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

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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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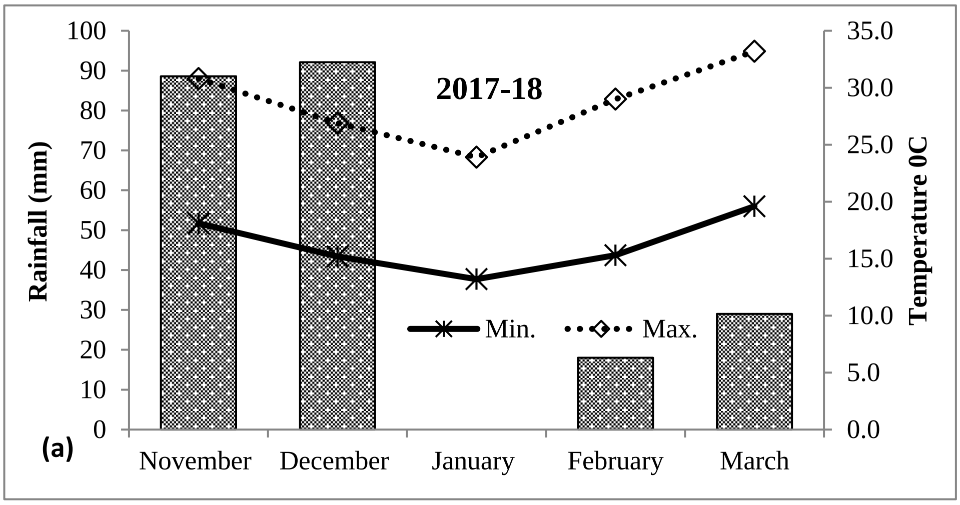
flower in Bangladesh have been published (Quddus *et al*., 2021). But the information regarding the optimum requirement of N, P, K and S for seed production of gypsophila flower is lacking in Bangladesh. Considering the above perspectives, the present study was undertaken to ascertain the requirement 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.



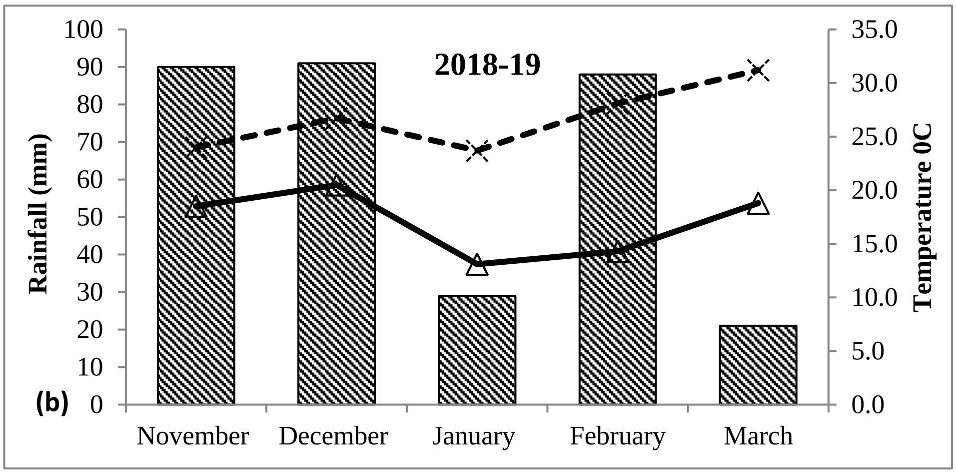


Fig. 1. Monthly mean minimum and maximum temperature ^{0}C and rainfall (a, b) during the experiment period of 2017-18 and 2018-19.

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*.

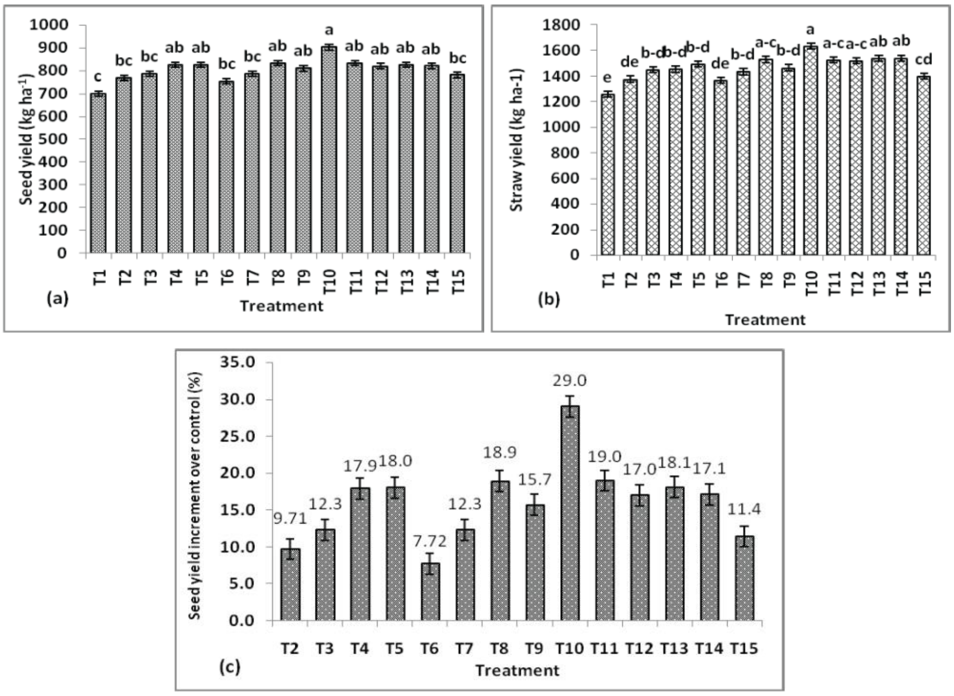


Fig. 2. Effects of nitrogen, phosphorus, potassium and sulphur on (a) seed yield, (b) straw yield and (c) seed yield increment over control of Gypsophila (pooled

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≤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≤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.

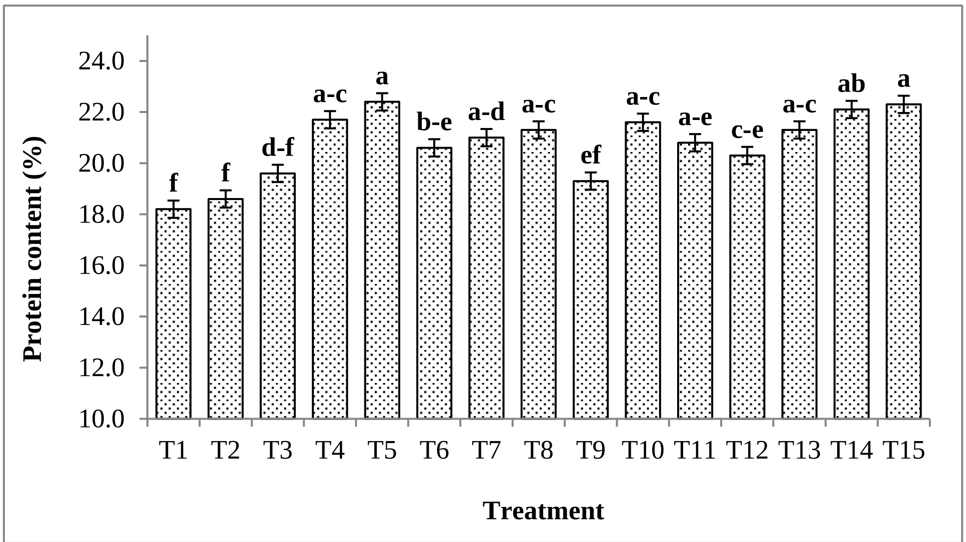


Fig. 3 Effect of N, P, K and S on protein content in seed of gypsophila (pooled data of two years). Mean values of above bars followed by the same letter are not significantly different according to the least significant difference (LSD) test at p≤0.05.

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 $p \leq 0.05$.

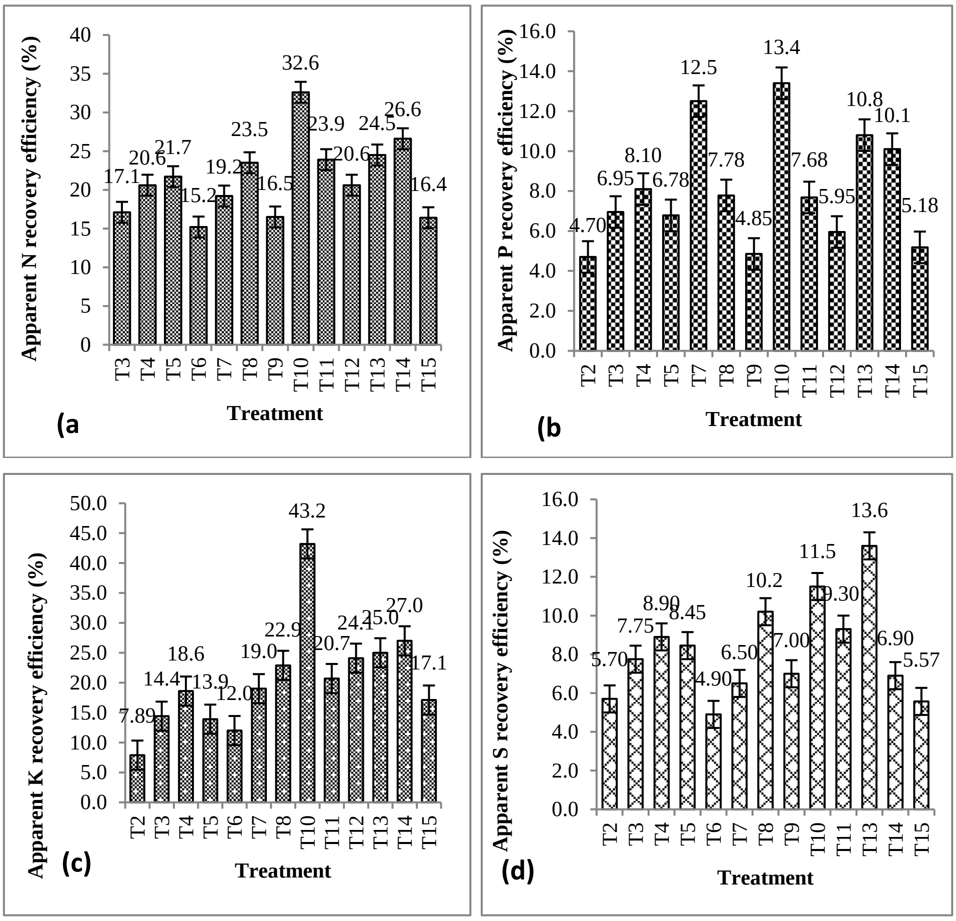


Fig. 4 Effect of nitrogen, phosphorus, potassium and sulphure on (a) apparent N recovery efficiency, (b) apparent P recovery efficiency, (c) apparent K recovery efficiency and (d) apparent S recovery efficiency of gypsophila.

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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