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Effect of Spacing and Organic Sources of nutrients on Growth and Yield of Chia (*Salvia hispanica* L.)

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Abstract

A field experiment was conducted at research and demonstration block of Research Institute on Organic Farming (RIFO), University of Agricultural Sciences, GKVK, Bengaluru during *rabi* 2020-21 and 2021-22 for two consecutive years to study the effect of different spacings and organic sources of nutrients on growth and yield of chia. The experiment was laid out in factorial randomized complete block design with fifteen treatment combinations which were replicated thrice. The treatments included five different spacings *viz*., S_1- 60 cm × 30 cm, S_2- 75 cm × 15 cm, S_3- 75 cm × 30 cm, S_4- 90 cm × 15 cm, S_5- 90 cm × 30 cm and three different organic nutrient levels *viz*., N_1 - 60 kg N equivalent ha^{-1}, N_2 - 80 kg N equivalent ha^{-1} and N_3 - 100 kg N equivalent ha^{-1} applied based on nitrogen (N) equivalent, where 75 per cent of nitrogen is supplied through farm yard manure and 25 per cent through vermicompost. The pooled data results of two consecutive years indicated that spacing of 75 cm × 15 cm recorded significantly higher plant height (89.12 cm), whereas 90 cm × 30 cm spacing recorded significantly higher number of leaves plant^{-1} (55.49) and dry matter accumulation plant^{-1}(151.23 gm). The higher grain yield, haulm yield and harvest index (1099 kg ha^{-1}, 1855 kg ha^{-1} and 0.372, respectively) were recorded with spacing of 90 cm × 15 cm. Among the organic nutrient levels, application of 100 kg N equivalent ha^{-1} recorded significantly higher plant height (85.88 cm), number of leaves plant^{-1} (54.38), dry matter accumulation plant^{-1} (150.32 gm), grain yield, haulm yield and harvest index (1078 kg ha^{-1}, 1827 kg ha^{-1} and 0.368 respectively). However, interaction of different spacings and organic nutrient levels were found nonsignificant.

Keywords : Chia, FYM, Grain yield, Spacing, Vermicompost

Chia (*Salvia hispanica* L.) is an annual herb, which is considered as nutrient rich crop belongs to the family Lamiaceae. It was originated in mountain areas of Mexico and Guatemala. Chia is well known for its nutraceutical value and was traditionally one of the four basic elements in the diet of central American civilization in the pre columbian epoch. Out of 900 species of genus *Salvia*, only *Salvia hispanica* can be grown domestically. Initially chia was grown in tropical and sub subtropical climates, presently it is being grown worldwide particularly in Mexico, Argentina, Peru, Ecuador, Paraguay, Nicaragua, Guatemala, Bolivia and Australia. Chia grows well in sandy loam and clay loam soils with good drainage facility. It can be grown at an altitude ranging from 400-2500 meters above mean sea level, it is intolerant to freezing in all developmental stages. The period of growth of chia and grain development depends upon the latitude where it grows. It is a short-day plant with a requirement of optimum temperature range of 16-26^{0}C.

Chia is a pseudo cereal packed with nutrients which are beneficial for human body and brain. The seed contains 30 to 40 per cent oil with 60 per cent of it comprising omega (ω) -3 alpha linolenic acid and 20 per cent of omega (ω) -6 linoleic acid. It is a rich source of protein (15 to 25 per cent), fats (30 to 33 per cent), carbohydrates (26 to 41 per cent), high dietary fiber (18 to 30 per cent), ash (4 to 5 per cent), minerals, vitamins and high number of antioxidants (Jaddu and Yadida, 2018). In recent years area under chia crop is increasing in Karnataka because of its higher market price and now the cultivation has spread to other parts of the state and also to the neighboring states due to high returns than the traditional crops. Among the various agro-techniques, crop geometry and nutrient management are the supreme important agronomic practices for exploring the higher yield of crops. Spacing is a very important factor to achieve higher production by better utilization of moisture and nutrients from the soil and above ground by harvesting maximum possible solar radiation and in turn better photosynthesis (Aliveni *et al.,* 2020). Since chia is a new crop, the information on agronomic practices is meager and technologies with less use of fertilizers and plant protection chemicals such as organic farming is much needed as the demand is more for the seeds produced without any chemical usage. With this background, current trial was undertaken with objective to find out optimum spacing required and nitrogen level to be supplied through organic sources, needed for higher yield of Chia.

Material and Methods

A field experiment was carried out during *rabi* season of 2020-21 and 2021-22 at research and demonstration block of RIOF, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru. It is situated in Eastern Dry Zone (Zone-V) of Karnataka at a latitude of 13^0 09' North latitude, 77^0 57' East longitude and at an altitude of 924 m above mean sea level. The soil of the experimental site was red sandy loam with slightly acidic reaction with pH 6.1 and electric conductivity of 0.40 ds m^{-1}. The soil was medium in available nitrogen (313.60 kg ha^{-1}), phosphorus (27.08 kg ha^{-1}) and potassium (149.45 kg ha^{-1}).The experiment with fifteen treatment combinations *viz.,* five different spacings (S_1- 60 cm × 30 cm, S_2- 75 cm × 15 cm, S_3- 75 cm × 30 cm, S_4- 90 cm × 15 cm, S_5- 90 cm × 30 cm) and three different nitrogen levels applied based on N equivalence through FYM and vermicompost (N_1 - 60 kg ha^{-1}, N_2 - 80 kg ha^{-1} and N_3 - 100 kg ha^{-1}) were laid out in a factorial randomized complete block design and replicated thrice.

Chia Local variety was sown with a spacing according to the treatment and agronomic practices were followed for raising of the crop. Nutrient sources *viz.*, Farm yard Manure, vermicompost were applied on N equivalent basis after analysis of nutrient content present in it. The nutrient composition of FYM and vermicompost used in the experiment were analyzed and mentioned in Table 1. Application of FYM 10 t ha^{-1} is common for all the treatments as per package of practices. Of the total, 75 per cent of nitrogen is supplied through FYM as basal and remaining 25 per cent of nitrogen was supplemented through top dressing of vermicompost at 30 days after sowing (DAS). Hand weeding was done at 15 DAS and cycle weeder was passed at 25 DAS and 40 DAS to maintain weed free environment. Biometric observations on growth parameters were recorded randomly selected five plants at 30, 60 DAS and at harvest in the net plot. Data related to yield was recorded at the time of

Table 1

Nutrient composition of FYM and Vermicompost used in the experiment

Nutrient sources	2020			2021		
	N (%)	P_2O_5 (%)	K_2O (%)	N (%)	P_2O_5 (%)	K_2O (%)
FYM	0.50	0.15	0.61	0.50	0.17	0.65
Vermicompost	1.00	0.65	0.80	1.01	0.69	0.81

harvest of the crop. The data collected from the experiment at different phenological growth stages were subjected to statistical analysis as described by Gomez and Gomez (1984). Wherever the F-test was found significant for comparison among treatment means, an appropriate value of critical difference (CD) was worked out. Otherwise, the abbreviation NS was indicated against the CD values.

Results and Discussion

Plant Height

The pooled data of two years pertaining to plant height at different growth stages of chia crop as influenced by spacings and organic nutrient levels is presented in Table 2. Plant height of chia crop varied significantly by spacing at 30 DAS, 75 cm × 15 cm spacing recorded significantly higher plant height (12.68 cm) which was on par with spacing of 90 cm × 15 cm (12.16 cm). Significantly higher plant height at 60 DAS was recorded with 75 cm × 15 cm (72.06 cm) which was on par with 90 cm × 15 cm spacing (71.14 cm). At harvest spacing of 75 cm × 15 cm recorded significantly higher plant height (89.12 cm) which was on par with 90 cm × 15 cm spacing with the plant height of 84.37cm, whereas lower plant height was recorded with 90 cm × 30 cm (11.04, 59.24, 77.87 cm at 30, 60 DAS and at harvest, respectively). The marked increase in plant height was noticed in 75 cm × 15 cm spacing and this could be attributed to its increased plant density (90,909 plants ha^{-1}) which resulted in less availability of sufficient space for development of branches and leaves and sunlight which forced the plants to produce more auxins and made the plant to grow vertically rather than horizontally compared to wider row spacing, the results were in conformity with Mounika *et al*. (2021). Organic nutrient application of 100 kg N equivalent ha^{-1} recorded significantly higher plant height of 12.46 cm at 30 DAS which was on par with application of 80 kg N equivalent ha^{-1} (12.28 cm). Significantly higher plant height of 70.94 cm at 60 DAS was recorded with 100 kg N equivalent ha^{-1} which was on par with application of 80 kg N equivalent ha^{-1} (69.93 cm). At harvest significantly, higher plant height of 85.88 cm was observed with application of 100 kg N

Table 2

Plant height (cm) of chia crop as influenced by spacing and different organic nutrient levels at 30, 60 DAS and at harvest (Pooled data of 2 years)

Treatments	Plant height (cm)		
	30 DAS	60 DAS	At harvest
Factor A - Spacing			
S_1- 60 cm × 30 cm	11.86	64.15	79.56
S_2- 75 cm × 15 cm	12.68	72.06	89.12
S_3- 75 cm × 30 cm	11.58	61.78	79.54
S_4- 90 cm × 15 cm	12.16	71.14	84.37
S_5- 90 cm × 30 cm	11.04	59.24	77.87
S. Em±	0.28	0.67	2.62
CD (P = 0.05)	0.80	1.93	7.59
Factor-B Nutrient levels			
N_1 - 60 kg N equivalent ha^{-1}	10.86	56.14	75.89
N_2 - 80 kg N equivalent ha^{-1}	12.28	69.93	84.50
N_3 - 100 kg N equivalent ha^{-1}	12.46	70.94	85.88
S. Em±	0.21	0.52	2.03
CD (P = 0.05)	0.62	1.49	5.88
Interaction (A×B)			
S_1N_1	10.92	56.03	76.05
S_1N_2	12.18	67.62	82.49
S_1N_3	12.48	68.82	80.15
S_2N_1	10.98	60.93	78.00
S_2N_2	13.38	77.99	91.65
S_2N_3	13.68	78.71	97.70
S_3N_1	10.92	53.48	75.86
S_3N_2	11.82	65.61	79.89
S_3N_3	12.00	66.23	82.88
S_4N_1	10.98	59.46	77.22
S_4N_2	12.72	75.68	86.78
S_4N_3	12.78	76.82	89.12
S_5N_1	10.50	50.82	72.35
S_5N_2	11.28	62.77	81.71
S_5N_3	11.34	64.13	79.56
S. Em±	0.48	1.15	4.54
CD (P = 0.05)	NS	NS	NS

Note : CD at 5 %, NS - Non-Significant, DAS- Days After Sowing

equivalent ha^{-1} which was on par with 80 kg N equivalent ha^{-1} (84.50 cm). Whereas, lower plant height was recorded with of 60 kg N equivalent ha^{-1} (10.86, 56.14 and 75.89 cm at 30, 60 DAS and harvest, respectively). Plant height increased with increase in level of nitrogen through more quantity of FYM and vermicompost which slowly released the nutrients throughout the crop growth period and hence are responsible for better growth of chia crop. Reddy *et al*. (2017) also reported that increase in plant height was due to application of higher level of FYM and vermicompost. However, interaction of different spacings and nutrient levels was found non-significant.

Number of Leaves per Plant

The pooled data of two consecutive years pertaining to number of leaves per plant at different growth stages of chia crop as influenced by spacing and organic nutrient levels is presented in Table 3. Number of leaves per plant of chia as influenced by spacing did not vary significantly at 30 DAS. However, higher number of leaves per plant (17.13) was recorded in spacing of 90 cm × 30 cm. Significantly higher number of leaves per plant at 60 DAS was recorded with spacing of 90 cm × 30 cm (100.34) which was on par with 75 cm × 30 cm spacing (93.72). At harvest 90 cm × 30 cm spacing recorded significantly higher number of leaves per plant (55.49) which was on par with 75 cm × 30 cm spacing which recorded 50.20 number of leaves per plant, whereas lower number of leaves per plant (12.38, 67.22 and 32.39 at 30, 60 DAS and at harvest, respectively) was recorded with 60 cm × 30 cm. Organic nutrient levels could not significantly influence number of leaves per plant at 30 DAS, however, more number of leaves per plant (16.00) was found with 100 kg N equivalent ha^{-1} . At 60 DAS significantly, higher number of leaves $plant^{-1}$ (103.96) was recorded with 100 kg N equivalent ha^{-1} which was on par with application of 80 kg N equivalent ha^{-1} with 97.50 leaves per plant. At harvest significantly higher number of leaves $plant^{-1}$ (54.38) was observed with application of 100 kg N equivalent ha^{-1} which was on par with 80 kg N equivalent ha^{-1} with number of leaves $plant^{-1}$ 51.44. Whereas, lower

TABLE 3

Number of leaves per plant of chia crop plant as influenced by spacing and different organic nutrient levels at 30, 60 DAS and at harvest (Pooled data of 2 years)

Treatments	No. of leaves per plant		
	30 DAS	60 DAS	At harvest
Factor A - Spacing			
S_1- 60 cm × 30 cm	12.38	67.22	32.39
S_2- 75 cm × 15 cm	14.23	72.64	37.39
S_3- 75 cm × 30 cm	14.44	93.72	50.20
S_4- 90 cm × 15 cm	15.59	89.27	46.98
S_5- 90 cm × 30 cm	17.13	100.34	55.49
S. Em±	1.18	3.22	1.63
CD (P = 0.05)	NS	9.33	4.73
Factor-B Nutrient levels			
N_1 - 60 kg N equivalent ha^{-1}	12.86	52.45	27.65
N_2 - 80 kg N equivalent ha^{-1}	15.41	97.50	51.44
N_3 - 100 kg N equivalent ha^{-1}	16.00	103.96	54.38
S. Em±	0.92	2.49	1.27
CD (P = 0.05)	NS	7.23	3.67
Interaction (A×B)			
S_1N_1	11.24	35.30	15.90
S_1N_2	12.59	82.99	40.58
S_1N_3	13.32	83.36	40.69
S_2N_1	12.84	38.75	19.80
S_2N_2	14.95	83.73	43.19
S_2N_3	14.91	95.43	49.20
S_3N_1	12.01	57.51	30.10
S_3N_2	15.23	110.88	60.13
S_3N_3	16.09	112.76	60.36
S_4N_1	13.77	59.40	32.54
S_4N_2	16.32	98.51	51.49
S_4N_3	16.68	109.88	56.90
S_5N_1	14.42	71.29	39.92
S_5N_2	17.97	111.36	61.79
S_5N_3	19.00	118.38	64.75
S. Em±	2.05	5.58	2.83
CD (P = 0.05)	NS	NS	NS

Note : CD at 5 %, NS - Non-Significant, DAS- Days After Sowing

number of leaves plant^{-1} was recorded with of 60 kg N equivalent ha^{-1} (12.86, 52.45 and 27.65 at 30, 60 DAS and at harvest, respectively), the results were in support with findings of Olofintoye *et al*. (2015). Higher number of leaves at wider row spacing might be due to lesser competition among the chia plants for nutrients, water and solar radiation compared to closer spacing with higher plant density, similar results were observed by Salmankhan *et al*. (2021) in buck wheat.

Dry Matter Accumulation Per Plant (g)

The pooled data of two years pertaining to dry matter accumulation per plant (g) at different growth stages of chia crop as influenced by spacings and organic nutrients is presented in Table 4. The significantly higher dry matter accumulation of 20.17 (g) was observed in 90 cm × 30 cm spacing at 30 DAS, which was on par with 75 cm × 30 cm spacing with 18.93 (g) of dry matter per plant. Significantly higher dry matter accumulation per plant at 60 DAS was recorded with spacing of 90 cm × 30 cm (68.11g) which was on par with 75 cm × 30 cm spacing (64.09 g). At harvest 90 cm × 30 cm spacing recorded significantly higher dry matter accumulation per plant (151.23 g) which was on par with 75 cm × 30 cm spacing which recorded 148.95 (g) dry matter accumulation per plant, whereas lower dry matter accumulation per plant (11.94, 41.89, 110.68 gm at 30, 60 DAS and at harvest, respectively) was recorded with 60 cm × 30 cm. The significantly higher dry matter accumulation per plant (20.53 g) was recorded with 100 kg N equivalent ha^{-1} at 30 DAS, which was on par with application of 80 kg N equivalent ha^{-1} with dry matter accumulation of 18.81 gm per plant. At 60 DAS significantly, higher dry matter accumulation plant^{-1} of 67.43 (g) was recorded with 100 kg N equivalent ha^{-1} which was on par with application of 80 kg N equivalent ha^{-1} with dry matter accumulation of 66.2g. At harvest, significantly higher dry matter accumulation of 150.32 (g) per plant was observed with application of 100 kg N equivalent ha^{-1} which was on par with organic nutrient application of 80 kg N equivalent ha^{-1} with dry matter accumulation of 148.76 (g) per plant. The lower dry matter accumulation of (10.03, 35.48 and

TABLE 4

Dry matter accumulation per plant (g) of chia crop as influenced by spacing and different organic nutrient levels at 30, 60 DAS and at harvest (Pooled data of 2 years)

Treatments	Dry matter accumulation per plant (g)		
	30 DAS	60 DAS	At harvest
Factor A - Spacing			
S_1- 60 cm × 30 cm	11.94	41.89	110.60
S_2- 75 cm × 15 cm	14.36	50.53	118.08
S_3- 75 cm × 30 cm	18.93	64.09	148.95
S_4- 90 cm × 15 cm	16.89	57.23	134.65
S_5- 90 cm × 30 cm	20.17	68.11	151.23
S. Em±	1.06	2.13	3.35
CD (P =0.05)	3.06	6.17	9.69
Factor-B Nutrient levels			
N_1 - 60 kg N equivalent ha^{-1}	10.03	35.48	99.03
N_2 - 80 kg N equivalent ha^{-1}	18.81	66.20	148.76
N_3 - 100 kg N equivalent ha^{-1}	20.53	67.43	150.32
S. Em±	0.82	1.65	2.59
CD (P =0.05)	2.37	4.78	7.51
Interaction (A×B)			
S_1N_1	6.43	23.97	79.73
S_1N_2	14.02	50.73	125.55
S_1N_3	15.37	50.97	126.53
S_2N_1	9.84	34.79	89.48
S_2N_2	15.45	57.67	131.40
S_2N_3	17.80	59.14	133.35
S_3N_1	11.97	41.19	118.73
S_3N_2	21.48	75.11	163.58
S_3N_3	23.33	75.97	164.55
S_4N_1	9.72	34.52	97.28
S_4N_2	19.82	67.95	154.80
S_4N_3	21.12	69.21	151.88
S_5N_1	12.20	42.93	109.95
S_5N_2	23.29	79.52	168.45
S_5N_3	25.01	81.87	175.28
S. Em±	1.83	3.69	5.80
CD (P =0.05)	NS	NS	NS

Note : CD at 5 %, NS - Non-Significant, DAS- Days After Sowing

99.03 g) at 30, 60 DAS and at harvest was recorded with 60 kg N equivalent ha^{-1}. Thongney *et al.* (2020) had observed that application of higher FYM and vermicompost improves the soil physical, chemical and biological properties, leading to adequate supply of nutrients to the plants which might have promoted the higher growth attributes, while minimum growth attributes were due to lower or non-availability of sufficient nutrients besides increase in concentration of FYM and vermicompost has enhanced the biological efficiency and greater sink efficiency of crop which helped in higher photosynthetic efficiency and nutrient absorption which reflected in increase of dry matter accumulation (Roopashree, 2013). Interaction of different spacings and nutrient levels was found to be nonsignificant at different growth stages of chia crop.

Grain Yield (kg ha^{-1}), Haulm Yield (kg ha^{-1}) and Harvest Index of Chia Crop as Influenced by Spacing and Organic Nutrient Sources at Harvest

The pooled data of two seasons pertaining to grain yield, haulm yield and harvest index of chia as influenced by spacing and nutrient levels is presented in Table 5. Grain yield, haulm yield and harvest index of chia varied significantly as influenced by spacing. Spacing of 90 cm × 15 cm recorded higher grain yield, haulm yield and harvest index (1099 kg ha^{-1},1855 kg ha^{-1} and 0.372, respectively) which was on par with spacing of 75 cm × 15 cm (1012 kg ha^{-1}, 1774 kg ha^{-1} and 0.364, respectively) and lowest grain yield, haulm yield and harvest index was recorded with spacing of 90 cm × 30 cm (846 kg ha^{-1} 1614 kg ha^{-1} and 0.335, respectively) which might be due to cumulative influence of higher plant population. The results are in conformity with Venkateshappa and Jayadeva (2019). Among the organic nutrient sources, supplying of 100 kg N equivalent ha^{-1} recorded higher grain yield, haulm yield and harvest index (1078 kg ha^{-1}, 1827 kg ha^{-1} and 0.368, respectively), which was on par with 80 kg N equivalent ha^{-1} with grain yield, haulm yield and harvest index of 1008 kg ha^{-1}, 1759 kg ha^{-1} and 0.364, respectively whereas lower grain yield, haulm yield and harvest index of chia was recorded with 60 kg N equivalent ha^{-1} (805 kg ha^{-1},

TABLE 5

Grain yield, haulm yield and harvest index of chia crop as influenced by spacing and different organic nutrient levels at harvest (Pooled data of 2 years)

Treatments	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index
Factor A - Spacing			
S_1- 60 cm × 30 cm	947	1681	0.359
S_2- 75 cm × 15 cm	1012	1774	0.364
S_3- 75 cm × 30 cm	916	1654	0.355
S_4- 90 cm × 15 cm	1099	1855	0.372
S_5- 90 cm × 30 cm	846	1614	0.335
S. Em±	32	57	0.0038
CD (P = 0.05)	94	165	0.0110
Factor-B Nutrient levels			
N_1 - 60 kg N equivalent ha^{-1}	805	1561	0.340
N_2 - 80 kg N equivalent ha^{-1}	1008	1759	0.364
N_3 - 100 kg N equivalent ha^{-1}	1078	1827	0.368
S. Em±	25	44	0.003
CD (P = 0.05)	73	128	0.009
Interaction (A×B)			
S1N1	804	1540	0.344
S1N2	1011	1744	0.367
S1N3	1026	1758	0.367
S2N1	885	1659	0.350
S2N2	1069	1828	0.370
S2N3	1083	1835	0.372
S3N1	794	1539	0.339
S3N2	974	1698	0.365
S3N3	980	1724	0.360
S4N1	831	1579	0.348
S4N2	1088	1853	0.375
S4N3	1377	2132	0.398
S5N1	712	1486	0.318
S5N2	899	1671	0.342
S5N3	927	1685	0.34
S. Em±	56	99	0.007
CD (P = 0.05)	NS	NS	NS

Note : CD at 5 %, NS - Non-Significant, DAS- Days After Sowing

1561 kg ha^{-1} and 0.340, respectively). Addition of FYM and vermicompost increases the nutrient concentration in soil and increases the adsorption power of soil for cations and anions particularly phosphates and nitrates which were released slowly for the benefit of crop during the entire growth period and this is in close proximity with results of Verma *et al.* (2017). Interaction of spacing and nutrient levels was found to be nonsignificant on grain yield, haulm yield and harvest index.

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