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RESEARCH PAPER

Assessing optimum spacing, sowing method and nutrient requirement for Chia (*Salvia hispanica* L.)

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Abstract : A field experiment was conducted at ICAR-KVK, University of Agricultural Sciences, Dharwad during *rabi* 2020 to develop suitable agro-techniques for chia (*Salvia hispanica* L). The experiment was laid out in split split plot design with three replications and twelve treatments. Treatments consists of three spacing (45 × 20 cm, 60 × 20 cm and 75 × 20 cm) as main plots, two methods of sowing (Line sowing and Transplanting) as sub plots, two fertilizer levels (30:20:20 kg and 60:40:40 kgN:P_2O_5:K_2O ha^{-1}) as sub-sub plots. Spacing of 45 × 20 cm (S_1) recorded significantly higher seed yield (797 kg ha^{-1}), haulm yield (2960 kg ha^{-1}), gross returns (₹ 1,59,462 ha^{-1}), net returns (₹ 1,29,702 ha^{-1}) and benefit cost ratio (5.36) compared to 60 × 20 cm (S_2) and 75 × 20 cm (S_3). Method of sowing had no significant influence on growth and yield parameters. However, line sowing (M_1) recorded higher seed yield (722 kg ha^{-1}) and haulm yield (2719 kg ha^{-1}), gross returns (₹ 1,44,421 ha^{-1}), net returns (₹ 1,14,640 ha^{-1}) and B:C ratio (4.85) compared to transplanting (M_2). Fertilizer level of (F_1) 60:40:40 kg N:P_2O_5:K_2O ha^{-1} recorded significantly higher seed yield (744 kg ha^{-1}) haulm yield (2766 kg ha^{-1}), gross returns (₹ 1,48,845 ha^{-1}), net returns (₹ 1,18,181 ha^{-1}) and benefit cost ratio (4.85) compared to the application of (F_2) 30:20:20 kg N:P_2O_5:K_2O ha^{-1}. Interaction effects of ($S_1M_1F_2$) recorded significantly higher seed yield (836 kg ha^{-1}), net returns (₹ 1,36,454 ha^{-1}) and benefit cost ratio (5.44) of chia in Northern transition zone of Karnataka.

Key words: Chia, Fertilizer level, Line sowing, Net return, Transplanting

Introduction

Chia (*Salvia hispanica* L.) also called as Mexican chia is a plant of Mexican and South American origin belonging to Lamiaceae family, sub family Nepetoideae, tribe Mentheae and genus *Salvia*. It is well known for its nutraceutical value. Seeds contain about 30-35 per cent oil which is the richest source of Omega-3 fatty acid (more than 60 %). This fatty acid is found to be very good for general health. The seeds are also rich source of proteins (20-22%), dietary fiber (around 40%), anti-oxidants and various vitamins and minerals. Chia is becoming very popular as 'super food' all around the world with dramatic increase in cultivation and consumption. With very high demand for it in international and Indian market, it can be cultivated as a profitable commercial crop and is being grown commercially in USA, Bolivia, Argentina, Ecuador, Nicaragua, Guatemala, Australia and Mexico.

Chia is an annual herb growing up to 175 cm tall with opposite leaves that are 4–8 cm long and 3–5 cm wide. Flowers are purple or white and are produced in numerous clusters in a spike at the end of each stem. Chia seeds are small ovals with a diameter of approximately 2 mm. They are mottle-colored, with brown, gray, black, and white. The seeds are hydrophilic, absorbing up to twelve times their weight in liquid when soaked. While soaking, the seeds develop a mucilaginous coating that gives chia-based beverages a distinctive gelatinous texture. The cultivation of chia is gaining popularity in Africa and Asia because it is considered as a good nutritional and healthy food. The Central Food Technological Research Institute (CFTRI) has introduced this crop to the farmers and also offered technical support for its cultivation, in rain fed areas of Mysuru and Chamarajanagara districts. (Mary *et al.,* 2018).The area under cultivation of Chia crop is expected to rise in the coming days as it requires less water and is a drought resistant crop which comes up very well under adverse climatic conditions. CFTRI also developed a wide variety of ready-to -eat foods from chia. This crop is also emerging as an alternative to tobacco crop and many of the tobacco growing farmers have switched over to chia crop in Mysuru district.

Chia is mainly grown in Karnataka and Andhra Pradesh. In Karnataka, this crop is gaining lot of importance throughout the state due to its wide adaptability and has taken commercial importance in Mysuru, Chamarajanagara, Mandya, Davangere, Belagavi, Yadgiri, Chitradurga, Bagalkote, Uttara Kannada and Haveri districts.

Material and methods

A field experiment was conducted to develop suitable agro-techniques for chia crop at ICAR-KVK, University of Agricultural Sciences, Dharwad during *rabi* 2020. The soil of experimental plot was red sandy loam with neutral in reaction (7.18) with normal electrical conductivity (0.27 dS m^{-1}). It was low in available nitrogen (246.5 kg ha^{-1}) and medium in phosphorus (22.5 kg ha^{-1}) and available potassium (251.4 kg ha^{-1}). The experiment was laid out in split split plot design with twelve treatments and three replications. Treatment consisted of three spacing (45 × 20 cm, 60 × 20 cm and 75 × 20 cm) as main plots, two methods of sowing (Line sowing and Transplanting) as sub plots, two fertilizer levels (30:20:20 kg and 60:40:40 kgN:P_2O_5:K_2O ha^{-1}) as sub-sub plots In this study, local variety of chia were used. All the agronomic practices were followed as recommended. Observations were recorded at 30,60 DAS and at harvest. Economics was assessed treatment wise considering prevailing market price at the time of harvest.

Experimental data obtained was compiled and subjected to statistic analysis by adopting Fischer's method of analysis of variance (Gomez and Gomez, 1984). The critical difference values given in the table at 5 percent level of significance were used. The mean values of main plot, sub plot, sub-sub plot and highest order interaction effects were separately subjected to Duncan's Multiple Range Test (DMRT) using the corresponding error mean sum of squares and degrees of freedom values under M-STAT-C programme.

Results and discussion

Effect of spacing on yield and yield parameters

Crop sown at of spacing of 45 × 20 cm recorded significantly higher seed yield and haulm yield (797 kg ha^{-1} and 2960 kg ha^{-1} respectively) compared to the spacing of 75 × 20 cm and 60 × 20 cm (Table 2) .This was due to higher plant density with the spacing of 45 × 20 cm. However, wider row spacing of 75 × 20 cm produced higher growth and yield parameters individual plants which was mainly due to better resource availability and reduced inter plant competition in the community. Higher seed yield and haulm yield was produced with a spacing of 45 × 20 cm , though the values of yield attributing character were better with the spacing of 75 × 20 cm, but these were not sufficient to compensate the increased plant density with 45 × 20 cm spacing. These results were similar to the findings of Yeboah *et al*. (2014).

Spacing of 75 × 20 cm recorded significantly higher yield components like seed yield, spike length and number of spikes per plant (10.00 g, 17.81 cm and 35.96, respectively) compared to 45 × 20 cm and 60 × 20 cm spacing. This was due to increased yield parameters due to wider plant spacing attributed to lesser competition for space, light, soil moisture and nutrients among the plants and also accumulation of more dry matter in reproductive parts. These results were in close conformity with the findings of Pozo *et al*. (2010) who reported that amount of nitrogen application as high as 115 kg ha^{-1} increased the productivity of Chia crop. Mary *et al.* (2018) reported that spacing 60 × 45 cm was recorded higher total yield (676.58) compared to other treatment.

Effect of method of sowing on yield and yield parameters of chia

In the present investigation on the effect of method of sowing were found non-significant. However, numerically higher grain yield (722 kg ha^{-1}) and haulm yield (2719 kg ha^{-1}) was recorded with the line sowing where compared to transplanting. This might be due to early establishment in the field due to direct sowing, while transplanted plant might have suffered shock during uprooting from the nursery (Table 2).

Table 1. Growth and yield parameters of Chia as influenced by different spacing, method of sowing and fertilizer levels

Treatment		Number of spikes per plant	Spike length (cm)	Test weight (g)	Seed yield (g plant^{-1})
Spacing (S)					
S_1	45 cm × 20 cm	25.93c	14.92c	1.66c	7.96a
S_2	60 cm × 20 cm	31.60b	16.93ab	1.77ab	9.43a
S_3	75 cm × 20 cm	35.96a	17.81a	1.78a	10.00a
S.Em. ±		0.53	0.44	0.03	0.34
Method of sowing (M)					
M_1	Line sowing	33.60a	17.12a	1.80a	9.60a
M_2	Transplanting	28.76a	16.03a	1.74a	8.70a
S.Em. ±		1.65	0.39	0.06	0.27
Fertilizer levels (F)					
F_1	30 : 20 : 20 kg N : P_2O_5 : K_2O ha^{-1}	29.41b	14.72b	1.66b	8.65b
F_2	60 : 40 : 40 kg N : P_2O_5 : K_2O ha^{-1}	32.92a	17.12a	1.81a	9.60a
S.Em. ±		0.93	0.31	0.03	0.23
Interaction (S × M × F)					
	$S_1M_1F_1$	23.24d	14.70ef	1.77a-c	8.00c-e
	$S_1M_1F_2$	29.00a-c	15.60c-f	1.90ab	8.90b-e
	$S_1M_2F_1$	17.80e	14.20f	1.63bc	7.30e
	$S_1M_2F_2$	25.25de	15.20d-f	1.73a-c	7.70de
	$S_2M_1F_1$	29.00cd	16.80a-f	1.57c	9.50a-d
	$S_2M_1F_2$	37.22ab	17.80a-c	1.77a-c	10.21ab
	$S_2M_2F_1$	31.77b-d	16.10b-f	1.57c	7.90c-e
	$S_2M_2F_2$	28.58cd	16.97a-e	1.73a-c	10.03ab
	$S_3M_1F_1$	34.00a-c	18.34ab	1.77a-c	9.74a-c
	$S_3M_1F_2$	40.80a	19.27a	1.93a	11.33a
	$S_3M_2F_1$	37.74a-b	16.32b-f	1.67a-c	9.42a-d
	$S_3M_2F_2$	31.40b-d	17.33a-d	1.77a-c	9.51a-d
	S.Em.±	2.27	0.75	0.08	0.57

Means followed by the same alphabet (s) within a column do not differ significantly by DMRT (P = 0.05)

These results were in conformity with the findings of Yeboah *et al*. (2014) wherein direct planting recorded a significantly higher seed yield as compared to transplanting.

Higher number of spikes per plant, seed yield per plant and test weight were recorded with the line sowing (33.61, 9.60 g $plant^{-1}$ and 1.78 g, respectively) compared to transplanting (28.71, 8.65 g $plant^{-1}$ and 1.68 g, respectively). This was because of early establishment with line sowing leading to early flowering of sorghum and uptake of nutrients Agbaje *et al*. (2002).

Effect of fertilizer levels on yield and yield parameters of chia

In the present study, application of 60:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} recorded significantly higher seed yield (744 kg ha^{-1}) and haulm yield (2766 kg ha^{-1}) compared to fertilizer level of 30:20:20 kg $N:P_2O_5:K_2O$ ha^{-1} with seed and haulm yield of 686 and 2636 kg ha^{-1}, respectively (Table 2). Higher yield levels associated with the application of higher fertilizer dose were related to higher values of yield parameters like spike length, number of spikes per plant, seed yield per plant (Table 1). The increase in yield may be attributed to adequate and balanced supply of plant nutrients during crop growth period, which increased the availability of nutrients to plants resulting in favourable increase in plant height, accumulation of dry matter, increased photosynthetic activity due to increased leaf area, higher number of spikes, 1000 seed weight and ultimately seed yield. These results agreed with the findings of Pozo (2010); Coates (2011) who also found that application of higher nitrogen increased the productivity of chia.

Significantly higher seed yield per plant, spike length and number of spikes per plant were recorded with the higher fertilizer level of 60:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} (9.60g, 17.12 cm and 32.92, respectively). This was due to increased uptake leading to increased branching and number of spikes per plant and also better interaction of nitrogen, phosphorus and potassium at higher level of fertilizer dose. (Table 1)

Interaction effect of spacing, method of sowing and fertilizer levels on yield and yield parameters of chia

In the present investigation, interaction effect of line sowing with spacing of 45 × 20 cm and application of 60:40:40 kg $N:P_2O_5:K_2O$ ha^{-1} ($S_1M_1F_2$) recorded significantly higher seed yield (835 kg ha^{-1}) and haulm yield (3017 kg ha^{-1}) compared to other treatment combinations (Table 2). This was might be due to synergistic effect between spacing, method of sowing and fertilizer levels which were more effective than their individual effects and also due to higher plant population, availability of optimum space, early growth, competition for solar light and nutrients for growth and development. Lower seed yield and haulm yields were observed with the spacing of 75 × 20 cm in transplanting along with the application of 30:20:20 kg $N:P_2O_5:K_2O$ ha^{-1} (590 and 2302 kg ha^{-1}, respectively). This might be due to less plant population, transplanting shock from uprooting seedling from nursery and less availability of nutrients. These results were in close conformity with the findings of Bochicchio *et al*. studied the effect of plant density and nitrogen top dressing on growth and yield of Chia. The

Table 2. Seed yield and harvest index of Chia as influenced by different spacing, method of sowing and fertilizer levels

Treatment		Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)
Spacing (S)				
S_1	45 cm × 20 cm	797a	2960a	21a
S_2	60 cm × 20 cm	730b	2749ab	20a
S_3	75 cm × 20 cm	618c	2394b	20a
S.Em.±		8.86	59.99	0.46
Method of sowing (M)				
M_1	Line sowing	722a	2719a	20a
M_2	Transplanting	708a	2683a	20a
S.Em. ±		11.61	22.06	0.18
Fertilizer levels (F)				
F_1	30 : 20 : 20 kg $N : P_2O_5 : K_2O$ ha^{-1}	686b	2636b	20a
F_2	60 : 40 : 40 kg $N : P_2O_5 : K_2O$ ha^{-1}	744a	2766a	21a
S.Em. ±		12.05	41.45	0.32
Interaction (S × M × F)				
	$S_1M_1F_1$	778ab	2927ab	21a
	$S_1M_1F_2$	835a	3017a	21a
	$S_1M_2F_1$	745ab	2930ab	20a
	$S_1M_2F_2$	819ab	2967a	21a
	$S_2M_1F_1$	708bc	2698a-c	20a
	$S_2M_1F_2$	765ab	2862ac	21a
	$S_2M_2F_1$	690b-d	2598b-d	21a
	$S_2M_2F_2$	765ab	2838ab	21a
	$S_3M_1F_1$	594d	2363cd	20a
	$S_3M_1F_2$	650cd	2445cd	21a
	$S_3M_2F_1$	590d	2302d	20a
	$S_3M_2F_2$	639cd	2464cd	20a
	S.Em. ±	29.52	101.53	0.79

Means followed by the same alphabet (s) within a column do not differ significantly by DMRT (P = 0.05)

Table 3. Economic of Chia cultivation as influenced by different spacing, method of sowing and fertilizer levels

Treatment		Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C
Spacing (S)				
S_1	45 cm × 20 cm	159462a	129702a	5.36a
S_2	60 cm × 20 cm	146013b	116302b	4.91b
S_3	75 cm × 20 cm	123707c	94036c	4.17b
S.Em. ±		1772.29	1772.29	0.06
Method of sowing (M)				
M_1	Line sowing	144421a	114640a	4.85a
M_2	Transplanting	141702a	112054a	4.78a
S.Em. ±		2321.87	2321.87	0.08
Fertilizer levels (F)				
F_1	30 : 20 : 20 kg N : P_2O_5 : K_2O ha^{-1}	137278b	108513b	4.77a
F_2	60 : 40 : 40 kg N : P_2O_5 : K_2O ha^{-1}	148845a	118181a	4.85a
S.Em. ±		2410.04	2410.04	0.08
Interaction (S × M × F)				
	$S_1M_1F_1$	155629ab	126798ab	5.40a
	$S_1M_1F_2$	167185a	136454a	5.44a
	$S_1M_2F_1$	151185ab	122394ab	5.25a
	$S_1M_2F_2$	163851a	133161ab	5.34a
	$S_2M_1F_1$	141722bc	112891bc	4.92ab
	$S_2M_1F_2$	153055ab	122325ab	4.98ab
	$S_2M_2F_1$	138166b-d	109475b-d	4.82ab
	$S_2M_2F_2$	151111b	120520b	4.94ab
	$S_3M_1F_1$	118933d	90102d	4.16ab
	$S_3M_1F_2$	130000cd	99269cd	4.23ab
	$S_3M_2F_1$	118031d	89419d	4.14b
	$S_3M_2F_2$	127866cd	97356cd	4.19ab
	S.Em. ±	5903.36	5903.36	0.20

Means followed by the same alphabet (s) within a column do not differ significantly by DMRT (P = 0.05)

yield of ripe fruits ranged between 133.7 kg ha^{-1} at plant density of 4 plants m^{-2} and N top dressing to 518.4 kg ha^{-1} at plant density of 125 plants m^{-2} and with nitrogen top dressing. Improvement in nutrient availability with the application of higher fertilizer levels resulted in increased yield parameters and which contributed to the higher seed yield and haulm yield.

Number of spikes per plant, spike length and seed yield per plant were significantly higher with the interaction of spacing of 75 × 20 cm in line sowing along with 60:40:40 kg N:P_2O_5:K_2O ha^{-1} ($S_3M_1F_2$). These higher yield parameters are due to wider row spacing, early establishment and higher fertilizer levels leading to efficient use of all available resources and continuous availability of nutrients throughout the crop growth period without any interruption for nutrient requirements. These results were in close conformity with the findings of Sobhana *et al.* (2012) who found that higher availability of source under higher N:P_2O_5:K_2O rates created more sink than at lower fertilizer levels.

Economics of chia cultivation

Among spacing, significantly higher gross returns (₹ 1,59,462 ha^{-1}), net returns (₹ 1,29,702 ha^{-1}) and benefit cost ratio of 5.36 was obtained with the 45 × 20 cm spacing compared to other spacing. Similar findings were reported by Mary *et al.* (2018) in chia. Higher net return and higher benefit cost ratio with 45 × 20 cm was mainly due to higher seed yield (Table 3).

Effect of method of sowing was found non-significant. However, numerically higher gross returns (₹ 1,44,421 ha^{-1}),net return (₹ 1,14,640 ha^{-1}) and benefit cost ratio (4.85) was recorded along with line sowing compared to transplanting. Among the fertilizer levels, 60:40:40 kg N:P_2O_5:K_2O ha^{-1} recorded significantly higher gross returns (₹ 1,48,845 ha^{-1}), net returns (₹ 1,18,181 ha^{-1}) and benefit cost ratio (4.85). These results were in close conformity with Mary *et al.* (2018) who found that higher economic advantage was due to higher seed yield of the treatment.

Significantly higher gross returns (₹ 1,67,185 ha^{-1}),net returns (₹ 1,36,454 ha^{-1}) and benefit cost ratio (5.44) was observed with interactions of spacing of 45 × 20 cm with line sowing along with the application of 60:40:40 kg N:P_2O_5:K_2O ha^{-1} fertilizer compared to other combinations. Lower gross returns (₹ 1,18,031 ha^{-1}), net returns (₹ 89,419 ha^{-1}) and benefit cost ratio of 4.14 was obtained with the spacing of 75 × 20 cm with transplanting along with the application of 30:20:20 kg N:P_2O_5:K_2O ha^{-1} fertilizer. This was mainly due to lower seed yield obtained with this interaction.

Conclusion

Based on the results it was concluded that line sowing at a spacing of 45 × 20 cm along with the application of 60:40:40 kg N:P_2O_5:K_2O ha^{-1} found optimum for higher seed yield and net returns of Chia in northern transition zone of Karnataka.

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