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# Effect of spacings and fertilizer levels on yield paramters, yield and quality of chia (*Salvia hispanica* L.)

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**Abstract**
A field experiment was conducted in *Kharif* 2016 at the research field of College of Agriculture, Shivamogga to determine the effect of different spacings and fertilizer levels on the yield and quality parameters of Chia crop. The experiment consisted of three levels of spacings ($S_1$: 60cm x 22.5cm, $S_2$: 60cm x 30cm and $S_3$: 60cm x 45cm) and three levels of fertilizers ($F_1$: 30:20:25 kg NPK ha$^{-1}$, $F_2$: 60:40:50 kg NPK ha$^{-1}$ and $F_3$: 90:60:75 kg NPK ha$^{-1}$). Experimental design adopted was two factor symmetrical experiment with RCBD having three replications. Crop was first established in nursery and then transplanted in main field at 18 days after sowing. Full dose of phosphorus and potassium fertilizers were applied as basal while, half of nitrogen was applied as basal and remaining half was applied 20 days after transplanting as top dressing. Result of the study shown significant increase in number of spikes plant$^{-1}$ and seed yield with spacing, 60cm x 45cm (76.01 and 597.59 kg ha$^{-1}$) and fertilizer level, 90:60:75 kg NPK ha$^{-1}$ (69.39 and 623.60 kg ha$^{-1}$). Significant number of spikes and yield (88.57 and 676.58 kg ha$^{-1}$) obtained in treatment combination, 60cm x 45 cm with 90: 60: 75 kg NPK ha$^{-1}$ compared to other treatment combinations. Oil per cent showed significantly different result with fertilizer dosage and gave significantly superior oil (30.64 %) at lower fertilizer dosage. Protein content in seeds increased significantly with increase in fertilizer levels and recorded significantly higher per cent in $F_3$ (23.85 %) and was superior to $F_2$ (21.50 %) and $F_1$ (20.17 %). Alpha linolenic acid content is significantly influenced by fertilizer dosage. Significantly higher content of alpha linolenic acid (55.66 %) is shown by $F_1$: 30:20:25 kg NPK ha$^{-1}$ compared to other higher dosage of fertilizers.

**Keywords:** Chia, oil, protein, alpha linolenic acid, spikes

## Introduction
The world population is increasing at an alarming rate and demand- supply curve for food production is not intersecting each other, there is a lacuna for achieving food and nutrition security. Around 795 million people are undernourished around the world and it's about 12.9 per cent for developing countries. In India also, the condition is not different. The food habit of the people is also changing across worldwide. The demand for functional food with several health benefits is increasing due to higher public health awareness worldwide. Therefore, there is a need for shifting into more nutritious and energy rich super food crops.

Chia (*Salvia hispanica* L.) is a plant of Mexican and South American origin belonging to Lamiaceae family. 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.

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 rainfed areas of Mysore and Chamarajanagara districts.

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 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 Mysore district. Standardisation of suitable location specific agronomic practices with respect to spacing and fertilizer application is essentially required to popularize this crop in Southern Transition Zone of Karnataka.

**Material & methods**

A field experiment was conducted during *Kharif* season of 2016 at experimental field of College of Agriculture, Navile, Shivamogga. The crop variety used in the experiment was CHIAmpion B-1. Experimental site was situated at $14^0$ $0^1$ to $14^0$ $1^1$ North Latitude and $75^0$ $40^1$ to $75^0$ $42^1$ East Longitude with an altitude of 650 meters above the mean sea level. The average rainfall of the zone was 817 mm received in 56 rainy days. Soil of the experimental site belonged to taxonomic class sandy loam texture. The experiment was laid out in factorial Randomized Complete Block design with nine treatment combinations and three replications. The treatments consist of three spacings (S) – $S_1$: 60cm x 22.5cm, $S_2$: 60cm x 30cm and $S_3$: 60cm x 45cm and three fertilizer levels (F) – $F_1$: 30:20:25 kg NPK/ha, $F_2$: 60:40:50 kg NPK/ha and $F_3$: 90:60:75 kg NPK/ha. The Chia crop was first established in a nursery and then transplanted to main field at eighteen DAS. Full dose of phosphorus and potassium were applied as basal during transplanting while fifty percent of nitrogen was applied as basal and remaining half was top dressed at 20 DAT.

Five plants were selected at random and labeled in each net plot for recording observations on growth and yield parameters at 30 DAT, 60 DAT, 90 DAT and at harvest. The quality parameters like oil, protein and fatty acid composition (α- linolenic acid, linoleic acid, oleic acid, palmitic acid and stearic acid) were determined by AOAC approved methods. Oil was estimated by the Soxhlet method using hexane as solvent. Protein content was determined by FLASH 2000 N/Protein Analyzer using modified Dumas principle. Using GCMS (Gas chromatography Mass spectrometer) method, fatty acid composition of Chia seeds was analysed. Further, statistical analysis of the data was carried out as per the method suggested by (Gomez and Gomez, 1984) [2].

**Results & discussion**

**Effect of different spacings and fertilizer levels on yield parameters and yield of Chia**

The data on seed yield and yield parameters as influenced by spacing and fertilizer levels are presented in Table 1. The spacing of 60cm x 45cm resulted in significant increase in spike number at harvest (76.01) as compared to spacing of 60cm x 30cm (60.38) and closer plant spacing of 60cm x 22.5cm (47.59). Significantly higher number of spikes was obtained with higher fertilizer level $F_3$: 90:60:75 kg NPK/ha (69.39) as compared to the other two fertilizer levels (52.66-61.93). Number of spikes had shown a significant difference due to interaction of plant spacing and fertilizer levels and recorded a maximum number of spikes in $S_3F_3$ (88.57) and it is superior to all other treatment combinations. Due to increase in spacing and fertilizer dosage, more space will be available for each plant and competition between plants will be less, it will finally results into more branching and more number of spikes.

Significant differences in seed yield per plant were noticed at spacing S3 (14.09 g/plant) as compared to other two spacings (7.01- 10.95 g/plant). The fertilizer level of 90:60:75 kg NPK/ha resulted a significantly higher yield per plant (11.90 g/plant) as compared to other two fertilizer levels of $F_1$: 30:20:25 kg NPK/ha (9.35 g/plant) and $F_2$: 60:40:50 kg NPK/ha (10.80 g/plant). The interaction of 60cm x 45cm spacing and fertilizer level of 90:60:75 kg NPK/ha resulted in higher seed yield per plant (15.33 g/plant) as compared to all other treatment combinations. The increase in per plant yield at wider spacing is attributed to less intra plant competition and more space was available for each plant results into increase in per plant yield. The availability of required quantity of nutrients is probably responsible for producing more number of productive branches.

Crop planted at a spacing of 60cm x 45cm spacing resulted in maximum seed yield (597.59 kg/ha) was on par with spacing 60cm x 30cm (580.69 kg/ha) and significantly superior to spacing 60cm x 22.5cm (489.15 kg/ha). Similar results have been reported by Yeboah. *et al.* (2014) [6] that 0.5mx0.5m (40,000 plants/ha) planting density produced the highest biomass and seed yield in both years of study (2012 & 2013). Crop maintained at fertilizer level 90:60:75 kg NPK/ha resulted into significantly superior yield (623.60 kg/ha) as compared to other fertilizer levels (477.95- 565.88 kg/ha). The treatment combination of 60cm x 45cm spacing and fertilizer level of 90:60:75 kg NPK/ha ($S_3F_3$) produced significantly highest yield (676.58 kg/ha) and was superior to all other treatment combinations (357.58- 582.75 kg/ha). The variation in yield was associated with variation in plant population and number of spikes produced as well as difference in the amount of nutrients available in the rhizosphere of plant system.

The haulm yield was highest at a spacing of 60cm x 45cm (3837.28 kg/ha) and was superior to all other spacings (2377.37- 3496.06 kg/ha). The fertilizer level of 90:60:75 kg NPK/ha resulted into significantly superior haulm yield (3669.16 kg/ha) as compared to other fertilizer levels (2703.71- 3337.84 kg/ha). The interaction effect of plant density and fertilizer levels was non-significant in relation to haulm yield. Planting of Chia at a spacing of 60cm x 22.5cm resulted a harvest index of 0.17 and was significantly superior to other spacings (0.13-0.15). The harvest index obtained by 90:60:75 kg NPK/ha (0.16) was on par with other fertilizer levels (0.15). The interaction effect of plant spacing and fertilizer levels was non-significant in relation to harvest index. The test weight of Chia seeds had shown non-significant result for both individual effect and interaction effect.

**Table 1:** Yield and yield parameters of Chia as influenced by different spacings and fertilizer levels.

| Treatment | No. of spikes (at harvest) | Seed yield/plant (g/plant) | Seed yield (kg/ha) | Haulm yield (kg/ha) | Test weight (g) | Harvest Index |
|---|---|---|---|---|---|---|
| **Spacing** | | | | | | |
| $S_1$ | 47.59 | 7.01 | 489.15 | 2377.37 | 1.12 | 0.17 |
| $S_2$ | 60.38 | 10.95 | 580.69 | 3496.06 | 1.14 | 0.15 |
| $S_3$ | 76.01 | 14.09 | 597.59 | 3837.28 | 1.15 | 0.13 |
| SEm± | 1.17 | 0.23 | 9.62 | 65.80 | 0.02 | 0.01 |
| CD (P= 0.05) | 3.51 | 0.68 | 28.83 | 197.28 | NS | 0.01 |
| **Fertilizer level** | | | | | | |
| $F_1$ | 52.66 | 9.35 | 477.95 | 2703.71 | 1.11 | 0.15 |
| $F_2$ | 61.93 | 10.80 | 565.88 | 3337.84 | 1.13 | 0.15 |
| $F_3$ | 69.39 | 11.90 | 623.60 | 3669.16 | 1.17 | 0.16 |
| SEm± | 1.17 | 0.23 | 9.62 | 65.80 | 0.02 | 0.01 |
| CD (P= 0.05) | 3.51 | 0.68 | 28.83 | 197.28 | NS | 0.01 |
| **Interaction** | | | | | | |
| $S_1F_1$ | 41.23 | 4.93 | 357.58 | 1876.58 | 1.08 | 0.16 |
| $S_1F_2$ | 47.83 | 7.15 | 520.23 | 2430.86 | 1.11 | 0.18 |
| $S_1F_3$ | 53.70 | 8.96 | 589.63 | 2824.69 | 1.16 | 0.19 |
| $S_2F_1$ | 54.73 | 10.18 | 542.82 | 2901.23 | 1.11 | 0.15 |
| $S_2F_2$ | 60.50 | 11.27 | 594.65 | 3636.33 | 1.13 | 0.14 |
| $S_2F_3$ | 65.90 | 11.41 | 604.59 | 3950.61 | 1.16 | 0.15 |
| $S_3F_1$ | 62.00 | 12.93 | 533.44 | 3333.33 | 1.13 | 0.13 |
| $S_3F_2$ | 77.47 | 14.00 | 582.75 | 3946.34 | 1.14 | 0.13 |
| $S_3F_3$ | 88.57 | 15.33 | 676.58 | 4232.17 | 1.17 | 0.14 |
| SEm± | 2.03 | 0.39 | 16.66 | 113.98 | 0.03 | 0.01 |
| CD (P= 0.05) | 6.08 | 1.17 | 49.94 | NS | NS | NS |

**Effect of different spacings and fertilizer levels on quality parameters of Chia seeds.**

The data on oil, protein and fatty acid composition of seeds as influenced by spacing and fertilizer levels are given in Table 2.

The spacing of 60cm x 30cm resulted in significantly higher oil content (29.50 %) as compared with other spacings (27.37-27.92 %). The other two spacings were statistically on par with each other. The lowest fertilizer treatment $F_1$: 30:20:25 kg NPK/ha registered high oil content (30.64%) and was significantly superior to other fertilizer levels (26.20-27.94 %). The results confirmed the findings of earlier researchers on various crops who pointed out that oil content decreased with the increasing rate of N (Cheema *et al*., 2001; Saleem *et al*., 2001) [1, 4]. Significant differences were not observed in oil yield due to interaction of spacing and fertilizer level. Spacing of $S_2$: 60cm x 30cm resulted into higher protein (22.67%) and was on par with 60cm x 45 cm (21.67%). Fertilizer level of 90:60:75 kg NPK/ha recorded high protein content (23.85%) and significantly superior to other fertilizer levels (20.17-21.50 %). Higher protein per cent may be attributed to more content of nutrients in the seeds at higher fertilizer level especially nitrogen content. The interaction between spacing and fertilizer levels did not show any significant effect of protein content.

The different spacings did not show any significant influence on fatty acid composition of oil present in seeds. The lower fertilizer level ($F_1$) application had shown a significant difference in different fatty acid contents and recorded 55.66 per cent ALA content which is on par with $F_2$ (53.78%). The lower fertilizer level contributed more for ALA content in oil. OA and PA content was recorded higher (11.77% and 8.94%, respectively) in $F_3$ and was on par with $F_2$ (11.64% and 8.44%, respectively). Similar results shown by Silva *et al.* (2015) [5] and reported that on average, the fatty acids can be ranked in the following order of abundance: linolenic acid (C18:3) > linoleic acid (C18:2) > palmitic acid (C16:0) > oleic acid (C18:1) > stearic acid (C18:0). Ixtaina *et al.* (2011) [3] reported a similar distribution between the fatty acids for chia oil obtained from solvent extraction (n-hexane) and pressing. The interaction of different spacings and fertilizer levels did not show any significant difference in fatty acid composition of oil in Chia seeds.

**Table 2:** Quality parameters of Chia as influenced by different spacings and fertilizer levels.

| Treatment | Oil (%) | Protein (%) | Fatty acid composition (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | ALA | LA | OA | PA | SA |
| **Spacing** | | | | | | | |
| $S_1$ | 27.37 | 21.18 | 54.14 | 22.95 | 10.91 | 8.39 | 3.92 |
| $S_2$ | 29.50 | 22.67 | 54.45 | 22.56 | 11.15 | 8.42 | 4.16 |
| $S_3$ | 27.92 | 21.67 | 53.09 | 22.56 | 11.31 | 8.79 | 4.27 |
| SEm± | 0.57 | 0.38 | 0.90 | 0.44 | 0.30 | 0.18 | 0.20 |
| CD (P= 0.05) | 1.70 | 1.14 | NS | NS | NS | NS | NS |
| **Fertilizer level** | | | | | | | |
| $F_1$ | 30.64 | 20.17 | 55.66 | 22.65 | 9.96 | 8.22 | 3.86 |
| $F_2$ | 27.94 | 21.50 | 53.78 | 22.84 | 11.64 | 8.44 | 4.03 |
| $F_3$ | 26.20 | 23.85 | 52.23 | 22.58 | 11.77 | 8.94 | 4.45 |
| SEm± | 0.57 | 0.38 | 0.90 | 0.44 | 0.30 | 0.18 | 0.20 |
| CD (P= 0.05) | 1.70 | 1.14 | 2.70 | NS | 0.91 | 0.55 | NS |
| **Interaction** | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $S_1F_1$ | 29.67 | 19.36 | 55.49 | 22.71 | 9.78 | 8.14 | 3.75 |
| $S_1F_2$ | 26.66 | 20.99 | 54.22 | 23.28 | 10.81 | 8.27 | 3.73 |
| $S_1F_3$ | 25.77 | 23.20 | 52.70 | 22.86 | 12.13 | 8.78 | 4.28 |
| $S_2F_1$ | 32.03 | 21.08 | 56.57 | 22.46 | 9.91 | 7.95 | 3.74 |
| $S_2F_2$ | 29.40 | 22.28 | 54.63 | 22.56 | 11.32 | 8.47 | 4.36 |
| $S_2F_3$ | 27.07 | 24.66 | 52.14 | 22.66 | 12.23 | 8.84 | 4.39 |
| $S_3F_1$ | 30.23 | 20.06 | 54.93 | 22.78 | 10.19 | 8.57 | 4.10 |
| $S_3F_2$ | 27.76 | 21.24 | 52.50 | 22.68 | 12.78 | 8.59 | 4.00 |
| $S_3F_3$ | 25.78 | 23.71 | 51.84 | 22.22 | 10.96 | 9.21 | 4.70 |
| SEm± | 0.98 | 0.66 | 1.56 | 0.75 | 0.52 | 0.32 | 0.35 |
| CD (P= 0.05) | NS | NS | NS | NS | NS | NS | NS |

ALA: Alpha linolenic acid, LA: Linoleic acid, PA: Palmitic acid, SA: Stearic acid, OA: Oleic acid

## Conclusion

It is concluded from the study that spacing at 60cm x 45cm with a fertilizer dose of 90: 60: 75 kg NPK/ha significantly increased the yield by 11.90 per cent in comparison to the spacing of 60cm x 30cm with 90:60:75 kg NPK/ha fertilizer level and was superior to all other treatments. The yield per plant also responds positively to increase in spacing and fertilizer levels. The quality of seeds with respect to protein content (23.85%) also improved with increase in fertilizer level and the composition of fatty acids did not show any significant difference due to the effect of different spacings and fertilizer levels.

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