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EFFECT OF PLANT SPACING ON GROWTH, SEED YIELD AND QUALITY OF GYPSOPHILA (*Gypsophila paniculata* L.)

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Abstract

Spacing is significant for determining desired plant population to achieve higher yields. Appropriate plant spacing makes more efficient use of nutrient and light leading to faster canopy establishment resulted in reducing moisture evaporation and weed growth. Hence, an experiment was conducted at the open research field of Floriculture Division, Horticulture Research Centre, BARI, Gazipur during 2019-20 and 2020-21 to determine the suitable plant spacing for growth, yield attributes, yield and quality of gypsophila. The experiment consisted of six plantspacing's viz. broadcast (farmer's practice), 20 cm × 05 cm, 20 cm × 10 cm, 20 cm × 15 cm, 30 cm × 05 cm and 30 cm × 10 cm.The experiment was arranged in a randomized complete block design with three replications.BARI Gypsophila-1 was used as a variety.The blanket doses of fertilizers were N:100 kgha^{-1}, P:40 kg ha^{-1}, K:60 kg ha^{-1}, S:20 kg ha^{-1}, Zn:3 kg ha^{-1}and B:1.5 kg per hectare was applied in the form of urea, TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. The results exhibited that the highest seed yield (1308 kg ha^{-1}) was obtained from the wider spacing of 30 cm × 10 cm. The same plant spacingachieved higher yield increment (8.28%) over farmer'spractice. The performance of growth and yield parameters were found better in the spacing of 30 cm × 10 cm. Economic analysis revealed that the highest gross margin and benefit cost ratio (2.21) wereachieved under the spacing of 30 cm × 10 cm.So, spacing 30 cm × 10 cm may be suitable for gypsophila cultivation but further research with wider spacing is needed for getting a conclusive result.

Keywords: *Gypsophila paniculata L.*, spacing, profitability, yield attributes, relative yield.

Introduction

Gypsophila (*Gypsophila paniculata*L.) is an important flower found in Eurosia, Africa, Australia and the Pacific Islands (Amini *et al*., 2018). Turkey has mainly high diversity of Gypsophila (Özdemir *et al*., 2010). The genus name is from the Greek gypsos (gypsum, calc) and philos (loving). Plants of this genus are known commonly to baby'sbreath. A few species are commercially cultivated for several uses, including floristry, herbal medicine and food (Korkmaz and Özçelik, 2011). The gypsophila is most commonly used in

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flower arrangements such as bouquets (Poornima *et al*., 2021). It is also used as cut flower and has great economic value in trade because of its prettiness (Wahome *et al.,* 2011).

The seed yield ofgypsophila could be increased by using improved management practices like plant spacing. Most of the farmers of Bangladesh are practicing broadcast seed sowing. It is well known that broadcast seed sowing always resulted in non-uniform plant spacing in crop field which reduced the crop yield. However, the yield and vase life of gypsophila areimproved byusing appropriate plant spacing as well as plant density. Plant spacing/planting density plays a vital role for producing quality of flowers and protects the incidence of diseases and pests (Poornima *et al*., 2021). Plant spacing is an important agronomic factor which influenced light capture during photosynthesis and increased nutrient availability (Nain *et al*., 2017). Appropriate plant spacing facilitated the good proliferation of photosphere and rhizosphere and for adequate air, light, moisture and plant nutrient uptake which ultimately improved the plant growth, yield and flower quality (Manimaran and Ganga, 2022; Khan *et al*., 2003; Ibeawuchi *et al*., 2008; Rafiei, 2009). There is little information on plant spacing for gypsophila cultivation in Bangladesh. Hence, the present study was undertaken to determine the optimum plant spacing for growth, yield, quality and profitability of gypsophilacultivation.

Materials and Methods

Experimental location and soil

The field experiment was conducted during the winter season of 2019-20 and 2020-21 at the research field of Floriculture division, Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur. The terrace soils of Gazipur is medium high land with fine-textured (clay loam) and belongs to *Chhiata* soil series under the agro-ecological zone- Madhupur Tract (AEZ-28) (Shil *et al*., 2016). The particle and bulk density of the soil was 2.51 g/cm^3 and 1.36 g/cm^3, respectively having the porosity of 46.2% and field capacity (FC) of 25.7%. Before beginning the experiment initial soil (0-15 cm) sample was collected from the field and analyzed for chemical properties by following the standard methods outlined by Page *et al*. (1982) which are presented in the Table 1.

Table 1. Nutrients status of the experimental soil

Properties	pH	OM	Ca	Mg	K	Total	P	S	Zn	B
		%	meq 100 g^{-1}			N%	μg g^{-1}			
Nutrient level	6.4	1.24	4.52	1.49	0.12	0.065	13.4	20.0	0.84	0.19
Critical level	-	-	2.0	0.50	0.12	0.12	7	10	0.6	0.20
*Interpretation	-	Low	Opt	Opt	Low	Very low	Optimum	Medium	Low	Low

*Anonymous, (2018)

Climatic condition: The site atmosphere was subtropical, humid, and subject to monsoons. The daily average temperatures was 13.0 to 36.1°C and yearly mean rainfall varied from 1500 to 2200 mm. Monthly minimum and maximum average temperature, and rainfall data of the experimental period of 2019-20 and 2020-21 were recorded from a meteorological station located about 369 m from the experimental field (Figure 1a, 1b).

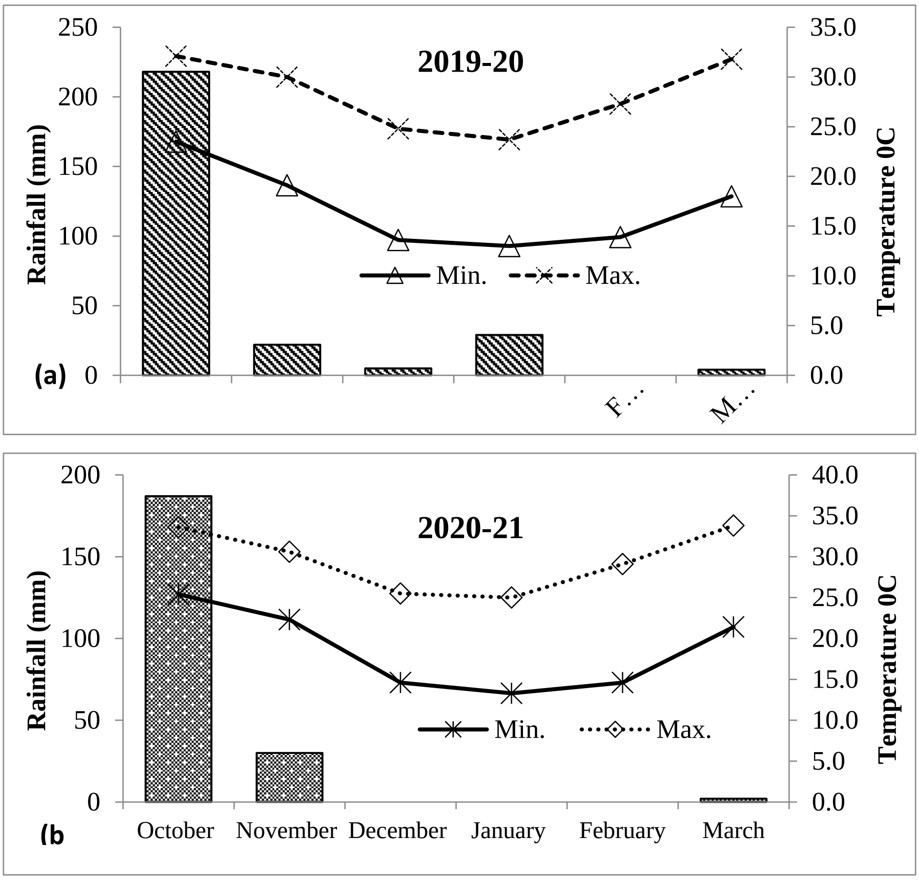

Fig. 1. Monthly mean minimum and maximum temperature ^{0}C and rainfall (a, b) during the experiment period of 2019-20 and 2020-21.

Land preparation, layout of experiment and planting material: The land was prepared with a tractor driven plough by 4 passes and it was leveled with a tractor driven rotavator. Weeds and stubble were eradicatedand cleaned manually.The experimental treatment was planned with six plant spacing such as S_1 (Farmer's broadcasting practice), S_2 (20 cm × 05 cm), S_3 (20 cm × 10 cm), S_4 (20 cm × 15 cm), S_5 (30 cm × 05 cm) and S_6 (30 cm × 10 cm). The experiment was laid out in a randomized complete block design with three replications.The unit plot size was 2 m × 2 m separated from each other by an alley of 50 cm widthThe doses of fertilizers were N:100 kgha^{-1}, P:40 kg ha^{-1}, K:60 kg ha^{-1}, S:20 kg ha^{-1}, Zn:3 kg ha^{-1}, B: 1.5 kg ha^{-1}in the form of urea, TSP, MoP, gypsum zinc sulphate and boric acid, respectively and cowdung@ 5t ha^{-1}were applied and incorporated into the soil (Quddus *et al*., 2021). The tested variety was BARI Gypsophila-1 released from Floriculture Division, Horticulture Research Centre, BARI, Gazipur.

Fertilizer application and seed sowing: Thefull dose of triple super phosphate (TSP), gypsum, zinc sulphate, boric acid, decomposed cowdung, 1/3 MoP and 1/3 urea were applied during final land preparation. Healthy seeds of gypsophila (var. BARI Gypsophila-1) were sown @ 2.5 kg ha^{-1}as per plant spacing continuously in rows on 12December 2019 and on 13 December 2020, respectively.

Intercultural management: Light irrigation was applied immediately after seed sowing by plastic hose pipe.After two days of seed sowing,irrigation was done twice in a week up to 40 days of seed sowing then it was applied single in a week before maturity.Hand weeding as well as thinning were done at 20 days after sowing maintaining the distances of treatment plant spacing (plant to plant and row to row). Second hand weeding was done at 40 days after sowing. The rest 2/3 Urea and 2/3 of MoP was applied in two equal splits. First split was applied at 20 days after sowing (DAS) and second split was applied 40 DAS.Seedlings were protected from disease (rot) by use of the fungicide Dithane M-45 for two times at the rate of 2 g L^{-1} water at 25 and 35 days after sowing.The crop was harvested on 15 March 2020 and on 16 March 2021.The maturity sign of gypsophila was determined when old stems with branches became brown in colour and about 80% capsules (fruits) became light black in colour. In this time some flowers still were present on top of the plants.

Data collection: Data ongrowth parameters like plant height (cm), number of branches per plant, number of internodesper plant and internode length (cm) were collected from 10 plants selected randomly from each unit plot and each data were averaged.Leaf chlorophyll content was measured by a soil-plant analysis development (SPAD) chlorophyll meter (Konica Minolta, model SPAD-502 plus, Tokyo, Japan) from randomly selected 10 plants of each treatment at 60 days after sowing. The SPAD readings were collected from mid-ribs of fully expanded individual leaves in each plant.Five plants from each treatment were randomly collected to record number of open and un-open flowers per plant. Five open flowers were detached from every plant of each treatment for measuring flower diameter and the data was averaged.Regarding number of filled and unfilled fruits per plant, 5 mature plants of gypsophila were randomly collected from the middle rows of each plot at the harvest time and the data were recorded and averaged. Filled fruits were detached from five plants and randomly selected five fruits from each treatment to record the number of seeds per fruit. Thousand seed weight (g) was determined by the counting of 500 seeds collected from composite seeds of each treatment and weighing through electronic balance and converting it into1000-seed weight.One square meter area of each treatment plot was selected for recoding the number of plants per plot (plant population) after 60 days of seed sowing. In the plot of farmer's broadcasting practice, all plants were considered as plant population, but flowers and fruits bearing plants were approximately 70%. In case of treatment plot S_2 (20 cm × 05 cm), flowers and fruits bearing plants were about 79%. Seed yield and straw yield were recorded on a whole plot basis and converted in kg ha^{-1}.

Relative data in percentage: For each plant spacing treatment, the value of relative data was presented as percentage relative to the farmer's broadcasting practice..

$$\textbf{Relative data}\ (\%) = \frac{\textbf{Treatment value} - \textbf{farmer broadcasting value}}{\textbf{farmer broadcasting value}} \times 100 \text{ --------- } (1)$$

Statistical analysis: Statistical analysis was done 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).

Economic analysis: The seed yield was utilized to calculate the gross return. The gross return was measured by multiplying the marketable unit price of seed. Gross margin was calculated by subtracting management cost from gross return.Treatment wise management cost was calculated by adding the cost incurred for labours, ploughing and inputs of each treatment. Theshadow prices (land rent, straw cost etc.) were not considered. The BCR was calculated from gross return divided by total cost of cultivation.

Results and Discussion

Growth and flower attributes of gypsophila: Growth attributes of gypsophila were affected significantly by different plant spacing (Table 2).The maximum plantheight (71.4 cm) was found in spacing30 cm × 10 cm, which was statistically similar to spacing20 cm × 10 cm and Farmer's broadcasting practice. The minimum plantheight (61.3 cm) was observed in spacing 20 cm × 15 cm. The tallest plant in S_6treatment might be related with increasing in the space between row to row for getting more light, nutrients, air and moisture as compared toother treatments. The result is in agreement with the findings of Poornima *et al*. (2021) in gypsophila who noted that the tallest plant (96.0 cm) was recorded in wider spacing (50 cm × 50 cm) under poly house condition. Similar results were also observed by Manimaran and Ganga (2022) in *Jasminum nitidum* andNaik and Kumar (2014) in *Dendrobium* orchids. Different treatment contributed significantly to increase the number of branches per plant of gypsophila. The treatment S_6 resulted gave more number of branches (6.90) per plant, which was comparable to S_3, S_4 and S_5 treatments (Table 2).The probable reason of increased branches per plant might be due to proper plant space,availability of air, water, sunlight and nutrition for proper physiological process of the plant. Similar result was documented by Poornima *et al*. (2021) in gypsophila and Niranjan *et al.* (2018) in *Gladiolus grandiflorus.*The maximum number of internodes per plant (9.28) of gypsophila wasobservedinS_6 followed by S_4 and S_5 treatments. The internode length of gypsophila was significantly influenced by different plant spacing where the maximum internode length (6.30 cm) was measured from S_6(30 cm × 10 cm) followed by S_4 and S_5 treatments. The wider spacing allowed the appropriate number of plants to receive better soil moisture, and helped to uptake proper nutrient, light for photosynthesis toplant which ultimately increased the number of internodes and internode length of gypsophila.Similar view was also verified by Jain *et al*. (2018) in *Limonium sinuatum* who reported that the highest plant length (73.9 cm) as well as internode length was recorded in spacing 45 cm × 30 cm.In this experiment, themaximum number of opened flowers per plant (54.4) was recorded from S_6treatment, which was statisticallysimilar to S_3, S_4 and S_2 treatments. The treatment S_6gave more number of unopened flowers (43.1) as compared to other treatments. The S_6 treatment (30 cm × 10 cm) recorded higher number of flowers which might be due to wider spacing, however this spacing greatly favored the nutritional availability and amount of sunlight resulting in higher number of flowers. Similar findings were outlined by Niranjan *et al.* (2018) in *Gladiolus grandiflorus* and Gaurav *et al.* (2005) in gerbera. Themaximum diameter of flower (0.90 cm) was recorded from S_4 (20 cm × 15 cm) closely followed by S_6 treatment (Table 2).Wider plant spacing(20 cm × 15 cm) might have affected the flower diameter. Spacing playsa significant role for activation of photosynthetic system to enhance biological efficiency, allowinghigher photosynthesis to increase flower diameter. Lakshmi *et al.* (2014) reported that African marigold (*Tagetes erecta* L.) under wider spacing (40 cm × 60 cm) got higher flower diameter.Similar view was outlined by Poornima *et al*. (2021) in gypsophila. Leaf chlorophyll content in leaves was responded positively by different spacing. The maximum SPAD value (49.4) was recorded from the treatment S_6 which was statistically similar to S_4, S_3 and S_5 treatments. The lowest value was found in S_2 treatment (Table 2). Wider plant spacing (30 cm × 10 cm) might be associated with higher leaf chlorophyll due to availability of light, air and nutrient from soil. The function of chlorophyll in a plant is to absorb sunlight. The energy absorbed from light is transferred to energy-storing molecules (Pavlović *et al.*, 2014). However, proper density of plant (population) modifies the canopy structure and influence light interception for photosynthesis to produce dry matter (Khenizy *et al.*, 2014).

Table 2. Effect of plant spacing on growth and flower attributes of gypsophila (Pooled data of two years)

Treatment	Plant height (cm)	No. of branch plant^{-1}	No. of internodes plant^{-1}	Internode length (cm)	No. of opened flower plant^{-1}	No. of unopened flower plant^{-1}	Flower diameter (cm)	SPAD value
S_1 (Farmer's practice)	66.0a-c	5.37c	8.25c	4.12d	45.4c	34.5c	0.59e	47.5bc
S_2 (20 cm × 05 cm)	64.3bc	5.91bc	8.34bc	4.64cd	52.7ab	37.8b	0.76d	46.8c
S_3 (20 cm × 10 cm)	69.7ab	6.61ab	8.46bc	5.20bc	52.6ab	41.6a	0.82c	48.6ab
S_4 (20 cm × 15 cm)	61.3c	6.59ab	8.88ab	5.59ab	52.4ab	41.8a	0.90a	49.3a
S_5 (30 cm × 05 cm)	63.5bc	6.06a-c	8.92ab	5.82ab	49.1bc	37.6b	0.84bc	48.5ab
S_6 (30 cm × 10 cm)	71.4a	6.90a	9.28a	6.30a	54.4a	43.1a	0.86ab	49.4a
CV (%)	5.72	8.21	3.69	8.09	5.72	2.94	2.69	3.92

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

Seed yield attributes of gypsophila

Yield attributes of gypsophila were affected by different plant spacing (Table 3). Maximum number of filled fruits per plant (73.4) was recorded from treatment S_6 which was significantly different from the other treatments but statistically alike with $S_3$and S_4 treatments (Table 3). The highest number of unfilled fruits per plant (26.9) was recorded inS_6treatment which was significantly higher than S_1 and S_2treatments, but statistically identical with S_5 andS_4 treatments. This increase in fruits per plant might be due to the minor competition among the plants for nutrient and water at wider spacing (30 cm ×

10 cm). Similar findings were recorded in different crops outlined by Nain *et al.* (2017) in African marigold; Kumar *et al.* (2012) in African marigold cv. PusaNarangi; Poornima *et al.* (2021) in gypsophila. Seeds per fruit are very important yield contributing character for achieving higher seed yield of any crop. However, different plant spacing contributed positively to achieve higher number of seeds per fruit over farmer's practice. Maximum number of seeds per fruit (16.8) was recorded from S_6 treatment that was statistically similar to S_5, S_4 and S_3 treatments and the lowest number of seeds per fruit was in S_1 treatment (Table 3). The 1000-seed weight (1.67 g) was found at par except farmer's practice (Table 3). Optimum plant density as well as spacing is very essential for higher number of seeds per fruit and getting heaviest seed for obtaining highest seed yield. Similar observation was also obtained by Niranjan *et al*. (2018) in gladiolus.

Table 3. Effect of plant spacing on seed yield attributes of gypsophila (Pooled data of two years)

Treatment	No. of filled fruit plant^{-1}	No. of unfilled fruit plant^{-1}	No. of seed fruit^{-1}	1000-seed wt. (g)
S_1 (Farmer's practice)	40.0d	15.9b	10.5b	1.48b
S_2 (20 cm × 05 cm)	46.7c	15.4b	11.2b	1.60a
S_3 (20 cm × 10 cm)	71.7ab	18.8b	15.1a	1.63a
S_4 (20 cm × 15 cm)	70.8ab	20.2ab	16.1a	1.67a
S_5 (30 cm × 05 cm)	67.2b	20.8ab	15.3a	1.61a
S_6 (30 cm × 10 cm)	73.4a	26.9a	16.8a	1.67a
CV (%)	5.07	19.5	6.73	2.74

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

Yields of gypsophila: Seed yield is a vital reflection for seed production of a crop. Seed yield depends on the branches per plant, number of fruits per plant, seeds per fruit, and seed weight. In the experiment, farmer's broadcasting practice (S_1) treatment had maximum plants but about 70% plants were flowered as well as fruits bearer. Similarly closer spacing 20 cm × 05 cm(S_2) treatment had 2nd highest number of plants but about 79% plants were flowered as well as fruits bearer.However, the plant spacing had a significant effect on seed yield of gypsophila (Table 4). The highest seed yield (1316 kg ha^{-1}in 2019-20 and1300 kg ha^{-1} in 2020-21) was recorded in the treatment S_6(30 cm × 10 cm) which was comparable with S_3 and S_5treatments in both the years.

Maximum percent yield increment over farmers practice (8.28%) was achieved in spacing 30 cm × 10 cm (S_6) followed by spacing 20 cm × 10 cm (S_3) (Table 4). Wider spacing might have facilitated photosynthesis process due to get proper light, air and easily uptake the nutrient from soil.Wider spacing facilitates easy translocation of photosynthetic products to the seed for increasing enzymatic activitycausingseed yield increment. The result of this experiment agrees with the findings of a number of previous research activities involving other flower crops (Nain *et al*., 2017; Khenizy *et al.*, 2014; Kumer *et al*., 2012; Sharma *et al.*, 2012). The highest straw yield of gypsophila (1673 kg ha^{-1}in 2019-20 and1723 kg ha^{-1} in 2020-21) was exhibited in S_6 comparable with most of the treatment. Similar result was supported by Sing *et al* (2015) in marigold who reported that the highest yield was observed at 40 cm× 20 cm spacing. The lowest seed yield and straw yield of gypsophila werenoted in S_2 treatment (Table 4).

Table 4. Effect of plant spacing on seed yield and straw yield of gypsophila

Treatment	Seed yield (kg ha^{-1})			% Seed yield increment over farmer practice	Straw yield (kg ha^{-1})	
	2019-20	2020-21	Mean		2019-20	2020-21
S_1 (Farmer practice)	1270ab	1145b	1208	-	1588ab	1634ab
S_2 (20 cm × 05 cm)	1160b	1123b	1142	-5.46	1543b	1567b
S_3 (20 cm × 10 cm)	1260ab	1297a	1279	5.88	1681a	1699ab
S_4 (20 cm × 15 cm)	1190ab	1195b	1193	-1.24	1609ab	1607ab
S_5 (30 cm × 05 cm)	1240ab	1211ab	1226	1.49	1671a	1700ab
S_6 (30 cm × 10 cm)	1316a	1300a	1308	8.28	1673a	1723a
CV (%)	6.05	4.11	-	-	4.17	5.05

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

Plant population of gypsophila: Plant population of gypsophila was influenced significantly by the different plant spacing (Figure 2). The maximum number (population) of plants per plot (485) was recorded from S_1 treatment and lowest was from S_4 treatment (Figure 2). The reason of maximum number of plants in S_1treatment (Farmer'sbroadcasting practice) plot might be due to non-uniform plant spacing.

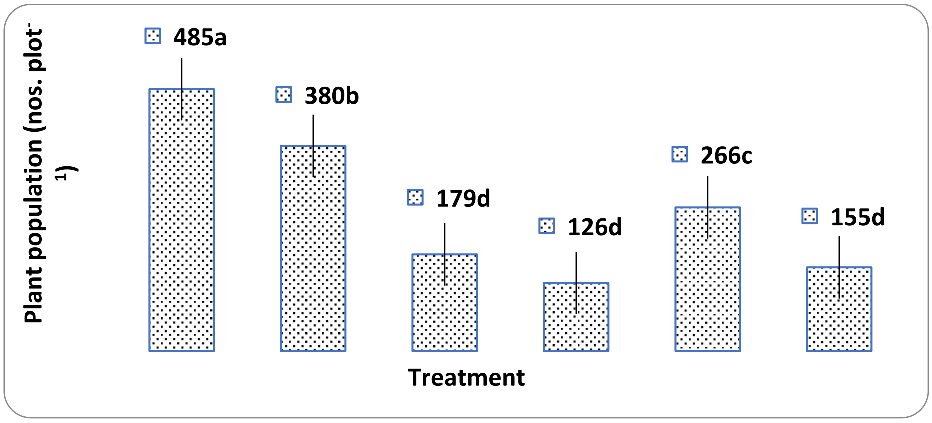

Fig. 2. Effect of plant spacing on number of plants (plant population) per plot (Pooled data of two years).

Means followed by the uncommon letter (s) are significantly different from each other by LSD test at $P \leq 0.05$.

Note: S_1 (Farmer's broadcasting practice), S_2 (20 cm × 05 cm), S_3(20 cm × 10 cm), S_4 (20 cm × 15 cm),

S_5 (30 cm × 05 cm)and S_6 (30 cm × 10 cm).

Cost and return analysis

Regarding the cost and return analysis, the maximum gross return Tk. 1569600 ha^{-1} wasrecorded from S_6 treatment followed by S_3. The minimum gross return was found from S_2 treatment. The highest gross marginwas also noted from S_6 treatment. The highest benefit cost ratio of 2.21 was obtained from S_6treatment followed by S_3. The lowest gross margin and benefit cost ratio were recorded from S_2 treatment (Table 5).

Table 5. Cost and return analysis of gypsophila due to different plant spacing (Pooled data of two years)

Treatment	Gross return (Tk. ha^{-1})	TC ((Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
S_1 (Farmer practice)	1449600	694500	755100	2.09
S_2 (20 cm × 05 cm)	1370400	708747	661653	1.93
S_3 (20 cm × 10 cm)	1534800	708747	826053	2.17
S_4 (20 cm × 15 cm)	1431600	708747	722853	2.02
S_5 (30 cm × 05 cm)	1471200	708747	762453	2.08
S_6 (30 cm × 10 cm)	1569600	708747	860853	2.21

Input prices: Urea= Tk.16 kg^{-1}, T.S.P= Tk. 24 kg^{-1}, MoP= Tk. 17 kg^{-1}, Gypsum= Tk.15 kg^{-1}, Zinc sulphate= Tk. 1400 kg^{-1} (lab grade), Boric acid= Tk. 1200 kg^{-1} (lab grade), Bavistin= Tk. 200 100^{-g}, Ribcord= Tk. 120 100^{-ml}, Gypsophila seed= Tk.1200 kg^{-1}, Ploughing= Tk. 1400 ha^{-1}(one pass), Cow dung= Tk. 2.0 kg^{-1}, Wage rate= Tk. 500 day^{-1}

Output price: Gypsophila seed price rate=Tk. 1200kg^{-1}

Gross returns were calculated on the basis of farm gate price of Gazipur, Bangladesh. TC = Total cost, BCR = Benefit cost ratio.

Conclusion

The gypsophila seed yield and yield traits were influenced significantly by plant spacing. The highest seed yield of gypsophila was achieved in the spacing of 30 cm × 10 cm. The highest benefit cost ratio and gross margin were also found from the same plant spacing. The result suggests that the wider plant spacing of 30 cm × 10 cm may be used for cultivation of gypsophila. Further research should be conducted on plant spacing including another wider spacing for confirmation of suitable plant spacing in maximizing seed yield of gypsophila.

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