-1}soil		
Madaripur sadar	7	27	66	15	$4.1x10^3$	$2.5x10^5$	$3.6x10^5$
Kalkini upazilla	12	29	59	15	$3.8x10^3$	$3.5x10^5$	$4.4x10^5$

Monthly total rainfalls, along with average temperatures during the study period are presented in Fig. 1. The highest amount of average monthly rainfall occurred in June followed by August, June and July, whereas lowest amount of rainfall occurred in January followed by December and February. Rainfall increases gradually from the month of March to June and then decreases. The monthly mean maximum air temperature was 31.77, 32.53 and 33.86 ^{O}C and minimum 20.43, 19.47 and 17.65 ^{O}C during crop season of 2019-20 and 2020-21. There was no adverse climatic effect observed during study period.

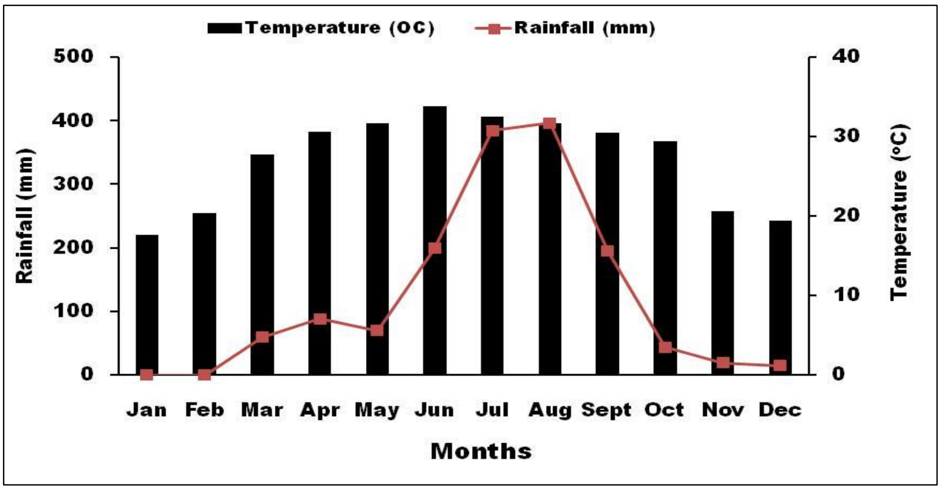

Fig. 1. Average of two years monthly total rainfall (mm) and temperature at Madaripur district during study period (2019-20 and 2020-21).

The cropping pattern of Mustard-Mungbean-T. *aman* were tested with mustard as the first crop in the pattern. After harvest of mustard, mungbean was sown in both the locations followed by T. *aman* rice. The experiment was laid out in a randomized complete block design with dispersed three replications. The study was comprised of the following crop varieties namely Mustard: BARI Sarisha-14, BARI Sarisha-17, BARI Sarisha-11; Mungbean: BARI Mung-6, BARI Mung-8, BINA Mung-8; T. *aman* rice: BRRI dhan57, BRRI dhan71 and BRRI dhan75 and three fertilizer management practices (F_1: Recommended Fertilizer Dose (RFD) from inorganic source as per soil test bases (STB); F_2: RFD on STB + 5 t ha^{-1} cowdung, integrated plant nutrient system (IPNS) approach; F_3: Farmers' practices). Urea, TSP, MoP, gypsum, Zinc sulphate, boric acid were used as a source of N, P, K, S, Zn and B, respectively. In case of mustard, mungbean, T. *aman* all P, K, S, Zn and B were applied as basal during final land preparation. Cowdung @ 5 tha^{-1} was applied before ploughing and laddering as treatment only. All the intercultural operations such as irrigation, weeding, insect control etc were done as and when necessary. The total crop residues or after picking of pods the brown biomass of munbean were incorporated into the soil before T. *aman* transplantation in both the years and experimental sites (Tables 2a and 2b).

Table. 2a. Crop managements of cropping pattern Mustard-Mungbean-T. *aman* at sadar upazilla of Madaripur during 2019-20 and 2020-21.

Parameters	Cropping pattern		
	Mustard	Mungbean	T. *aman*
Variety	BARI Sarisha-14 BARI Sarisha-17 BARI Sarisha-11	BARI Mung-6 BARI Mung-8 BINA Mung-8	BRRI dhan57 BRRI dhan71 BRRI dhan75
Date of sowing/ transplanting time	14-20 Nov. 2019 12-15 Nov. 2020	21 Mar. 2020 27 Mar. 2021	13 Aug. 2020 22 Aug. 2021
Seed rate (Kg ha^{-1})	6-7	15-18	50
Plot size	8m x 6m	8m x 6m	8m x 6m
Fertilizer dose	<u>Fertilizer : 3 level</u> F_1 = Recommended Fertilizer Dose (RFD) from inorganic source on STB F_2 = RFD on STB + 5 t ha^{-1} cowdung (IPNS approach) F_3 = Farmers practices <u>Recommended dose</u> Mustard: N_{120} P_{46} K_{122} S_{26} Zn_3 B_2 kg ha^{-1}; Mungbean: N_{24} P_{22} K_{24} S_{14} Zn_2 B_2 kg ha^{-1}; T. *aman*: N_{120} P_{26} K_{100} S_{15} Zn_2 kg ha^{-1}		
Seedling age (Day)	-	-	25-30

Parameters	Cropping pattern		
	Mustard	Mungbean	T. *aman*
No of ploughing	3-4	2-3	3
No of irrigation	1 time at 23 DAS	1	10
No of weeding	1	2	2
No of pesticide application	IPM	IPM	IPM
Crop duration	85-88	65-68	110-115
Turnaround time	8-10	7-9	75-89
Date of Harvesting	4-10 Feb. 2020 2-8 Feb. 2020	22-28 July 2020 18-22 July 2021	26-28 Oct. 2020 22-26 July 2021

Table 2b. Crop managements of cropping pattern Mustard-Mungbean-T. *aman* at Kalkini upazilla, Madaripur during 2019-20 and 2020-21.

Parameters	Cropping pattern		
	Mustard	Mungbean	T. *aman*
Variety	BARI Sarisha-14 BARI Sarisha-17 BARI Sarisha-11	BARI Mung-6 BARI Mung-8 BINA Mung-8	BRRI dhan57 BRRI dhan71 BRRI dhan75
Date of sowing/ transplanting time	18-22 Nov. 2019 16-20 Nov. 2020	28 Mar. 2020 30 Mar. 2021	17 Aug. 2020 27 Aug. 2021
Seed rate (Kg ha^{-1})	6-7	15-18	50
Plot size	8m x 6m	8m x 6m	8m x 6m
Fertilizer dose	Fertilizer : 3 level F_1 = Recommended Fertilizer Dose (RFD) from inorganic source on STB F_2 = RFD on STB + 5 t ha^{-1} cowdung (IPNS approach) F_3 = Farmers practices Recommended dose Mustard: N_{120} P_{46} K_{122} S_{26} Zn_3 B_2 kg ha^{-1}; Mungbean: N_{24} P_{22} K_{24} S_{14} Zn_2 B_2 kg ha^{-1}; T. *aman*: N_{120} P_{26} K_{100} S_{15} Zn_2 kg ha^{-1}		
Seedling age (Day)	-	-	25-30
No of ploughing	3-4	2-3	3
No of irrigation	1 time at 25 DAS	2	12
No of weeding	1	2	2
No of pesticide application	IPM	IPM	IPM
Crop duration	84-86	69-72	112-117
Turnaround time	10-12	9-11	70-85
Date of Harvesting	09-14 Feb. 2020 13-18 Feb. 2020	22-28 July 2020 18-22 July 2021	26-28 Oct. 2020 22-26 July 2021

Estimation of Rice Equivalent Yield (REY)

Based on the existing market price of the individual crops, the yield of every single crop was converted into rice equivalent yield for making the relationship between crop sequences (Verma and Modgal, 1983).

$$\text{Rice equivalent yield (t ha}^{-1}\text{ yr}^{-1}) = \frac{\text{Yield of individual crop x Market price of that crop}}{\text{Market price of Rice}}$$

Cost and return analysis

The economic analysis was done for gross return, gross margin and marginal benefit cost ratio (MBCR) and it was calculated on the basis of prevailing market price of the produces. Economic analysis involved collection of data on prices and quantities of inputs used and output produced. The inputs used included seed, fertilizer, labour and insecticides. The output and inputs were valued at market prices. The MBCR of the farmer's prevalent pattern and any replacement for it can be computed as the marginal value product (MVP) over the marginal value cost (MVC). The Marginal of prevalent pattern (F) and any potential replacement (E) for it was computed as (CIMMYT, 1988).

$$\text{Marginal Benefit cost ratio (MBCR)} = \frac{\text{Gross return (E) – Gross return (F)}}{\text{Total variable cost (E) – Total variable cost (F) of production}} = \frac{\text{MVP}}{\text{MVC}}$$

Statistical analysis

Grain yield and straw yields were taken from whole plot. Rice equivalent yield and economics of different cropping systems were estimated to judge their performance. Mustard, mungbean and T. *aman* rice and total rice equivalent data were analyzed statistically and all the collected data related to cropping pattern were subjected to analysis using R software.

Results and Discussions

Mustard

The data regarding yield and yield contributing characters of different mustard varieties as influenced by the different nutrient management are presented in Table 3 and Table 4. Plant height, siliqua plant^{-1}, seeds siliqua^{-1}, 1000-seed weight, seed yield, straw yield and field duration of mustard at Madaripur sadar and Kalkini upazilla were differed significantly among the varieties (BARI Sarisha-14, BARI Sarisha-17 and BARI Sarisha-11). It was observed that IPNS based fertilized plots gave higher yield over farmers practices and RFD from inorganic source. Mustard var. BARI Sarisha-14 (1.74 to 1.78 tha^{-1}) yielded higher than BARI Sarisha-17 (1.46 to 1.59 tha^{-1}) and BARI Sarisha-11 (1.53 to 1.77 tha^{-1}) in both locations. About 21.92 and 16.33% higher yield was obtained in mustard than farmers practices. Similar trend of increased yield in mustard due to added fertilizers in three or four crops pattern was also reported by Barman *et al.* (2021) and Saha *et al.* (2016). Dobermann *et al.* (2013) and Anowar *et al.* (2012) also reported that site-specific plant nutrient management (IPNS or STB) could increase yield as well as nutrient use efficiency of cropping patterns.

Table. 3. Performance of mustard varieties under integrated nutrient management system at Madaripur sadar upazila during 2019-20 and 2020-21.

Treatment combination		Madaripur sadar upazila, Madaripur						
Variety	Fertilizer dose	Days to maturity	Plant height (cm)	Siliqua plant^{-1} (no)	Seed Siliqua^{-1} (no)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
BARI Sarisha- 17	F_1	85b	86.67c-e	83.67a	22.67a-c	3.64ab	1.53c	2.11b
	F_2	87b	84.67de	84.33a	25.02a	3.67a	1.62b	2.29a
	F_3	85b	80.00e	75.67b	21.03cd	3.24cd	1.46d	1.95c
BARI Sarisha- 14	F_1	87b	95.01bc	84.67a	25.01a	3.43a-c	1.64b	2.21ab
	F_2	87b	95.02b-d	84.02a	24.67ab	3.56a-c	1.74a	2.31a
	F_3	86b	89.67cd	73.33b	24.33ab	3.25cd	1.51cd	1.92c
BARI Sarisha- 11	F_1	105a	107.00a	64.33c	21.67bc	3.32b-d	1.71a	2.23ab
	F_2	106a	108.01a	66.67c	22.33a-c	3.46a-c	1.73a	2.30a
	F_3	105a	102.03ab	59.67d	18.33d	3.01d	1.62b	2.08bc
CV (%)		5.96	7.74	4.08	7.64	5.71	2.89	2.06

*Figures in column followed by different letters differ significantly at 5% level of significance. F_1 = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F_2 = RFD on STB + 5 t ha^{-1}cowdung (IPNS approach); F_3 = Farmers' practices.

Mungbean

The yield and yield contributing characters of mungbean varieties are presented in Table 5 and 6. Most of the yield contributing character, straw and seed yield of mungbean was influenced by the different fertilizer managements. The highest number of pods plant^{-1} (32.01 to 36.67), seed pod^{-1} (10.67 to 11.33) and seed yield (1.76 to 1.79 tha^{-1}) in BARI Mung-6 was recorded from IPNS based fertilized plots in both years and locations. The lowest number of pods plant^{-1} (21.00 to 27.00), seed pod^{-1} (8.0 to 10.01) and seed yield (1.19 to 1.51 tha^{-1}) in BARI Mung-8 and BINA Mung 8 were recorded from farmers' practices. Similarly, the highest biomass (4.09-4.91 tha^{-1}) yield was recorded in IPNS based fertilized plots and lowest (2.89 to 3.07 tha^{-1}) in BARI Mung-8 and BINA Mung 8 from farmers' practices, respectively. It was also observed that IPNS based fertilized plots yielded higher than farmer's practices and RFD. Similar results were obtained by Mondal *et al.* (2015), Nazrul *et al.* (2017), Khan *et al.* (2018). After picking of pods the brown biomass of mungbean was incorporated into the soil before T. *aman* transplantation in both the years and experimental sites.

Table. 4. Performance of mustard varieties under integrated nutrient management system at Kalkini upazila, Madaripur during 2019-20 and 2020-21.

Treatment combination		Kalkini upazila, Madaripur						
Variety	Fertilizer dose	Days to maturity	Plant height cm)	Siliqua plant^{-1} (no)	Seed Siliqua^{-1} (no)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
BARI Sarisha-17	F1	86.01b	83.33ef	72.01ef	27.33a	3.95ab	1.59c	1.99bc
	F2	87.67b	86.33de	77.67cd	29.33a	4.18a	1.67bc	2.19ab
	F3	84.33b	81.01f	68.33f	20.01bc	3.76ab	1.46d	1.75d
BARI Sarisha-14	F1	87.67b	87.67cd	78.67b-d	29.67a	3.70ab	1.57c	2.01bc
	F2	88.33b	91.02c	85.33a	28.02a	3.94ab	1.78a	2.24a
	F3	84.67b	85.67de	70.67f	21.67b	3.49ab	1.47d	1.82cd
BARI Sarisha-11	F1	106.01a	110.02a	81.01a-c	20.33bc	3.87ab	1.73b	2.20ab
	F2	105.67a	111.67a	83.33ab	19.03c	3.20b	1.77a	2.23a
	F3	105.01a	99.67b	76.02de	18.02c	3.37b	1.53cd	1.88c
CV (%)		5.41	8.62	5.71	5.79	12.23	3.96	2.21

* Figures in column followed by different letters differ significantly at 5% level of significance. F_1 = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F_2 = RFD on STB + 5 t ha^{-1}cowdung (IPNS approach); F_3 = Farmers' practices.

Table 5. Performance of mungbean varieties under integrated nutrient management system at Madaripur sadar upazila during 2019-20 and 2020-21.

Treatment combination		Madaripur sadar upazila, Madaripur				
Variety	Fertilizer dose	Pod plant^{-1}	Seed pod^{-1}	100 seed wt. (g)	Stover yield (t ha^{-1})	Seed yield (t ha^{-1})
BARI Mung- 8	F_1	27.01cd	12.02ab	3.36b	3.64bc	1.63c
	F_2	29.33b	13.33abc	3.78ab	3.89ab	1.69bc
	F_3	23.67e	10abc	3.07b	2.89e	1.39d
BARI Mung- 6	F_1	29. 67b	9.67bc	3.66ab	3.66bc	1.77ab
	F_2	32.01a	10.67abc	3.94ab	4.09a	1.79a
	F_3	26.33cd	9.01bc	3.08b	3.13de	1.31d
BINA Mung -8	F_1	26.01d	11.67ab	4.18ab	3.40cd	1.59c
	F_2	28.01bc	12.01ab	3.91ab	4.08a	1.61c
	F_3	21.00f	8.01c	5.78a	3.07de	1.19e
CV (%)		3.83	19.41	12.37	6.41	3.79

*Figures in column followed by different letters differ significantly at 5% level of significance. F_1 = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F_2 = RFD on STB + 5 t ha^{-1}cowdung (IPNS approach); F_3 = Farmers' practices.

Table 6. Performance of mungbean varieties under integrated nutrient management system at Kalkini upazila during 2019-20 and 2020-21.

Treatment combination		Kalkini upazila, Madaripur				
Variety	Fertilizer dose	Pod plant^{-1}	Seed pod^{-1}	100 seed wt. (g)	Stover yield (t ha^{-1})	Seed yield (t ha^{-1})
BARI Mung- 8	F_1	33abc	10.67b-d	3.13cd	3.78c	1.71a-c
	F_2	35.33ab	12.67a	3.50ab	4.57b	1.72ab
	F_3	27bcd	8.33e	2.31f	3.26d	1.51de
BARI Mung- 6	F_1	32.33a-c	11.33a-c	3.21b-d	3.40d	1.67a-c
	F_2	36.67a	11.33abc	3.58a	4.91a	1.76a
	F_3	25.33cd	10.01c-e	2.99de	3.06d	1.56cd
BINA Mung -8	F_1	26.33cd	10.67b-d	3.17cd	3.74c	1.59b-d
	F_2	28b-d	12.01ab	3.41a-c	4.94a	1.60b-d
	F_3	22.67d	9.33de	2.77e	3.27d	1.40e
CV (%)		16.54	10.54	5.79	3.98	5.49

*Figures in column followed by different letters differ significantly at 5% level of significance. F_1 = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F_2 = RFD on STB + 5 t ha^{-1}cowdung (IPNS approach); F_3 = Farmers' practices.

T. *aman*

The third component of the cropping pattern was T. *aman* rice. Yield and yield contributing characters of different T. *aman* rice varieties as influenced by the different fertilizer rate has been presented in Table 7 and 8. Plant height, panicle m^{-2}, no. of grains panicle^{-1}, 1000-grain wt., straw yield and grain yield of T. *aman* at Madaripur sadar and Kalkini upazilla has been differed significantly among the varieties (BRRI dhan57, BRRI dhan71 and BRRI dhan75). Rice var. BRRI dhan71 (5.48 to 5.61 tha^{-1}) yielded higher than BRRI dhan57 (4.64 to 4.77 tha^{-1}) and BRRI dhan75 (5.41 to 5.44 tha^{-1}) in both locations. It was observed that IPNS based fertilized plots produce higher yield than farmers' practices and RFD (from inorganic source as per STB fertilizer treated plots). In the two consecutive years, about 20.21% and 17.61% more yield was obtained than farmers practices. Anowar *et al.* (2012) reported that the maximum grain yield was observed from IPNS based fertilized plots than farmer's practices. Similar results were also obtained by Mondal *et al.* (2015), Barman *et al.* (2019). Ali *et al.* (2009) showed that maximum grain yield from soil test value for high yield goal while Saha *et al.* (2016) reported higher yield from 20% higher yield from the STB dose in potato-maize-T. *aman* cropping pattern of AEZ-3.

Table 7. Performance of T. *aman* varieties under integrated nutrient management system at Madaripur sadar upazila during 2019-20 and 2020-21

Treatment combination		Madaripur sadar upazila, Madaripur					
Variety	Fertilizer dose	Plant height (cm)	Panicle m^{-2}	Grain panicle^{-1} (no)	1000 grain wt. (g)	Straw yield (t ha^{-1})	Grain yield (tha^{-1})
BRRI dhan 57	F_1	113de	461cde	164b	20.33d	4.24c	4.63abc
	F_2	121cd	482bc	184a	25.00b	4.51c	4.77abc
	F_3	105e	439e	150cd	18.33e	3.75c	3.96c
BRRI dhan 71	F_1	132ab	502ab	179a	22.67c	5.84ab	5.51ab
	F_2	138a	518a	188a	28.33a	6.44a	5.61a
	F_3	120cd	472cd	153bc	20.67d	4.86bc	4.61abc
BRRI dhan 75	F_1	137a	484bc	164b	23.00c	6.17b	4.94abc
	F_2	140a	504ab	177a	27.33a	6.18a	5.41ab
	F_3	125bc	455de	140d	21.67cd	4.82bc	4.50bc
CV (%)		4.71	3.14	4.11	4.65	12.44	11.91

*Figures in column followed by different letters differ significantly at 5% level of significance. F_1 = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F_2 = RFD on STB + 5 t ha^{-1}cowdung (IPNS approach); F_3 = Farmers' practices.

Table 8. Performance of T. *aman* varieties under integrated nutrient management system at Kalkini upazila during 2019-20 and 2020-21

Treatment combination		Kalkini upazila, Madaripur					
Variety	Fertilizer dose	Plant height (cm)	Panicle m^{-2}	Grain panicle^{-1} (no)	1000 grain wt. (g)	Straw yield (t ha^{-1})	Grain yield (tha^{-1})
BRRI dhan 57	F_1	119de	300b-d	23.23b	25b	6.25ab	4.38cd
	F_2	125cd	311a-c	29.6a	28a	6.71a	4.64cd
	F_3	108f	288d	21.5c	21d	5.73b	3.09d
BRRI dhan 71	F_1	128bc	319ab	19.67d	21cd	6.06ab	5.41ab
	F_2	134ab	322a	20.7cd	24bc	6.35ab	5.48a
	F_3	113ef	301bcd	17.33e	16e	6.04ab	4.26ab
BRRI dhan 75	F_1	130abc	314abc	21.7bc	22cd	5.85b	5.33ab
	F_2	138a	323a	29.07a	29a	5.98ab	5.44ab
	F_3	114.01f	296cd	20.7cd	19de	4.67c	4.87bc
CV (%)		3.76	3.63	3.80	8.05	7.98	7.01

*Figures in column followed by different letters differ significantly at 5% level of significance. F_1 = Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F_2 = RFD on STB + 5 t ha^{-1}cowdung (IPNS approach); F_3 = Farmers' practices.

Bi-product yield of the cropping pattern

The Mustard-Mungbean-T. *aman* cropping pattern, highest biomass 3.06 to 4.91 tha^{-1} yield of mungbean and 1.99 to 2.24 tha^{-1} yield of mustard were recorded in IPNS and RFD based fertilized plots and lowest 2.89 to 3.27 tha^{-1} in mungbean and 1.99 to 1.75 tha^{-1} in mustard from farmers' practices, respectively. It was also observed that IPNS and RFD based fertilized plots bi-product yielded higher than farmer's practices in both the years and experimental sites. After picking of pods the brown biomass of mungbean was incorporated into the soil before T. *aman* transplantation. Mustard is providing special advantage regarding utilization of mustard straw as fuel instead of cowdung.

Table. 9. Rice equivalent yield (REY) and total rice (system) yield of Mustard-Mungbean -T. *aman* cropping pattern at Kalkini upazila and sadar upazila Madaripur.

Treatment combination	Sadar upazila Madaripur				Kalkini upazila				Average REY $tha^{-1}yr^{-1}$
	T.*aman* yield (tha^{-1})	Rice equivalent yield (REY)		Total REY $tha^{-1}yr^{-1}$	T.*aman* yield (tha^{-1})	Rice equivalent yield (REY)		Total REY $tha^{-1}yr^{-1}$	
		Mustard	Mung			Mustard	Mung		
V_1F_1	4.63	3.83	5.91	14.36	4.38	4.31	6.06	14.74	14.55
V_1F_2	4.77	4.05	6.34	15.16	4.64	4.52	6.09	15.25	15.21
V_1F_3	3.96	3.65	4.64	12.25	3.09	3.95	5.35	12.39	12.32
V_2F_1	5.51	3.98	5.78	15.26	5.41	4.25	5.91	15.58	15.42
V_2F_2	5.61	4.31	5.99	15.90	5.48	4.63	6.23	16.34	16.12
V_2F_3	4.61	3.78	4.93	13.31	4.26	3.95	5.53	13.74	13.55
V_3F_1	4.94	4.33	5.64	14.91	5.33	4.96	5.63	15.92	15.45
V_3F_2	5.41	4.43	5.71	15.54	5.44	5.36	5.67	16.47	16.05
V_3F_3	4.50	3.98	4.22	12.69	4.87	4.14	4.96	13.97	13.33

V_1: BARI Sarisha-17, BARI Mung-8, BRRI dhan57; V_2: BARI Sarisha-14, BARI Mung-6, BRRI dhan71; V_3: BARI Sarisha-11, BINA Mung-8, BRRI dhan75; F_1: Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F_2: RFD on STB + 5 t ha^{-1} cowdung (IPNS approach); F_3: Farmers' practices

Total rice (system) yield

Productivity of different crops on the rice based cropping system was determined by Rice Equivalent Yield (REY) which was calculated from yield of component crops. Average yield of component crops and REY of mustard and mungbean were shown in Table 9. Average yield of two years and locations, it was observed that the highest REY (16.12 t $ha^{-1}yr^{-1}$) was recorded from treatment combination of V2F2 (BARI Sarisha-14 + BARI Mung-6 + BRRI dhan71 with RFD on STB + 5 t ha^{-1} cowdung (IPNS approach) and lowest REY (12.32 t $ha^{-1}yr^{-1}$) was recorded from treatment combination of V1F3 (BARI Sarisha-17 + BARI Mung-8 + BRRI dhan57 with Farmers practices). Higher rice equivalent yield indicates higher productivity of the pattern. This finding was supported by Nazrul *et al.* (2017) and Khan *et al.* (2018). Barman *et al.* (2020) also documented higher rice equivalent yield of mustard from 25% NPK+ 100% STB dose. Mondal *et al.* (2015) also claimed of having 49 to 67% higher productivity from the intensified land use system under four cropped based cropping pattern. Inclusion of mustard in rice based cropping pattern increase REY about 45.3-51.6% (Hossain *et al.,* 2014).

Cost and return analysis

Cost and return analysis was done on the basis of prevailing market price of the commodities. Economics analysis of the cropping pattern Mustard-Mungbean-T. *aman* was shown in Table 10. It was observed that highest gross return (3,86,880 Tk $ha^{-1}yr^{-1}$), total variable cost (1,36,621 Tk $ha^{-1}yr^{-1}$), and gross margin (2,50,259 Tk $ha^{-1}yr^{-1}$) were obtained from treatment combination V_2F_2 (BARI Sarisha-14 + BARI Mung-6 + BRRI dhan71 with RFD on STB + 5 t ha^{-1} cowdung (IPNS approach) and the lowest gross return (2,95,680 Tk $ha^{-1}yr^{-1}$), total variable cost (1,46,308 Tk $ha^{-1}yr^{-1}$), and gross margin (2,29,732 Tk $ha^{-1}yr^{-1}$) were obtained from treatment combination of V1F3 (BARI Sarisha-17 + BARI Mung-8 + BRRI dhan57 with Farmers practices. The maximum marginal benefit cost ratio (2.83) was also gained from treatment combination V_2F_2 (BARI Sarisha-14 + BARI Mung-6 + BRRI dhan71 with RFD on STB + 5 t ha^{-1} cowdung (IPNS approach). These findings are supported by Sarker *et al.* (2014) who reported that Wheat–Mungbean-T. *aman* rice produced the higher economic benefit in terms of BCR. Marginal benefit cost ratio (MBCR) was found 2.83 which further indicated the superiority of the improved practice over farmers' one. Thus, inclusion of mungbean in the existing pattern might be agronomically viable and economically profitable for the farmers' in the study sites.

Table 10. Cost-benefit analysis of the cropping pattern Mustard-Mungbean T. *aman* at Madaripur during 2019-20 and 2020-21

Treatment combination	Gross return	Total variable cost	Gross margin	MBCR
	(Tk ha^{-1} yr^{-1})			
V_1F_1	349200	136308	212892	2.56
V_1F_2	365040	135308	229732	2.71
V_1F_3	295680	146308	149372	2.02
V_2F_1	370080	134560	235520	2.75
V_2F_2	386880	136621	250259	2.83
V_2F_3	325200	149360	175840	2.18
V_3F_1	370800	143364	227436	2.59
V_3F_2	385200	147862	237338	2.61
V_3F_3	319920	133324	186596	2.41

Note: Price: Mustard = 70 Tk kg^{-1}, Mungbean = 90 Tk kg^{-1}, Rice = 30 Tk kg^{-1}, Urea = 16 Tk kg^{-1}, TSP = 25 Tk kg^{-1} , MoP = 15 Tk kg^{-1} , Gypsum = 12 Tk kg^{-1}, Zinc sulphate = 200

Tk kg^{-1}, Boric acid: 220 Tk kg^{-1}, Labour = Tk. 500 day^{-1}, Land preparation for all crops 3 times ploughing and laddering = Tk 1000 $bigha^{-1}$, Irrigation for T. *aman* = Tk. 800 $bigha^{-1}$; V_1: BARI Sarisha-17, BARI Mung-8, BRRI dhan57; V_2: BARI Sarisha-14, BARI Mung-6, BRRI dhan71; V_3: BARI Sarisha-11, BINA Mung-8, BRRI dhan75; F_1: Recommended Fertilizer Dose (RFD) from inorganic source as per STB; F_2: RFD on STB + 5 t ha^{-1} cowdung (IPNS approach); F_3: Farmers' practices

Soil fertility status

Nutrient uptake by grain and straw of all crops of the cropping pattern were influenced by different fertilizer treatments. The status of soil pH, organic matter content, total N, available P, K, S, Zn and B in initial soil as well as after completion of two cropping cycle of Mustard-Mungbean-T. *aman* rice cropping pattern is shown in Table 11. Soil chemical and microbial status analysis of cropping pattern revealed that organic matter content of the soil increased due to biomass addition of the crops. Somewhere it was changed positively. As potassium showed negative balance, more potassium is to be added to improve soil fertility status. However, K in the improve pattern tended to be lower than the farmers one, which indicated to add more K in soil to improve K content. Rao and Bhardwaj (1980) conclusively proved that pulses receiving optimum fertilizer, especially P, had more pronounced residual effect both in terms of N and P on the succeeding cereals. Organic matter added to soil through incorporation of non-economic plant parts helped to maintain the quality of soil. These results are supported by Mondal *et al.* (2015) and Khan *et al.* (2018) who found that inclusion of mungbean in the existing farmer's cropping pattern improve the soil fertility status.

Table. 11. Physical, chemical and microbial status of post soil in experimental plots of Kalkini and sadar upazilla Madaripur during 2019-20 and 2020-21.

Chemical data of the experimental plots (post soil in Madaripur sadar upazilla)

Location	pH	OM %	Ca	Mg	K	Total N%	P	S	B	Fe	Zn
			meq 100 g^{-1}				μg g^{-1}				
Madaripur sadar	8.08	1.89	22.32	4.06	0.13	0.109	78	21	0.41	98.69	0.93
Kalkini upazilla	8.11	1.77	23.77	3.89	0.18	0.088	10	11	0.37	98.55	0.88
Critical level	-	-	2	0.50	0.12	-	10	10	0.20	4.0	0.60

Physical and microbial status of experimental plots

Location	Sand	Silt	Clay	Moisture	*Rhizobium*	PSB	*Azotobacter*
			%			$cfug^{-1}soil$	
Madaripur sadar	7	28	65	16	$5.1x10^3$	$3.5x10^5$	$4.6x10^5$
Kalkini upazilla	11	31	60	16	$5x10^3$	$3.5x10^5$	$4.6x10^5$

Conclusions

It could be concluded that crop diversification in the existing T. *aman*-Fallow-Boro cropping cycle of Low Ganges River Floodplain of Bangladesh with the introduction of the high yielding and short duration mustard, mungbean and T. *aman* rice, improved cropping pattern Mustard (var. BARI Sarisha-14/BARI Sarisha-17)–Mungbean (var. BARI Mung-6)-T. *aman* (var. BRRI dhan71/BRRI dhan75) could be found economically profitable and biologically suitable. Similarly, IPNS based fertilizer management approach in this cropping pattern was found better perform compared to farmers' practices or other fertilizer management approaches. The farm level adoptions of improved oilseeds, pulses in rice based cropping system have already been created a wide range of socio-economic impacts that need to be evaluated properly to understand the output of research and development.

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GRAPHICAL (Vr-Wr) APPROACH AND GENETIC COMPONENT ANALYSIS FOR DIALLEL ANALYSIS FOR FRUIT YIELD, YIELD ATTRIBUTES AND OTHER TRAITS IN SNAKE GOURD

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Abstract

A Vr-Wr graphical approach and genetic component analysis study for diallel analysis was carried out on snake gourd for fruit yield, yield attributes along with fruit quality traits at the farm of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh during March to June 2019. Griffing half-diallel fashion involving seven parents *viz*., P_1 (TC 01), P_2 (TC 05), P_3 (TC 24), P_4 (TC 33), P_5 (TC 02), P_6 (TC 46) and P_7 (TC 53) were effected to evolve 21 hybrids in snake gourd. The Vr-Wr graphical analysis demonstrated that over dominant gene action mainly responsible for early flowering and higher yield, partial dominant gene action accounted for number of fruits/ plant and complete dominance gene action responsible for fruit flesh thickness and number of seeds/ fruit. Estimates of genetic components such as D, H_1 and H_2 on traits revealed that the predominance of additive components over dominance components was found for fruit length, while for other remaining characters the predominance of dominance effect over additive effects in their expression.. The value $(H_1/D)^{1/2}$ indicated that a partial dominance was observed for fruit length and number of fruits/ plant but over-dominance was observed in the heritance of other characters in the parents. The unequal distribution of positive and negative alleles were found for all the characters. Narrow sense heritability was moderately high in days to 1st male flowering but high in days to 1st female flowering and fruit length, while it was low for other characters, indicating major part of additive gene action was responsible for the 1st three characters. The selection potential for days to 1st male flower open, days to 1st female flower open and fruit length would be high but it would not be high for other traits; therefore, recurrent selection for these three characters in early generation and hybridization and selection-based breeding methods in advanced generations may be effective for improvement of these traits in snake gourd.

Keywords: Snake gourd, Genetic analysis, Diallel graphical analysis, Additive and non-additive gene, Over dominance.

Introduction

Snake gourd [(*Trichosanthes cucumerina var. anguina (L.)* Haines] is a rapid-growing vine , cultivated for its edible fruits. It is a diploid (2n = 2x = 22) annual climber of the genus *Trichosanthes* in the family 'Cucurbitaceae' (Devi, 2017). Snake gourd originated in India or the Indo-Malayan region in tropical Asia

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(Adebooye, 2008 ; Roy *et al*., 1991) and is widely distributed in Asian countries (Arawwawala *et al*., 2009; Liyanage *et al*., 2016; Ojiako *et al*., 2008). Its green, tender stems, leaves and fruits are consumed as edible vegetables (Devi, 2017; Liyanage *et al*., 2016), which have high nutritional value, because they are rich in vitamins, essential minerals, dietary fiber and other nutrients, and are a wholesome, healthy addition to diets (Ojiako *et al*., 2008; Rana and Pandit, 2011). The fruits of snake gourd are frequently consumed when immature.

Being a monoecious and cross-pollinated crop, a wide range of genetic variability exits in the snake gourd population. Thus, by understanding the genetic structure, the heritability and genetic influence of different traits can improve yield (Hallauer *et al.*, 2010). Therefore, breeding programs to produce a new cultivar need more information about the genetic components as well as the type of gene action of traits in order to increase yield and produce tolerant cultivars (Shajari *et al*., 2021). Horticultural and yield traits of snake gourd are highly environmentally sensitive and regulated by multiple genes, making them quantitatively complex traits with low inheritance. The genetic improvement of snake gourd for fruit yield and yield attributes is imperative in national economy. Diallel analysis is useful breeding tool to predict additive and dominant effects of a population which can then be used to predict the genetic variability and heritability. The combining ability analysis can be conducted using the Griffing Method (Griffing, 1956), whereas, to study the action of genes, genetic components and heritability can use the Hayman Method (Hayman, 1954). In the plant breeding of high yielding varieties of plants, the plant breeder is challenged with the problem of the selection of parents. The knowledge of the genetic architecture of yield will help to sort out the better crosses much efficiently. The present investigation was therefore, carried out to study of genetics and inheritance pattern of fruit yield and yield attributes as well as fruit quality traits by diallel mating design followed by graphical analysis.

Materials and Methods

The experiment was conducted at the experimental farm of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during March to June 2019. The location of the site is 24.09^{0}N latitude and 90.26^{0}E longitude with an elevation of 8.20 m from sea level under agro-ecological zone (Madhupur Tract) AEZ - 28 (Anon., 1995). The experiment was carried out on 7 parents, namely TC 01 (P_1), Tc 05 (P_2), TC 24 (P_3), TC 33 (P_4), TC 02 (P_5), TC 46 (P_6) and TC 53 (P_7). Among the 55 snake gourd genotypes that were collected from different parts of Bangladesh, these 7 parents were chosen based on their performances from an evaluation trial, genetic diversity and heritability. From August to November 2018, 7 parental lines were grown for crossing all the parents together based on the 7 x 7 half-diallel cross with no reciprocals; it produced 21 hybrids with 7 parental lines. The 7 parental lines and their 21 F_1s were grown in a Randomized Complete Block Design (RCBD) with three replications during summer season (March to June). Each 63 (21 x 3) F_{1s} and 21 (7 x 3) parents were grown in 84 unit plots measuring 7.5 x 1.5 m^2, one row of 7.5 long with a plant to plant distance of 1.5 m and a row to row distance of 1.5 m; thus one unit plot accommodated 5 plants. Fifteen days old healthy seedlings were transplanted in well prepared pits on 20 March 2019. Fertilizers were applied @ 5000-50-24-40-14-1.5-1.0 kg/ha of cow dung-N-P-K-S-Zn-B according to FRG (2012). The sources of N, P, K, S, Zn, and B were Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum, Zinc Sulphate, Boric Acid (Laboratory Grade). During the final land preparation, the entire amount of cowdung, P, S, Zn, B, and one-third of K, as well as N and the remaining part of K were applied in four equal installments at 7, 21, 35 and 49 days after transplantation of seedlings. Plants were supported with the tops of bamboos for twining. The cultural practices such as irrigation, weeding, thinning and gap filling were done as and when necessary. Observations were recorded on 19 quantitative traits viz., days to male flower open, days to female flower open, node number of first male flower open, node number of first female flower open, main vine length (cm), node number on main vine, number of primary branches/plant, days to 1^{st} harvest, fruit fly infestation (%), number of fruits/plant, fruit yield/plant (kg), fruit yield/ha (ton), individual fruit weight (g), fruit length (cm), fruit diameter (cm), fruit flesh thickness (cm), number of locules/fruit, number of seeds/fruit and 100-seed weight (g).

Statistical analysis

This approach utilizes the graphical (Vr-Wr) analysis as well as genetic component analysis to ascertain the role of additive and non-additive type of gene action in the expression of the traits. Based on parental array variance (Vr) and parent-offspring co-variance (Wr) relationships in diallel cross progenies, a two-way representation or distribution of parental arrays along a regression line of Wr on Vr was first suggested by Jinks and Hayman (1953), and later refined by Hayman (1954). This two-directional depiction is widely known as Vr-Wr graph and the analysis as ‘graphical approach’. One of the essential factors for the graph, Wri values were computed for all the arrays with the aid of the formula given by Phundhan and Narayanan (2000); $Wri = (Vri \times V_O L_O)^{1/2}$, where, Vri is the variance of rth array and $V_O L_O$ is the variance of parents. These values (Wri and Vri) were used in constructing the Vr-Wr graph for all 19 characters. By utilizing the regression values, the Wr-Vr graph was drawn for 19 characters studied and the limiting parabola was constructed. The expected values of Wri are needed for drawing the regression line. These Wri values are obtained by the formula: Wri = Wr- bVr + bVri for drawing regression line, where, Vri is array mean of variances, Wr is array mean of covariances and b is regression coefficient. In general, $b>0.5$ means absence of epistasis and $b<0.5$ means presence of epistasis (Sharma, 1988). In addition, the genetic analysis was performed using the diallel analysis of Hayman (1954). It provides information about six components viz. D, H_1, H_2, E, F and h^2, where, D = additive genetic variance, H_1 = dominance variance, $H_2 = H_1 [1-(u-v)^2]$; where, u and v are the proportions of positive and negative genes, respectively, in the parents, E = expected environmental component of variance, F = mean of Fr over the arrays, where, Fr is the covariance of additive and dominance effects in a single array, h^2 = dominance effect, as algebraic sum over all the heterozygous loci phase in all the crosses. Some genetic ratios were determined from the above estimates. The $(H_1/D)^{0.5}$ ratio was used for showing the average degree of dominance of the loci controlling each trait (if the value of this ratio is zero, there is no dominance; if it is greater than 0 (zero) but less than 1, there is partial dominance; if it is equal to 1, there is complete dominance; and if it is greater than 1, it denotes over-dominance;. $H_2/4H_1$ is the proportion of genes with positive and negative effects in parents (if this ratio equals 0.25, positive and negative alleles are symmetrically distributed, otherwise the alleles are asymmetrically distributed; h^2/H_2 denotes the number of gene groups/genes, which control the character and exhibit dominance; $K_d/K_r = [(4DH^1)^{0.5} + F]/[4DH_1)^{0.5} - F]$ denotes the ratio of dominant and recessive genes in the parents (if the ratio is 1, the dominant and recessive genes in the parents are in equal proportion; if it is less than 1, it indicates an excess of recessive genes; but being greater than 1, it indicates excess of dominant genes. In the F_1 generation, narrow sense heritability values were calculated for each trait from the following relationship:

$h^2n = \frac{1/4D}{\frac{1}{4(D+H1-F)}+E}$ (Crumpacker and Allard, 1962)

or

$h^2n = [((D+H_1)/2) - 0.5H_2 - 0.5F)] / [((D+H_1)/2) - 0.25H_2 - 0.5F + E]$ Zare *et al*. (2011)

or

Heritability (narrow sense), $h^2n = ½D/(½D+¼H_1 + E)$.

Results and Discussion

Interpretation of Vr-Wr graph

Direction and Order of Dominance

Vr-Wr graphs, the two dimensional depiction made based on the parent offspring covariance (Wr) and parental variance (Vr) are presented in Fig. 1 to 19. Hayman's graphical approach to half diallel analysis is based on monogenic additive model. The regression coefficients (slope b) were positive and greater than 0.50 for days to 1st male flower open (Fig. 1), days to 1st female flower open (Fig. 2), node number of 1st male flower initiation (Fig. 3), main vine length (Fig. 5), node number on main vine (Fig. 7), individual fruit weight (Fig. 10), fruit yield/plant (Fig. 12), fruit yield/ ha (Fig. 13) and fruit length (Fig. 14), fruit diameter (Fig. 15), indicating absence of epistasis and less than 0.5 for node number of 1st female flower initiation (Fig. 4), fruit fly infestation (Fig. Fig. 9), fruit flesh thickness (Fig. 16), number of locules/fruit (Fig. 17), number of seeds/fruit (Fig. 18), 100-seed weight (Fig. 19) and indicating presence of epistasis. The regression coefficient (slope b) for number of primary branches per plant (Fig. 6) and days to 1st fruit harvest (Fig. 8) were negative indicating presence of non-allelic interaction i.e. epistasis playing role for these two traits.

The Vr - Wr graph (Fig. 1) for days to 1st male open gave a slope b = 0.86 ± 0.20 which was less than 1.0 but greater than 0.5 indicating presence of additive-additive nature of genetic system. The regression line for days to 1st male flower open intersected Wr axis below the point of origin, which suggested over dominance gene action for controlling the trait (Fig. 1). The order of dominance of parent for this character was P_2, P_6, P_7, P_1, P_3, P_4 and P_7. The parent P_2, P_6 and P_7 fell close to the origin and hence provided with maximum frequency of dominant alleles, while the parent P_5 occupied a position furthest away from the origin and thus it contained maximum frequency of recessive alleles. The remaining parents P_1, P_3 and P_4 occupied intermediate position and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found partial dominance gene action for days to 1st male flower open in snake gourd. Singh *et al.*, 2019 observed over dominant gene action for this trait in pumpkin.

The Vr - Wr graph (Fig. 2) for days to 1st female open gave a slope b = 0.87 ± 0.20 which was greater than 0.5 but less than 1.0 indicating presence of additive-additive nature of genetic system. The regression line intercepted for Wr axis below the origin which suggested over-dominance gene action to regulate days to 1st female flower open (Fig. 2). The order of dominance of parents to this trait was P_6, P_7, P_1, P_2, P_3, P_4 and P_5. The parents P_6, P_7, P_1, P_2 and P_3 occupied the nearest position to the point of origin, hence possessed maximum frequency of dominant gene for earliness. The remaining parent P_4 had equal proportion of dominant-recessive alleles because their points lying middle in the graph, while the parent P_5 occupied a position furthest away from the origin and thus it contained maximum frequency of recessive alleles. The remaining parent P_4 had equal proportion of dominant-recessive alleles because its point lying middle in the graph. Banik (2003) in snake gourd and Dubey and Ram (2007) in bottle gourd found partial dominance gene action for days to 1st female flower open. Singh *et al.*, 2019 observed over dominant gene action for this trait in pumpkin.

The slope of the regression line for node number of 1st male flower initiation was less than one but greater than 0.5 (b = 0.84±0.28) indicating presence of additive-additive nature of genetic system (Fig. 3). The Vr-Wr graph indicated the regression line intercepted for Wr axis below the origin which suggested over-dominance gene action for the inheritance of node number at 1st male flower initiation (Fig. 3). The order of dominance of parent for this character was P_2, P_1, P_6, P_7, P_3, P_5 and P_4. Array point P_2 was nearer to the origin and contained high frequency of dominant alleles as it held closest to the point of origin, while P_4 and P_5 were away from the origin contained the maximum frequency of recessive alleles. The remaining parents P_1, P_3, P_6 and P_7 occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found partial dominance gene action in snake gourd and Dubey and Ram (2007) observed over dominance gene action in bottle gourd for node order to 1st male flower initiation. Banik (2003) found partial dominance gene action in snake gourd and Dubey and Ram (2007) observed over dominant gene action in bottle gourd for node order to 1st male flower initiation.

The slope of the regression line for node number of 1st female flower initiation, was less than 0.5 (b = 0.09±0.39) indicating absence of additive-additive nature of genetic system (Fig. 4). For node number of 1st female flower initiation, the regression line passed above the origin, indicating the presence of partial dominance gene action for the trait (Fig. 4). The order of dominance of parent for this character was P_6, P_1, P_7, P_3, P_5 and P_4. The parent P_6 occupied the closest position to the point of origin in Vr-Wr graph indicating preponderance of dominant gene, while the parents P_2 and P_4 possessed farthest suggesting recessive gene action for the expression of the trait. The parents P_1, P_3, P_5 and P_7 were at intermediate position suggesting almost equal control of dominant and recessive gene. Banik (2003) found over dominance gene action for node order to 1st female flower initiation in snake gourd.

The Vr - Wr graph (Fig. 5) for main vine length gave a slope b = 0.65 ± 0.22 which was less than 1.0 but greater than 0.5 indicating presence of additive-additive nature of genetic system. The regression line for main vine length cut the Wr axis below the point of origin suggesting over dominance gene action (Fig. 5). The order of dominance of parent for this character was P_4, P_3, P_7, P_2, P_5, P_1 and P_6. The parent P_6 was farthest from the origin exhibiting higher proportion of recessive genes, whereas the parent P_4 was closest to the origin as it had highest proportion of dominant genes. The other parents P_1, P_2, P_3, P_5 and P_7 occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found over dominance gene action in snake gourd and Dubey and Ram (2007) observed over dominant gene action in bottle gourd for vine length in bottle gourd.

The Vr - Wr graph (Fig. 6) for number of primary branches per plant gave a slope b = -0.14 ± 0.07 which was less than 0.5 and negative indicating presence of non-allelic interaction i.e. epistasis playing role for this trait. Intersection of regression line above the origin on Wr axis clearly indicated the presence of partial dominance for number of primary branches/ plant (Fig. 6). The order of dominance of parent for this character was parent P_5, P_4, P_1, P_6, $P_{7.,}P_2$ and P_3. The parent P_3 was farthest from the origin and thus possessed higher proportion of recessive genes, whereas the parent possessed equal number of dominant and recessive genes as it was lying intermediate position. The parents P_5, P_4, P_1, P_6 and P_7 were closest to the origin and thus it revealed more proportion of dominant genes. Banik (2003) was found partial dominance gene action for primary branches/ plant in snake gourd.

The Vr - Wr graph (Fig. 7) for number of nodes on main vine gave a slope b = 0.52 ± 0.22 which was less greater than 0.5 and less than 1.0 indicating presence of additive-additive nature of genetic system. The regression line for number of nodes on main vine intersected the Wr axis above the origin which revealed partial-dominance gene action to regulate the trait (Fig. 7). The parent P_5 exhibited greater proportion of recessive alleles being furthest from the origin, whereas the parent P_4 exhibited greater proportion of dominant alleles for the trait, being closest to the origin. The remaining parents P_1, P_2, P_3, P_6 and P_7 possessed nearly equal proportion of dominance and recessive genes as they fell nearly in the middle of the regression lines. Dubey and Ram (2007) observed partial dominant gene action in bottle gourd for this trait.

The Vr - Wr graph (Fig. 8) for days to 1st fruit harvest gave a slope b = -0.03 ± 0.10 which was negative indicating presence of non-allelic interaction i.e. epistasis playing role for this trait. The regression line for days to 1st fruit harvest intersected Wr-axis above the point of origin, indicating partial dominance gene action to influence the trait (Fig. 8). The order of dominance of parent for this character was parent P_6, P_7, P_4, P_1, P_3, P_2 and P_5. Parents P_2 and P_5 possessed higher proportion of recessive alleles, being furthest from the origin, whereas parent P_6 revealed more proportion of dominant alleles as it fell nearest to the origin. The remaining parents P_1, P_3, P_4, and P_7 occupied intermediate positions and hence, contained nearly equal frequencies of dominant and recessive alleles. Dubey and Ram (2007) observed partial dominance gene action for days to 1st harvest in bottle gourd. Krishnamoorthy and Marxmathi, 2019 observed similar findings in pumpkin.

The Vr - Wr graph (Fig. 9) for fruit fly infestation gave a slope b = 20 ± 11. The regression line for fruit fly infestation passed through the point of origin, which revealed complete dominance for controlling this trait (Fig. 9). The order of dominance of parent for this character was parent P_3, P_1, P_6, P_7, P_5 and P_4. The parents P_3, P_1, P_6, and P_7 exhibited greater proportion of dominant alleles as they fell closest to the origin, whereas P_4 exhibited greater proportion of recessive alleles for the trait as it occupied a position furthest away from the origin. The remaining P_2 and P_5 possessed nearly equal proportion of dominance and recessive genes as they fell nearly in the middle of the regression lines.

The Vr - Wr graph (Fig. 10) for individual fruit weight gave a slope b = 0.85 ± 0.39 which was less than 1.0 but greater than 0.5 indicating presence of additive-additive nature of genetic system. The regression line for individual fruit weight intersected Wr axis below the point of origin, suggesting over dominance gene action for controlling the trait (Fig. 10). The order of dominance of parent for this character was parent P_4, P_5, P_6, P_3, P_7 and P_1. The parent P_4 occupied the nearest position to the point of origin hence possessed maximum number of dominant genes. On the contrary the parents, the parent P_1, P_7 and P_3 occupied far away from the origin, which indicated that it contained maximum number of recessive genes among them. The other parents P_2, P_5 and P_6 occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found over dominance gene action for individual fruit weight in snake gourd. Singh *et al.*, 2019 revealed over dominant gene action for this trait in pumpkin.

The Vr - Wr graph (Fig. 11) for number of fruits /plant gave a slope b = 0.24 ± 0.36 which was less than 0.5 indicating absence of additive-additive nature of genetic system. The regression line for number of fruits/ plant intersected Wr-axis above the point of origin, which implied partial dominance gene action to influence the trait (Fig. 11). The order of dominance of parents for this character was parent P_3, P_1, P_4, P_5, P_6, P_7 and P_1. The parent P_1 and P_3 fell close to the origin and hence provided with a maximum frequency of dominant alleles, while the parent P_2 occupied a position furthest away from the origin, and thus it contained maximum frequency of recessive alleles. The other parents P_4, P_5, P_6 and P_7 occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found over dominant gene action in snake gourd. Dube and Ram (2007) also observed over dominant gene action in bottle gourd for number of fruits/plant.

The Vr - Wr graph (Fig. 12) for fruit yield /plant gave a slope b = 0.52 ± 0.26 which was less than 1.0 but greater than 0.5 indicating presence of additive-additive nature of genetic system. The regression line of unit slope intercepted Wr axis below the origin and this suggested over-dominance gene action for controlling fruit yield per plant (Fig. 12). The order of dominance of parents for this character was parent P_1, P_3, P_4, P_5, P_6, P_7 and $P_{2.}$ None of the parent fell close to the origin and hence not provided with a maximum frequency of dominant alleles, while the parent P_2, occupied a position furthest away from the origin, and thus it contained the maximum frequency of recessive alleles. The other parents P_1, P_3, P_4, P_5, P_6 and P_2 occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found partial dominance gene action in snake gourd. Dubey and Ram (2007) observed over dominant gene action in bottle gourd for the yield of fruits/plant. Quamruzzaman *et al.*, 2022 revealed over dominant gene action for this trait in bottle gourd.

The regression of Wr on Vr for yield of fruits/ ha (Fig. 13) gave a slope b = 0.52 ± 0.26 which was less than 1.0 but greater than 0.5 indicating presence of additive-additive nature of genetic system. The regression line intersected below the point of origin which indicated the presence of over dominance for this trait. The order of dominance of parents for this character was parent P_1, P_3, P_4, P_5, P_6, P_7 and P_2. None of the parents fell close to the origin and hence not provided with a maximum frequency of dominant alleles, while the parent P_2, occupied a position furthest away from the origin and thus it contained the maximum frequency of recessive alleles. The other parents P_1, P_3, P_4, P_5, P_6 and P_7 occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles. Dubey and Ram (2007) observed over dominant gene action in bottle gourd for the yield of fruits/ ha. Quamruzzaman *et al.*, 2022 revealed over dominant gene action for this trait in bottle gourd.

The regression of Wr on Vr for fruit length (Fig. 14) gave a slope b = 0.94 ± 06 which was less than 1.0 but greater than 0.5 indicating presence of additive-additive nature of genetic system. The regression line intersected above the point of origin which indicated the presence of partial dominance for fruit length. The order of dominance of parents for the fruit length P_4, P_5, P_7, P_3, P_6, P_2 and $P_{1.}$ The distribution of array points in the graph suggested that the parental genotypes P_4 and P_5 apparently contained maximum frequency of dominant alleles as they fell more or less close to the origin, while P_1 had the most recessive alleles as it fell far away to the point of origin. The other parents P_2, P_3, P_6 and P_7 occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found partial dominant gene action in snake gourd. Dubey and Ram (2007) observed partial dominant gene action in bottle gourd for fruit length.

The regression of Wr on Vr for fruit diameter (Fig. 15) gave a slope b = 0.83 ± 0.39 which was less than 1.0 but greater than 0.5 indicating presence of additive-additive nature of genetic system. The regression line for fruit diameter intersected Wr axis below the point of origin, which implied over dominance gene action for controlling fruit diameter (Fig. 15). The order of dominance of parent for fruit diameter P_3, P_2, P_2, P_1, $P_{4,}$ P_6, P_5 and P_7. The parent P_2 and P_3 fell more or less close to the origin and hence provided with a maximum frequency of dominant alleles, while the parent P_5 and P_7 occupied a position furthest away from the origin, and thus it contained maximum frequency of recessive alleles. The other parents P_1, P_4 and P_6 occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found partial dominance gene action in snake gourd for fruit diameter. Dubey and Ram (2007) observed over dominant gene action in bottle gourd for the same trait. Singh *et al.*, 2019 revealed over dominant gene action for this trait in pumpkin. Krishnamoorthy and Marxmathi, 2019 observed identical findings in pumpkin.

The Vr - Wr graph (Fig. 16) for fruit flesh thickness gave a slope b = 0.13 ± 0.26 which was less than 0.5 indicating absence of additive-additive nature of genetic system. The regression line intersected through the point of origin which indicated the presence of complete dominance for fruit flesh thickness. The order of dominance of parent for the fruit length P_2, P_3, P_5, $P_{6,}$ P_4, P_7 and P_1. None of the parents fell close to the origin and hence not provided with a maximum frequency of dominant alleles, whereas the parents P_1, P_7, and P_4 occupied a position furthest away from the origin and thus it contained maximum frequency of recessive alleles. The remaining parents P_2, P_3, P_5 and P_6 were in intermediate position and hence contained more or less equal frequencies of dominant and recessive alleles.

The regression of Wr on Vr for number of locules/ fruit (Fig. 17) gave a slope b = 0.024 ± 0.31 which was far away from 0.5 indicating absence of additive-dominance nature of genetic system. The regression line intersected above the point of origin suggested partial dominance gene action for controlling the trait. The order of dominance of parent for the fruit length P_6, P_1, P_7, P_5, P_2, P_3 and P_4. The distribution of array points indicated that among five parents P_6 and P_1 contained the maximum frequency of dominant alleles as they held the closest position to the point of origin. The parent P_4 contained the maximum frequency of recessive alleles as it occupied a position furthest away from the origin. The other parents P_2, P_3, P_5, and P_7 occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles.

The regression of Wr on Vr for number of seeds per fruit (Fig. 18) gave a slope b = 0.21 ± 0.11 which was less than than 0.5 indicating absence of additive-dominance nature of genetic system. The regression line intercepted the Wr axis below the origin in number of seeds per fruit showing a clear cut case of over dominance. The order of dominance of parent for the fruit length P_1, P_7, P_2, P_3, P_5, P_6 and P_4. The relative position of array points on Vr-Wr graph indicated that parental genotypes P_1 and P_7 contained high frequency of dominant alleles as they fell close to the origin. However, both dominant and recessive alleles were approximately of equal proportion in the genetic makeup of the other parents P_2, P_3, P_5 and P_6 for this trait because they occupied intermediate positions and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found over dominant gene action for seeds/fruit in snake gourd. Krishnamoorthy and Marxmathi, 2019 found partial dominance gene action in pumpkin.

The regression of Wr on Vr for 100-seed weight (Fig. 19) gave a slope b = 0.041 ± 0.09 which was less than than 0.5 indicating absence of additive-dominance nature of genetic system. For 100-seed weight (Fig. 19) partial dominance was found to control this trait, as the regression line passed above the point of origin. The order of dominance of parent for the fruit length P_5, P_7, P_1, P_2, P_6, P_3 and P_4. The parent P_5 fell close to the origin and hence provided with maximum frequency of dominant alleles, while the parent P_4 occupied a position furthest away from the origin, and thus it contained maximum frequency of recessive alleles. The other parents P_2, P_3, P_6 and P_7 occupied intermediate position and hence contained more or less equal frequencies of dominant and recessive alleles. Banik (2003) found partial dominant gene action for 100-seed weight in snake gourd.

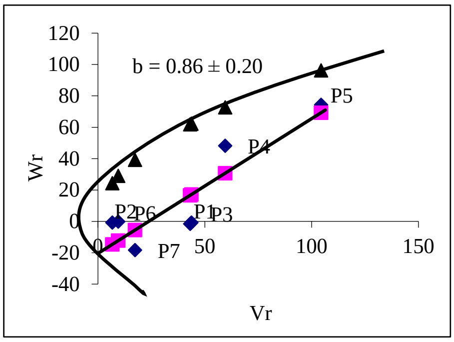

Fig. 1. Vr-Wr graph for days to 1st male flower open.

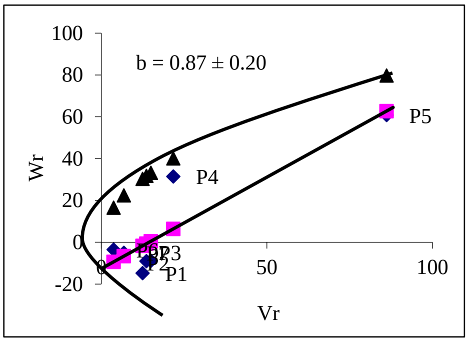

Fig. 2. Vr-Wr graph for days to 1st female flower open.

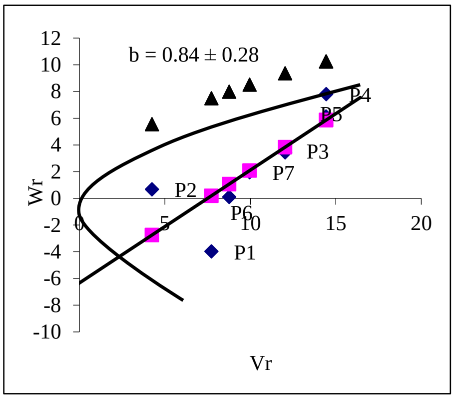

Fig. 3. Vr-Wr graph for node number to 1st male flower initiation.

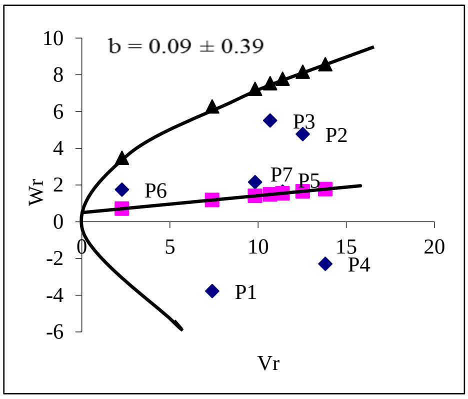

Fig. 4. Vr-Wr graph for node number to 1st female flower initiation.

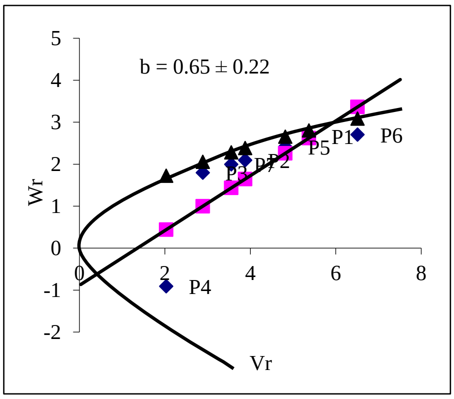

Fig. 5. Vr-Wr graph for main vine length.

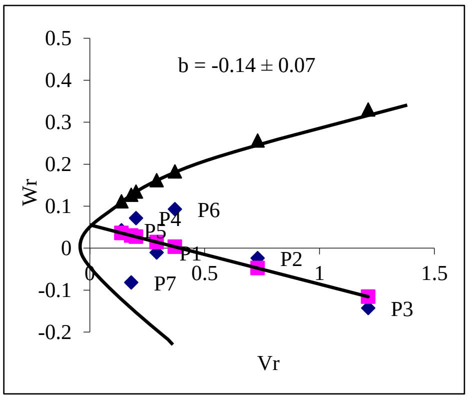

Fig. 6. Vr-Wr graph for primary branches per plant.

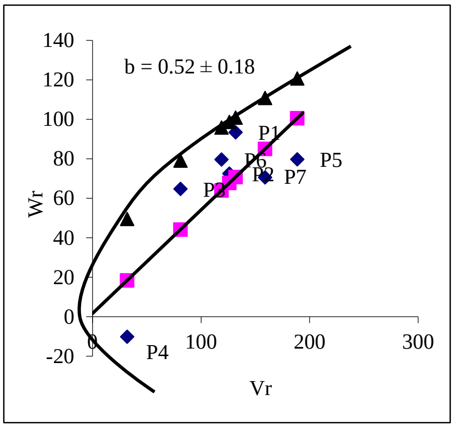

Fig. 7. Vr-Wr graph for nodes on main vine.

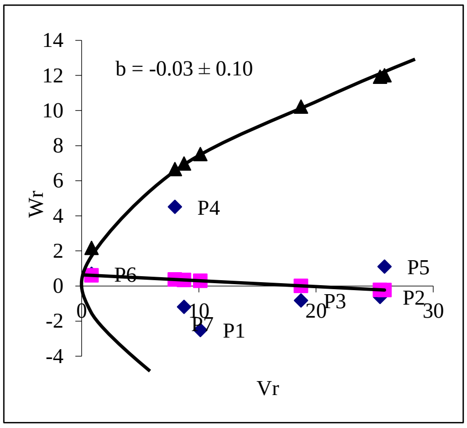

Fig. 8. Vr-Wr graph for days to 1st harvest.

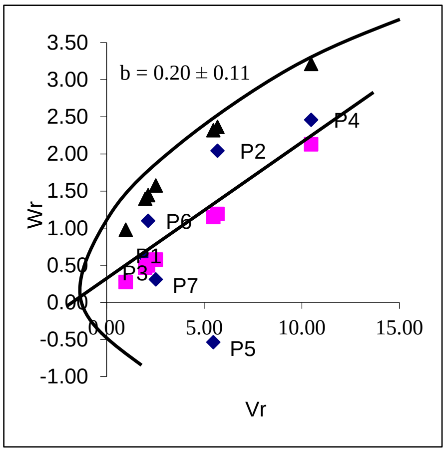

Fig. 9. Vr-Wr graph for fruit fly infestation (%).

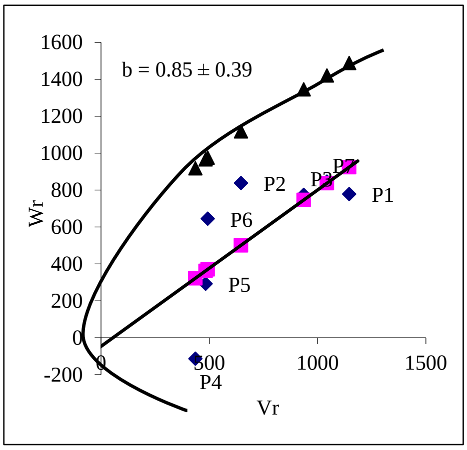

Fig. 10. Vr-Wr graph for individual fruit weight.

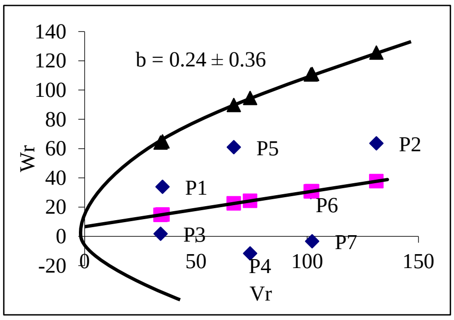

Fig. 11. Vr-Wr graph for fruits per plant.

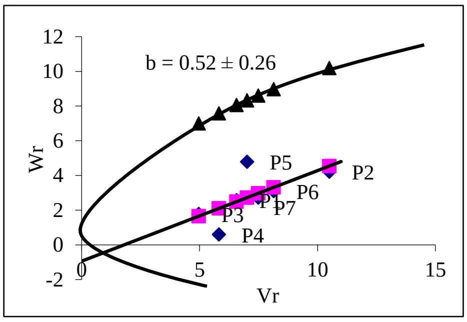

Fig. 12. Vr-Wr graph for fruit yield per plant.

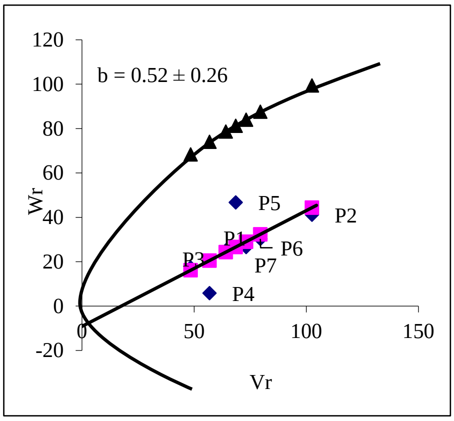

Fig. 13. Vr-Wr graph for yield of fruits per hectare.

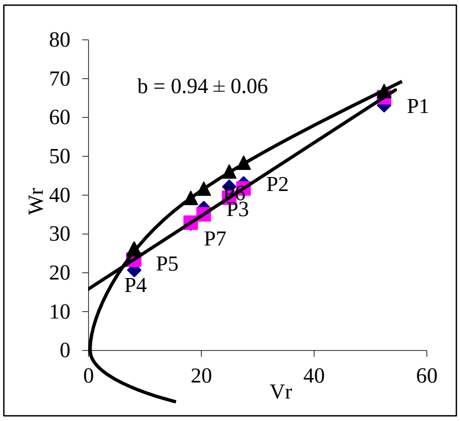

Fig. 14. Vr-Wr graph for fruit length.

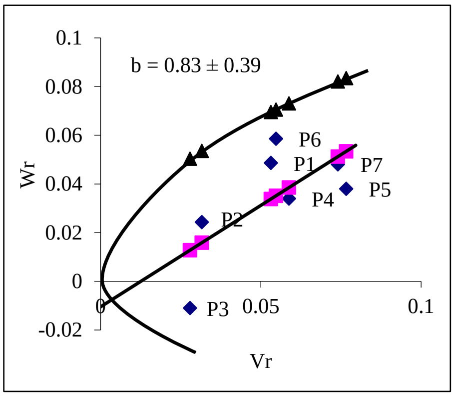

Fig. 15. Vr-Wr graph for fruit diameter.

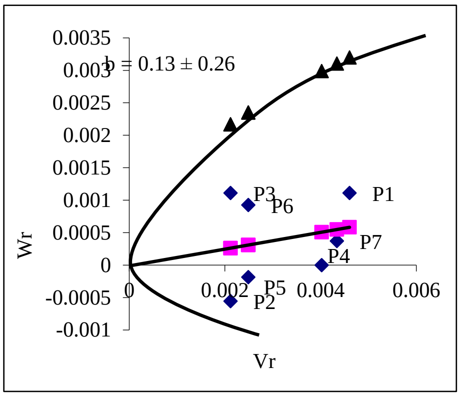

Fig. 16. Vr-Wr graph for fruit flesh thickness.

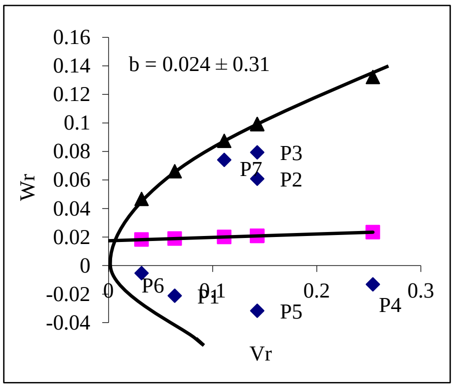

Fig. 17. Vr-Wr graph for locules per fruit.

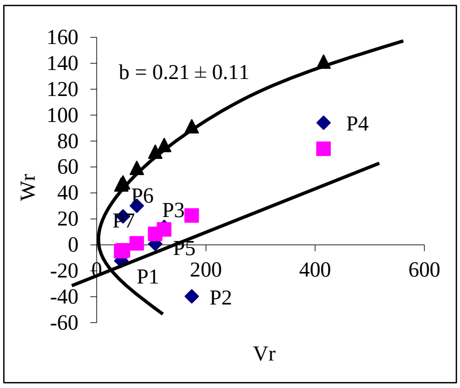

Fig. 18. Vr-Wr graph for seeds per fruit.

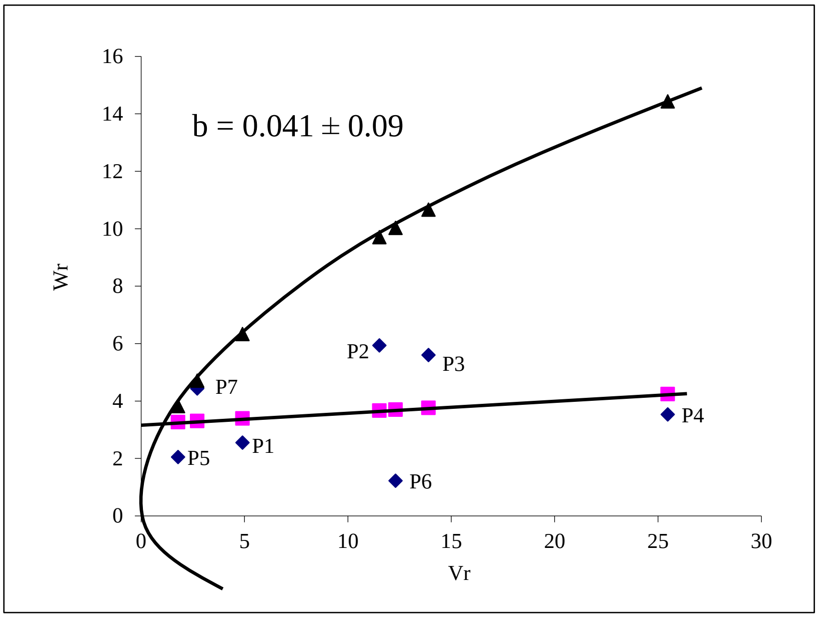

Fig. 19. Vr-Wr graph for 100-seed weight.

Genetic Components

The Influence of Additive (D) and Dominance (H_1)

The component D, which reflect the additive genetic variance was highly significant for all the characters studied, indicating the importance of additive gene effects in their inheritance. The component H_1, which measures the dominance variation, was highly significant for all the traits (Table 1) indicating the importance of dominance gene effects in controlling them. The estimation of D was higher than H_1 in case of fruit length, indicating the predominance of additive components over dominance components. So that selection based on these traits may be useful for improvement program. However, in other characters viz., days to 1st male flower open, days to 1st female flower open, node number of 1st male flower open, node number of 1st female flower open, main vine length, node number on main vine, number of primary branches/ plant, days to 1st fruit harvest, fruit fly infestation (%), number of fruits/ plant, fruit yield/ plant, fruit yield/ ha, individual fruit weight, fruit diameter, fruit flesh thickness, number of locules/ fruit, number of seeds/ fruit and 100-seed weigh, the estimates of H_1 was higher than D, indicating the predominance of dominance effect over additive effects in their expression (Table 1). Therefore, hybridization may be effective for these traits. The results agreed with the findings of Banik (2003) in the same crop.

Gene Distribution in the Parents

Distribution of genes in the parents can be observed from the value of H_2. The genes controlling the inheritance of all characters studied were not spread evenly in the parents, because the values of the H_2 against all characters indicated significant differences (Table 1). The proportion of positive genes will be seen from the value of H_1 against H_2. If $H_1 > H_2$ then the genes were more positive genes, on the other hand, if $H_1 < H_2$ then the genes were more negative genes. Genes involved more heavily in determining all the characters were positive genes reflected in the value of $H_1 > H_2$ (Table 1).

Dominance Level

The amount of dominance effects can be seen from the value $(H_1/D)^{1/2}$. The value $(H_1/D)^{1/2}$ of number of fruits per plant and fruit length was less than one indicating a partial dominance, while the value of $(H_1/D)^{1/2}$ of other remaining characters viz., days to male flower open, days to female flower open, node number of first male flower open, main vine length, fruit yield/ plant, fruit yield/ ha, individual fruit weight and fruit diameter was more than one indicating over-dominance in the heritance of those characters in the parents (Table 1).

Proportion of Dominant to Recessive Genes.

Table 1 shows that all the characters except main vine length, node number on main vine length, fruit fly infestation (%) and 100-seed weight had a value of $Kd/Kr > 1$. This result indicated that the genes were more dominant in these characters, mainly days to male flower open, days to female flower open, node number of first male flower open, node number of first female flower open, number of primary branches/plant, days to 1st fruit harvest, fruit yield/plant, fruit yield/ha, individual fruit weight, fruit diameter, fruit flesh thickness, number of locules/fruit and number of seeds/fruit in the parents. Meanwhile, main vine length, node number on main vine, fruit fly infestation (%) and 100-seed weight had a value of $Kd/Kr < 1$ (0.25, 0.44, 0.52 and 0.80, respectively), showing that the recessive genes were more in the parents.

Distribution of positive and negative alleles

The ratio of $H_2/4H_1$ provides an estimation of the average frequency of positive and negative alleles in all the parents (Table 1). The values of this ratio for all the characters studied were less than i.e. far away from 0.25 indicating unequal distribution of positive and negative alleles.

Number of Genes Controlling Characters.

The degree of controlling genes was reflected in the value h^2/H_2. The ratio of h^2/H_2 estimates the number of gene or group of genes which control the character exhibiting the degree of dominance to some extent. The estimated number of factors (h^2/H_2) for all characters studied having this ratioes smaller than 1 indicated the involvement of single dominant gene or one group of genes which are responsible for their genetic control (Table 1).

Frequency of dominant and recessive alleles

In the present study, the values of F for all the characters except main vine length, primary branches/ plant, nodes on main vine, percentage of fruit fly infestation and 100-seed weight were positive (Table 1), which expressed that dominant alleles were more frequent than recessive alleles in these characters. In case of vine length, primary branches /plant, nodes on main vine, percentage of fruit fly infestation and 100-seed weight were negative, which expressed that recessive alleles were more frequent than dominant alleles in the character.

Environmental effect

The environmental component E exhibited significant value for all the traits indicating the influence of environmental factors in the expression of those traits (Table 1). However, the magnitude of E for each character was much lower than their respective value of D and H_1. Such results indicated that the environmental influence upon the character was comparatively lower than that of additive and dominant effects. However, E was higher than D for primary branches /plant and locule number, indicating environmental effects exist on these characters.

Narrow sense heritability

The narrow sense heritability (h^2n) was found moderately high in days to 1^{st} male flower open (0.54) and high for days to 1^{st} female flower open (0.81) and fruit length (0.91) (Table 1). These values were more than 50% for these characters, indicating major part of additive gene action in phenotypic variability in nature and selection should be effective for improvement of these characters in snake gourd. Estimates of narrow sense heritability were less than 0.5 for node number of first male flower open, node number of first female flower open, main vine length, node number on main vine, number of primary branches/ plant, days to 1^{st} fruit harvest, fruit fly infestation (%), number of fruits/ plant, fruit yield/ plant, fruit yield/ ha, individual fruit weight, fruit diameter, fruit flesh thickness, number of locules/ fruit, number of seeds/ fruit and 100-seed weight, indicating low heritability of these traits. Therefore, given the high contribution of non-additive effect of genes on controlling these traits, selection potential for these traits would not be high; therefore, hybridization and selection based breeding methods in advanced generations may be useful (Zare *et al*., 2011).

Table 1. Estimation of genetic components of variation and ratios for nineteen traits in snake gourd

Components of variation/ traits	D	H_1	H_2	F	h^2	E	$(H_1/D)^{1/2}$	$H_2/4H_1$	$\{(4DH_1)^{1/2} + F\}/\{(4DH1)^{1/2} - F\}$	h^2/H_2	h^2 (ns)
Days to 1st male flower open	88.20** ±0.10	191.84** ±0.23	-41704.59** ±0.20	118.89** ±0.23	-98.019** ±0.13	0.57** ±0.03	1.47	-54.35	2.68	0.002	0.54
Days to 1st female flower open	73.41** ±0.08	134.57** ±0.19	-46987.69** ±0.17	117.82** ±0.19	-102.72** ±0.11	0.44** ±0.03	1.35	-87.29	3.91	0.002	0.81
Node number to 1st male flower initiation	6.55** ±0.01	36.98** ±0.03	-2368.25** ±0.03	4.31** ±0.03	-20.03** ±0.02	0.73** ±0.01	2.38	-16.01	1.32	0.008	0.16
Node number to 1st female flower initiation	3.84** ±0.03	34.52** ±0.07	-5022.15** ±0.06	2.95** ±0.07	-25.98** ±0.04	1.49** ±0.01	3.00	-36.38	1.29	0.005	0.09
Vine length (m)	1.34** ±0.01	10.44** ±0.01	-680.03** ±0.01	-4.53** ±0.01	-7.13** ±0.01	0.12** ±0.002	2.79	-16.28	0.25	0.01	0.08
Primary branches per plant	-0.07** ±0.003	1.47** ±0.006	-212.09** ±0.006	-0.02* ±0.006	-5.60** ±0.004	0.16** ±0.001	-4.55	-36.13	1.06	0.03	-0.03
Nodes on main vine	71.45** ±0.18	282.23** ±0.45	-37707.65** ±0.40	-111.27** ±0.45	-70.55** ±0.27	5.83** ±0.07	1.99	-33.4	0.44	0.002	0.146
Days to 1st harvest	4.96** ±0.06	59.02** ±0.14	-68901.15** ±0.13	9.59** ±0.14	-126.1** ±0.08	0.63** ±0.02	3.45	-291.88	1.78	0.002	0.087
Fruit fly infestation (%)	0.73** ±0.02	13.41** ±0.04	-381.93** ±0.03	-1.98** ±0.04	-6.25** ±0.02	0.25** ±0.006	4.28	-7.12	0.52	0.02	0.04
Individual fruit weight (g)	1911.52** ±1.54	2511.73** ±3.71	-647512.5** ±3.26	1515.59** ±3.69	-302.11** ±2.19	23.03** ±0.54	1.15	-64.45	2.06	0.001	0.64

Components of variation/ traits	D	H_1	H_2	F	h^2	E	$(H_1/D)^{1/2}$	$H_2/4H_1$	$\{(4DH_1)^{1/2} + F\}/\{(4DH1)^{1/2} - F\}$	h^2/H_2	h^2 (ns)
Number of ruits/ plant	117.42** ±0.23	323.72** ±0.56	-31933.31** ±0.50	136.31** ±0.56	-73.92** ±0.33	2.97** ±0.08	1.66	-24.66	2.07	0.002	0.37
Fruit yield/ plant (kg)	9.73** ±0.01	27.02** ±0.02	-1515.92** ±0.02	8.25** ±0.02	-12.16** ±0.01	0.15** ±0.002	0.15	-14.02	1.68	0.008	0.33
Fruit yield/ ha (t)	95.06** ±0.8	263.88** ±0.19	-14803.95** ±0.16	80.54** ±0.19	-38.50** ±0.11	1.46** ±0.03	1.67	-14.02	1.68	0.003	0.33
Fruit length (cm)	84.23** ±0.01	24.69** ±0.03	-17692.81** ±0.03	19.78** ±0.03	-60.51** ±0.01	0.88** ±0.005	0.54	- 179.11	1.55	0.003	0.91
Fruit diameter (cm)	0.08**	0.15** ±0.0002	-235.76** ±0.0002	0.03** ±0.0002	-6.91** ±0.0002	0.008**	1.33	- 404.47	1.35	0.029	0.36
Fruit flesh thickness (cm)	0.002**	0.012**	-4.180**	0.002**	-0.876**	0.001**	2.69	-89.77	1.59	0.21	0.117
Locules/Fruit	0.030**	0.391** ±0.001	-149.38** ±0.001	0.001 ±0.001	-5.08**	0.038**	3.58	-95.49	1.01	0.034	0.053
Seeds/ fruit	39.19** ±0.62	525.81** ±1.49	-48863.1** ±1.31	21.50** ±1.49	-79.82** ±0.88	8.81** ±0.22	3.66	-23.23	1.16	0.002	0.07
100-seed weight (g)	5.05** ±0.05	26.69** ±0.11	-11627.1** ±0.10	-2.59** ±0.11	-49.93** ±0.07	3.13** ±0.02	2.30	- 108.89	0.8	0.004	0.11

** Significant at 1% level, * Significant at 5% level, Without star indicates non-significant, h^2 (ns)= heritability in narrow sense

Conclusion

Hayman's graphical approach to diallel analysis is based on monogenic additive model. The regression line for days to 1st male flower open, days to 1st female flower open, node number of 1st male flower initiation, main vine length, individual fruit weight , fruit yield/ plant/ ha, fruit diameter and number of seeds/ fruit were below the origin indicating the presence of over-dominance, while for node number of 1st female flower initiation, number of primary branches/ plant, days to 1st fruit harvest, number of fruits/ plant, fruit length, number of locules/ fruit and 100-seed weight was above the origin suggesting the presence of partial dominance. The regression lines for nodes on main vine, fruit flesh thickness and fruit fly infestation percentage were through the origin indicating the presence of complete dominance. Thee additive component (D) and dominance component (H_1) of genetic variance were found highly significant for all the characters. The estimation of narrow sense heritability is a very useful selection parameter in plant breeding. It was found moderately high for days to 1st male flower open (0.54) and high for days to 1st female flower open (0.81) and fruit length (0.91). For other characters narrow sense heritability was found low. Based on this genetic information in this study, hybridization, selection-based breeding method, evaluation and isolation of superior genotypes in advanced generation are suggested for snake gourd crop improvement.

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NUTRIENT MANAGEMENT FOR MUSTARD AS RELAY CROP WITH T. *AMAN* RICE UNDER GANGES TIDAL FLOODPLAIN

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Abstract

The field experiment was carried out at Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Rahmatpur, Barishal during two consecutive *Rabi* seasons of 2019-2020 (Y_1) and 2020-2021 (Y_2) to develop nutrient management package for mustard as relay crop with T.*aman* rice for higher yield and economic return of the crop under Ganges Tidal Floodplain. The treatments of the experiment were: T_1 = 100% Recommended dose (RD: 90-27-16-15-1.5-1-1 kg/ha N-P-K-S-Mg-Zn-B), T_2 = 75% of RD, T_3 = 50% of RD, T_4 = 25% of RD, and T_5 =(72-22-13-12-1.5-0.8-0.8 kg/ha N-P-K-S-Mg-Zn-B, respectively) on soil test based (STB).. Fertilizer dose for previous T. *aman* rice was: 75-10-18-4-1 kg/ha N-P-K-S-Zn, respectively. The variety of mustard was BARI Sarisha-14. The experiment was laid out in a randomized complete block design with three replications. The experimental results revealed that nutrient management packages had significant effect on plant height, number of siliqua/plant, seed yield and straw yield in Y_1. On the other hand, in Y_2, number of siliqua /plant, number of seed/siliqua, seed yield and straw yield differed significantly by the nutrient packages. The maximum seed yield was obtained from T_1 treatment (1235 kg/ha) in Y_1, which was at par to that of T_2 (1183 kg/ha) and T_5 (1112 kg/ha), respectively. In Y_2, the maximum seed yield was found in T_2 (1228 kg/ha) that was statistically at par to that of T_1 (1225 kg/ha) and T_5 treatment (1189 kg/ha). The results further revealed that 75 - 100% RD of fertilizers as well as soil test based (STB) fertilizer dose gave similar seed yield. The fertilizers applied in previous T.*aman* rice had residual effect in succeeding mustard crop. Therefore, application of 75% RD or STB fertilizer dose along with residual fertilizer nutrients produced almost higher yield as per full dose of fertilizers. In average of two years, the highest gross return (Tk. 82524 /ha) and total variable cost (Tk. 53643/ha) were found in treatment T_1 (100% RD) but the treatment T_2 gave the highest gross margin (Tk. 29354 /ha) with BCR (1.57), which was closely followed by T_1 (1.54) and T_5 treatments (1.48, respectively).

Keywords: Mustard, relay crop, T.*aman* rice, nutrient management.

Introduction

Mustard is an important oilseed crop in Bangladesh covering an area of 2.70 lac hectare with annual production of 3.12 lac metric ton. The total annual demand of edible oil in the country is 14.60 lac metric ton where the local production (mainly

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mustard, sesame and sunflower oil) is only 2.36 lac metric ton and deficit about lac 12.24 metric ton (BBS, 2020). In the Ganges Tidal Floodplain that comprises of mostly southern region of Bangladesh, about 29.45 and 55.10% lands remain fallow during *Rabi* and *Kharif*-1 seasons, respectively due to delay harvest of T.*aman* rice, soil and water salinity, drought, tidal flooding, water logging etc. (Rahman, 2015). Relay mustard with T. *aman* rice is a traditional cropping pattern in Bangladesh. Relay cropping is a complex suite of different resource-efficient technologies, which possesses the capability to improve soil quality, to increase net return, to increase land equivalent ratio, as well as control the weeds and pest infestation (Tanveer *et al*., 2017). In southern region, late harvest of previous T.*aman* rice under rice based cropping systems, makes delay the sowing time (January) of mustard due to unfavourable field capacity (*zoh* condition) of soil. On the other hand, late sowing of mustard after conventional tillage causes moisture deficit at early growth stage of the plant, which is not favourable for getting reasonable yield. Relay cropping of mustard under zero tillage condition with preceding T.*aman* rice using residual soil moisture help in timely seeding of mustard crop (at least 15 days earlier as compared to conventional method of seeding) that provides favourable environment for proper growth and development of the crop plant. Farmers traditionally cultivate relay mustard based on their indigenous knowledge and perception, which is not given satisfactory yield (Mian *et al*., 2016). However, nutrient management package for relay mustard is yet to be developed considering the residual effect of preceding application of fertilizer nutrients in T.*aman* rice towards increasing the crop productivity and soil fertility. Therefore, the experiment was undertaken to develop nutrient management package for mustard as relay crop with T.*aman* rice under Ganges Tidal Floodplain in Bangladesh.

Materials and Methods

The field experiment was carried out at Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Rahmatpur, Barishal, Bangladesh during two consecutive *Rabi* seasons of 2019-2020 and 2020-2021 to develop nutrient management package for mustard as relay crop with T.*aman* rice (monsoon rice) under Ganges Tidal Floodplain (AEZ 13). The experimental site was situated in the latitudes 22°47′6.50629″N and longitudes 90°17′30.977″E. The land topography was medium high land and soil texture was loamy. The treatments of the experiment were: T_1 = 100% Recommended dose (RD: 90-27-16-15-1.5-1-1 kg/ha N-P-K-S-Mg-Zn-B, respectively) [BARC, 2018], T_2 = 75% of RD, T_3 = 50% of RD, T_4 = 25% of RD, and T_5 = Nutrient dose on soil test based (STB: 72-22-13-12-1.5-0.8-0.8 kg/ha N-P-K-S-Mg-Zn-B, respectively) t. The variety of mustard was BARI Sarisha-14. Mustard seeds were broadcasted at the rate of 6 kg/ha on 26 November, 2019 and 21 November, 2020 as relay crop with previous T.*aman* rice (var. BRRI dhan52) before 15 days of rice harvest (in standing rice crop). The experiment was laid out in randomized complete block design with three replications. The initial soil moisture of the experimental land was 32% on oven dry basis at the time of mustard seeding. Before seeding of mustard, soil samples of the experimental plots were taken for analysis of plant nutrient in the laboratory. The soil samples were tested in the laboratory of Soil Resource Development Institute (SRDI), Barishal. The analysis results of the soil samples are presented below:

Table 1. Nutrient status of the soil sample of the experimental field at RARS, Rahmatpur, Barishal

Soil pH	Salinity (dS/m)	Organic matter (%)	Nitrogen (%)	Potassium (meq /100g soil	Phosphorus (µg/g soil)	Sulphur (µg/g soil)	Boron (ppm)	Zinc (ppm)
7.60	0.72	0.11	0.006	0.13	17.20	1.30	0.45	1.12
Critical level (CL)		1.00	0.12	0.12	10.00	10.00	0.20	0.60
Nutrient status against CL		Below	Below	Above	Above	Below	Above	Above

The experimental plots were fertilized as per the treatment specifications for relay mustard crop. Fertilizer dose for previous T.*aman* rice was: 75-10-18-4-1 kg/ha N-P-K-S-Zn, respectively. The fertilizer nutrient requirement based on soil test results was calculated following the formula as suggested by BARC, 2018:

$$F_r = U_r - \frac{Ci}{Cs} \text{ x } (S_t - L_s),$$

Where, F_r = Fertilizer nutrient required for given soil test value, U_r = Upper value of the recommended fertilizer nutrient for the respective STV1 class, C_i = Units of class intervals used for fertilizer nutrient recommendation, C_s = Units of class intervals used for STV1 class, S_t = Soil test value and L_s = Lower limit of the soil test value within STV1 class. Thus, the calculated soil test base fertilizer dose for mustard was 72-22-13-12-0.8-0.8 kg/ha N-P-K-S-Zn, respectively. Half amount of N fertilizer (urea) and full amount of other nutrients were applied as basal, five days before sowing seeds of mustard. The rest amount of urea was top dressed after 23 days after emergence of seedling (i.e. before flowering) followed by irrigation. Irrigation was applied two times, one at 23 days after emergence (DAE), i.e. before flowering stage and another at 55 DAE (during siliqua formation). Other intercultural operations were done as and when necessary following the recommended production technologies of mustard (BARI, 2019). Data were collected on different parameters such as plant population/m^2, days to maturity, plant height, number of siliqua /plant, number of seed/siliqua, 1000-seed weight and seed yield. Data were analyzed statistically using windows based computer software of Statistix 10 version and then the mean differences were adjudged with Duncan's Multiple Range Test (DMRT) as suggested by Gomez and Gomez (1984). Besides, economic analysis was done based on the existing market prices of inputs, products and bi-products.

Results and Discussion

Effect of nutrient management on yield and yield contributing characters of mustard as relayed with T.*aman* rice

During, 2019-2020 (Y_1, nutrient management package had significant effect on plant height, number of siliqua/plant, seed and straw yield but no significant effect was observed on plant population/m^2, days to maturity, number of seed/siliqua and 1000-seed weight (Table 2). Number of siliqua/plant, number of seed/siliqua, seed yield and straw yield differed significantly but no significant effects were observed in plant population/m^2, days to maturity, plant height and 1000-seed weight in Y_2 (2020-2021). In Y_1, treatment T_1 (100% RD) produced the maximum plant height (68.27 cm), which was similar to that of T_2 (75% RD) and T_5 (STB). The plant height of treatment T_3 (50% RD) was statistically similar to T_4 (25% RD), which was 51.67 and 47.53 cm, respectively. The number of siliqua/plant attained the maximum (12.69) in T_1, which was statistically at par to that of T_5 (12.44) followed by T_2 (12.12) and T_3 (10.29). The lowest number of siliqua /plant was found in T_4 treatment (8.40). In Y_2, the maximum number of siliqua /plants was recorded in treatment T_1 (30.07), which was at par to that of T_2 and T_5 treatments (21.80 and 20.93, respectively). The treatment T_4 (25%RD) gave the lowert number siliqua/plant (10.87) and it was statistically identical to that of T_3 (15.13). The treatment T_1 gave the maximum number of seed /siliqua (30.07) and it was statistically similar to that of T_2 and T_5 treatments (24.93 and 24.33, respectively) in Y_2. The treatment T_3 (50%RD) showed the lower number of seed/siliqua (19.07), which was statistically similar to that of T_5 treatment (21.87). In Y_1, seed yield became the maximum in T_1 treatment (1235 kg/ha), which was statistically similar to that of T_2 (1183 kg/ha) and T_5 (1112 kg/ha). The treatment T_3 gave the seed yield of 866 kg/ha but the lowest yield was obtained from T_4 (613 kg/ha). The maximum seed yield (1228 kg/ha) was obtained from T_2 that was statistically at par to that of T_1 (1225 kg/ha) and of T_5 treatment (1189 kg/ha) in Y_1. The seed yield obtained from T_3 treatment was 950 kg/ha while T_4 gave the lowest yield of seed (614 kg/ha). In Y_1, treatment T_1 gave the maximum yield of straw (4321 kg/ha), which was statistically identical to that treatment T_2 (4141 kg/ha) followed by T_5 treatment (3891 kg/ha) and the lowest yield (2144 kg/ha) was obtained from T_4 treatment. On the other hand, treatment T_2 showed the maximum yield of straw (4457 kg/ha) in Y_2 that was statistically identical to that of T_1 and of T_5 treatments (4413 and 4268 kg/ha, respectively) in Y_2. The results further revealed that 75-100% RD of fertilizers as well as soil test based (STB) fertilizer dose gave similar yields of seed. The fertilizers particularly P-K-S-Zn as applied in previous T.*aman* rice had residual effect in succeeding mustard crop. Therefore, application of 75% RD or STB fertilizer dose along with residual fertilizer nutrients produced almost higher seed yield as per full dose of fertilizers. The results of the present investigation are in agreement with the findings by Das *et al*. (2010) that application of full dose of inorganic fertilizer application to maize not only enhanced productivity of maize-mustard cropping system, but also this nutrient management option had considered able residual effect on succeeding mustard in terms of yield and income. Similar findings were also found by Uddin *et al*. (2003) who noted that after application of full recommended dose NPKS in the preceding mustard, a reduced dose (50%) of PK along with a full N in the succeeding *boro* (spring rice) and T.*aman* rice gave a similar yield to when recommended NPKS or NPK was used.

Relay cropping of mustard under zero tillage condition with previous T.*aman* rice ensured the timely sowing of mustard crop that helped to become necessary vegetative growth of the plant. On the other hand, application of balanced dose of fertilizers helped in improving the yield contributing characters and seed yield of mustard under favourable growing conditions (air temperature, rainfall etc.).

Table 2. Effects of nutrient management on mustard as relayed with T.*aman* rice at RARS, Rahmatpur, Barishal during 2019-2020 and 2020-2021

Treatment	Plants/m^2 (no.)		Days to maturity		Plant height (cm)		Siliqua/plant (no.)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_1 = 100%RD	192.13	189	71	82	68.27a	67.73	12.69a	29.87a
T_2 = 75%RD	190.33	190	70	81	61.20ab	51.80	12.12ab	21.80ab
T_3 = 50%RD	190.00	188	70	81	51.67b	66.60	10.29ab	15.13bc
T_4 = 25%RD	173.00	175	70	81	47.53b	59.13	8.40b	10.87c
T_5 = STB	183.00	181	70	80	56.53ab	69.53	12.44a	20.93a-c
CV (%)	8.95	9.74	8.95	1.57	14.58	13.04	20.08	18.27

Table 2. Contd.

Treatment	Seed/siliqua (no.)		1000-seed wt. (g)		Seed yield (kg/ha)		Straw yield (kg/ha)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_1 = 100%RD	19.15	30.07a	2.63	2.63	1235a	1225a	4321a	4413a
T_2 = 75%RD	19.27	24.93ab	2.63	2.63	1183ab	1228a	4141ab	4457a
T_3 = 50%RD	17.39	19.07b	2.55	2.55	866b	950b	3032bc	3396bc
T_4 = 25%RD	16.64	21.87b	2.53	2.53	613c	614c	2144c	2244c
T_5 = STB	18.67	24.33ab	2.62	2.62	1112ab	1189ab	3891ab	4268ab
CV (%)	6.12	12.01	2.88	2.82	11.32	10.12	11.87	12.53

Means followed by the same letters within each column do not differ significantly by DMRT

Note: Y_1 = 2019-2020; Y_2 = 2020-2021; RD = Recommended dose, STB = Soil Test Based, CV = Coefficient of Variation

Air temperature data presented in Figure 1 and 2 revealed that the maximum temperature range was 25-28^{0}C and the minimum temperature was 13-15^{0}C during the crop growing period (December to February) in both the years (Y_1 and Y_2). Although small amount of rainfall occurred during the crop growing period but application of irrigation water as per requirement promoted the growth of the crop that helped in getting higher yield of mustard (Figure 3 and 4).

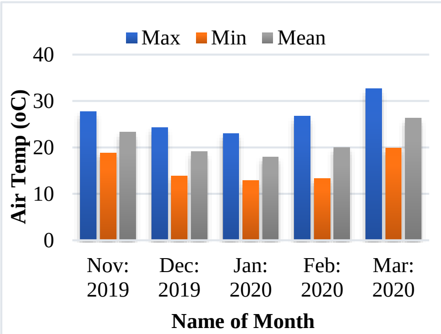

Fig. 1. Monthly air temperature during the cropping season (2019-2020).

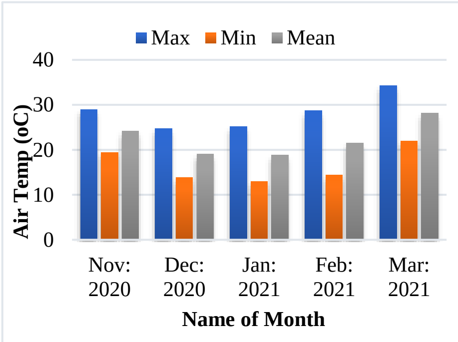

Fig. 2. Monthly air temperature during the cropping season (2020-2021).

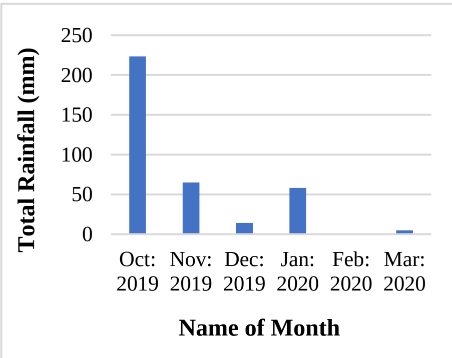

Fig. 3. Monthly total rainfall during the cropping season (2019-2020)

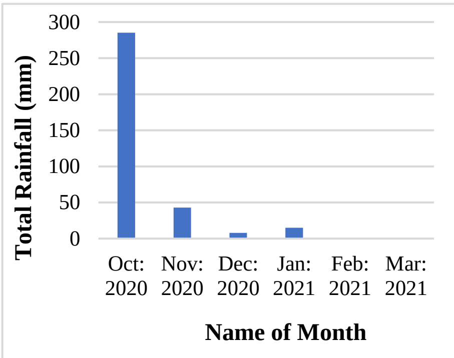

Fig. 4. Monthly total rainfall during the cropping season (2020-2021)

Economic return

The economic analysis of nutrient management of mustard as relayed with T.*aman* rice revealed that the gross return became the maximum (Tk. 82723/ha) in T_1 (100% RD) but slightly lower gross return (Tk. 79271/ha) from treatment T_2 (75% RD) in Y_1 (2019-2020). The treatment T_5 (STB) and T_3 (50% RD) contributed the gross return of Tk. 74490 and Tk. 58033/ha, respectively. The lowest gross return (Tk. 41040/ha) was found in T_4 (25% RD). In Y_2 (2020-2021), the gross return exhibited the maximum (Tk. 82580/ha) in T_2 closely followed byT_1 treatment (Tk. 82326/ha). The treatments T_5 and T_3 produced the gross returns of Tk. 79869 and Tk. 63791/ha, respectively. The lowest gross return (Tk. 41321/ha) was found in treatment T_4 treatment. In average of two years, the highest gross return (Tk. 82524/ha) was found in treatment T_1 (100% RD). However, slightly lower gross returns were achieved from T_2 and T_5 treatments (Tk. 80926 and 77179/ha, respectively). The average total cost was the highest (Tk. 53643/ha) in T_1 because more inputs were used in this treatment, which cumulative cost was higher. However, slightly reduced total cost was found in T_5 and T_2 treatments (Tk. 51986 and 51572/ha, respectively). Treatment T_4 showed the lowest total cost (Tk. 47431/ha) among the treatments. The gross margin was found to be the maximum (Tk. 30080/ha) in T_1 followed by T_2 (Tk. 28699/ha) in Y_1 while the treatment T_5 (STB) showed the gross margin of Tk. 23504/ha. The minimum gross margin (Tk. 9532/ha) was computed in T_3 treatment but the treatment T_4 produced negative gross margin (Tk. - 5391/ha). In Y_2, the maximum gross margin (Tk. 30008/ha) was found in T_2 treatment followed by T_1 (Tk. 27683/ha) and T_5 (Tk. 26883/ha). But on an average, the treatment T_2 gave the maximum gross margin (Tk. 29354/ha) followed by T_1 and T_5 treatments (Tk. 28882 and 25193/ha, respectively). On the other hand, treatment T_4 showed negative gross margin (Tk. - 6250/ha). In terms of benefit cost ratio (BCR), T_1 and T_2 produced same value (1.57) followed by T_5 treatment (1.46) in Y_1. In Y_2, the maximum value of BCR (1.57) was found in T_2 treatment followed by T_1 and T_5 exhibited the same BCR value (1.51). On an average, treatment T_2 also contributed the maximum BCR (1.57) closely followed by T_1 and T_5 treatments (1.54 and 1.48, respectively). The lowest BCR (0.87) was found in T_4 treatment. The results further revealed that treatment T_2 (75% RD) contributed more economic return in terms of gross margin and benefit cost ratio when mustard was cultivated as relay cropping with previous T.*aman* rice under Ganges Tidal Floodplain.

Table 3. Economic return of nutrient management of mustard as relayed with T.*aman* rice during 2019-2020 and 2020-2021

Treatment	Gross return (Tk./ha)			Total cost (Tk./ha)		
	Y_1	Y_2	Average	Y_1	Y_2	Average
T_1 = 100% RD	82723	82326	82524	52643	54643	53643
T_2 = 75% RD	79271	82580	80926	50572	52572	51572
T_3 = 50% RD	58033	63791	60912	48501	50501	49501
T_4 = 25% RD	41040	41321	41180	46431	48431	47431
T_5 = STB	74490	79869	77179	50986	52986	51986

Table 3. Contd.

Treatment	Gross margin (Tk./ha)			Benefit cost ratio (BCR)		
	Y_1	Y_2	Average	Y_1	Y_2	Average
T_1 = 100% RD	30080	27683	28882	1.57	1.51	1.54
T_2 = 75% RD	28699	30008	29354	1.57	1.57	1.57
T_3 = 50% RD	9532	13290	11411	1.20	1.26	1.23
T_4 = 25% RD	-5391	-7110	-6250	0.88	0.85	0.87
T_5 = STB	23504	26883	25193	1.46	1.51	1.48

Note: Y_1 = 2019-2020; Y_2 = 2020-2021

Prices of input, product and bi-product: Urea Tk. 16, TSP 20, MoP 15, Gypsum 10, Zinc fertilizer 120, Boron fertilizer 120/kg, Labour wage: Tk. 500/man-day (8 hours); mustard seed: Tk. 60 and straw: Tk. 2/kg

Conclusion

Fertilizer nutrients (both macro and micro nutrients) as applied in previous crop contribute residual effect in the succeeding crop. As a result, the application of 75% recommended dose (RD) of fertilizers or soil test based (STB) fertilizer dose along with residual fertilizer nutrients produced almost similar yields of relay mustard as given by the full dose of fertilizers. Because of better nutrient utilization by more healthy and vigorous plants under recommended and balanced level and resulting in more biomass production and yield. In terms of economic return, 75% RD (70-20-12-11-1.3-0.75-0.75 kg/ha N-P-K-S-Mg-Zn-B, respectively) also contributed the highest gross margin and benefit cost ratio when mustard was cultivated as relay cropping with previous T.*aman* rice under Ganges Tidal Floodplain in Bangladesh.

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EFFECT OF VERMICOMPOST AND INORGANIC FERTILIZER ON THE YIELD AND QUALITY OF CABBAGE

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Abstract

Vermicompost is an important organic manure for maintaining soil fertility and sustainable crop production. Hence, the present study was conducted to evaluate the effectiveness of vermicompost (VC) with inorganic fertilizer on the yield and quality of cabbage (*Brassica oleracea var. capitata*) during two consecutive years of 2019-2021. There were five treatments: T_1 = 100% RDF ($N_{115}P_{70}K_{125}S_{20}Zn_2$ kg ha^{-1}), T_2 = 75% RDF + 4 t ha^{-1} vermicompost (VC), T_3 = 100% RDF+ 3t ha^{-1} VC, T_4 = 75% RDF + 3 t ha^{-1} VC and T_5 = Control. The experiment was laid out in randomized complete block design with three replications. The highest cabbage head yield was found in T_3 (100% RDF+ 3 t ha^{-1}VC), which was 409% higher over the control. The maximum protein content (10.6%), vitamin- C (40.0 mg 100g^{-1}) and firmness (1.93 kgf) were recorded in the same treatment. The treatment T_3 also showed the highest gross margin while the maximum BCR (5.33), soil organic matter and total-N were recorded in T_4. Therefore, 100% RDF + 3 t VC ha^{-1} can be recommended for quality cabbage production.

Keywords: Vermicompost, cabbage yield, quality, nutrient requirement, profitability

Introduction

Improper and continuous use of chemical fertilizers reduce soil fertility, increase of planting cost, hamper sustainable practices of agriculture as well as cause health hazard of consumers (Bisht and Chauhan, 2020; Chuan *et al*., 2019; Rahman and Debnath, 2015). Combined application of organic and inorganic fertilizers is necessary to improve soil health and increases sustainable crop production. Organic fertilizer is ensured healthy and safe crop production by recycling of organic matter. In this context, farmer are gradually increasing to use of organic fertilizers in their crop field for sustaining productivity, keeping good soil health (Pozza and Field, 2020; Chatterjee *et al*., 2012). Vermicompost is the good source of organic fertilizer which is processed by the utilization of earthworms with organic waste made from livestock product (Chowdhury *et al*. 2020). Vermicompost is rich in essential plant nutrients (Korav *et. al*., 2021; Olle, 2017) and influences the plant growth by improving the physical and chemical properties of soil (Ceritoğlu *et al*., 2018).

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Cabbage (*Brassica oleracea var. capitata L.*) is one of the most common important winter vegetables (Ray *et al*., 2018) in Bangladesh occupied by 18.6 thousand hectares of land with the production of 323 thousand metric tons fresh cabbage (BBS, 2020). It is an excellent source of vitamin C, vitamin B, minerals and provides fibers to our diet. The average yield of cabbage 17.4 t ha^{-1} in Bangladesh is much below than the potential yield (BBS, 2020). The cultivation of cabbage requires proper supply of plant nutrients from inorganic and organic sources like vermicompost. Vermicompost is rich in plant nutrient elements, various hormones, enzymes, humic substances and especially organic matter (Ceritoğlu *et al*., 2018). The organic matter content in Bangladesh soil is less than 1 to 1.5% (Islam *et al*., 2018). Depletion of soil organic matter is the major barrier to produce higher yield. Increased sustainable production of crops cannot be maintained by using chemical fertilizer alone because of deterioration of soil physical and chemical properties. So, integrated use of both organic manure and chemical fertilizer is the best approach. However, it is utmost necessary to improve the yield of cabbage through judicious use of inorganic fertilizer and organic manure. Therefore, the present investigation was initiated to find out the suitable combination of vermicompost and inorganic fertilizer for increasing sustainable cabbage production and investigate the post-harvest soil properties.

Materials and Methods

Description of the study area

The experiment was conducted at Horticulture Research Centre (HRC) in Bangladesh Agricultural Research Institute (BARI), Gazipur during winter season (October to March) of 2019-2020 and 2020-2021. Geographically, it is located at 23.99° N latitude and 90.41° E longitude and elevated of 8.4 m above sea level. The soil was terrace and the texture was clay loam belonging to the *Chhiata* soil series (Aeric Haplaquepts) under the Madhupur Tract (AEZ-28) (Shil *et al*., 2016). The particle and bulk density of the soil was 2.50 g/cm^3 and 1.35 g/cm^3, respectively and the field capacity (FC) was 26%. Soil samples (0 to15 cm depth) collected before beginning of the experiment was analyzed by the standard methods and the results are presented in Table 1.

Table 1. Fertility status of initial soil of the experimental plot

Soil	pH	OM[a]	Total N	K	P	S	B	Zn
		%		meq. 100 g^{-1}	mg kg^{-1}			
Initial	6.5	1.24	0.060	0.12	11.0	14.5	0.17	0.83
Critical level	5.5-6.5	3-5	0.12	0.12	8	10	0.20	0.60
	Slightly[b] acidic	Low	Very low	Low	Low	Low	Low	Low

[a] OM = organic matter, [b]Interpretation source: Anonymous (2018).

The environment was subtropical, humid, and subjected to monsoons. The daily average temperatures was 13.0 to 36.1°C and yearly mean rainfall varied from 1500 to 2200 mm. Maximum and minimum monthly average temperature and average humidity, and monthly rainfall data of the experimental period of 2019-20 and 2020-21 were recorded from a meteorological station located about 351 m from the experimental field (Figures1a, b, c).

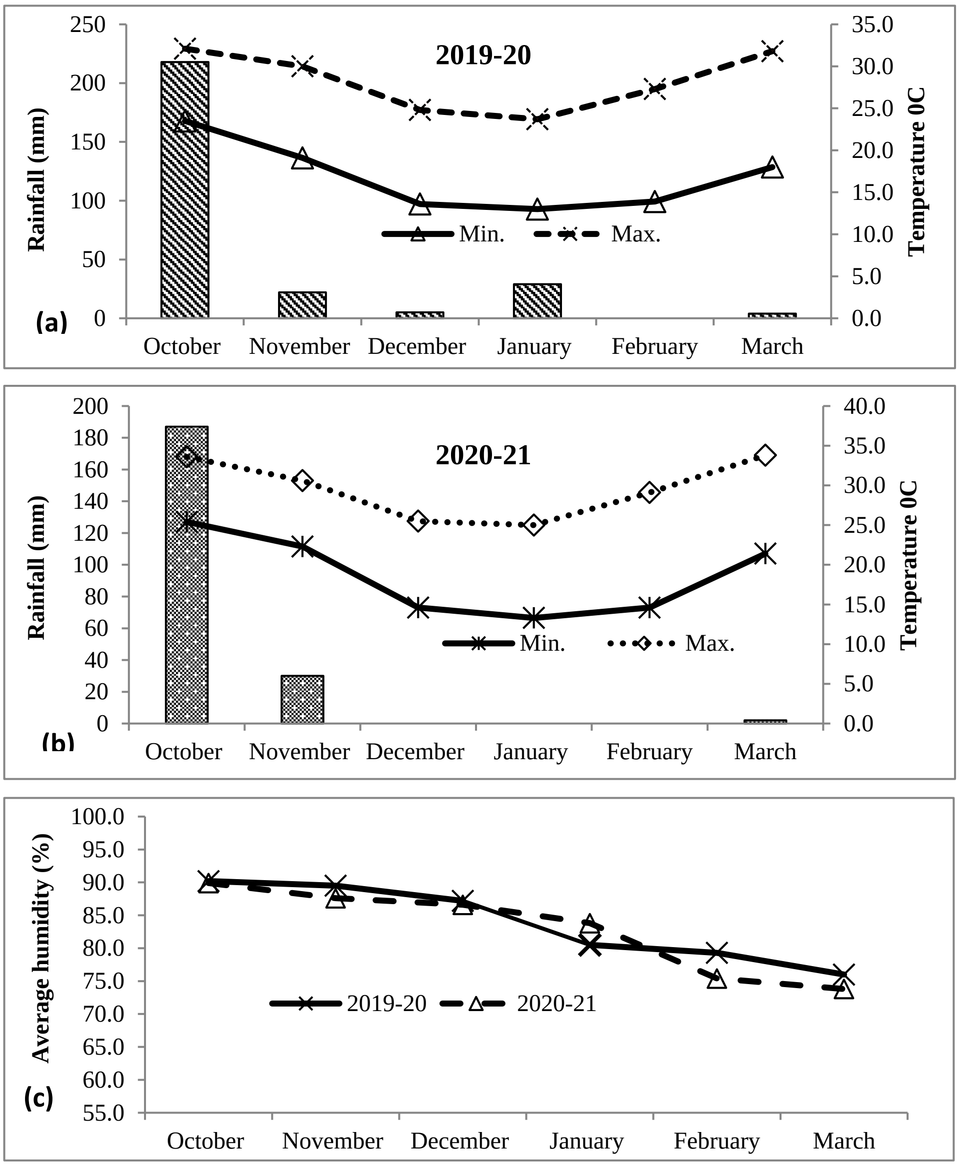


Fig. 1 Monthly average minimum and maximum temperature and rainfall (a, b) and monthly average humidity (c) during the experimental period of 2019-20 and 2020-21.

Chemical properties of vermicompost

The chemical properties of vermicompost were analyzed by standard methods and the properties are presented in Table 2.

Table 2. Nutrient status of vermicompost used in the experimental field

Name of the manure	pH	OC	K	Total N	P	S	B	Zn
		%						
Vermicompost	7.1	19.2	1.00	1.08	1.8	0.96	0.01	0.018

Cabbage seedling arising and land preparation

Cabbage seeds (cv. Atlas 70) were sown on 30 October 2019 and 31 October 2020 in raised seed bed which had been prepared manually. Irrigation was provided immediately after seed sowing. After emergence, developing seedlings were watered twice weekly. Seedlings were saved from infestation of disease (damping off) and insects using the fungicide Bavistin® and insecticide Sevin®. The soil was prepared by 4 passes with a tractor driven plough and leveled with a tractor driven rotavator. Weeds and stubbles were removed and cleaned manually.

Treatment details, manure and fertilizer application

The experimental treatments were: T_1=100% recommended dose of chemical fertilizer (RDF: $N_{200}P_{50}K_{80}S_{20}Zn_3B_{1.5}$), T_2 = 75% RDF + VC 4 t ha^{-1}, T_3 = 100% RDF+ VC 3 t ha^{-1}, T_4= 75% RDF+ VC 3 t ha^{-1} and T_5 = Control. The experiment was laid out in a randomized complete block design with 3 replications. The unit plot size was 2.4 m× 2 m. Plots were separated by 50 cm width. Urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate hyptahydrate and boric acid were used as sources of N, P, K, S, Zn and B, respectively.

Entire quantity of compost and full of TSP, gypsum, zinc sulphate, boric acid and half of MoP were applied manually during the final land preparation at two days before transplanting. The total amount of urea and rest half of MoP was applied in two equal installments as ring method under moist soil condition and mixed with soil immediately by hand at 15 and 35 days after transplanting.

Planting, harvesting and intercultural operation

Thirty-day-old healthy and uniform sized cabbage seedlings were transplanted maintaining spacing row to row 60 cm and plant to plant 40 cm on 29 November 2019 and 30 November 2020, respectively. Irrigation water was applied immediately to transplanted seedlings. The second, third, fourth, fifth, sixth and seventh irrigations were provided at 2, 5, 8, 12, 16 and 20 days, respectively, to enable establishment of transplants and cabbage plants were earthen up. Irrigation water was applied uniformly in all plots using a hose pipe, 2 to 3 times in a week. Weeding was done manually at 20 and 50 days after transplanting (DAT). Imitaf 20 SL® was applied @ 0.5 mLL^{-1} at 40 and 50 days after transplanting to control insect pest like cutworm. The mature cabbage head was harvested from each plot at different days started on 20 February to first week of March 2020 and 2021.

Data collection

The field data viz. plant height (cm), leaf length (cm), leaf breath (cm), head thickness (cm), head diameter (cm) and individual head weight (kg) were recorded from 5 randomly selected plants with tag in inner row. Cabbage head yield (t ha^{-1}) was measured from the whole plot technique which was calculated from the head weight of randomly selected 5 cabbage plants and head weight of rest cabbage plants in plot. Fresh cabbage samples were collected from each plot and brought to the laboratory and preserved by freezing at -30°C and held for cabbage head quality analysis. Cabbage head samples were removed from the freezer to determine total soluble solid (TSS), titratable acidity, pH and vitamin C. Firmness of cabbage head was measured in ambient conditions (25±1°C). Each head sample was sliced and squeezed to extract juice. The TSS was measured by placing about 0.4 mL of juice on the prism surface of a hand refractometer (Atago Ltd., PAL-1, Tokyo, Japan) and results expressed in °Brix according to an accepted method (932.12; Anon., 1994). Titratable acidity was determined by diluting a 2 mL aliquot of juice to 10 mL with 8 mL of distilled water and 2 drops of phenolphthalein with the pH adjusted to 8.2 using 0.1 N (w/v) NaOH. Titratable acidity was estimated according to the method of Rangana (1986). The pH of the juice was determined with a digital pH meter (Metter-Toledo GbH, CH-8603, Schwerzenbach, Switzerland). Vitamin C (ascorbic acid) was determined according to standard methods (Anon., 1994). A texture analyzer (GUSS, model GS-25, Western Cape, South Africa) was used to determine the cabbage head firmness on fresh samples. The 8 mm diameter flat end probe was inserted to 3 mm depth into cabbage head (same position of each sample) at 5 mm per sec speed. The most penetration force was used as firmness value. Three samples from each treatment were examined and averaged.

Soil and plant samples analysis

Postharvest soil samples at 0-15 cm depth were collected from each treatment for analysis. Plant samples (cabbage biomass) from each treatment were oven-dried at 70 °C for 48 h and finely ground. Each sample was preserved in polythene bags. The initial and postharvest soil samples were analyzed following standard methods. The soil pH was measured by glass electrode pH meter and organic carbon was wet oxidation method outlined by Page *et al*. (1982) and organic matter content calculated by multiplying %organic carbon with the Van Bemmelen factor of 1.73; Total N was determined by Microkjeldahl method (Page *et al*., 1982), available P was determined by Bray and Kurtz method (Bray and Kurtz,1945), exchangeable K by 1N NH_4OAc method (Jackson, 1973), available S by turbidity method using $BaCl_2$ (Fox *et al*., 1964); available Zn by DTPA method (Lindsay and Norvell, 1978); available B by azomethine-H method (Page *et al*., 1982).

Di-acid mixture (HNO_3-$HClO_4$) (5:1) was used for digestion of plant samples. The following methods were used for the determination of NPKSZnB: N (Micro-Kjeldahl method), P (spectrophotometer method), K (atomicabsorption spectrophotometer method), S (turbidity method using $BaCl_2$ by spectrophotometer), Zn (atomic absorption spectrophotometer method) and B (spectrophotometer following azomethine-H method).

Protein content and nutrient uptake estimation

Protein content in cabbage was estimated considering the nitrogen content as percentage. The protein content was estimated by multiplying the %N content with constant factor 6.25 that means %N × 6.25 (Hiller *et al*., 1948).

Nutrient (N, P, K, S, Zn and B) uptake by cabbage was calculated from the result of crop biomass dry matter yield and nutrient (N, P, K, S, Zn and B) content in cabbage (Anon., 2018).

Nutrient uptake = Yield in kg ha^{-1} × nutrient content in %/100

Statistical analysis

Collected data were subjected to analyses by statistical software Statistix-10 (Statistix-10, 1985). The means of all data were compared using the least significant difference (LSD) at a significant level $p \leq 0.05$.

Cost and return analysis

The benefit cost ratio (BCR) was calculated for a hectare of land. Management costs were calculated by adding the cost incurred from labor, ploughing, inputs etc. Cabbage head yield was utilized to calculate gross return. Shadow prices (land rent and others) were not considered. Gross return was measured by multiplying the crop yield by unit price (farm gate). Gross margin was calculated by subtracting management cost from gross return.

Results and Discussion

Plant parameters

The plant height, leaf length and leaf breadth of cabbage were significantly influenced by the application of vermicompost and inorganic fertilizers (Table 3). The maximum plant height (36.2 and 39.4 cm for 2019-20 and 2020-21, respectively) was found in T_3 (100% RD+ VC 3 t ha^{-1}), which was closely followed by T_1 (100% RDF). The lowest plant height (28.1 and 25.1 cm for 2019-20 and

2020-21, respectively) was observed in the control. Similar results were also reported by Alam *et al*. (2017) in cabbage where the maximum plant length was recorded in combination of vermicompost and inorganic fertilizer. The leaf length and leaf breadth were also followed the same trend.

The highest leaf length (31.5 cm in 2019-20 and 35.6 cm in 2020-21) was recorded from T_3 which were statistically similar to the most of the treatment in both years (Table 3). Vermicompost improves the soil structure, soil porosity, water holding capacity and boosts to supply proper nutrient for cabbage leaf length and development (Reza *et al*., 2016). The maximum leaf breadth (21.3 cm in 2019-20 and 16.6 cm in 2020-21) was also recorded from the same T_3 treatment which was close comparable with T_4 and T_2 treatment in 2019-21 and with T_1 in 2020-21. The lowest leaf length and breadth was noted from control T_5 treatment. The result is in agreement with the findings of Ali and Kashem (2018) who reported that highest leaf length and breadth was achieved in vermicompost with inorganic fertilizer treated plot. Getnet and Raja (2013) corroborated similar that leaf length and breadth was bigger in vermicompost treated plot than others.

Table 3. Effect of vermicompost and inorganic fertilizer on growth characters of cabbage

Treatment	Plant height (cm)			Leaf length (cm)			Leaf breadth (cm)		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
T_1 = 100% RDF	35.2ab	39.1a	37.2	30.8a	34.7a	32.8	19.1b	15.8ab	17.5
T_2 = 75% RDF + VC 4 tha^{-1}	30.9bc	38.2a	34.6	28.8a	34.5a	31.7	19.6ab	15.4b	17.5
T_3 = 100% RDF+ VC 3 tha^{-1}	36.2a	39.4a	37.8	31.5a	35.6a	33.6	21.3a	16.6a	19.0
T_4= 75% RDF+ VC 3 tha^{-1}	31.5a-c	32.2b	31.9	29.5a	32.0a	30.8	21.3a	13.4c	17.4
T_5 = Control (Native nutrient?)	28.1c	25.1c	26.6	17.3b	21.9b	19.6	10.4c	8.96d	9.68
CV (%)	9.88	7.36	-	9.25	6.30	-	6.35	4.06	-

Values within the same column with a common letter do not differ significantly ($P \leq 0.05$).

RDF= Recommended dose of fertilizer, VC= Vermicompost

Yield attributes of cabbage

The yield attributes of cabbage were significantly influenced by the vermicompost and inorganic fertilizer (Table 4). The maximum head thickness (12.3 cm in 2019-20 and 13 cm in 2020-21) was found in T_3 , which was followed by T_2. The minimum head thickness (9.40 and 10.7 cm for 2019-20 and 2020-21, respectively) was recorded in the control (Table 4). Similar result was also reported by Ali and Kashem (2018). The individual head weight also followed the same trend (Table 4). The head diameter was significantly influenced by the integrated nutrient management. The mean head diameter of cabbage ranged from 13.5 to 26.5 cm, having the maximum in T_3 closely followed by T_4 and the lowest in the control (Table 4). The highest yield attributes were recorded in T_3 might be due to organic (vermicompost) amendments enhanced beneficial soil microorganisms, increased soil organic matter, total carbon, and cation exchange capacity (CEC), and lowered bulk density thus improved soil quality resulted higher growth of cabbage (Bulluck *et al.*, 2002). Moreover, inorganic fertilizer supplied readily available essential plant nutrients.

Table 4. Effect of vermicompost and inorganic fertilizer on the yield attributes of cabbage

Treatment	Head thickness (cm)			Head diameter (cm)			Individual head wt. (kg)		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
T_1 = 100% RDF	11.1b	12.6a	11.9	21.9a	25.5ab	23.7	2.03b	2.34ab	2.19
T_2 = 75% RDF + VC 4 tha^{-1}	11.1b	12.8a	12.0	21.8a	24.6b	23.2	2.05b	2.12b	2.09
T_3 = 100% RDF+ VC 3 tha^{-1}	12.3a	13.0a	12.7	23.8a	26.5a	25.2	2.37a	2.47a	2.42
T_4= 75% RDF+ VC 3 tha^{-1}	11.7ab	11.7ab	11.7	23.2a	25.8a	24.5	2.16a	2.18b	2.17
T_5 = Control	9.40c	10.7b	10.1	13.5b	15.3c	14.4	0.24c	0.57c	0.41
CV (%)	5.97	5.66	-	6.49	2.59	-	9.04	7.14	-

Values within the same column with a common letter do not differ significantly ($P \leq 0.05$).

RDF= Recommended dose of fertilizer, VC= Vermicompost

Head yield of cabbage

The head yield of cabbage was significantly variable among the treatments (Figure 2a). The maximum fresh head yield (98.9 and 112 t ha^{-1} for 2019-20 and 2020-21, respectively) was found in T_3, which was identical with T_1 and T_4. The lowest mean head yield (20.6 t ha^{-1}) was noted in the control (Figure 2c). The similar results were also reported by Alam *et al.* (2017). Addition of vermicompost with inorganic fertilizer in soil enhanced the microbial activities helping nutrient availability to the crop which results higher yield (Alam *et al.*, 2017). Vimala *et al.* (2006) reported that conjunctive use of organic and inorganic sources would improve the soil health and increase yield of cabbage. Reza *et al.* (2016) reported similarly that vermicompost with inorganic fertilizer contributed to attain higher yield of cabbage. The mean fresh head yield varied from 20.6 to 105 t ha^{-1}, having the maximum in T_3 treatment (Figure 2c). The yield due to different treatments followed the order: $T_3>T_1>T_4>T_2>T_5$ (Figure 2c). The highest biomass dry matter (DM) yield was found in T_3, which was significantly higher than the other treatments (Figure 2b). The lowest biomass dry matter (DM) yield was recorded in the control (Figure 1b). Karmegam and Daniel (2008) also reported that in hyacinth beans, higher dry matter production was recorded in vermicompost added plot. In the experiment, the highest head yield increment (409%) over control was found in T_3 treatment and lowest increment was in T_2 treatment (Figure 2d).

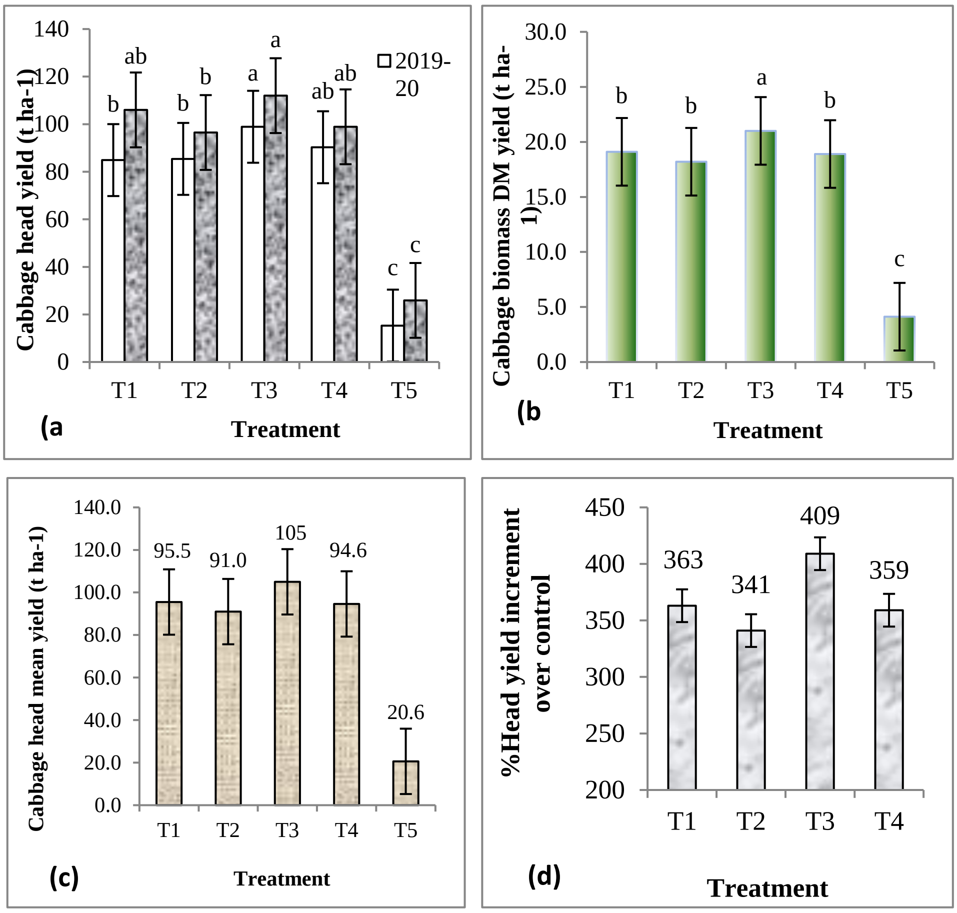


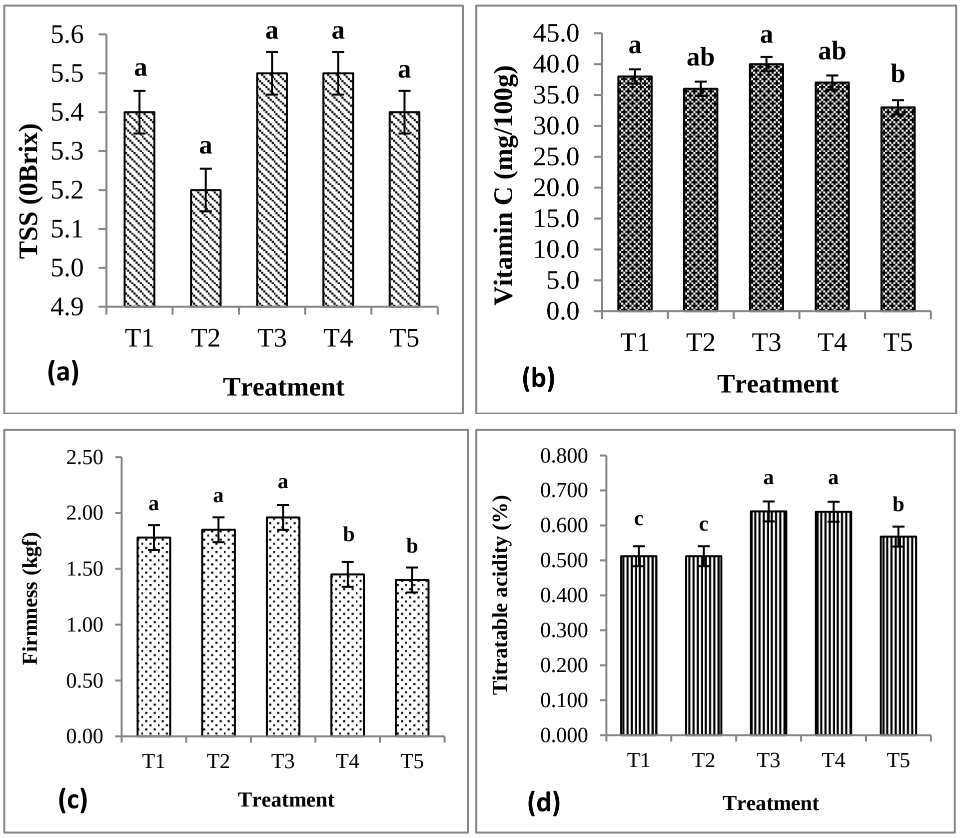
Fig. 2 Effect of vermicompost and inorganic fertilizer on fresh head yield (a), biomass dry matter mean yield (b), mean head yield of cabbage (c) and % head yield increment over control (d).

Notes: T_1 = 100% RDF, T_2 = 75% RDF + VC 4 t ha^{-1}, T_3 = 100% RDF+ VC 3 tha^{-1}, T_4= 75% RDF+ VC 3 tha^{-1} and T_5 = Control.

Values followed by the same letter are not significantly different according to the least significant difference (LSD) test at $p \leq 0.05$.

Quality attributes of cabbage

The vitamin C, firmness, titratable acidity, pH and protein content in cabbage were significantly influenced by the application of vermicompost and inorganic fertilizer (Figure 3 (a, b, c, d, e, f)). The highest vitamin C content (40.0 mg 100 g^{-1}) was recorded in T_3 which was followed by T_1 and T_4. The lowest vitamin C was noted in the control (Figure 3b). Vitamin C content generally varied based on cultivar, plant nutrition, production practice and maturity (Antonio *et al.*, 2007). Nurhidayati *et al*. (2016) corroborated that vermicompost treated cabbage increased the content of vitamin C 57% over control. The maximum firmness (1.96 kgf) was found in T_3 which was identical to T_1 and T_2 (Figure 3c). The lowest value was recorded in the control. Mean titratable acidity varied from 0.512 to 0.640%, having the maximum (0.640%) in T_3 followed by T_4 and the lowest noted in T_1 (Figure 3d). The maximum cabbage pH (7.42) was recorded in T_1 and the lowest in T_4 treatment (Figure 3e). The protein content of cabbage was significantly variable among the treatments (Figure 3f). The highest protein content (10.6%) was found in T_3 and the lowest noted in the control (Figure 3f). Upadhyay *et al*. (2012) reported that the maximum protein content was recorded in cabbage with vermicompost treated plot.



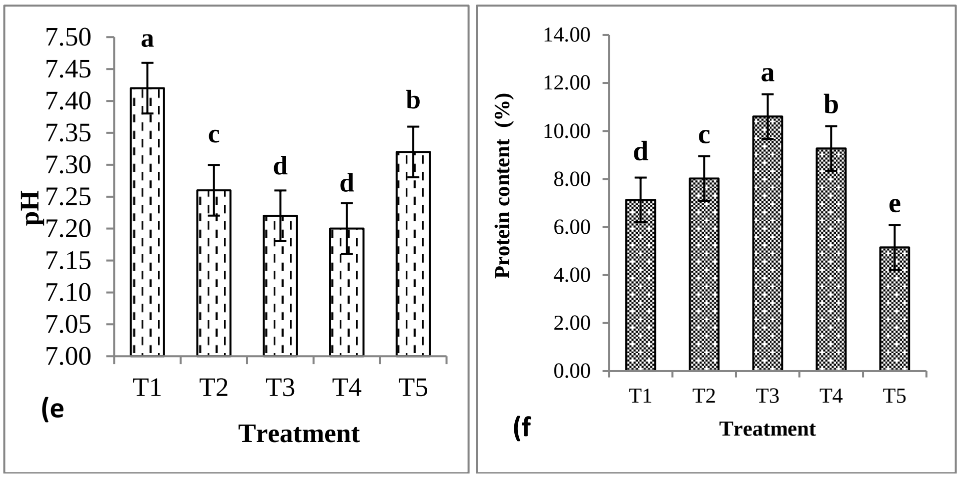


Fig. 3 Effect of vermicompost and inorganic fertilizer on TSS (a), vitamin C (b), firmness (c), titratable acidity (d), pH (e) and protein content of cabbage (f) (mean data of two years).

Notes: T_1 = 100% RDF, T_2 = 75% RDF + VC 4 t ha^{-1}, T_3 = 100% RDF+ VC 3 tha^{-1}, T_4= 75% RDF+ VC 3 tha^{-1} and T_5 = Control.

Mean values followed by the same letter are not significantly different at 5% level of LSD

Nutrient content in cabbage

The content of N, P, K, S, Zn, and B in cabbage was significantly influenced by the application of vermicompost and inorganic fertilizer (Table 5). Result revealed that significantly highest N content (17.0 g kg^{-1}) was found in T_3 while the minimum N content (8.23 g kg^{-1}) in the control (Table 5). The Zn and B content also showed the similar trend. The T_4 treatment showed the highest P, K and S content (4.00, 15.6 and 1.53 g kg^{-1}, respectively) in cabbage, which were significantly higher over other treatment (Table 5). The lowest P, K and S content (1.06, 5.67 and 0.47 g kg^{-1}, respectively) was recorded in the control (Table 5). The higher amount of N, Zn and B content in T_3 and P, K and S content in T_4 might be due to application of vermicompost with inorganic fertilizer increased availability of plant nutrients, organic matter content and CEC in resulted higher N, Zn, B, and P, K, S accumulation by the cabbage plant. Similar results were also reported by Reza *et al*. (2016); Maselesele *et al*. (2022); Nguyen *et al.* (2013); Anguria *et al.* (2017) in cabbage.

Table 5. Effect of vermicompost and inorganic fertilizer on nutrient content in cabbage (Pooled data of two years)

Treatment	N	P	K	S	Zn	B
	g kg^{-1}					
T_1 = 100% RDF	11.4d	1.07c	11.6c	1.07b	0.19b	0.17b
T_2 = 75% RDF + VC 4 tha^{-1}	12.8c	2.27b	11.5c	1.23b	0.23b	0.20b
T_3 = 100% RDF+ VC 3 tha^{-1}	17.0a	2.93b	13.8b	1.23b	0.32a	0.30a
T_4= 75% RDF+ VC 3 tha^{-1}	14.8b	4.00a	15.6a	1.53a	0.31a	0.29a
T_5 = Control	8.23e	1.06c	5.67d	0.47c	0.16b	0.16b
CV (%)	3.80	16.5	5.64	13.7	14.2	15.2

Values within the same column with a common letter do not differ significantly at 5% level of LSD.

Nutrient uptake by cabbage

The uptake of N, P, K, S, Zn and B by the cabbage was significantly influenced by the application of vermicompost and inorganic fertilizer (Figure 4a, b). The highest N uptake (359 kg ha^{-1}) was found in T_3 (100% RDF+ VC 3 t ha^{-1}), and the lowest in the control (Figure 4a). Similarly the maximum Zn and B uptake were observed in T_3, which were identical to T_4 and the minimum was noted in the control (Figure 4b). The T_4 treatment showed the maximum P, K and S uptake by the cabbage (75.6, 295 and 29 kg ha^{-1}, respectively) followed by T_3 and the lowest in the control (Figure 4a). Higher uptake of N, P and K in vegetative parts of cabbage under combined application of vermicompost and inorganic fertilizer might be due to good proliferation of root system, resulting in better absorption of these nutrients. Konyak and Sanjay-Swami (2018) reported that combination of organic (vermicompost) and inorganic fertilizer showed the higher uptake of N, P and K by the cabbage plant. Reza *et al.* (2016) also reported that vermicompost (5 t ha-1) with IPNS based chemical fertilizer exhibited higher uptake of N, P, K, S, Zn and B by cabbage. Similar report corroborated by Singh *et al*. (2011).

Effect of vermicompost and inorganic fertilizer on Postharvest Soil Properties

The post-harvest properties of soil were significantly influenced by the combined application of vermicompost and inorganic fertilizer (Table 6). The soil pH of all treatment was found almost static or slightly decreased with the initial reference status (Table 6). The organic matter (OM) and total N content in soil varied significantly due to the variation of the treatments. The maximum OM (1.30%) was noted in T_2 followed by T_4. The total N content was maximum (0.064%) in T_4 treatment statistically similar to T_2 treatment (Table 6). Similar result was also corroborated by Reza *et al*. (2016) who noted that vermicompost with IPNS based inorganic fertilizer showed the highest organic matter and total N content in postharvest soil. Kamla *et al*. (2002) reported the similar view. Ali and Kashem (2018) also reported that vermicompost with inorganic fertilizer increased the soil organic matter and total N content. The OM and total N content of all treatments were found slightly increased over the initial status. The K content in postharvest soil varied non-significantly among the treatment but decreasing trend of exchangeable K content was exhibited with the initial soil K status. The variation of post-harvest soil S was also non-significant. The Zn and B content in postharvest soil were maximum in T_3 treatment but statistically similar to T_2 treatment. The Zn and B content were slightly increased from the initial soil Zn and B status (Table 6).

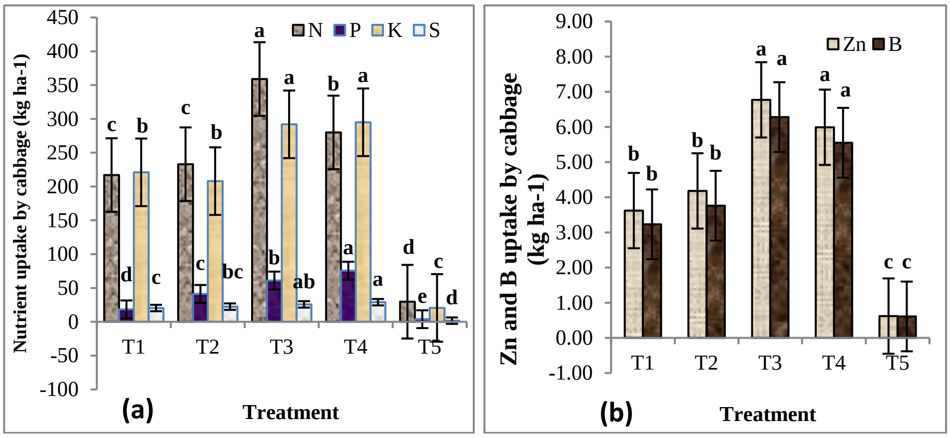


Fig. 4. Effect of vermicompost and inorganic fertilizer on N, P, K, S uptake (a) and Zn, B uptake (b) by cabbage (mean data of two years). Notes: T_1 = 100% RDF, T_2 = 75% RDF + VC 4 tha^{-1},

T_3 = 100% RDF+ VC 3 tha^{-1},T_4= 75% RDF+ VC 3 tha^{-1}and T_5 = Control.

Values followed by the same letter are not significantly different at 5% level of LSD.

Table 6. Effects of application of vermicompost and inorganic fertilizer on chemical properties of postharvest soil

Treatment	pH	OM	Total N	K	P	S	Zn	B
		------- %-------		meq. 100 g^{-1}	-------------- mg kg^{-1} -------------			
Initial soil	6.5	1.24	0.060	0.12	11.0	14.5	0.83	0.17
T_1 = 100% RDF	6.4a	1.25b	0.061cd	0.11a	12.0ab	14.5a	0.90bc	0.18a
T_2 = 75% RDF + VC 4 tha^{-1}	6.5a	1.30a	0.063ab	0.11a	12.0ab	15.0a	0.91ab	0.17ab
T_3 = 100% RDF+ VC 3 tha^{-1}	6.4a	1.28a	0.062bc	0.10a	13.0a	14.5a	0.92a	0.18a
T_4= 75% RDF+ VC 3 tha^{-1}	6.5a	1.30a	0.064a	0.11a	12.0ab	15.0a	0.89c	0.18a
T_5 = Control	6.5a	1.24b	0.060d	0.10a	11.0b	14.0a	0.80d	0.16b
CV (%)	1.30	0.89	1.44	8.44	7.45	5.63	1.01	5.14

Values within the same column with a common letter do not differ significantly ($P \leq 0.05$)

Cost and Return Analysis

Application of vermicompost with inorganic fertilizer showed positive effect on the cost and return analysis (Table 7). Economic analysis revealed that the highest gross return (Tk.735000 ha^{-1}) and gross margin (Tk. 579340 ha^{-1}) were found in T_3. Similar results were also reported by Ray *et al*. (2018) in cabbage production. Other researchers observed comparable result like highest gross return and gross margin in cabbage by the application of vermicompost with 100% recommended chemical fertilizer (Alam *et al*. 2017). The maximum benefit cost ratio (5.33) was recorded in T_4, which was closely followed by T_1 and the lowest was observed in the control (Table 7). However the highest BCR increment 255% over control was achieved in T_4 treatment.

Table 7. Cost and benefit analysis for cabbage production as influenced by integrated nutrient management

Treatment	TVC (Tk. ha^{-1} yr^{-1})	Gross return (Tk. ha^{-1} yr^{-1})	Gross margin (Tk. ha^{-1} yr^{-1})	BCR
T_1 = 100% RDF	125660	668500	542840	5.32
T_2 = 75% RDF + VC 4 tha^{-1}	134245	637000	502755	4.75
T_3 = 100% RDF+ VC 3 tha^{-1}	155660	735000	579340	4.72
T_4= 75% RDF+ VC 3 tha^{-1}	124245	662200	537955	5.33
T_5 = Control	96000	144200	48200	1.50

Inputs price: Ploughing (single pass) = BDT 3000 ha^{-1}, Wage rate = BDT 400 day^{-1},

Urea = BDT 16 kg^{-1}, Triple super phosphate = BDT 22 kg^{-1}, Muriate of potash = BDT 17 kg^{-1} , Gypsum = BDT 12 kg^{-1}, Borax = BDT 150 kg^{-1}, Zinc sulphate = BDT 160 kg^{-1}, Vermicompost= BDT 10 kg^{-1}, Cabbage seed = BDT 1000 kg^{-1}, Sevin = BDT 200/100g, Imitaf= BDT 155/100 ml, Irrigation = BDT 100 $hour^{-1}$. Output price: Fresh cabbage head = BDT 7 kg^{-1}

Conclusion

The yield attributes and head yield of cabbage were significantly influenced by the integrated use of vermicompost and chemical fertilizer. The highest yield and yield attributes of cabbage as well as the maximum vitamin C, protein content, gross return and gross margin were found in T_3 (100% RDF + 3 t VC ha^{-1}) treatment. The maximum nutrient availability and organic matter content were recorded in T_3 and T_4 treatments. Therefore, vermicompost at 3 t ha^{-1} along with 100% recommended dose of chemical fertilizer can be recommended for sustainable cabbage production.

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EFFECT OF PLANT SPACING AND NUTRIENT MANAGEMENT ON BULB YIELD OF RATOON ONION

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M. I. HAQUE[4] AND R. ARA[5]

Abstract

A field experiment was conducted at Regional Spices Research Centre, BARI, Gazipur during two growing seasons of 2020-2021 and 2021-2022. The objective of the study was to find out the suitable plant spacing and develop a nutrient management package for maximizing the yield of ratoon onion. The experiment was conducted in a Factorial Randomized Complete Block Design having three replications. There were 9 treatments comprising three levels of plant spacing: 10 cm X 10 cm, 15 cm X 10 cm and 20 cm X 10 cm with three nutrient management packages: Soil test basis ($N_{90}P_{37}K_{80}S_{15}Zn_{1.5}B_{1}$ kg ha^{-1}) with cowdung 3 t ha^{-1}, RDF ($N_{110}P_{45}K_{120}S_{30}Zn_{3}B_{1.5}$ kg ha^{-1}) with cowdung 5 t ha^{-1} and farmer's practices ($N_{120}P_{50}K_{85}S_{20}$kg ha^{-1}). Results revealed significant effect for plant spacing and nutrient management as well as their interaction on the yield components and bulb yield of ratoon onion. The highest bulb yield (12.1 and 14.33 t ha^{-1} in 2020-2021 and 2021-2022, respectively), was obtained with plant spacing (10 cm x 10 cm) along with the RDF ($N_{110}P_{45}K_{120}S_{30}Zn_{3}B_{1.5}$ kg ha^{-1}) with cowdung 5 t ha^{-1}. The cost benefit analyses also showed the maximum net income (594857 taka) from the same treatment combination. Therefore, the same treatment package (10 cm x 10 cm spacing and $N_{110}P_{45}K_{120}S_{30}Zn_{3}B_{1.5}$ kg ha^{-1} with cowdung 5 t ha^{-1}) may be recommended for maximizing the bulb yield of ratoon onion in Grey Terrace Soil of Madhupur Tract (AEZ-28) at Gazipur and under similar agro-climatic condition elsewhere in the country.

Keywords: Ratoon onion or *murikata piaz*, plant spacing, nutrient management and bulb yield

Introduction

Onion (*Allium cepa* L.) belongs to the family Alliaceae, originated in Central Asia, is an important cash crop cultivated throughout the world. Its bulbs, some cases leaves and inflorescences are used as spices or vegetables for its medicinal, nutritional and seasoning properties (Yousuf *et al.*, 2022). The annual production of onion bulbs is about 22.69 lakh Metric tons, covering 1.94 lakh hectares of land in Bangladesh (BBS, 2022), which is insufficient from the annual total demand. There are many obstacles behind increasing bulb production of onion such as lack of improved and hybrid varieties, inadequate supply of quality seeds, environmental vulnerability, suitable land availability, limitation of agricultural

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policy and unstable marketing facilities. Decreasing cultivable lands restricts horizontal expansion of onion production, Therefore, inclusion of summer onion and also ratoon onion production are getting practical significance. The cultivation of onion, locally known as *murikata piaz*, could be one of the ways to solve onion crisis during period of September to January. For ratoon onion, at first bulblets are producted in *rabi* season, then these bulblets in next late *kharif* and early *rabi* season. Bulblets to bulb production of onion are influenced by several factors: bulblets size, planting time, plant spacing, climatic vulnerability, weed-insect-disease pest infestation, plant nutrients, water management and cultural management etc. (Alemu *et al*., 2022; Yousuf *et al.*, 2022). Among these, plant spacing and nutrient management play very important role in bulblets to bulb production of onion (Wassie *et al.*, 2022). Optimum plant spacing avoids competition between plants for sunlight, water, nutrients, lands and ensures optimum bulb size, shape, weight and yield (Gebretsadik and Dechassa, 2018). Closer spacing accommodates higher plant populations resulted in higher total bulb yield with smaller bulb size, shape and lower shelf-life in storage than wider spacing (Islam *et al.*, 2019; Walle *et al*., 2018). Nutrient management is essential for optimum crop yield and conserving environment when application in balanced ways with right time and right method (Khokhar, 2019). Combination of chemical fertilizers with organic manures had positive influence on vegetative growth (Plant height, Number of leaves per plant, neck thickness, dry matter), reproductive growth (bulb size, weight and yield) and qualitative parameters (TSS, bulb shape, color, shelf life and chemical composition) of onion (Mekonnen *et al*., 2017; Fekry, 2017). Application of deficient amounts of nutrient elements results small sized and early mature bulb on the other hands excess levels, cause large necks, doubles, soft bulbs with poor shelf-life (Hamasaki *et al*., 1999). Many other researchers also reported that suitable plant spacing and judicious application of plant nutrients can produce optimum plant growth, yield, quality and storability of onion (Fekry, 2017; Gebrekorkos *et al*., 2017). Production of ratoon onion from bulblets is a highly specialized task; maintaining optimum plant density and nutrient management. To rationalize the above-mentioned situation this study was undertaken: to identify the best suited plant spacing for onion from bulblets to bulb production and to develop a standard nutrient management package for maximization of the yield.

Materials and Methods

The present study was conducted at the research field of Regional Spices Research Center, BARI, Gazipur, during two consecutive growing seasons of 2020-2021 and 2021-2022. The experimental site was situated at $23^0 59^/$ North Latitude and $90^0 24^/$ East Longitude, at an altitude of 8.4 m above the mean sea level. The soil of the experimental site belongs to Chhiata Soil series and has been classified as Grey Terrace Soil, which falls under Inceptisol in Taxonomy under the AEZ-28 (Madhupur Tract) reported by Brammer, 1971. The initial soil samples of the experimental field were collected (0-15 cm depth) and analyzed in the Soil Science Laboratory, BARI, Gazipur following standard and recommended methods both the years (Table 1). The trial was laid out in a factorial Randomized Complete Block Design with three replications. There were 9 treatment combinations formulated with 3 levels of spacing such as S_1: 10 cm X 10 cm, S_2: 15 cm X 10 cm and S_3: 20 cm X 10 cm (accommodating 10,00,000, 6,70,000 & 5,00,000 plant populations per hectare, respectively) with 3 nutrient management packages viz., NM_1: Soil test basis ($N_{90}P_{37}K_{80}S_{15}Zn_{1.5}B_1$kg ha^{-1}) plus cowdung 3 t ha^{-1}, NM_2: RDF($N_{110}P_{45}K_{120}S_{30}Zn_3B_{1.5}$ kg ha^{-1}) plus with cowdung 5 t ha^{-1} and NM_3: Farmer's dose ($N_{120}P_{50}K_{85}S_{20}$ kg ha^{-1}). The cowdung contained 0.99% N, 0.19% P, 0.49% K, 0.11% S, 0.39% Ca and 0.20% Mg on dry weight basis.The test crop was onion cv. BARI Piaz-4, which was released by BARI in 2008 for *rabi* season. The bulb is a single (non-splitted), flat–round shape, shining red color, pungent medium sized and short duration high yielding variety, grown all over the country. Before planting, the bulblets (10±2 g sized) of onion were treated with Autostin (*Carbendazim*) @ 2 g kg^{-1} to control primary seed-borne diseases. After that the bulblets were dried in a shade, the planted-on 10 October 2021 and 13 October 2022 in the experimental plot. The unit plot size was 3.0 m x 1.2 m with 30 cm deck around the plot. Cowdung, P, K, S, Zn and B were applied to soil as basal before final land preparation. Nitrogen from urea was applied at two equal splits at 25 and 60 days after planting. The intercultural operations like three hand weeding, spraying of Ridomil Gold (*Mancozeb* + ***Metalaxyl***) @ 2.5 g l^{-1} for disease management and Imitaf (*Imidacloprid*) @ 2.0 m l^{-1} for insect pests management at 12 days interval. The mature bulbs were harvested on 20 December both in the years. Data on plant height, number of leaves per plant, bulb size and individual bulb weight were recorded for each treatment from randomly selected 10 plants. Total yield of bulbs per plot was converted to yield per hectare. The recorded data on different parameters were statistically analyzed by using *R* version 3.5.0 software to find out the significant variation resulting from different treatments. The difference between treatment means were judged by Least Significant Difference (LSD) test at 5% level of significance.

Table 1. Physical and chemical properties of initial soil at the experimental field during 2020-2021 and 2021-2022

Soil characteristics	Analytical value		Analytical method
	2020-2021	2021-2022	
Soil Textual class	Silty clay loam	Silty clay loam	Hydrometer method
Bulk density (g cm^{-3})	1.39	1.38	Core sampling method
Particle density (g cm^{-3})	2.61	2.63	Pycnometer method
Soil pH	5.93	5.84	Soil: water=1:2.5
Total N (%)	0.09	0.09	Modified Kjeldhal Method
Organic C (%)	0.9	0.86	Wet oxidation method

Soil characteristics	Analytical value		Analytical method
	2020-2021	2021-2022	
Available P (ppm)	7.01	6.80	Bray and Kurtz method
Exchangeable K ($meq 100g^{-1} soil$)	0.07	0.06	N NH_4OAc extraction method
CEC ($meq\ 100g^{-1}$ soil)	9.35	9.05	N NH_4OAc extraction method
Available B (ppm)	0.12	0.12	Calcium chloride extraction method
Available Zn (ppm)	0.38	0.41	DTPA Extraction method
Available Cu (ppm)	0.2	0.15	DTPA Extraction method
Available Mn (ppm)	0.66	0.68	DTPA Extraction method
Available S (ppm)	7.0	6.9	Calcium dihydrogen phosphate extraction method

Average monthly weather parameters

During the experimental periods, the monthly average maximum and minimum temperature, monthly average relative humidity and monthly average rainfall data were recorded and presented in Figure 1a, 1b, 2a and 2b.

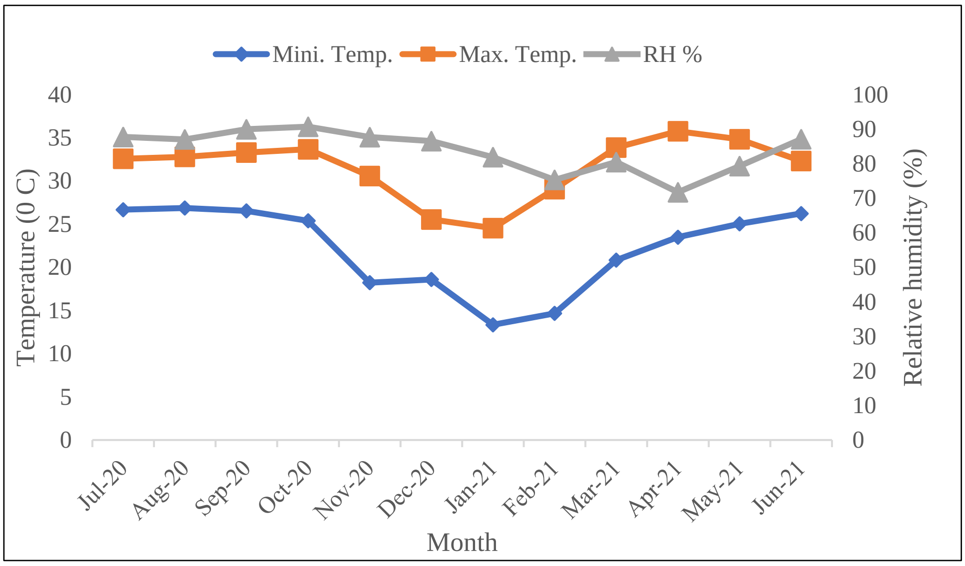

Fig. 1a. Monthly average maximum & minimum temperature with monthly average relative humidity of the BARI experimental farm during July 2020 to June 2021.

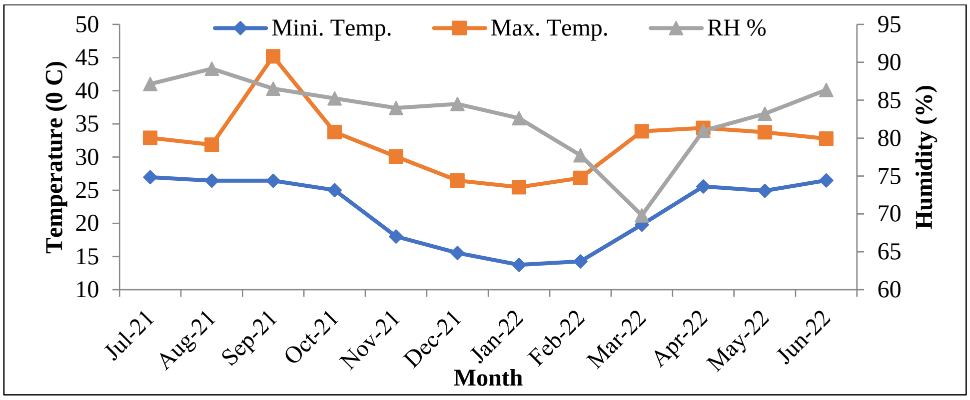

Fig. 1b. Monthly average maximum & minimum temperature with monthly average relative humidity of the BARI experimental farm during July 2021 to June 2022.

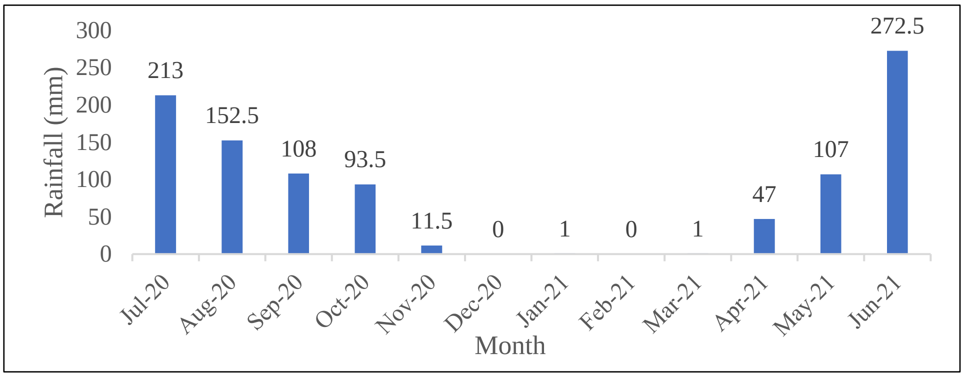

Fig.2a. Monthly average rainfall of the BARI experimental farm during July 2020 to June 2021.

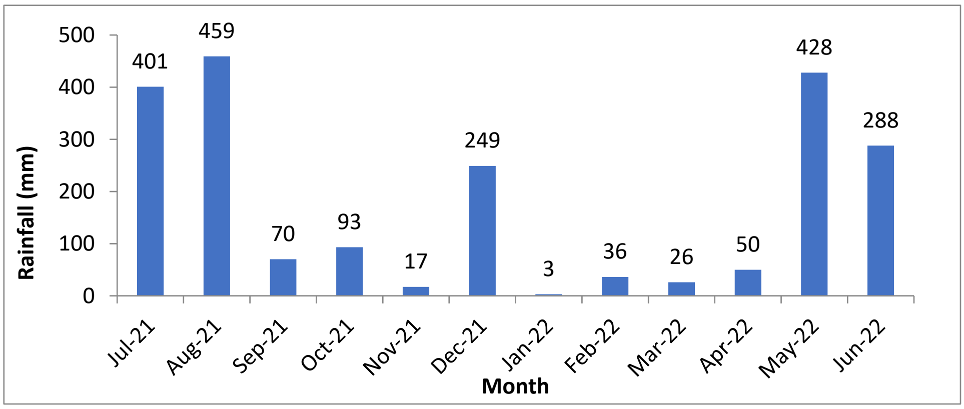

Fig. 2b. Monthly average rainfall of the BARI experimental farm during July 2021 to June 2022.

Results and Discussion

Plant height

The highest plants height (55.7 cm) was recorded from S_3 x NM_2 (plant spacing: 20 cm X 10 cm with application of RDF: $N_{110}P_{45}K_{120}S_{30}Zn_3B_{1.5}$ kg ha^{-1} plus cowdung at 5 t ha^{-1}), which was significantly higher over rest of the combinations in 2020-2021. In case of the second year (2021-2022), the same treatment attained the maximum plant height (41.8 cm) was statistically similar to S_1 x NM_1 and S_3 x NM_3 but significantly higher over rest of the treatments (Table 2). The lowest plant height (26.3 and 29.7 cm in 2020-2021 and 2021-2022, respectively) was recorded from S_1 x NM_3 (plant spacing: 10 cm X 10 cm and with farmers' dose: $N_{120}P_{50}K_{85}S_{20}$ kg ha^{-1}). The optimum plant spacing and fertilizer dose might have contributed to elongate the plant height. The results are in agreement with the findings of Khan *et al.* (2021) and Ahmed *et al.* (2021).

Number of leaves per plant

The combined effects of plant spacing and nutrient management on the was also on the variation of statistically number of leaves per plant was also found significant (Table 2). The maximum number of leaves per plant (13.0 and 15.7 in 2020-2021 and 2021-2022, respectively) was observed in S_3 x NM_2 treatment which was statistically identical to S_2 x NM_2 but significantly higher over rest of the treatments. Although similar trend was observed in the second year too, but the same treatment (S_3 x NM_2) was significantly higher only over S_2 x NM_3. The minimum number of leaves per plant (6.7 and 10.3 in 2020-2021 and 2021-2022, respectively) were recorded in S_1 x NM_3 (plant spacing: 10 cm X 10 cm with farmer's dose). The results are in agreement with the findings of Mazumder *et al.* (2019) and Gebretsadik and Dechassa (2018).

Bulb size

The treatment combination (S_3 x NM_2) gave the maximum bulb length (4.4 cm and 4.8 cm in 2020-2021 and 2021-2022, respectively), which was significantly higher over S_1 x NM_3, S_2 x NM_3 and S_3 x NM_3 but statistically similar to rest of treatments in the first year. The maximum bulb diameter (3.4 cm and 4.1 cm in 2020-2021 and 2021-2022, respectively) was recorded from S_3 x NM_2 combination closely flowed by S_2 x NM_2 and S_1 x NM_2 in both years, S_1 X NM_1 and S_3 x NM_1 in first year. Wider spacing revealed optimum sunlight, nutrient availability and sufficient moisture gave bigger sized bulb of onion. Almost similar trend or result was noted in the second year (Table 2). Gebrekorkos *et al.* (2017) and Khan *et al.* (2021) reported that optimum plant spacing and judicious nutrient management enhance bulb size.

Table 2. Combined effects of plant spacing and nutrient management on the vegetative growth components of onion

Plant spacing X Nutrient management	Plant height (cm)		No. of leaves per plant		Bulb size			
					Bulb length (cm)		Bulb diameter (cm)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
S_1 X NM_1	42.3cd	37.5ab	8.3de	12.3ab	4.0ab	2.7d	2.9abc	2.9bc
S_1 X NM_2	34.0e	35.3bcd	9.7cd	12.7ab	4.4a	3.7bc	3.2ab	3.5ab
S_1X NM_3	26.3f	29.7d	6.7f	10.3b	3.6bc	3.1cd	2.7c	3.3bc
S_2 X NM_1	50.0b	34.0bcd	9.7cd	12.0ab	3.9abc	3.3cd	2.8bc	3.1bc
S_2 X NM_2	44.3c	35.7bc	12.0ab	13.7ab	4.1ab	3.9abc	3.2ab	3.4ab
S_2 X NM_3	33.3e	30.7cd	8.0ef	11.3b	3.3c	2.7d	2.7c	2.6c
S_3 X NM_1	48.7b	33.7bcd	10.7bc	13.7ab	4.2ab	4.6ab	3.1abc	2.9bc
S_3 X NM_2	55.7a	41.8a	13.0a	15.7a	4.4a	4.8a	3.4a	4.1a
S_3 X NM_3	40.3d	37.0ab	9.0de	13.0ab	3.7bc	4.4ab	2.8bc	2.6c
CV (%)	4.99	9.79	9.6	12.08	8.78	14.17	8.79	12.51

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD test

Single bulb weight

Single bulb weight was increased significantly due to interaction effect between plant spacing and nutrient management (Table 3). The highest weight (52.3 and 55.7 g in 2020-2021 and 2021-2022, respectively) of individual bulb was documented in S_3 x NM_2 treatment. The similar single bulb weight was also recorded from S_1 x NM_1, S_2 x NM_1 and S_2 x NM_2 combinations in 2020-2021. The S_3 x NM_2 combination gave significantly the maximum single bulb weight (55.7 g) compared to other combinations in 2021-2022. In case of interaction, nutrient management played major role than plant spacing for increasing the single bulb weight. Similar kind of results were reported by Islam *et al*. (2019); Ferky (2017).

Total bulb yield

The combined effect of plant spacing and nutrient management on bulb yield of ratoon onion was significant (Table 3). The highest bulb yield of onion (12.1 t ha^{-1} and 14.3 t ha^{-1} in 2020-2021 and 2021-2022, respectively) was obtained from S_1 x NM_2. The lowest total bulb yield (8.7 t ha^{-1} and 8.37 t ha^{-1} in 2020-2021 and 2021-2022, respectively) was recorded from S_3 x NM_3. Closer spacing accommodated higher plant populations and increased total bulb yield and the mean bulb size was proportionately reduced (Walle *et al*., 2018). Widening spacing accommodates lower plants significantly increased individual bulb size and bulb production due to lesser competition among them than onion cultivated in closer spacing (Kumar *et al*., 2018; Gebretsadik and Dechassa, 2018).

Total soluble solids (TSS)

Total soluble solid (TSS ^{0}Brix) content in onion bulb was significantly influenced by the combined effects of plant spacing and nutrient management on ratoon onion (Table 3). The treatment combination S_3 x NM_2 gave the highest TSS of onion (12.0 ^{0}Brix ^{1} in 2020-2021 and 11.0 ^{0}Brix ^{1} in 2021-2022), which was significantly higher over S_1 x NM_3, S_2 x NM_3 and S_3 x NM_3 but statistically similar to rest of the treatment combinations. This result revealed that nutrient management played major role in increasing the TSS and appeared as the dominant factor in comparison to plant spacing but their suitable combination in better performance of the crop. The results are in agreement with the findings of Walle *et al*., (2018) and Mekonnen *et al.* (2017).

Table 3. Combined effects of plant spacing and nutrient management on the bulb yield and TSS of onion

Plant spacing x Nutrient management	Single bulb weight (g)		Bulb yield (tha^{-1})		TSS(^{0}Brix)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
S_1 X NM_1	41.7c	37.3cd	10.5abc	11.83bc	10.7bc	10.67ab
S_1 X NM_2	44.7abc	47.7b	12.1a	14.33a	11.7ab	10.33ab
S_1X NM_3	39.3c	32.7d	11.0ab	9.03de	10.3bc	9.33b
S_2 X NM_1	47.7abc	39.7cd	8.9cd	10.84bc	11.0abc	9.33b
S_2 X NM_2	51.3ab	48.0b	9.9bcd	12.30b	11.7ab	10.33ab
S_2 X NM_3	43.3bc	33.7d	8.7cd	8.50de	10.7bc	9.67ab
S_3 X NM_1	45.0bc	44.0bc	8.8cd	10.23cd	11.0abc	11.0a
S_3 X NM_2	52.3a	55.7a	9.3bcd	10.93bc	12.0a	11.0a
S_3 X NM_3	45.0bc	39.3cd	8.4d	8.37e	10.3c	10.0ab
CV (%)	10.85	9.96	11.53	9.39	5.91	8.24

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD

Cost-benefit analysis of Onion

The cost-benefit analysis of onion production using plant spacing and nutrient management (considering the mean bulb yield of both the years) is presented in Table 4 and 5. The benefit of optimum plant spacing and nutrient management practices exceeds farmer`s traditional practice both in yield and return. The highest net benefit (594847 Taka ha^{-1}) was recorded in the treatment combination S_1 x NM_2 and the minimum (368223 Taka) in S_2 x NM_3 (Table 4). Among the treatment combinations the highest marginal rate of returns (MMR: 87.34%) was recorded in S_1 x NM_3 (Table 5). MRR implies what an investor can get to receive by switching technologies from the traditional practice to the improved new one, hence, (87.34%) MRR indicates that by investing 1 taka a farmer can get benefit 0.87 Taka by using combination S_1 x NM_2 treatment which accommodated 10,00,000 plants.

Table 4. Cost benefit analysis of onion as affected by plant spacing and nutrient management

Plant spacing X Nutrient management	Mean bulb Yield (tha^{-1})	Variable cost (Taka ha^{-1})				Income (Taka ha^{-1})		Rank
		Input cost	Labor cost	Fixed cost	Total variable cost	Gross income	Net income	
S_1 X NM_1	11.2	29342	36000	36250	101592	599200	497608	2
S_1 X NM_2	13.2	36843	38250	36250	111343	706200	594857	1
S_1X NM_3	10.0	24607	34900	36250	95757	535000	439243	5
S_2 X NM_1	9.9	25715	33750	36250	95715	529650	433935	6
S_2 X NM_2	11.1	33213	36450	36250	105913	593850	487937	3
S_2 X NM_3	8.6	20977	34650	36250	91877	460100	368223	9
S_3 X NM_1	9.5	23845	31500	36250	91595	508250	416655	7
S_3 X NM_2	10.1	31343	32400	36250	99993	540350	440357	4
S_3 X NM_3	8.9	19107	30600	36250	85957	476150	390193	8

Unit price: Urea=16 tk kg^{-1}, TSP=22 tk kg^{-1}, MoP=15 tk kg^{-1}, Gypsum=12.5 tk kg^{-1}, Cowdung= 1.5 tk kg^{-1}, Boric acid= 150 tk kg^{-1}, zinc sulphate=180 tk kg^{-1}, irrigation cost 2250 tk ha^{-1}, land rent=20000 tk ha^{-1}, tractor cost=3200 tk ha^{-1}, bulblets cost=120 and 100 tk kg^{-1} (in 2020-2021 and2021-2022, respectively), onion sale price=52 and 55 tk kg^{-1} (in 2020-2021 and 2021-2022, respectively), labor=450 tk/day/Person and marketing cost=5000 and 7500 tk ha^{-1} (in 2020-2021 and 2021-2022, respectively)

Table 5. Marginal rate of return (MRR) in onion cultivation as affected by plant spacing and nutrient management

Treatment	Variable cost (TK ha^{-1})	Net income (TK ha^{-1})	MRR (%)	Rank
S_2 X NM_3	91877	368223	-	-
S_3 X NM_3	85957	390193	25.56	4
S_3 X NM_1	91595	416655	28.89	3
S_2 X NM_1	95715	433935	18.05	5
S_1X NM_3	95757	439243	5.52	7
S_3 X NM_2	99993	440357	1.11	8
S_2 X NM_2	105913	487937	46.83	2
S_1 X NM_1	101592	497608	9.52	6
S_1 X NM_2	111343	594857	87.34	1

Conclusion

Combination of suitable plant spacing and nutrient management augmented yield attributes and bulb yield of ratoon onion with higher economic return as revealed from consecutive two years study conducted in Grey Terrace Soil of Madhupur Tract (AEZ-28) at Joydebpur, Gazipur. The highest bulb yield (12.1 & 14.33 t ha^{-1} in 2020-2021 and 2021-2022, respectively), and MRR (87.34% in both the years) was recorded from the combination of plant spacing (10 cm x 10 cm, which accommodated 10,00,000 plants) and application of RDF ($N_{110}P_{45}K_{120}S_{30}Zn_3B_{1.5}$ kg ha^{-1}) with cowdung 5 t ha^{-1}. Plant spacing 10 cm x 10 cm and application of $N_{110}P_{45}K_{120}S_{30}Zn_3B_{1.5}$ kg ha^{-1} with cowdung 5 t ha^{-1} may be suitable for ratoon onion cultivation in Grey Terrace Soil of Madhupur Tract (AEZ-28).

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INCREASING CROPPING INTENSITY, PRODUCTIVITY AND DIVERSITY OF CROPS THROUGH RICE BASED CROPPING PATTERN IN TANGAIL

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Abstract

The experiment was conducted at Farming Systems Research and Development site under On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail during the period of 2019-20 and 2000-21 having eight rice-based cropping patterns viz., Mustard-Boro-T. Aman rice, Potato-Boro-T. Aman, Mustard-T. Aus-T. Aman, Lentil- Jute-T. Aman, Wheat-Jute-T. Aman, Wheat-Sesame-T. Aman, Garden pea-Boro-T. Aman and Fallow-Boro-T. Aman (as check). The treatments were replicated five times in randomized complete block design with a plot size of 8.0 m × 5.0 m. Result showed that the highest rice equivalent yield (31.77 t ha^{-1}) was obtained from Potato-Boro-T. Aman cropping pattern which was followed by Garden pea-Boro-T. Aman cropping pattern (26.42 t ha^{-1}). The lowest rice equivalent yield (11.37 t ha^{-1}) was obtained from Fallow-Boro-T. Aman cropping pattern. Highest gross return (Tk. 557514 ha^{-1} and gross margin (Tk.260964 ha^{-1}) and production efficiency (108.43 kg ha^{-1}day^{-1}) was recorded from Potato-Boro-T. Aman cropping pattern. Maximum land use efficiency (86%) was observed in Wheat-Jute-T. Aman cropping pattern. Highest benefit cost ratio was recorded from Mustard (var. BARI Sarisha-14)-Boro-T. Aman and Mustard (var. BARI Sarisha-18)-T. Aus-T. Aman pattern (2.16 and 2.13). On the other hand, highest by-product yield was obtained from Potato-Boro-T. Aman rice sequence. However, the higher sustainable yield index value was recorded in Potato-Boro-T. Aman rice (97.30%), which was closely followed by Garden pea-Boro-T. Aman (95.74%) and Mustard-Boro-T. Aman (93.3 %). The more labour (537man days ha^{-1}) intensive cropping pattern was Potato-Boro-T. Aman rice. However, the profitable and viable cropping patterns were found Mustard-Boro-T. Aman followed by Potato-Boro-T. Aman and Garden pea-Boro-T. Aman which need to be disseminated in the farmer's fields.

Keywords: Cropping intensity, Diversity, Productivity, Profitability, Sustainable index, and Land utilization index.

Introduction

Rice is the major staple food crop in Bangladesh. The harvested area covers 11.5 million hectares (because of 2-3 crops per year) or 80% of the cultivated area. Rice is grown in single, double, and triple crop patterns across Bangladesh in the Boro, Aus and Aman season. Cropping pattern is an important indicator of a farmer's

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decision-making ability and also influences the consumption pattern as well as health and nutritional status of the people. Sustainable crop production in Bangladesh through improvement of cropping intensity in rice-based cropping system is regarded as increasingly important in national issues such as food security, poverty alleviation and creation of job opportunity. The main challenge of the new millennium is to increase 50% yield per unit land area through manipulating the limited land resource. In order to produce more food within a limited area, the most important options: are i) to increase the cropping intensity by producing three or more crops over the same piece of land in a year and ii) to increase the production efficiency of the individual crop by using optimum management practices (Salam *et al*., 2014). To meet the challenges of a globalizing market in agriculture as well as the growing and changing needs of the population, diversification is taking place either through area augmentation or by crop substitution.

Fallow-Boro-T. Aman, Mustard-Boro-T. Aman, Potato-Boro-T. Aman, Mustard-T. Aus-T. Aman, Lentil-Jute-T. Aman, Wheat-Jute-T. Aman, Wheat-Sesame-T. Aman, Garden pea-Boro-T. Aman are the major cropping patterns at Tangail region.

Potential adoption of these improved cropping patterns intensifying mustard, pulses, potato, wheat, jute, sesame and garden pea in Fallow-Boro-T. Aman cropping pattern would generate employment and additional income for the rural poor through producing more of these crops utilizing fallow and unused lands in the country. The farm level adoptions of improved oilseeds, pulses, potato, wheat, jute and garden pea in rice-based cropping patterns have already been created a wide range of socio-economic impacts that need to be evaluated properly. Considering the above issues, this study was undertaken with the objectives: i) to increase cropping intensity, productivity and diversity in rice-based cropping systems and ii) Increase farmer's income, access to food and nutrition and create employment opportunity in agriculture.

Materials and Method

The study was conducted at Farming Systems Research and Development (FSRD) site Atia, Delduar under On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail during two consecutive years of 2019-20 and 2020-21. The geographical position of the area is between $24^0 17'$ N latitude and $89^0 90'$ E longitude. The meteorological data of the experimental site revealed that maximum rainfall was received during the months of April to September where peak in July (558 mm). The meteorological data in 2019-20, monthly mean maximum 31.3^0C and minimum 20.9^0C air temperature and annual total rainfall 2439 mm and in 2020-21, monthly mean maximum 30.6^0C and minimum 20.6^0C air temperature and annual total rainfall 2240 mm were prevailing in the study area (Appendix1). The experimental site belongs to Old Brahmaputra Floodplain Agro-ecological

Zone (AEZ-9) of Tangail. The land type was medium high and general soil type predominantly includes Dark Grey Floodplain soils. Organic matter content is low (1.38 %), soils are slightly acidic (6.08) in reaction. General fertility level including N (0.099 %), P (6.96 µg g^{-1}), K (0.11 meq $100g^{-1}$ soil), S (9.12 µg g^{-1}) and B (0.18 µg g^{-1}) are low (Appendix 2).

The study consisted of eight rice-based cropping patterns, i.e., i. Mustard - Boro-T. Aman, ii. Potato-Boro-T. Aman, iii. Mustard -T. Aus-T. Aman, iv. Lentil-Jute-T. Aman, v. Wheat-Jute-T. Aman, vi. Wheat-Sesame-T. Aman and vii. Garden pea-Boro-T. Aman and viii. Fallow-Boro-T. Aman. The treatments were replicated (dispersed) five times in randomized complete block design with a plot size of 8.0 m × 5.0 m. Details of varieties of crops, fertilizer dose, sowing/transplanting and harvesting dates and duration of crops under different crop sequences are presented in Table 1. All crops were grown with recommended package of practices. Intercultural operations such as irrigation, weeding and pest control were done properly for normal growth and development of the crops.

Yield data were collected from 4m × 3m area of each plot. Grains and straw were sun dried and weighed adjusting at 10 % moisture content for T. Aman rice. Agronomic performance viz., field duration, rice equivalent yield (REY), production efficiency (PE) and land utilization index (LUI), sustainable yield index (SYI) and harvest index (HI) of cropping patterns were calculated as follows.

Rice equivalent yield (REY): For comparison between crop sequences, the yields of all crops were converted into rice equivalent on the basis of prevailing market prices of individual crop (Verma and Modgal, 1983). Rice equivalent yield (REY) was computed as yield of individual crop multiplied by prevailing market price of that crop divided by market price of rice.

$$\text{Rice equivalent yield (t ha}^{-1}\text{)} = \frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{market price of rice}}$$

Production Efficiency (PE): Production efficiency value in terms of kg ha^{-1} day^{-1} was calculated by total main product in a cropping pattern divided by total duration of crops in that pattern (Tomar and Tiwari, 1990).

$$\textbf{Production Efficiency} = \left(\frac{Y_1 + Y_2 + Y_3}{d_1 + d_2 + d_3}\right) \text{ kg ha}^{-1} \text{ day}^{-1}$$

Where, Y_1= Yield of 1^{st} crop and d_1= Duration of 1^{st} crop of the pattern, Y_2= Yield of 2^{nd} crop and d_2= Duration of 2^{nd} crop of the pattern and Y_3= Yield of 3^{rd} crop and d_3= Duration of 3^{rd} crop of the pattern

Land utilization index (LUI): It was worked-out by taking total duration (days) of crops in an individual cropping pattern divided by 365 (Rahman *et al.* 1989). It was calculated by the following formula:

Land utilization index (LUI) = $\frac{d_1 + d_2 + d_3}{365} \times 100$

Where d_1, d_2 and d_3 the duration of 1^{st}, 2^{nd} and 3^{rd} crop of the pattern

Sustainable yield index (SYI) of different cropping patterns were worked out by the following formula suggested by Krishna and Reddy, 1997

$$\text{SYI (\%)} = \frac{A^{-}\text{-}Y^{-}}{Y_{\text{max.}}} \times 100$$

where, A^{-} = Mean of particular treatment, Y^{-} = Standard deviation of the treatment and $Y_{\text{max.}}$=Potential yield of treatment in different years

Harvest index (HI) was calculated as per following equation:

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Final crop yields (main product and by-product yield) were recorded and converted into rice equivalent yield. Total gross returns, total production cost, gross margin and benefit cost ratio were calculated on the basis of prevailing market price of the crops. The number of labourers (man-days) required for growing each crop of the pattern were also accounted.

Table 1. Varieties, fertilizer dose, sowing and harvesting dates and duration of crops under different cropping patterns during the years of 2019-20 and 2020-21.

Crop	Variety	Fertilizer dose (kg ha^{-1}) N-P-K-S-Zn-B	Sowing/Transplanting dates		Harvesting Dates		Duration		Mean
			2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	
Mustard	BARI Sarisha-14	90-35-40-30-2-2	18.11.19	21.11.20	08.02.20	14.02.21	82	84	83
Mustard	BARI Sarisha-18	90-35-40-30-2-2	19.11.19	22.11.20	07.03.20	12.03.21	109	111	110
Garden pea	BARI Motorshuti-3	20-16-15-10-0-2	28.11.19	24.11.20	06.02.20	04.02.21	70	72	71
Potato	BARI Alu-41	160-45-130-15-5-2	25.11.19	21.11.20	21.02.20	19.02.21	89	91	90
Lentil	BARI Masur-8	20-40-25-0-0-2	04.12.19	29.11.20	22.03.20	18.03.21	108	110	109
Wheat	BARI Gom-32	90-30-55-22-4-1	22.11.19	20.11.20	12.03.20	10.03.21	112	110	111

Crop	Variety	Fertilizer dose (kg ha^{-1}) N-P-K-S-Zn-B	Sowing/Transplanting dates		Harvesting Dates		Duration		Mean
			2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	
Boro	BRRI dhan29	140-15-60-15-3-0	08-02-20	11.02.21	25.05.20	28.05.21	106	108	107
T. Aus rice	BRRI dhan48	60-20-32-10-3-0	04.05.19	07.05.20	06.08.19	11.08.20	94	96	95
T. Aman rice	BRRI dhan87	70-20-35-10-3-0	04.08.19	05.08.20	08.11.19	10.11.20	95	97	96
Sesame	BARI Til-4	55-28-22-10-2-2	14.04.19	16.04.20	26.07.19	29.07.20	103	105	104
Jute	BJRI Toshapat-8	90-10-30-184-0	14.04.19	18.04.20	25.07.19	05.08.20	102	109	106

Results and Discussion

Crop management of cropping patterns: The details of crop management under different improved cropping patterns are shown in Table 1. The newly introduced crops in the farmers existing pattern were mustard (var. BARI Sarisha-14 and BARI Sarisha-18), garden pea (var. BARI Motorshuti-3), potato (var. BARI Alu-41), lentil (var. BARI Masur-8), wheat (var. BARI Gom-32), T. Aus (var. BRRI dhan48), T. Aman (var. BRRI dhan87), sesame (var. BARI Til-4) and jute (var. BJRI Toshapat-8). Total field duration under different improved cropping patterns were ranged from 274-313 days with total turnaround period ranged from 91-52 days. Farmers' pattern: Fallow-Boro-T. Aman has needed average 203 days field duration in two consecutive years. Thus, long turnaround period of 162 days in the farmers' existing pattern was utilized. Result indicated that one additional crop could be easily fitted in Rice-Rice cropping pattern. Similar trend was also observed by Khan *et al.* (2018) who reported that all the tested patterns can be grown successfully one after another in sequence.

Crops and system Rice equivalent yield: The yields of main product, by-product and equivalent yield of different component crops of the cropping patterns are presented in Table 2. For T. Aman rice, the higher grain yield (5.50 t ha^{-1}) was obtained from Potato-Boro-T. Aman cropping pattern and lower grain yield (4.56 t ha^{-1}) from farmers' pattern. In Boro rice, the higher grain yield (7.20 t ha^{-1}) was obtained from Garden pea-Boro-T. Aman cropping pattern and lower grain yield (6.81 t ha^{-1}) from farmers' pattern. Mustard seed yield (1.51 & 1.91 t ha^{-1}), potato tuber yield (37.58 t ha^{-1}), lentil seed yield (1.75 t ha^{-1}), jute fibre yield (3.54 t ha^{-1}), wheat grain yield (4.30 t ha^{-1}), sesame grain yield (1.42 t ha^{-1}) and garden pea green pod yield (7.20 t ha^{-1}) were additional yield obtained from alternate cropping patterns. In farmers pattern these crops were not cultivated. In alternate cropping patterns, T. Aus rice produced grain yield of 4.75 t ha^{-1}. In farmers pattern T. Aus rice was not cultivated. Individual crop yield increased due to use of high yielding modern varieties, balanced fertilizers and optimum management practices. The results revealed that the highest rice equivalent yield (31.77 t ha^{-1}) was obtained from Potato-Boro- T. Aman followed by Garden pea – Boro – T. Aman (26.42 t ha^{-1}). The lowest rice equivalent yield (11.37 t ha^{-1}) was obtained from farmers pattern involving two rice crop patterns i.e., Fallow-Boro-T. Aman. The rice equivalent was higher 30.17 to 179.41% higher over farmers' pattern due to inclusion of a new crop and use modern technologies. The rice-based cropping pattern with potato incurred higher rice equivalent yield compared to other cropping patterns due to higher productivity of potato crop. Khan *et al*. (2018) in their study recorded the maximum rice equivalent yield (15.33 t ha^{-1}) in Wheat-Jute-Rice cropping pattern.

Land use efficiency of cropping patterns: Land use efficiency was highest (86 %) in Wheat-Jute-T. Aman rice cropping pattern because this pattern occupied 313 days in the field for longest period (Table 2). These results are in agreement with Khan *et al*. (2018) who reported that the highest land use efficiency of 70.69 % in improved Wheat-Mungbean-T. Aman rice cropping sequence followed by Lentil-Jute-T. Aman rice and Wheat-Sesame-T. Aman rice (85 %). The lowest (56 %) land use efficiency was recorded in Fallow-Boro-T. Aman rice cropping pattern because of two crops involved in this pattern. Khan *et al*. (2018) reported that the lowest land use efficiency of 61% in Jute-Fallow -Wheat cropping sequence where two crops are involved.

Production efficiency of cropping patterns: Maximum production efficiency (108.43 kg $ha^{-1}day^{-1}$) was obtained from Potato-Boro-T. Aman rice pattern might be due to the higher productivity of potato crop. The lowest production efficiency (54.40 kg $ha^{-1}day^{-1}$) was observed in Fallow-Boro-T. Aman rice cropping pattern involving two rice crop-based pattern

Sustainable yield index of cropping patterns: The highest sustainable yield index value was recorded in Potato-Boro-T. Aman rice (97.30%), which was closely followed by Garden pea-Boro-T. Aman rice (95.74%) (Table 2). It indicated that Potato-Boro-T. Aman rice and Mustard -Boro-T. Aman rice cropping patterns were more stable than other cropping patterns.

Harvest Index of cropping patterns: Improved cropping pattern Potato (var. BARI Alu-41) - Boro (var. BRRI dhan29) - T. Aman rice (var. BRRI dhan87) recorded the higher harvest index (77.46 %) followed by Garden pea (var. BARI Motorshuti-3)- Boro (var. BRRI dhan29) - T. Aman rice (var. BRRI dhan87) and Lentil (var. BARI Masur-8)-Jute (var. BJRI Toshapat-8)-T. Aman (var. BRRI dhan87) where as two rice crop-based cropping pattern Fallow-Boro (var. BRRI dhan29)-T. Aman (bar. BRRI dhan49) recorded the lower harvest index (50.69 %). The harvest index of improved cropping pattern had higher value due to inclusion of potato, garden pea, lentil and T. Aman varieties which contributed the higher economic and biological yield.

Table 2. Average yield, rice equivalent yield and agronomic indicators of rice-based cropping patterns during the years of 201920 and 2020-21

Cropping Pattern	Average Yield Grain/Tuber/ Fibre ($t\ ha^{-1}$)			Average By-Product Yield ($t\ ha^{-1}$)			REY ($t\ ha^{-1}$)	Total Field Duration (days)	Land Use Efficiency (%)	Production Efficiency ($kg\ ha^{-1}\ day^{-1}$)	Harvest Index (%)	Sustainable Yield Index (%)
	Crop I	Crop II	Crop III	Crop I	Crop II	Crop III						
Mustard-Boro-T. Aman	1.51	6.96	5.47	2.64	6.09	4.53	16.22	286	78	56.71	51.25	93.53
Potato-Boro-T. Aman	37.58	6.81	5.50	3.46	6.05	4.85	31.77	293	80	108.43	77.46	97.30
Mustard-T. Aus-T. Aman	1.91	4.75	5.32	3.45	4.15	4.34	19.62	301	83	65.18	50.08	85.66
Lentil-Jute-T. Aman	1.75	3.57	4.84	0.65	2.98	4.32	21.85	311	85	70.25	56.10	91.30
Wheat-Jute -T. Aman	4.20	3.50	4.90	3.00	2.90	4.25	20.44	313	86	65.30	46.59	91.88
Wheat-Sesame-T. Aman	4.40	1.42	4.72	3.50	1.42	4.45	14.80	311	85	47.59	52.99	89.40
Garden pea -Boro-T. Aman	7.20	7.48	4.55	1.47	6.05	4.94	26.42	274	75	75.44	60.68	95.74
Fallow- Boro-T. Aman	-	6.27	4.56	-	6.63	4.45	11.37	203	56	54.40	50.69	81.77

REY= Rice Equivalent Yield

Crops and System Profitability: Among the eight rice-based cropping patterns, the pattern with potato and garden pea resulted in higher gross return and gross margin than that of other crops. The gross return (Tk. 557514 ha^{-1}) was recorded maximum from Potato-Boro-T. Aman rice sequence, which was closely followed by Garden pea-Boro-T. Aman rice (Table 3). The production cost (Tk. 274150 ha^{-1} and Tk. 261700 ha^{-1}) was also higher in potato and garden pea might be due to use of costly inputs i.e., seeds, fertilizers, irrigation, labour as well as intensive management practices. The lowest production cost was found in Fallow-Boro-T. Aman rice cropping pattern. The maximum t gross margin (Tk. 283364 ha^{-1}) was also obtained from Potato-Boro-T. Aman cropping pattern followed by Garden pea-Boro-T. Aman cropping pattern (Tk 264490 ha^{-1}). The higher gross margin of these two patterns were achieved mainly due to higher yield advantages as well as higher price of the component crops. The lowest gross margin was recorded in Fallow-Boro-T. Aman rice cropping pattern due to less gross return for two rice cultivation. The gross margin was 154% higher in Potato-Boro-T. Aman rice pattern and 134 % higher in Garden pea-Boro-T. Aman rice cropping pattern than farmers' pattern Fallow-Boro-T. Aman due to inclusion of high value crops potato and garden pea. But higher benefit cost ratio of 2.16 and 2.13 were obtained from Mustard (var. BARI Sarisha-14)-Boro-T. Aman and Mustard (var. BARI Sarisha-18)-T. Aus-T. Aman cropping patterns. The benefit cost ratio of potato and garden pea containing patterns were lower compared to mustard containing cropping pattern might be due to costly inputs (seeds and fertilizer) and labour required for potato and garden pea cultivation. Hence, the benefit cost ratio (2.03 and 2.01) of potato and garden pea containing patterns were low despite of higher gross return and gross margin. These findings are supported by Sarker *et al.* (2014) who reported that among the six patterns, three crop based patterns produced higher economic benefit in terms of BCR. It was noted here that rice-based cropping pattern with potato and garden pea as a third crop generated more labour employment which was 39 and 34 % higher than that of Fallow-Boro-T. Aman rice cropping pattern (Table 3). This was mainly due to two intensive crops (Potato and Garden pea) contained in these patterns.

Table 3. Cost and return analysis of different rice-based cropping patterns during the years of 2019-20 and 2020-21 (average of 2 years).

Cropping Pattern	Gross return (Tk. ha^{-1})	Total cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR	Labour Employment (man-days ha^{-1})
Mustard-Boro-T. Aman	364950	168945	196005	2.16	467
Potato-Boro-T. Aman	557514	274150	283364	2.03	537
Mustard-T. Aus-T. Aman	381950	178945	203005	2.13	457
Lentil-Jute-T. Aman	494910	236259	258651	2.09	480
Wheat-Jute -T. Aman	496250	236750	259500	2.10	477
Wheat-Sesame-T. Aman	328650	179226	149424	1.83	425
Garden pea Boro-T. Amar	526190	261700	264490	2.01	520
Fallow- Boro-T. Aman	248343	136659	111684	1.82	386

Conclusion

It can be concluded that rice-based cropping pattern containing mustard, garden pea and potato with improved cultivation practices would be the best cropping patterns in Tangail. Mustard, Garden pea and Potato based patterns are most profitable because of their higher gross margin and total monetary return. These patterns can generate more employment and may be suitable for the farmers who can afford higher investment. Thus, the rice-based cropping system including oilseed, tuber and pulses crops could be considered balanced and need oriented cropping patterns in the present agro-economic situation of AEZ-9.

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Appendix 1. Monthly air temperature, relative humidity and total rainfall in the experimental area of Tangail, during 2019-20 to 2020-21

Month	Temperature (°C)				Average RH (%)		Total rainfall (mm)	
	Avr. Max		Avr. Min					
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
July	33.99	33.38	27.36	25.74	80.61	82.74	540.50	576.10
August	33.44	34.13	26.85	26.68	82.68	79.00	356.50	200.10
September	33.54	33.07	25.99	25.71	81.69	82.90	270.50	254.30
October	31.45	31.99	22.80	23.10	80.68	82.00	75.80	163.60
November	29.84	29.92	17.89	19.22	76.83	82.00	46.00	19.50
December	25.63	24.31	13.29	13.51	78.35	85.30	22.80	10.00
January	26.31	23.15	11.57	11.87	74.71	83.58	00.00	44.30
February	28.09	26.26	14.73	13.29	71.71	74.25	73.60	01.00
March	31.26	31.51	19.10	18.47	67.52	66.80	99.70	44.60
April	33.18	33.13	22.37	21.48	74.70	74.77	281.20	273.30
May	34.79	32.93	24.36	23.09	77.13	79.00	360.30	350.40
June	34.13	33.57	25.32	25.45	80.8 0	82.73	312.40	303.40
Yearly average	31.30	30.61	20.97	20.63	77.28	79.59	2439.30	2240.60

Table 2. Initial soil test values of the experimental field at FSRD site Atia, Delduar, Tangail.

Sample	Rainfed/ Irrigated	pH	OM (%)	Total N (%)	K(meq/ 100 g soil)	P (Bray)	S	Zn	B
						($\mu g\ g^{-1}$)			
Initial	-	6.08	1.35	0.098	0.11	6.96	9.12	1.21	0.18
Critical level	-	-	-	0.12	0.12	7.00	10.00	0.60	0.20
Interpretation	Irrigated	SA	L	L	L	L	L	(M)	L

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Bangladesh J. Agril. Res. 47(4): 473-476, December 2022 **Short Communication**

FIRST REPORT OF WHITE MOLD CAUSED BY *SCLEROTINIA SCLROTIORUM* ON ZINNIA (*ZINNIA ELEGANS*) IN BANGLADESH

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Keywords: White mold, *Sclerotinia sclerotiorum*, Koch's postulates, Molecular characteristics, Bangladesh.

Zinnia (*zinnia elegans*) is an annual shrub native to Mexico but grown as an ornamental in many places including North America, Africa, Australia Europe and Asia. In Bangladesh, this flower is suitable as beds, pots and borders crops. The cut flowers are commonly used in flower arrangements and decoration. In January 2021, zinnia plants were found infected with white mold symptoms on about 80% plants of the flower beds in front of the guest house of BARI, Gazipur, Bangladesh (23° 59' 20.4504" N, 90° 25' 5.4012" E). The symptoms included wilted, dried and died flower plants (Fig. 1A). Black sclerotia (1.7 to 8.5 × 1.0 to 4.4 mm) were noticed inside the pith cavity of the plant (Fig. 1B). Three flower beds Zinnia (*zinnia elegans*) were surveyed where the incidence was 60% -100 % and higher disease severity was recorded. A good number of Sclerotia, the fruiting bodies of the fungus, were collected from the infected Zinnia plants. The collected sclerotia were surface sterilized with 0.5% NaOCl solution. After washing twice with sterilized distilled water, the sclerotia were plated on PDA (HiMedia, India) medium. After incubating at 25° C for 4 days, identical whitish mycelia were developed (Fig. 1C). Black sclerotia were formed after 15 days of incubation in the dark (Fig. 1D). Harvested sclerotia were irregular in shape. The diameter of sclerotia was 1.8 - 7.2 mm, which was measured based on the average diameter of 25 sclerotia grown on 3 PDA plates. The morphological characters of mycelia and sclerotia were similar to *Sclerotinia sclerotiorum* (Kohn, 1979).

For molecular identification, ITS rDNA gene region was amplified using the primer pair ITS1/ITS4. Mycelia of the isolate (ZMJ) were multiplied on potato dextrose (PD) broth. Mycelial agar plugs were cut aseptically from 3-day-old culture and were transferred to conical flasks containing PD broth. After 3 days of incubation at 26 °C on a rotary shaker at 200 rpm, total genomic DNA was extracted from mycelial mat using Wizard DNA purification kit (Promega Corporation, Madison, WI, USA) following the standard protocol. PCR was performed in a thermal cycler (Bio-Rad PTC-200, California, USA) in total volume of 25 µL PCR reaction containing 12.5 µL GoTaq Green master mix (Promega Corporation, Madison, WI), 9.5 µL nuclease-free water, 1 µL of each primer (10µM), and 1µL template DNA. The PCR condition was: one cycle of denaturation at 95° C for 5 min, followed by 30 cycles at 95° C for 30 s, 55° C for 40 s, 72° C for 1 min, and a final extension at 72° C for 10 min (White *et al*., 1990).

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Fig. 1. A. White mold infected zinnia bed B. Sclerotia inside the pith of plants C. 4 days old culture of *S. sclerotiorum* D. Black sclerotia formation in PDA plate after 15 days of incubation at 25 °C E. Zinnia seedlings showing typical symptoms of white mold infection after artificial inoculation

The amplified PCR product was cleaned using Wizard@SV gel and PCR Cleanup kits (Promega, USA) following the manufacturer's instructions. The purified DNA of the isolate ZMJ was successfully sequenced (National Institute of Biotechnology, Bangladesh) and deposited to GenBank under the accession no. OP102544. The possible identity of the isolate was established by comparing the ITS sequence with those in GenBank database (National Center for Biotechnology Information [NCBI]) under US National Institute of Health, Bethesda, MD, USA. BLAST search analysis showed that the isolate (GenBank OP102545) is 99% identical to the reference strain MT393753, MT378216 and MT177216.

Phylogenetic analysis of the ITS sequence data was done by means of Maximum Composite Likelihood (MCL) method using MEGA 6.0 software. The sequence distance was calculated by Tamura-Nei parameter model (Tamura, 1993). The sequence alignments of the rDNA regions were performed utilizing ClustalW program. Bootstrap values were obtained 1000 replicates to determine the support from each group. In the Phylogenetic tree, the isolate of Bangladesh (OP102545) was placed in distinct *S. sclerotiorum* group with 88% bootstrap support while other species of *Sclerotinia* clustered in different group. Thus, the fungal isolate (ZMJ) was identified as *Sclerotinia sclerotiorum* (Fig. 2).

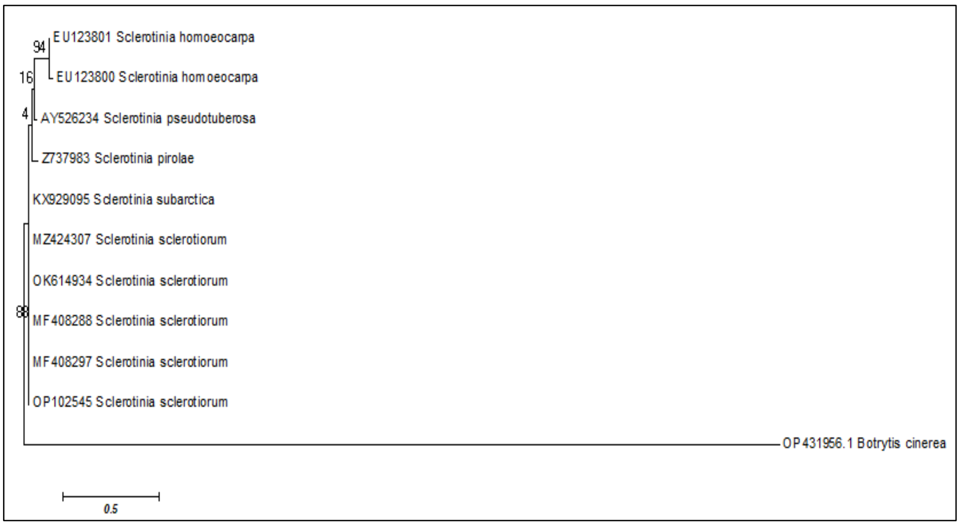

Fig. 2. Phylogenetic tree obtained from ITS region sequences from *Sclerotinia* spp. The numbers above the nodes are the bootstrap values obtained from 1000 replicates. The numbers before taxa are the GenBank accession numbers. Other genus *Botrytis cinerea* was used as an out group

S. sclerotiorum was grown in sterile wheat kernel in 1 Liter conical flasks at 25° C in the Plant Pathology laboratory, BARI, Gazipur. Twenty days old three seedlings of zinnia were grown on one pot (14-cm dia.). Seven days old *S. sclerotiorum* inoculum was incorporated with the sterile surface soil of each pot (3 pots). There were another set of three pots served as control (without inoculum). The experiment was conducted with three replications (three pots inoculated and three pots non-inoculated). The inoculated plants were kept in the pothouse of PPD, BARI at 25° C for 3 weeks. Within 4 days of inoculation, the plants showed wilted symptoms including white necrotic spots on leaves and mycelia covered the stems and surface of soil (Fig. 1E). White cottony mycelia were plated on PDA from the infected stems. The control plants were symptomless and the same deposited isolate (ZMJ) was used for the fulfillment of Koch's postulates. Previously, white mold was recorded in red salvia and marry gold flower in Bangladesh (Islam *et al*., 2019; Rahman *et al*., 2015). To our best knowledge, this is the first report of *S. sclerotiorum* causing white mold disease of *Zinnia elegans* in Bangladesh.

Declaration

Conflict of interest: The authors have declared that they have no conflict of interest.

Research involving human and animal participants: No Human subject or vertebrate animal was used in this study.

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