EFFECT OF VARIOUS CROP SPACINGS AND FERTILIZERS ON YIELD AND ECONOMICS OF CHIA (*SALVIA HISPANICA* L.)

UMILSINGH, N.[1*] – VENKATACHALAPATHI, V.[2] – LATHA, H. S.[3] – BOBBE, S.[4] – MADHU, B.[5] – SREE, Y. S.[1] – ANUSHKA, A. S.[1]

[1]*Department of Agronomy, Tamil Nadu Agricultural University (TNAU) Coimbatore, Tamil Nadu, India*

[2]*Department of Agronomy, Agricultural Research Station (ARS), Chintamani, Karnataka, India*

[3]*AICRP for Dryland Agriculture, University of Agricultural Sciences (UAS), GKVK, Bangalore, Karnataka, India*

[4]*School of Agriculture, Mohanbabu University, Tirupati, Andhra Pradesh, India*

[5]*Department of Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu, India*

**Corresponding author*
e-mail: umilsingh1459@gmail.com

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Abstract. Chia, prized for its medicinal properties and high omega-3 fatty acids, gained traction in India when farmers in the Mysore region began cultivating it, leading to its spread across the state due to its superior returns over traditional crops. During the *kharif* season of 2019, a field study was conducted at the Agricultural Research Station in Chintamani, Karnataka, India to assess the impact of various crop geometries and nutrient management strategies on the yield and economic viability of Chia (*Salvia hispanica* L.). The experiment involved twelve different treatment combinations arranged in a Factorial Randomized Block Design, each replicated three times. The results of the study showed that compared to other crop geometries, Chia planted at a wider spacing (60×30 cm) produced significantly greater seed yield (1015 kg ha^{-1}), net returns (₹ 113883 ha^{-1}), and B:C ratio (3.95). Applying 80:60:60 kg NPK ha^{-1} was shown to be superior to other treatments in the study and produced considerably better seed production (1020 kg ha^{-1}), net returns (₹ 113580 ha^{-1}), and B:C ratio (3.88) among other nutrient management approaches. Treatment combination of 60×30 cm with 80:60:60 kg NPK ha^{-1} resulted maximum yield (1122 kg ha^{-1}), net return and B: C ratio (₹ 128915 ha^{-1} and 4.26, respectively).
Keywords: *B: C ratio, gross returns, net returns, seed, spacing*

Introduction

The high nutritional value of chia seeds (Ixtaina et al., 2011), which include minerals, carbs, protein, fatty acids, high dietary fiber, lipids, vitamins, and a significant amount of antioxidants led to the plants rise in popularity (Coates, 2009). Because of its nutrient-rich grain and leaves, this seed crop has been grown for thousands of years (Umilsingh et al., 2023). Native to mountainous regions of Mexico and Guatemala, chia (*Salvia hispanica* L.) is an oil-rich annual herbaceous plant of the Lamiaceae (mint) family (Ixtaina et al., 2008). It has been consumed and domesticated as a staple food crop by Mesoamerican Indian Tribes since 2600 BC (Manasa et al., 2023). The demand for chia seeds in the United Kingdom registered a Compound Annual Growth Rate (CAGR) of 7% during the forecast years. China and India are poised to witness a

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growth rate of 6.1% and 8.9% in the production of chia seeds by 2033 (https://www.globenewswire.com).

Growing chia typically costs about Rs. 15000 per acre in Indian currency, which is comparable to other crops *viz.,* finger millet and maize (Prasanna et al., 2021). An acre of chia will typically generate 500–600 kg of seed (Cahill, 2003; Prasanna et al., 2021) but under appropriate agronomic conditions the yield of 2120 kg/hectare has also been reported (Ayerza and Coates, 2005). Chia is the richest botanical oil source of α-linolenic acid (omega-3) known and Chia is an oilseed crop with potential use as human food (Coorey et al., 2012; Zanqui et al., 2015). Global demand for chia seeds has increased due to growing knowledge of functional foods (Ayerza, 2013 and Singh et al., 2023a). Its short growing season (90–105 days), reduced water requirements and cultivation costs, immunity to pests, diseases, and animals, and excellent yields are the main factors influencing its popularity among Indian farmers. Despite its great nutritional value and extensive adaptability, its commercial potential has not been realized. There is a dearth of literature on ideal densities, seed rates, spacing, and other agronomic practices for its growing in India. Because of its high nutritious content and ability to withstand harsh weather, chia seeds are becoming increasingly commonplace. It becomes clear that developing context-specific agronomic practices-such as appropriate spacing and accurate fertilizer application is necessary to promote the widespread acceptance of this crop in Eastern dry zone of Karnataka. With this in mind, the current test was supported to evaluate the influence of various spacing and fertilizer levels on yield and economics of chia.

Materials and methods

Experimental site

The current study was carried out at the Agricultural Research Station, Chintamani, Karnataka, India, during the rainy (*Kharif*) season of 2019. The station is located in the Eastern Dry Zone of Karnataka (EDZ), 918 meters above mean sea level (MSL), at 13° 24’ N latitude and 78° 04’ E longitude. June was the month with the most rainfall (217.60 mm), while the least amount (13.60 mm) was recorded in December. 497.50 mm of rain fell between July 2019 and November 2019 during cropping season. It was noted that the mean maximum temperature in June was 33.59°C, while the mean minimum temperature in December was 17.96°C. In December, the mean maximum monthly relative humidity was recorded at 84.03 percent, while in July, the mean minimum monthly relative humidity was recorded at 73.68 percent with mean maximum (7.06) and minimum (3.84) sunshine hours recorded from June 2019 to December 2019 (*Table 1; Fig. 1*).

Experimental details

The soil was sandy loam in texture with water holding capacity 38.60%, the pH of the soils was acidic (5.60) and electrical conductivity was normal (0.16 dSm^{-1}). The soil was medium in organic carbon content (0.54%), medium in available nitrogen (366.91 kg ha^{-1}), phosphorus (46.69 kg ha^{-1}) and high in potassium (373.10 kg ha^{-1}). Factorial Randomized Complete Block Design (FRCBD) was used to set up the experiment, with three fertilizer dosages (40:20:20, 60:40:40, and 80:60:60 kg NPK ha^{-1}) and four varied spacing levels (45×15, 45×30, 60×15, and 60×30 cm).

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There were three replications for each of the twelve treatment combinations. The details of treatment were in *Table 2*.

Table 1. *Comparative study of monthly meteorological data for the cropping period 2019 and mean of 10 years (2008-2018) recorded at the agricultural meteorological observatory, Agricultural Research Station, Chintamani*

Months	Rainfall (mm)		No of rainy days	Monthly maximum temperature (°C)		Monthly minimum temperature (°C)		Relative humidity at 07:17 (%)		Relative humidity at 14:17 (%)		Sunshine hours	
	N	A		N	A	N	A	N	A	N	A	N	A
January	4.44	12.80	1	28.67	29.00	15.12	16.28	75.26	80.74	51.81	54.55	7.36	8.50
February	2.40	0.00	0	30.62	31.57	16.66	18.43	66.87	66.07	43.62	55.89	9.27	9.13
March	46.40	0.00	0	33.69	36.63	19.36	20.65	59.19	61.45	42.65	52.97	8.56	9.06
April	45.30	134.80	4	35.76	37.25	21.19	20.50	55.78	61.23	42.31	56.93	8.36	7.80
May	126.24	47.20	7	34.93	36.53	20.84	20.80	60.84	72.45	48.63	68.71	7.43	3.26
June	58.00	217.60	7	31.65	33.59	20.28	20.24	68.94	78.57	57.76	74.47	5.31	7.06
July	71.64	45.70	3	30.34	30.88	20.09	20.89	70.50	78.10	60.84	73.68	3.75	4.18
August	95.80	74.10	7	30.10	29.54	20.03	20.56	73.86	79.65	64.75	76.74	4.86	4.23
September	112.16	130.40	11	29.81	29.79	19.85	20.56	72.64	81.43	63.82	76.67	5.35	5.09
October	136.98	99.00	9	29.81	29.95	19.09	19.81	71.92	81.03	64.65	78.26	6.80	5.26
November	80.92	45.30	3	28.39	29.04	16.87	18.95	71.71	82.40	64.28	78.53	6.10	6.44
December	24.32	13.60	2	27.79	27.60	15.46	17.96	74.57	84.03	63.18	80.94	6.98	3.84
Total	804.06	820.50	54	371.56	381.37	224.84	235.63	822.08	907.15	668.3	828.34	80.13	73.85

N: Normal (Mean of 2008-2018) A: Actual

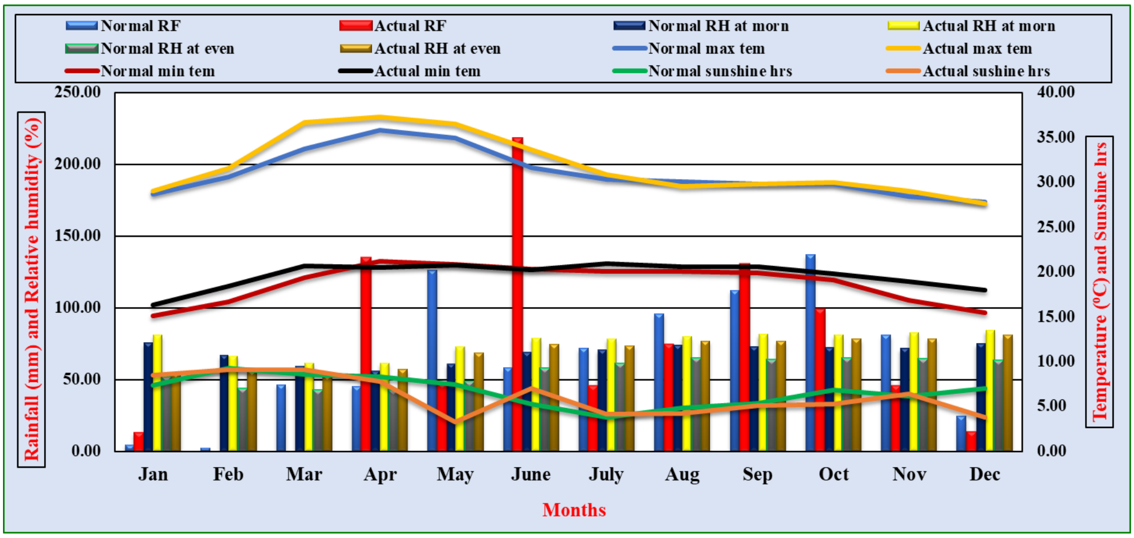

Figure 1. *Comparative study of monthly meteorological data for the cropping period 2019 and mean of 10 years (2008-2018) recorded at the agricultural meteorological observatory, Agricultural Research Station, Chintamani*

Crop management

Chia seeds (CHIAmpion B-1) were obtained from the Central Food Technological Research Institute (CFTRI) in Mysore, manually sown during the II FN of June (25th June, 2019), and harvested on the I FN of November (4th November, 2019). Crop density and fertilizer were maintained according to the suggested procedures. Nitrogen,

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phosphorus, and potassium were applied using urea, single super phosphate (SSP), and muriate of potash (MOP) according to treatment. During planting, a full dose of potassium, phosphorus, and half of the nitrogen dose were given as basal, the remaining half of the nitrogen was top dressed at 40 DAS. Africa and Asia are seeing an increase in the growth of chia because it is regarded as a wholesome, high-nutrient food. In rainfed parts of Mysore and Chamarajanagara districts, the Central Food Technological Research Institute (CFTRI) has introduced this crop to farmers and provided technical support for its growth. As a new crop, in chia the pest and diseases were not observed during experimental period (Mary et al., 2018a). The harvesting was done when spikes were separated and dried. The process of threshing involved gently striking the spikes inside a tarpaulin with sticks. At harvest, the cleaned, threshed seeds were recorded along with their haulm yield.

Table 2. *The details of treatments*

Treatments	Details
T_1	45×15 cm spacing with 40:20:20 kg NPK ha^{-1}
T_2	45×15 cm spacing with 60:40:40 kg NPK ha^{-1}
T_3	45×15 cm spacing with 80:60:60 kg NPK ha^{-1}
T_4	45×30 cm spacing with 40:20:20 kg NPK ha^{-1}
T_5	45×30 cm spacing with 60:40:40 kg NPK ha^{-1}
T_6	45×30 cm spacing with 80:60:60 kg NPK ha^{-1}
T_7	60×15 cm spacing with 40:20:20 kg NPK ha^{-1}
T_8	60×15 cm spacing with 60:40:40 kg NPK ha^{-1}
T_9	60×15 cm spacing with 80:60:60 kg NPK ha^{-1}
T_{10}	60×30 cm spacing with 40:20:20 kg NPK ha^{-1}
T_{11}	60×30 cm spacing with 60:40:40 kg NPK ha^{-1}
T_{12}	60×30 cm spacing with 80:60:60 kg NPK ha^{-1}

Seed and haulm yield

The net plots were harvested and sun dried for 5 days in the field and then the total biomass yield was recorded. After threshing, cleaning and drying seed yield was recorded. Haulm yield was obtained by subtracting seed yield from total biomass yield. Yield was expressed in kg ha^{-1}.

Harvest index

The harvesting index was calculated by using the formula as outlined by Donald (1963):

$$HI = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{) (seed + haulm)}}$$

Cost of cultivation

The cost of input that prevailed at the time of their use was considered to work out the cost of cultivation. The cost of cultivation was worked out considering the material input cost like the seed, manure, fertilizer, plant protection chemicals etc. and labor for

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all the operations. Treatment wise cost of cultivation was worked out and expressed as rupees (₹) hectare^{-1}. The detail of cost of cultivation is furnished in *Table 3*.

Table 3. *Prices of inputs and outputs*

Sl. No	Components	No of units ha^{-1}	Price unit^{-1} (₹)	Total (₹)
1	Main land preparation			
	(a) Disc ploughing	3	1000	3000
	(b) Cultivator	3	1000	3000
	(c) Rotavator	3	1000	3000
2	Seed cost	1.5 kg	300	450
3	Sowing	10	200	2000
4	Thinning and gap filling (Women labor)	5	200	1000
5	Weeding (Women labor)	15	200	3000
6	Earthing up (Men labor)	5	250	1250
7	Farm yard manure (5 t ha^{-1})	2 tractors	3500	7000
8	Harvesting			
	Women labor	20	200	4000
9	Post harvesting			
	(a) Men labor	5	250	1250
	(b) Women labor (threshing, winnowing and cleaning)	12	200	2400
10	Marketing and transportation	1	5000	5000
11	Market price of chia seeds	-	150 kg^{-1}	-
12	Fertilizer			
	(a) Urea	-	5.5 kg^{-1}	-
	(b) SSP	-	18.5 kg^{-1}	-
	(c) MOP	-	26 kg^{-1}	-

Gross returns

The procuring price of seeds by Central Food Technological Research Institute (CFTRI), Mysore was used for calculation of gross returns and expressed as rupees per hectare:

$$\text{Gross returns (₹ ha}^{-1}\text{)} = \text{Market price (₹ per kg) x Seed yield (kg/ha)}$$

Net returns

The net return per hectare was calculated by subtracting the total cost of cultivation from gross return and expressed in rupees per hectare:

$$\text{Net returns (₹ ha}^{-1}\text{)} = \text{Gross returns (₹ ha}^{-1}\text{)-Cost of cultivation (₹ ha}^{-1}\text{)}$$

B:C ratio

Benefit cost ratio was worked out by using the following formula:

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$$\text{B:C ratio (₹)} = \frac{\text{Gross returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

In order to understand the data and reach a conclusion, additional statistical analysis of the data was performed using Fisher's methods of analysis of variance (ANOVA), as described by Gomez and Gomez (1984).

Results and discussion

Seed and haulm yield

The seed and haulm yield were influenced significantly due to varying spacings and fertilizers levels (*Table 4*). Compared to other spacings, a wider spacing of 60×30 cm produced significantly higher seed and haulm yield (1015 and 4765 kg ha^{-1}) whereas a closer spacing of 45×15 cm produced the lowest yields. In comparison to the other fertilizer dosages, the application of 80:60:60 kg NPK ha^{-1} produced a much greater seed and haulm yield (1020 and 4124 kg ha^{-1}). The least seed and haulm yield was noticed under 40:20:20 kg NPK ha^{-1}, but was shown on par outcomes with application of 60:40:40 kg NPK ha^{-1} (3844 kg ha^{-1}) with pertaining to haulm yield. Among various spacing and fertilizer combinations revealed that 60×30 cm with 80:60:60 NPK kg ha^{-1} produced considerably more seed and haulm yields (1122 and 5248 kg ha^{-1}) than the other combinations. In terms of seed yield, it was also found to be statistically similar to T_{11}, T_9, and T_6. However, the least yield was attained with treatment combination of 45×15 cm with 40:20:20 kg NPK ha^{-1}. Data in *Table 4* shown that the different spacings and interactions did not find any significant effect on harvest index. Application of 80:60:60 kg NPK ha^{-1} had recorded significantly higher harvest index (0.20) which was statistically at par with fertilizer level of 60:40:40 kg NPK ha^{-1} and superior over 40:20:20 kg NPK ha^{-1}.

The seed and haulm yield were influenced significantly due to varying spacings. *Table 4* shows that the wider spacing (60×30 cm) resulted in a 43.97% higher seed output of chia than the 45×15 cm spacing. Expanding the spacing to 60×30 cm may result in a higher seed yield, which could be attributed to more spikes and spikelets per plant, longer spikes, and more seed produced per plant. Yeboah et al. (2014) and Mary et al. (2018b) also reported significantly higher seed yield with wider spacing of 50×50 cm and 60×45 cm spacing, respectively. Similarly, the significantly increased haulm yield of chia with wider spacing of 60×30 cm was 59.58% more over 45×15 cm spacing. The notable improvement in growth components, such as the number of branches and leaves plant^{-1} and dry matter deposits, might have led to the increased haulm production at 60×30 cm spacing as compared to narrow spacings. As fertilizer dosage was increased, chia seed output increased dramatically (*Table 4*). Applied highest fertilizer dose (80:60:60 kg NPK ha^{-1}) noticed higher seed yield at the rate of 43.86% as compared to lower fertilizer level (40:20:20 kg NPK ha^{-1}). Increased use of fertilizer, which led to an increase in plant nutrient uptake, cell elongation, leaf area, photosynthetic synthesis, and improved nutrient translocation to the site of usage. Rahman et al. (2023) reported that more branching, inflorescences, leaves, and total dry matter accumulation plant^{-1} were all aided by the maximum spacing and fertilizer levels, which ultimately produced a larger yield. Less intra plant competition and greater room for each plant, which promoted plant growth and ultimately increased seed yield, were blamed for the rise in seed yield with wider spacing.

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Table 4. *Influence of spacing and fertilizer levels on seed, haulm yield and harvest index of chia*

Treatments	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index
Spacing (S)			
S_1: 45 × 15 cm	705	2986	0.19
S_2: 45 × 30 cm	915	4140	0.18
S_3: 60 × 15 cm	814	3457	0.19
S_4: 60 × 30 cm	1015	4765	0.17
S.Em ±	**28.8**	**152.4**	**0.01**
CD (P = 0.05)	**84.4**	**447.1**	**NS**
Fertilizer levels (F)			
F_1: 40:20:20 kg NPK ha^{-1}	709	3542	0.17
F_2: 60:40:40 kg NPK ha^{-1}	857	3844	0.18
F_3: 80:60:60 kg NPK ha^{-1}	1020	4124	0.20
S.Em ±	**24.9**	**132.0**	**0.01**
CD (P = 0.05)	**73.1**	**387.2**	**0.02**
Interaction (S×F)			
S_1F_1: 45 × 15 cm with 40:20:20 kg NPK ha^{-1}	579	2822	0.17
S_1F_2: 45 × 15 cm with 60:40:40 kg NPK ha^{-1}	686	2952	0.19
S_1F_3: 45 × 15 cm with 80:60:60 kg NPK ha^{-1}	848	3184	0.21
S_2F_1: 45 × 30 cm with 40:20:20 kg NPK ha^{-1}	809	3964	0.17
S_2F_2: 45 × 30 cm with 60:40:40 kg NPK ha^{-1}	904	4107	0.18
S_2F_3: 45 × 30 cm with 80:60:60 kg NPK ha^{-1}	1031	4349	0.19
S_3F_1: 60 × 15 cm with 40:20:20 kg NPK ha^{-1}	532	3023	0.15
S_3F_2: 60 × 15 cm with 60:40:40 kg NPK ha^{-1}	831	3630	0.19
S_3F_3: 60 × 15 cm with 80:60:60 kg NPK ha^{-1}	1079	3718	0.23
S_4F_1: 60 × 30 cm with 40:20:20 kg NPK ha^{-1}	916	4362	0.17
S_4F_2: 60 × 30 cm with 60:40:40 kg NPK ha^{-1}	1008	4685	0.18
S_4F_3: 60 × 30 cm with 80:60:60 kg NPK ha^{-1}	1122	5248	0.17
S.Em ±	**49.8**	**264.0**	**0.01**
CD (P = 0.05)	**146.2**	**NS**	**NS**

NS: Non-significant DAS: Days after sowing

Better yield qualities were linked to greater yield levels that resulted from applying higher concentrations of fertilizer. These results are in accordance with the findings of Mary et al. (2018a) who found application of fertilizers as high as 90:60:75 kg NPK ha^{-1} increased the productivity of chia. Haulm yield was significantly lower at low level of fertilizer, which was reduced at the rate of 14.11% at 40:20:20 kg NPK ha^{-1} as compared to highest dose of fertilizer (80:60:60 kg NPK ha^{-1}). Similar results were reported in chia where positive yield was found under wider spacing and higher dose of fertilizer treatment by Mary et al. (2018b), Mohanty et al. (2021) and Singh et al. (2023b). Assessment of the production of dry matter and its distribution to different regions was crucial for determining the ultimate biological and economic return (Donald, 1963). Haulm yield at harvest mainly depends on the dry matter production. Up to 90 DAS, the production of dry matter increased linearly; beyond that, it decreased since most plant leaves had fallen off. Wider spacing and increased NPK fertilizer

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levels reduced competition for nutrients, which in turn affected the height and branch count of the plants, increasing haulm output (Rahman et al., 2023). The amount of nutrients accessible in the plant system rhizosphere, the number of spikes produced, and variations in plant population were all linked to variations in output However, compared to lower fertilizer levels, dry matter was larger at higher fertilizer levels due to persistence of higher no. of leaves. There was a noticeable difference in the harvest index between different fertilizer levels. However, appreciable improvement of harvest index with higher dose of fertilizer was mainly due to higher economic yield.

Economics

Gross returns, net returns and B: C ratio of chia varied due to spacing and fertilizer levels (*Table 5*).

Table 5. *Influence of spacing and fertilizer levels on economics of chia*

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B: C ratio
Spacing (S)				
S_1: 45 × 15 cm	38505	105749	67244	2.74
S_2: 45 × 30 cm	38505	137259	98754	3.56
S_3: 60 × 15 cm	38505	122179	83674	3.16
S_4: 60 × 30 cm	38505	152388	113883	3.95
S.Em ±	**0.000**	**4317.4**	**4317.4**	**0.11**
CD (P = 0.05)	**NS**	**12662.6**	**12662.6**	**0.33**
Fertilizer levels (F)				
F_1: 40:20:20 kg NPK ha^{-1}	37510	106441	68931	2.84
F_2: 60:40:40 kg NPK ha^{-1}	38505	128661	90155	3.34
F_3: 80:60:60 kg NPK ha^{-1}	39499	153079	113580	3.88
S.Em ±	**0.000**	**3739.0**	**3739.01**	**0.10**
CD (P = 0.05)	**0.001**	**10966.1**	**10966.14**	**0.29**
Interaction (S×F)				
S_1F_1: 45 × 15 cm with 40:20:20 kg NPK ha^{-1}	37510	86950	49439	2.32
S_1F_2: 45 × 15 cm with 60:40:40 kg NPK ha^{-1}	38505	103042	64537	2.68
S_1F_3: 45 × 15 cm with 80:60:60 kg NPK ha^{-1}	39499	127257	87757	3.22
S_2F_1: 45 × 30 cm with 40:20:20 kg NPK ha^{-1}	37510	121353	83842	3.24
S_2F_2: 45 × 30 cm with 60:40:40 kg NPK ha^{-1}	38505	135641	97136	3.52
S_2F_3: 45 × 30 cm with 80:60:60 kg NPK ha^{-1}	39499	154783	115284	3.93
S_3F_1: 60 × 15 cm with 40:20:20 kg NPK ha^{-1}	37510	79948	42438	2.13
S_3F_2: 60 × 15 cm with 60:40:40 kg NPK ha^{-1}	38505	124725	86220	3.24
S_3F_3: 60 × 15 cm with 80:60:60 kg NPK ha^{-1}	39499	161863	122364	4.10
S_4F_1: 60 × 30 cm with 40:20:20 kg NPK ha^{-1}	37510	137514	100003	3.67
S_4F_2: 60 × 30 cm with 60:40:40 kg NPK ha^{-1}	38505	151235	112729	3.92
S_4F_3: 60 × 30 cm with 80:60:60 kg NPK ha^{-1}	39499	168415	128915	4.26
S.Em ±	**0.0006**	**7478.02**	**7478.02**	**0.19**
CD (P = 0.05)	**NS**	**21932.28**	**21932.28**	**0.57**

NS: Non-significant DAS: Days after sowing

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Application 60×30 cm with 80:60:60 kg NPK ha^{-1} reported highest cost of cultivation (₹ 39499 ha^{-1}) and lowest in 40:20:20 kg NPK ha^{-1} (₹ 37510 ha^{-1}). The higher gross returns, net returns and B:C ratio registered significantly with spacing level of 60×30 cm (₹ 152388 ha^{-1}, ₹ 113883 ha^{-1} and 3.95, respectively) and which was statistically superior than other spacings and least in 45×15 cm. Among all fertilizer dosages, 80:60:60 kg NPK ha^{-1} resulted significantly higher gross returns, net returns and B: C ratio ₹ 153078 ha^{-1}, ₹ 113580 ha^{-1} and 3.88, respectively) as compared to other levels. Nevertheless, least was obtained under 40:20:20 kg NPK ha^{-1} (₹ 106441 ha^{-1} 68931 ha^{-1} and 2.84, respectively). Combination of 60×30 cm with 80:60:60 kg NPK ha^{-1} was registered significantly higher gross, net return and B: C ratio (₹ 168415 ha^{-1}, ₹ 128915 ha^{-1} and 4.26, respectively) which was statistically on par with T_9, T_6 followed by T_{11} and superior over rest of the treatments. A least net return was recorded in treatment combination of 45×15 cm with 40:20:20 kg NPK ha^{-1} (₹ 86950 ha^{-1}, ₹ 49439 ha^{-1} and 2.32, respectively).

Wider spacing in conjunction with higher fertilizer levels (60×30 cm with 80:60:60 kg NPK ha^{-1}) produced the highest gross, net income, and B: C ratio. This was attributed to higher market prices (₹ 150 kg^{-1}), lower cultivation costs, and higher seed yields due to optimal plant population and adequate fertilizer supply, which in turn produced more dry matter, spikes, and seed yield per plant. The similar results were reported by Thakur et al. (2014) in sweet basil and Mary et al. (2018a) in chia. The higher gross returns, net returns and B: C ratio was mainly due to higher seed yield and prevailing higher market prices were reported by AL-mansour et al. (2017) and Manasa et al. (2023).

Conclusion

It is concluded that when chia were planted at 60×30 cm spacing and 80:60:60 kg NPK ha^{-1} fertilizer level, the maximum seed output with better net returns and B: C ratio was recorded. This was determined to be more cost-effective and long-lasting than the other therapies. Therefore, it might be advised to obtain both the highest possible yield and larger returns.

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APPENDIX

Base ANOVA tables

ANOVA table for seed yield

SV	Df	SS	MSS	F cal	Table F
Replication	2	9734.22	4867.11	0.65	3.44
Treatment	11	1178037.84	107094.35	14.36	2.26
Spacing (S)	3	480677.56	160225.85	21.49	3.05
Fertilizer (F)	2	580461.06	290230.53	38.92	3.44
SXF	6	116899.22	19483.20	2.61	2.55
Error	22	164034.26	7456.10		
Total	**35**	**1351806.32**			

SV: Source of variation; df: degrees of freedom; SS: Sum of Square; MSS: Mean sum of square; F cal: Calculated F value; Table F: Table F value

ANOVA table for haulm yield

SV	df	SS	MSS	F cal	Table F
Replication	2	265118.53	132559.27	0.63	3.44
Treatment	11	18886366.92	1716942.45	8.21	2.26
Spacing (S)	3	16392757.04	5464252.35	26.12	3.05
Fertilizer (F)	2	2032817.47	1016408.74	4.86	3.44
SXF	6	460792.40	76798.73	0.37	2.55
Error	22	4601444.65	209156.57		
Total	**35**	**23752930.10**			

SV: Source of variation; df: degrees of freedom; SS: Sum of Square; MSS: Mean sum of square; F cal: Calculated F value; Table F: Table F value

ANOVA table for harvest index

SV	df	SS	MSS	F cal	Table F
Replication	2	0.001	0.001	1.17	3.44
Treatment	11	0.013	0.001	1.85	2.26
Spacing (S)	3	0.001	0.000	0.700	3.05
Fertilizer (F)	2	0.007	0.003	5.376	3.44
SXF	6	0.005	0.001	1.248	2.55
Error	22	0.014	0.001		
Total	**35**	**0.028**			

SV: Source of variation; df: degrees of freedom; SS: Sum of Square; MSS: Mean sum of square; F cal: Calculated F value; Table F: Table F value

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ANOVA table for gross return

SV	df	SS	MSS	F cal	Table F
Replication	2	219019861.44	109509930.72	0.65	3.44
Treatment	11	26505851473.74	2409622861.25	14.36	2.26
Spacing (S)	3	10815245001.39	3605081667.13	21.49	3.05
Fertilizer (F)	2	13060373959.01	6530186979.51	38.92	3.44
SXF	6	2630232513.35	438372085.56	2.613	2.55
Error	22	3690770771.17	167762307.78		
Total	**35**	**30415642106.35**			

SV: Source of variation; df: degrees of freedom; SS: Sum of Square; MSS: Mean sum of square; F cal: Calculated F value; Table F: Table F value

ANOVA table for net return

SV	df	SS	MSS	F cal	Table F
Replication	2	219019861.44	109509930.72	0.65	3.44
Treatment	11	25416536164.21	2310594196.75	13.77	2.26
Spacing (S)	3	10815245001.39	3605081667.13	21.49	3.05
Fertilizer (F)	2	11971058649.48	5985529324.74	35.68	3.44
SXF	6	2630232513.35	438372085.56	2.61	2.55
Error	22	3690770771.17	167762307.78		
Total	**35**	**29326326796.82**			

Note: SV: Source of variation; df: degrees of freedom; SS: Sum of Square; MSS: Mean sum of square; F cal: Calculated F value; Table F: Table F value

ANOVA table for B:C ratio

SV	df	SS	MSS	F cal	Table F
Replication	2	0.15	0.08	0.67	3.44
Treatment	11	15.68	1.43	12.57	2.26
Spacing (S)	3	7.36	2.45	21.64	3.05
Fertilizer (F)	2	6.46	3.23	28.50	3.44
SXF	6	1.85	0.31	2.73	2.55
Error	22	2.49	0.11		
Total	**35**	**18.33**			

SV: Source of variation; df: degrees of freedom; SS: Sum of Square; MSS: Mean sum of square; F cal: Calculated F value; Table F: Table F value

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