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YIELD PERFORMANCE OF CHIA (S*ALVIA HISPANICA* L.) IN RESPONSE TO PLANTING SPACING AND NPK FERTILIZERS

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Abstract

Optimization of plant spacing, and fertilizer dose is very important for realizing maximum yield of a crop. An experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh during November 2020 to March 2021 to determine the effect of different spacing and NPK fertilizer levels on yield and yield attributes of chia seed. The experiment consisted of four different spacing *viz.* 30 cm × 15 cm (S_1), 30 cm 30 cm (S_2), 40 cm × 15 cm (S_3) and 40 cm × 30 cm (S_4) and five levels of NPK fertilizer *viz.* No NPK (F_0), 30: 20: 25 kg NPK ha^{-1} (F_1), 60: 40: 50 kg NPK ha^{-1} (F_2), 90: 60: 75 kg NPK ha^{-1} (F_3) and 120: 80: 100 kg NPK ha^{-1} (F_4). The experiment was laid out in a factorial randomized complete block design (RCBD) with three replications. The results revealed that 40 cm × 30 cm spacing produced the highest number of inflorescences plant^{-1}, seed yield and haulm yield. The fertilizer level 90: 60: 75 kg NPK ha^{-1} showed the highest seed yield and haulm yield while 120:80 :100 kg NPK ha^{-1} exhibited the maximum number of inflorescences plant^{-1}. The combination of 30 cm 30 cm spacing and 90: 60: 75 kg NPK ha^{-1} produced the highest number of inflorescences plant^{-1} and seed yield whereas the combination of 40 cm × 30 cm spacing and 90: 60: 75 kg NPK ha^{-1} had the highest haulm yield. The present study concluded that cultivation of chia at a spacing of 30 cm × 30 cm and fertilized with 90: 60: 75 kg NPK ha^{-1} could be considered as the promising practice for reasonable seed yield.

Introduction

Malnourishment is a major problem in developing countries (Mary *et al.*, 2018a). This problem can be alleviated to some extent by increasing production and consumption of 'super foods'. Chia (*Salvia hispanica* L.) is a new 'super food crop' in Bangladesh which is a rich source of Omega-3 fatty acid (-linolenic acid), soluble and insoluble fibers and proteins in addition to other important nutritional components, such as vitamins, minerals and natural antioxidants. The seed is composed of protein (15%-25%), fats (30%-33%), carbohydrates (26%-41%), high dietary fiber (18%-30%), ash (4%-5%), dry matter (90%-93%), minerals (calcium, iron, magnesium, manganese, phosphorus, potassium, zinc etc.), vitamins (vitamin A, thiamine, riboflavin, niacin, vitamin C, vitamin E) and also contains a large number of antioxidants such as beta-carotene, tocopherol, chlorogenic acid, caffeic acid and flavonoids (Ixtaina *et al.*, 2008). Chia seeds can be widely used in vegetarian and gluten-free diets. The seed has been considered as an important ingredient for human health and nutrition because of its high content of ω-3 fatty acid that promotes beneficial health effects (Vuksan *et al.*, 2010).

Chia is a short-day plant and is grown both in tropical and subtropical environments. The environmental conditions of Bangladesh are suitable for cultivation of this new crop. Before recommended for mass cultivation of the new crop, the optimization of different agronomic management practices is necessary for harvesting maximum yield. Karim *et. al.* (2015) reported that November is the most suitable time for sowing of chia seed. However, information related to plant population, their spatial arrangement and nutrient requirement is highly scarce under

Bangladesh condition. Therefore, an experiment was undertaken to find out the optimal spacing and NPK fertilizer doses for maximizing chia seed production.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during November 2020 to March 2021. The experimental field is located at 24.75° N latitude and 90.50° E longitude and at an altitude of 18 m. The site belongs to the Sonatola series of the Old Brahmaputra Floodplain i.e Agro-ecological Zone-9 (AEZ-9). The experimental land was characterized by non-calcareous dark grey floodplain soils. The land was medium high and well drained with silty loam texture. The soil pH of the experimental site was 6.30 and the soil contained 1.35% organic matter.

The experimental area is under the sub-tropical climate which is characterized by high temperature and heavy rainfall during *Kharif* season (April to September) and scanty rainfall with moderately low temperature during *Rabi* season (October to March). The overall relative humidity remains high during most part of the year except winter season. The experiment included 4 levels of planting spacing: 30 cm × 15 cm (S_1), 30 cm × 30 cm (S_2), 40 cm × 15 cm (S_3) and 40 cm × 30 cm (S_4) and 5 levels of NPK fertilizers: No NPK (F_0), 30: 20: 25 kg NPK ha^{-1} (F_1), 60: 40: 50 kg NPK ha^{-1} (F_2), 90: 60: 75 kg NPK ha^{-1} (F_3), and 120: 80: 100 kg NPK ha^{-1} (F_4). The trial was conducted in a Factorial Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 3.0 m × 2.5 m.

The experimental land was prepared with a power tiller and subsequently leveled by laddering. Weeds and stubbles of the previous crop were collected and removed from the field as much as possible after leveling. The land was finally prepared, and the plots were laid out on 23 November 2020. The experimental plots were fertilized with nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca) and zinc (Zn), respectively in the form of urea, triple superphosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate as per experimental specification. Moreover, each plot was equally treated with 15, 4 and 1.0 kg ha^{-1} S, Ca and Zn respectively to boost up the plant growth. All the fertilizers were applied at final land preparation, but urea was applied in three equal splits at final land preparation, 30 and 55 days after sowing (DAS). The seeds were sown on 24 November 2020 at spacings as per experimental treatments. The crops were infested with different weeds.

Weeds were removed manually from the experimental field two times i.e., at 25 DAS and at 40 DAS. To maintain the field at moist soil condition and for successful crop growth and development, irrigation was done once (1 January 2021) during the crop growth season. Proper drainage was maintained to facilitate draining out of excess water from the plots. The infestations of insect-pests were negligible in the plots.

However, Fungus Fighter (herbal fungicide) @ 10 ml 15L^{-1} and Amistar Top 325 SC (Azoxystrobin + Difenoconazole) @ 1.0 ml L^{-1} were applied on 16 January 2021 and 26 January 2021, respectively to prevent fungal diseases. The crop was harvested on 14 March 2021 as soon as the pretty purple flowers of the chia flower stalk started to dry and most of the petals had fallen off the flower. Five plants (excluding border plants) were randomly selected and uprooted from each unit plot before harvesting for recording the necessary data on various plant characters and yield attributes.

The harvested crops of each unit plot were bundled separately and properly tagged. After proper sun drying the yield of seed and straw of each unit plot was recorded and converted to ton per hectare (t ha^{-1}). The collected data were compiled and tabulated in proper form and were subjected to statistical analysis by using a computer package program Statistix10 and mean differences were adjudged by least significance difference (LSD) test.

Results and Discussion

Plant height

The spacing had significant no significant effect on plant height (Table 1) while NPK fertilizer exerted significant effect (Table 2). Table 2 showed that the fertilizer level 90: 60: 75 kg NPK ha^{-1} produced the tallest plant (111.08 cm) while no NPK fertilizer showed the shortest plant (98.14 cm). It was also noted that the higher NPK dose above 90: 60: 75 kg NPK ha^{-1} reduced the plant height. The over application of fertilizer increased the interplant competition that reduced the plant height. It was further noted that the combined effect of spacing NPK fertilizer level were not significant for plant height of chia (Table 3).

Table 1. Effect of planting spacing on growth, yield and yield attributes of chia

Spacing	Plant height (cm)	No. of main branches $plant^{-1}$	No. of inflorescence $plant^{-1}$	Length of inflorescence (cm)	1000- seeds weight (g)	Seed yield (t ha^{-1})	Haulm yield (t ha^{-1})
S_1	108.07	12.18	29.45 c	38.21	1.41	0.67 c	1.31 c
S_2	104.31	12.21	31.87 ab	35.55	1.45	0.70 bc	1.56 b
S_3	104.68	12.43	30.02 bc	38.36	1.42	0.74 b	1.70 a
S_4	100.78	12.51	33.55 a	37.61	1.43	0.81 a	1.72 a
LS	NS	NS	**	NS	NS	***	***
SE (±)	2.75	0.35	1.06	1.22	0.03	0.02	0.04
CV (%)	7.22	7.74	9.28	8.93	5.11	9.47	8.24

In a column, the figures with same letter (s) or without letter do not differ significantly, whereas figures with dissimilar letter (s) differ significantly. ** = Significant at 1 % level of probability, *** = Significant at 0.1 % level of probability and NS = Not significant. S_1 = 30 cm × 15 cm, S_2 = 30 cm × 30 cm, S_3 = 40 cm × 15 cm, S_4 = 40 cm × 30 cm

Table 2. Effect of NPK fertilizer on growth, yield and yield attributes of chia

Fertilizer	Plant height (cm)	No. of main branches $plant^{-1}$	No. of inflorescences $plant^{-1}$	Length of inflorescence (cm)	1000- seeds weight (g)	Seed yield (t ha^{-1})	Haulm yield (t ha^{-1})
F_0	98.14 c	12.20	27.85 d	35.92	1.41	0.55 c	1.05 d
F_1	101.52 c	12.21	30.11cd	37.15	1.43	0.60 c	1.47 c
F_2	103.55 bc	12.43	31.00 bc	36.62	1.40	0.74 b	1.61 b
F_3	111.08 a	12.92	33.33 ab	38.28	1.46	0.90 a	1.90 a
F_4	108.00 ab	11.85	33.83 a	39.20	1.45	0.84 a	1.82 a
LS	**	NS	***	NS	NS	***	***
SE (±)	3.08	0.39	1.18	1.37	0.03	0.02	0.05
CV (%)	7.22	7.74	9.28	8.93	5.11	9.47	8.24

In a column, the figures with same letter (s) or without letter do not differ significantly, whereas figures with dissimilar letter (s) differ significantly. ** = Significant at 1 % level of probability, *** = Significant at 0.1 % level of probability, NS = Not significant. F_0 = No NPK, F_1 = 30: 20: 25 kg NPK ha^{-1}, F_2 = 60: 40: 50 kg NPK ha^{-1}. F_3 = 90: 60: 75 kg NPK ha^{-1}, F_4 = 120: 80: 100 kg NPK ha^{-1}

Number of Main Branches $Plant^{-1}$

Number of main branches $plant^{-1}$ was not influenced by spacing, NPK fertilizer levels and interaction of spacing and NPK fertilizers. However, apparently, it was found that the number of branches $plant^{-1}$ increased with the increase of fertilizer level. The fertilizer level 90: 60: 75 kg NPK ha^{-1} resulted the highest number of branches $plant^{-1}$ (Table 2).

Number of Inflorescences $Plant^{-1}$

The main effects of spacing and NPK fertilizer levels as well as the interactions of spacing and NPK fertilizers levels were significant on number of inflorescences $plant^{-1}$. The highest number of inflorescences $plant^{-1}$ (33.55) was recorded at a spacing of 40 cm × 30 cm and the lowest

(29.45) at 30 cm × 15 cm (Table 1). The highest number of inflorescences plant^{-1} (33.83) was observed at the fertilizer level of 120: 80: 100 kg NPK ha^{-1} (Table 2). The result clearly showed that number of inflorescences plant^{-1} increased with the increase of fertilizer levels. The maximum number of inflorescences plant^{-1} (39.27) was recorded at 30 cm × 30 cm spacing fertilized with 90: 60: 75 kg NPK ha^{-1} and the lowest (25.67) at the spacing of 30 cm × 30 cm treated with no NPK fertilizer (Table 3).

Table 3. Interaction effect of spacing and NPK fertilizer on growth, yield and yield attributes of chia

Spacing Fertilizer	Plant height (cm)	No. of main branches plant^{-1}	No. of inflorescences plant^{-1}	Length of inflorescence (cm)	1000-seeds weight (g)	Seed yield (t ha^{-1})	Haulm yield (t ha^{-1})
$S_1 \times F_0$	99.87	11.00	27.60 h-j	36.13	1.41	0.45 j	0.63 j
$S_1 \times F_1$	105.07	12.40	28.60 g-j	37.13	1.47	0.50 ij	1.42 gh
$S_1 \times F_2$	103.27	12.33	30.00 e-j	36.93	1.48	0.52 h-j	1.53 e-g
$S_1 \times F_3$	118.87	13.00	35.40 a-d	40.00	1.48	0.60 g-i	1.64 c-f
$S_1 \times F_4$	113.37	11.60	28.50 g-j	40.87	1.40	0.69 gh	1.76 b-d
$S_2 \times F_0$	93.13	12.00	25.67 j	34.20	1.38	o.63 gh	0.84 j
$S_2 \times F_1$	99.87	12.53	30.67 b-g	32.53	1.39	0.79 d-f	1.43 f-h
$S_2 \times F_2$	104.80	12.40	32.60 d-i	36.13	1.43	0.88 b-d	1.58 d-g
$S_2 \times F_3$	113.20	12.60	39.27 a	36.80	1.43	1.04 a	1.72 b-e
$S_2 \times F_4$	113.87	12.60	36.00 a-c	38.07	1.45	0.89 b-d	1.82 bc
$S_3 \times F_0$	101.40	12.27	25.80 j	35.60	1.49	0.61 g-i	1.11 i
$S_3 \times F_1$	108.00	12.53	26.40 ij	3.87	1.41	0.69 fg	1.50 f-h
$S_3 \times F_2$	109.07	12.47	29.70 e-i	38.93	1.33	0.78 d-f	1.73 b-e
$S_3 \times F_3$	101.20	12.60	33.80 b-f	39.53	1.40	0.91 bc	2.13 a
$S_3 \times F_4$	103.73	11.57	31.53 c-h	39.87	1.50	0.81 c-e	1.85 bc
$S_4 \times F_0$	101.50	11.60	29.53 f-j	34. 47	1.37	0.63 gh	1.30 hi
$S_4 \times F_1$	89.80	12.73	29.93 e-j	38.33	1.42	0.75 ef	1.45 f-h
$S_4 \times F_2$	97.07	12.53	31.93 c-h	37.73	1.35	0.80 c-e	1.77 b-d
$S_4 \times F_3$	111.07	13.47	34.40 b-e	38.20	1.52	0.87 b-d	2.28 a
$S_4 \times F_4$	101.13	12.40	37.10 ab	39.33	1.47	0.97 ab	1.91 b
LS	NS	NS	***	NS	NS	***	***
SE (±)	6.16	0.78	2.37	2.73	0.06	0.05	0.11
CV (%)	7.22	7.74	9.28	8.93	5.11	9.47	8.24

S_1 = 30 cm 15 cm, S_2 = 30 cm 30 cm, S_3 = 40 cm 15 cm, S_4 = 40 cm 30 cm, LS = Level of significance, *** = Significant at 0.1 % level of probability, NS = Not significant F_0 = No NPK, F_1 = 30: 20: 25 kg NPK ha^{-1}, F_2 = 60: 40: 50 kg NPK ha^{-1}, F_3 = 90: 60: 75 kg NPK ha^{-1}, F_4 = 120: 80: 100 kg NPK ha^{-1}

The increased level of fertilizer helped in growth of plants and increased spacing offered less interplant competition that resulted in highest number of inflorescence plant^{-1} (Mary *et al.,* 2018b).

Length of Inflorescence

Effect of spacing, NPK fertilizer levels and their interactions were not significant for length of inflorescence. The spacing of 40 cm × 15 cm occupied the highest inflorescence length (38.36 cm) and the lowest inflorescence length (35.55 cm) was found at 30 cm × 30 cm spacing (Table 1). Numerically the highest inflorescence length (40.87 cm) was observed in the treatment combination of 30 cm × 15 cm spacing and fertilizer level of 120: 80: 100 kg NPK ha^{-1} followed by fertilizer level of 90: 60: 75 kg NPK ha^{-1} (Table 3).

Weight of 1000-Seeds

Weight of 1000- seeds did not vary significantly due to either main effect of spacing and NPK fertilizer levels or their interaction. The maximum weight (1.52 g) of 1000-seeds was observed at 40 cm × 30 cm spacing fertilized with 90: 60: 75 kg NPK ha^{-1} and the lowest weight (1.33 g) at 40 cm × 15 cm spacing fertilized with 60: 40: 50 kg NPK ha^{-1} (Table 3). Mary *et al.* (2018a) reported that the weight of chia seeds was not affected for the interaction of spacing and fertilizer levels.

Seed Yield

Seed yield was significantly influenced by spacing, NPK fertilizer levels and interaction between spacing and NPK fertilizer levels. In case of main effect of spacing, crops planted at a spacing of 40 cm × 30 cm resulted highest seed yield (0.81 t ha^{-1}) and the lowest seed yield (0.67 t ha^{-1}) at 30 cm × 15 cm spacing (Table 1). Table 2 showed that the maximum seed yield (0.90 t ha^{-1}) was found at fertilizer level of 90: 60: 75 kg NPK ha^{-1} which was statistically similar 120: 80: 100 kg NPK ha^{-1} (0.84 t ha^{-1}). The interaction effect showed the highest seed yield (1.04 t ha^{-1}) at a spacing of 30 cm × 30 cm fertilized with 90: 60: 75 kg NPK ha^{-1} (Table 3). The highest spacing and fertilizer levels helped in more branching, inflorescences, leaves and total dry matter accumulation $plant^{-1}$ which finally resulted into higher yield. The increase in seed yield at wider spacing was attributed to less intra plant competition and more space available for each plant that enhanced the plant growth and finally resulted into increasing the seed yield. Mary *et al.* (2018b) also reported the highest seed yield at 60 cm × 45 cm spacing with the fertilizer level of 90: 60: 75 kg NPK ha^{-1} while Mohanty *et al.* (2021) also found the highest seed yield at a spacing of 50 cm × 20 cm with 100 kg N ha^{-1}.

Haulm Yield

Haulm yield was significantly influenced by different spacing, NPK fertilizer levels and interaction of different spacing and NPK fertilizer levels. Table 1 exhibited that the maximum haulm yield (1.72 t ha^{-1}) was recorded at a spacing of 40 cm 30 cm which was statistically similar with the spacing of 40 cm × 15 cm (1.70 t ha^{-1}). Table 2 revealed that the maximum haulm yield (1.90 t ha^{-1}) was observed at the fertilizer level of 90: 60: 75 kg NPK ha^{-1} which was statistically similar with the fertilizer level of 120: 80: 100 kg NPK ha^{-1} (1.82 t ha^{-1}). In Table 3, it was found that the treatment combination of 40 cm 30 cm spacing and fertilizer level of 90: 60: 75 kg NPK ha^{-1} had the maximum haulm yield (2.28 t ha^{-1}) which was at par with the combination of 40 cm × 15 cm spacing and the fertilizer level of 90: 60: 75 kg NPK ha^{-1} (2.13 t ha^{-1}). The combination of wider spacing and higher NPK fertilizer levels resulted in less competition for nutrients that influenced the plant height and number of branches which resulted in higher haulm yield. Mary *et al.* (2018a) was also found the maximum haulm yield at 60 cm × 45 cm spacing while interaction effect of spacing and fertilizer levels was non-significant in relation to haulm yield. The increase in haulm yield at wider spacing is attributed to less intra plant competition and more space was available which resulted into vigorous growth of the plants that translated into the increased haulm yield.

Conclusion

The present result showed the highest seed yield of 1.04 t ha^{-1} at a spacing of 30 cm × 30 cm fertilized with 90: 60: 75 kg NPK ha^{-1}. The highest seed yield was obtained due to more branching, inflorescences and total dry matter accumulation $plant^{-1}$. Based on this study it may be concluded that cultivation at 30 cm × 30 cm spacing and the fertilized with 90: 60: 75 kg NPK ha^{-1} could be considered as the promising practice for obtaining the highest seed yield of chia.

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