Original Research Article

Optimization of spacing and fertilizer levels on growth, yield parameters and yield of chia (*Salvia hispanica*. L)

ABSTRACT

A field experiment was conducted during *Kharif* season-2019 at Agricultural Research Station, Chintamani, Karnataka. The experiment consisted of four levels of spacing (45 × 15, 45 × 30, 60 × 15 and 60 × 30 cm) and three levels of fertilizer (40:20:20, 60:40:40 and 80:60:60 kg NPK ha^{-1}) to determine the influence of different spacing and fertilizer levels on growth and yield of chia (*Salvia hispanica*. L). The experiment was arranged in statistical design of Factorial Randomized Complete Block Design (FRCBD) with three replications. The report of study indicated that, among different spacings 60 × 30 cm was recorded significantly higher number of leaves plant^{-1} (108), number of primary and secondary branches plant^{-1} (22.38 and 27.69, respectively), Dry matter accumulation plant^{-1} (146.09 g) and seed yield (1015 kg ha^{-1}) however, spacing of 45 cm × 15 cm produced significantly superior plant height (125.57 cm). Among different fertilizer levels the application dose of 80:60:60 kg NPK ha^{-1} recorded significantly higher plant height (125.59 cm), number of leaves plant^{-1} (103.67), number of primary and secondary branches plant^{-1} (22.47 and 27.63, respectively), Dry matter accumulation plant^{-1} (131.47 g), seed yield (1020 kg ha^{-1}). Significantly higher seed yield (1122 kg ha^{-1}) was obtained in the treatment combination of 60 × 30 cm with 80:60:60 kg NPK ha^{-1} compared to other treatments.

Key words: chia, fertilizer, spacing, growth parameters and yield

1. INTRODUCTION

India is likely to be the most populous country on this planet by 2030 with 1.6 billion people. It currently accounts for more than 17 per cent of the global population and 456 million poor, or 41.6 per cent living on less than $1.25 a day (Chen and Ravallion, 2008).

Ensuring food and nutrition security is thus a challenge for India. Despite historically high levels of food production in India, undernourishment problem persists. At present, 22.5 per cent of adults are underweight and 38 per cent are still stunted. Current high levels of malnutrition are often due to unbalanced diets with insufficient nutrition diversity.

Chia (*Saliva hispanica* L.) is an annual pseudo cereal and oilseed crop belonging to the family of Lamiaceae originated in Mexico and Guatemala (Ixtaina *et al*., 2008). Chia is dicotyledonous, approximately a meter tall, with opposite, petiolate and serrated leaves that are 4 to 8 cm long and 3 to 5 cm wide. The plant has quadrangular stems that are ribbed and hairy. The flowers are hermaphrodite and grow in numerous clusters in a spike protected by small bracts with long pointed tips. The fruit of chia, as in other plants of the Lamiaceae family, is a schizocarp consisting of indehiscent locules that separate to form four fruitlets, referred to mericarps or nutlets. As chia is a rich source of omega-3 and 6 fatty acids, dietary fibre (25 %), proteins (20 %), oil (35 %), minerals, vitamins and great source of antioxidants and amino acids particularly lysine, which are essential for normal human growth and development and further appears to be important for the prevention and treatment of several diseases, it has a major role to play in human nutrition and health (Samantha *et al*., 2019).

Chia is very sensitive to low temperature and day length, the growing cycle is strictly depending on latitude from where it is planted (Coates, 2011). Chia seeds can be a food supplement and are widespread in vegetarian and gluten-free diets. Chia is a plant characterized by low water requirement and well adapted to arid and semiarid regions (Ayerza and Mealia, 1993) The flour, a byproduct of oil extraction, can be used as human and animal feed supplement is high in fiber and constituents with antioxidant activity (Ayerza and Coates, 1999). The cultivation of Chia (*Salvia hispanica* L.) is gaining popularity in world due to its health benefits hence, this recognised as super food crop for its superior nutritional value. It is consumed as seeds and can be used as food supplements (Ayerza and Coates, 2000).

Commercial cultivation of Chia is gaining momentum all over the world, but in India it is in budding stage. In recent years' cultivation of this crop was started in Karnataka by the farmers of Mysore and chamarajanagara districts under the technical guidance of Central Food Technological Research Institute (CFTRI), Mysore about its nutritional quality. Agronomic management is one of the most important aspects for the success of any crop with efficient utilization of all the resources. Investigations of the past have clearly brought out the significance of the cultural practices viz., crop geometry, irrigation, weeding, and nutritional strategies are the major determinants of crop productivity. However, information regarding suitability of this crop under different agro-climatic conditions, optimum spacing and fertility levels *etc*. To be followed is not properly ascertained as it is a newly introduced crop to India in general and Karnataka in particular.

2. MATERIAL AND METHODS

The field study was carried out in the Kharif season of 2019 at Agricultural research Station, Chintamani, Karnataka, situated at 13° 24' N Latitude and 78° 04' E Longitude with at elevation of 918 m above the mean sea level (MSL) In Eastern Dry Zone of Karnataka

(EDZ). The average annual rainfall of the zone was 820.50 mm received in 54 rainy days. The other distinct climatic features of experimental site has tropical climate, characterized by high temperature and low humidity. The soil chemical analysis revealed that soil was sandy loam in texture with water holding capacity of 38.60 per cent, the pH of the soils is acidic (5.60) and electrical conductivity was normal (0.16 dSm^{-1} at 25°C). 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}). The experiment was set up using Factorial Randomized Complete Block Design (RBD) having four spacing levels (45×15, 45×30, 60×15 and 60×30 cm) and three levels of fertilizers (40:20:20, 60:40:40 and 80:60:60 kg NPK ha^{-1}). There were twelve treatments replicated thrice, with plot size of 19.44 m^2 (5.4 m × 3.6 m) each.

Table 01: Treatment details

Factor A	**Spacing (cm)**
S_1	45 × 15 cm
S_2	45 × 30 cm
S_3	60 × 15 cm
S_4	60 × 30 cm
Factor B	**Levels of fertilizer (kg ha^{-1})**
F_1	40:20:20 kg NPK ha^{-1}
F_2	60:40:40 kg NPK ha^{-1}
F_3	80:60:60 kg NPK ha^{-1}

Crop variety 'CHIAmpion B-1' seeds were collected from Central Food Technological Research Institute (CFTRI), Mysore and seeded manually on fourth week of June and harvested on first week of November. The crop geometry was maintained as per the spacing prescribed for the treatments. Nitrogen, phosphorus and potassium were provided through Urea, Single super phosphate (SSP) and Muriate of potash (MOP) according to treatments. Full dose of phosphorus, potassium and half dose of nitrogen was applied as basal during sowing while, the remaining half of nitrogen was top dressed at 40 days after sowing.

Five plants were selected at random and labelled in each net plot for recording non-destructive observations on growth and yield parameters. The observations on growth parameters *viz.* plant height, number of primary and secondary branches, number of leaves and dry weight were taken at 30, 60, 90 DAS and at harvest and the data on yield characters *viz.* Number of spikes per plant, Number of spikelets per spike, Spike length per spike,test weight, seed and haulm yield were recorded at harvest.

3. RESULTS AND DISCUSSION

A. Effect of spacing and fertilizer levels on growth parameters of chia

The data on growth parameters at different days after sowing as influenced by spacing and fertilizer levels are presented in table 2 to 6. During crop growth, the crop spaced at 45 × 15 cm was attained significantly taller plant (Table 2) at 30 DAS over 60 × 30 cm spacing but at par with the spacing of 45 × 30 and 60 × 15 cm. Also, at 60, 90 DAS and at harvest with spacing of 45 × 15 cm was attained significantly higher plants, which was on par with spacing of 60 × 15 cm. Statistically, superior over other spacing of 45 × 30 cm and 60 × 30.

Spacing plays an important role in crop production as non-monetary input. This was apparently because individual plant with narrow spacing did not get the opportunity to proliferate laterally due to the less lateral space. Hence plants were compelled to grow more in upward direction for the fulfilment of light requirement for photosynthesis. Significant increase in plant height from early stages of crop growth under closer spacing (45 × 15 cm) might be due to mutual shading because of dense population which might have decreased the availability of light to the plants. These results are in close agreement with the findings of Singh *et al.* (2004) in basil, Yeboah *et al.* (2014), Bilalis *et al.* (2016) and Mary *et al.* (2018) in chia and Pooja *et al.* (2018) in sacred basil.

The wider spacing of 60 × 30 cm produced significantly higher number of leaves per plant (Table 3), number of primary and secondary branches per plant (Table 4) at all growth stages throughout the crop growth period as compared to 45 × 30, 45 × 15 cm and 60 × 15 cm spacing. Data pertaining to number of leaves at wider spacing of 60 × 30 cm was at par with 45 × 30 cm spacing at all the stages of crop growth while number of secondary branches was on par with 45 × 30 cm spacing at harvest stage. Plants at wider spacing received higher growth inputs (sunlight, water and nutrient) and availability of more space for spreading of branches which helped in more interception of light due to higher leaf surface area with lesser competition as compared to plants grown under closer spacing. This resulted in increased higher number of primary and secondary branches, this in turn resulted in production of more number of leaves per plant. The results were in agreement with the findings of Kailash and kushwaha (2013) in basil, Yeboah *et al.* (2014) in chia, Mahantesh *et al.* (2017) in Japanese mint and Mary *et al.* (2018) in chia.

Table 02: Effect of spacing and fertilizer levels on plant height (cm) at different growth stages of chia

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Spacing (S)				
S_1: 45 × 15 cm	22.00	68.98	101.47	125.57
S_2: 45 × 30 cm	19.81	57.55	90.86	112.96
S_3: 60 × 15 cm	20.08	64.02	94.44	118.60
S_4: 60 × 30 cm	18.07	52.83	83.29	108.93
S.Em±	**0.82**	**2.30**	**2.89**	**2.70**
CD (P=0.05)	**2.42**	**6.77**	**8.48**	**7.92**
Fertilizer levels (F)				
F_1: 40:20:20 kg NPK ha^{-1}	17.48	53.64	83.20	108.35
F_2: 60:40:40 kg NPK ha^{-1}	19.84	59.45	93.40	115.60
F_3: 80:60:60 kg NPK ha^{-1}	22.65	69.45	100.95	125.59
S.Em±	**0.71**	**2.00**	**2.50**	**2.33**
CD (P=0.05)	**2.10**	**5.86**	**7.35**	**6.86**
Interaction (S×F)				
S.Em ±	**1.43**	**3.99**	**5.01**	**4.67**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**

Dry matter accumulation per plant (Table 5) was recorded significantly superior in 60 × 30 cm spacing than 45 × 30, 60 × 15 and 45 × 15 at 60, 90 DAS and at harvest. However, it was found on par with 45 × 30 cm spacing at 30 DAS. Data on dry matter accumulation in different plant parts had significant influence on leaf, stem and spike was recorded significantly higher in 60 × 30 cm compared with others but at par with 45 × 30 cm spacing. (Table 5). The significant increase in total dry matter accumulation per plant at wider spacing (60 × 30 cm) was ascribed to production of more number of primary and secondary branches, more number of leaves per pant under wider spacing (60 × 30 cm). The major portion of dry matter was accumulated in stem at all growth stages due to more branching pattern and more inter row and intra row spacing (60 × 30 cm). These results are in accordance with the findings of Kailash and kushwaha (2013) in basil and Mary *et al.* (2018) in chia.

Table 03: Influence of spacing and fertilizer levels on number of leaves per plant at different growth stages of chia

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Spacing (S)				
S_1: 45 × 15 cm	38.73	109.81	131.24	79.56
S_2: 45 × 30 cm	42.77	145.13	176.12	101.89
S_3: 60 × 15 cm	41.40	130.87	142.05	88.56
S_4: 60 × 30 cm	44.12	154.50	187.41	108.00
S.Em±	**0.90**	**5.21**	**4.54**	**4.25**
CD (P=0.05)	**2.64**	**15.27**	**13.31**	**12.48**
Fertilizer levels (F)				
F_1: 40:20:20 kg NPK ha^{-1}	38.20	126.32	133.60	81.83
F_2: 60:40:40 kg NPK ha^{-1}	41.52	133.50	167.32	98.00
F_3: 80:60:60 kg NPK ha^{-1}	45.55	145.42	176.68	103.67
S.Em±	**0.78**	**4.51**	**3.93**	**3.68**
CD (P=0.05)	**2.29**	**13.22**	**11.53**	**10.81**
Interaction (S×F)				
S.Em±	**1.56**	**9.02**	**7.86**	**7.37**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**

Among the fertilizer levels, application of 80:60:60 kg NPK ha^{-1} noticed significantly higher plant height, number of leaves, primary, secondary branches and dry matter accumulation compared to other fertilizer levels *i.e.*, 60:40:40 kg NPK ha^{-1} and 40:20:20 kg NPK ha^{-1} at all the stages of crop growth. Where as, number of leaves per plant was at par with 60:40:40 kg NPK ha^{-1} at 60, 90 DAS and at harvest. The increased growth components might be nitrogen which triggers the growth of meristematic tissue and efficient utilization of resources by the plants manifested in production of taller plants. Split application of nitrogen at higher dosage might have contributed production of more number of branches per plant particularly secondary branches due to availability of nitrogen in optimum quantities. Increased number of branches per plant at higher fertility levels resulted in production of more the number of leaves per plant. The outcomes of this studies agreed with findings of Singh *et al*. (2004) in french basil, Coates *et al*. (2011), Kailash and kushwaha (2013) in basil, Mahantesh *et al.* (2017) in mint, Mary *et al.* (2018) in chia, Pooja *et al*. (2018) in sacred basil and Salman *et al.* (2019) in chia.

Table 04: Influence of spacing and fertilizer levels on number of primary and secondary branches per plant at different growth stages of chia

Treatments	30	60 DAS	90 DAS	At harvest

	DAS	Primary	Secondary	Primary	Secondary	Primary	Secondary
Spacing (S)							
S_1: 45 × 15 cm	2.22	13.24	15.13	18.40	20.79	20.76	23.69
S_2: 45 × 30 cm	3.43	14.30	18.01	19.20	23.06	21.60	26.80
S_3: 60 × 15 cm	3.14	13.89	16.74	18.81	22.26	21.02	25.59
S_4: 60 × 30 cm	4.07	15.63	19.83	20.51	25.80	22.38	27.69
S.Em±	**0.22**	**0.36**	**0.29**	**0.37**	**0.44**	**0.27**	**0.55**
CD (P=0.05)	**0.63**	**1.06**	**0.84**	**1.09**	**1.31**	**0.78**	**1.61**
Fertilizer levels (F)							
F_1: 40:20:20 kg NPK ha^{-1}	2.48	13.08	15.39	18.35	20.07	20.35	24.22
F_2: 60:40:40 kg NPK ha^{-1}	3.20	13.98	17.28	19.09	22.80	21.50	25.98
F_3: 80:60:60 kg NPK ha^{-1}	3.98	15.74	19.61	20.25	26.07	22.47	27.63
S.Em±	**0.19**	**0.31**	**0.25**	**0.32**	**0.38**	**0.23**	**0.48**
CD (P=0.05)	**0.55**	**0.91**	**0.73**	**0.94**	**1.13**	**0.68**	**1.39**
Interaction (S×F)							
S.Em±	**0.37**	**0.63**	**0.49**	**0.64**	**0.77**	**0.46**	**0.95**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**2.26**	**NS**	**NS**

Similarly, at 30 DAS application of 80:60:60 kg NPK ha^{-1} attained significantly higher dry matter accumulation per plant but found statistically on par with 60:40:40 kg NPK ha^{-1}. Significantly superior in higher amount of leaf, stem and spike dry matter accumulation per plant was at fertilizer level of 80:60:60 kg NPK ha^{-1} compared to all others at harvest stage. The dry matter production of entire plant (Table 5) increased linearly with the time up to 90 DAS and then reduced due to defoliation of majority of the leaves from the plants. However, the persistence of leaves was higher at higher fertilizer level, hence dry matter existed more compared to lower fertilizer level. Out of total dry matter produced per plant, major portion of dry matter was contributed by stem, which was increased at the rate of 19.80 per cent at harvest in higher fertilizer level (80:60:60 kg NPK ha^{-1}) compared to lower fertilizer level. Spike weight also linearly increased with increased fertilizer levels. This was ascribed to better availability of metabolites and nutrients, which synchronized to the demand for growth and development of each reproductive structure of the plant. These results are line with the findings of Kailash and Kushwaha, (2013) in basil, Bilalis *et al.* (2016) and Mary *et al.* (2018) in chia.

Treatment combinations of spacing and fertilizer levels did not attain the level of significance with respect to plant height, number of leaves, primary, secondary branches, dry matter accumulation per plant at all the growth durations and its distribution at harvest. But treatment combination of 60 × 30 cm with 80:60:60 kg NPK ha^{-1} produced significantly higher number of secondary branches per plant at 90 DAS when compared to all other interactions.

Table 05: Influence of spacing and fertilizer levels on dry matter accumulation per plant (g) at different growth stages of chia

Treatments	30 DAS	60 DAS	90 DAS	At harvest			
				Leaf	Stem	Spike	Total

Spacing (S)							
S_1: 45 × 15 cm	13.61	57.45	99.86	9.37	57.35	20.34	87.06
S_2: 45 × 30 cm	16.01	78.25	147.36	20.19	70.67	40.40	131.26
S_3: 60 × 15 cm	15.00	69.34	129.91	17.11	65.99	33.49	116.60
S_4: 60 × 30 cm	16.68	85.59	163.16	21.60	72.14	52.36	146.11
S.Em±	**0.34**	**0.96**	**2.18**	**0.87**	**2.16**	**2.41**	**3.17**
CD (P=0.05)	**1.02**	**2.83**	**6.41**	**2.54**	**6.35**	**7.08**	**9.30**
Fertilizer levels (F)							
F_1: 40:20:20 kg NPK ha^{-1}	14.49	65.61	115.67	14.25	59.88	32.98	107.08
F_2: 60:40:40 kg NPK ha^{-1}	15.38	72.78	135.58	17.25	68.00	35.93	121.17
F_3: 80:60:60 kg NPK ha^{-1}	16.11	79.59	153.97	19.69	71.74	41.03	132.52
S.Em±	**0.30**	**0.83**	**1.89**	**0.75**	**1.87**	**2.09**	**2.75**
CD (P=0.05)	**0.88**	**2.45**	**5.55**	**2.20**	**5.50**	**6.13**	**8.06**
Interaction (S×F)							
S.Em±	**0.60**	**1.67**	**3.78**	**1.50**	**3.75**	**4.18**	**5.49**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Effect of spacing and fertilizer levels on yield and yield parameters of chia

Yield attributes

The perusal data on yield attributes presented in the table 6, indicated that chia sown at wider spacing of 60 × 30 cm has produced significantly more number of spikes per plant, spikelets per spike and seed yield per plant than other spacing levels of 45 × 30 cm, 60 × 15 cm and 45 × 15 cm. However, spikelets per spike were sown at wider spacing was found on par with 45 × 30 cm. Among the fertilizer dosage of 80:60:60 kg NPK ha^{-1} has produced significantly greater number of spikes per plant, spikelets per spike and seed yield per plant which were statistically superior over 60:40:40 kg NPK ha^{-1} and 40:20:20 kg NPK ha^{-1}.

However, spacing, fertilizer levels and its interaction were failed to register significant difference in spike length per spike and test weight (1000 seed weight) though the maximum spike length and test weight was recorded when the crop was maintained at wider spacing at 60 × 30 cm. The treatment combination of wider spacing 60 × 30 cm and application of higher dose of 80:60:60 kg NPK ha^{-1} produced significantly higher number of spikes per plant and seed yield per plant as compared to other levels.

This yield attributing characters may be attributed to greater inputs resulted in profused branching which in turn production of higher number of spike per plant and also ascribed to the increased branching and translocation of photosynthates to reproductive parts. The results are agreeing with the findings of Mary *et al*. (2018) in chia and Jaybhay (2019) in soybean. Similar result was reported by Robin *et al.* (2016) stated that longest inflorescences were observed on plants sown by 20 × 20 cm with 16.62 cm length compared to broadcasted plants had shortest inflorescence. Production of seed yield per plant due to better interaction of nitrogen, phosphorus and potassium at higher levels. These results are confirmed with the findings of Malik *et al*. (2001), Mary *et al*. (2018) in chia, Kwizera *et al.* (2018) in sunflower, Sewnet (2005) recognized that lesser seed yield per plant in closer spacing due to the proportion of non-photosynthetic area in the plant is increased by an increase in plant density and carbohydrate production was inhibited. Thus, seed formation also reduced. This was attributed to higher uptake of nutrients at higher fertilizer levels as a result of which foliage cover and canopy spread was more which resulted in higher dry matter per plant due to better interaction of nitrogen, phosphorus and potassium. These results are consistent with the finding of Mary *et al.* (2018) in chia.

Yield and harvest index

The seed and haulm yield (table 6) were influenced significantly due to varying spacings. The per cent increase in seed yield of chia due to wider spacing of 60 × 30 cm was 24.69, 10.92 and 43.97 more over of 60 × 15 cm, 45 × 30 cm and 45 × 15 cm spacing, respectively, (Table 5). In percentage of haulm yield of chia due to wider spacing of 60 × 30 cm was 37.83, 15.09 and 59.58 per cent more over of 60 × 15 cm, 45 × 30 cm and 45 × 15 cm spacings, respectively. Higher seed yield achieved from wider spacing of 60 × 30 cm might be due to number of spikes and spikelets per plant, spike length and seed yield per plant and the haulm yield was probably due to significant improvement in the parameters like number of branches and leaves per plant, dry matter accumulation than the narrow spacing of 60 × 15 cm, 45 × 30 cm and 45 × 15 cm. Yeboah *et al.* (2014) also reported significantly higher seed yield with wider spacing of 50 × 50 cm and 60 × 45 cm spacing, respectively. These results are in accordance with the findings of Mary *et al.* (2018) who found application of fertilizers as high as 90:60:75 kg NPK ha^{-1} increased the productivity of chia. The harvest index in contrast to the higher straw yield was noticed in the closer spacing of 45 × 15 cm and 60 × 15 cm (0.19 similar for both the spacing) was mainly due to higher economic yield (seed yield).

Seed and haulm yield of chia crop significantly increased with increase in fertilizer levels (Table 5). Highest fertilizer level $\mathbf{F_1}$ (80:60:60 kg NPK ha^{-1}) gave highest seed yield at the rate of 43.86 per cent as compared to lower fertilizer level ($\mathbf{F_3}$) and 19.01 per cent higher as compared to moderate level ($\mathbf{F_2}$). This was attributed to increased fertilizer application which let to nutrient uptake by plants and increased synthesis of photosynthates and better translocation of nutrients. The higher yield levels associated with application of higher levels of fertilizers were related to higher yield attributes such as number of spikes, longer spikes, higher number of spikelts per plant and seed weight per plant. These results are in accordance with the findings of Mary *et al.* (2018) 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 lower fertilizer levels ($\mathbf{F_2}$ and $\mathbf{F_3}$) which was reduced at the rate of 14.11 per cent at 40:20:20 and 7.86 per cent at 60:40:40 kg NPK ha^{-1}, respectively as compared to highest dose of fertilizer (80:60:60 kg NPK ha^{-1}). Haulm yield at harvest mainly depends on the dry matter production per plant. It increased linearly with time up to 90 DAS and then declined due to defoliation of leaves. But, the persistence of leaves was more at higher fertilizer levels, therefore dry matter was higher compared to lower fertilizer levels. Such as increase in dry matter production could be attributed to increase in number of leaves, number of branches (primary and secondary) and number of spikes per plant.

Various levels of fertilizer were shown significant effect on harvest index. However, appreciable improvement of harvest index with higher dose of fertilizer (80:60:60 kg NPK ha^{-1}) was mainly due to higher economic yield (seed yield). Among interactions 60 × 30 cm with 80:60:60 NPK kg ha^{-1} found significantly higher seed yield as compared to other treatments and was noticed statistically on par with **S_4F_2** (60 × 30 cm with 60:40:40 kg NPK ha^{-1}), **S_3F_3** (60 × 15 cm with 80:60:60 kg NPK ha^{-1}) and **S_2F_3** (45 × 30 cm with 80:60:60 kg NPK ha^{-1}). With respect to haulm yield and harvest index did not show any significant influence chia.

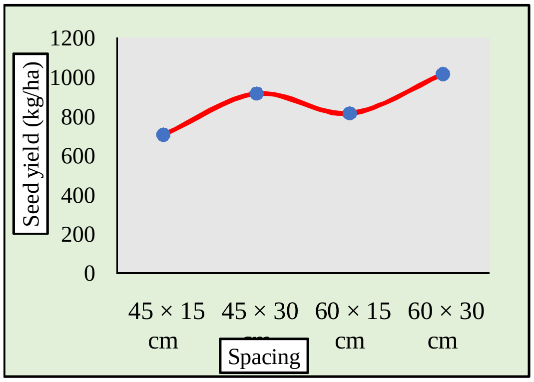

Fig 01: Optimization of spacings on seed yield

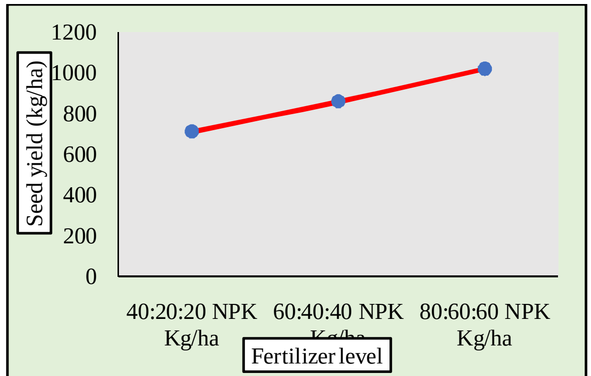

Fig 02: Optimization of fertilizer levels on seed yield

Optimization of inputs

Optimization of spacing and fertilizer levels on seed yield (kg ha^{-1}) was presented in fig. 01 and fig. 02. Optimization of these inputs were based on graphical presentation and peak of the curve on seed yield was taken as optimum. The figures show that spacing of 60 × 30 cm and application of 80:60:60 kg NPK ha^{-1} depicted maximum peak and maximum seed yield (1015 and 1020 kg ha^{-1}, respectively) during *Kharif*-2019. Hence, spacing of 60 × 30 cm and fertilizer level of 80:60:60 kg NPK ha^{-1} were found to be optimum in the present investigation.

Conclusion

On findings of the above-summarized results from one year experimentation the following conclusions have been drawn that the crop which was grown at 60 × 30 cm and 45 × 30 spacings were found that increased all the growth parameters (except plant height) yield and yield attributes. However, the higher plant height was more in spacing of 45 × 15 cm. Among the different fertilizer dosages, application of 80:60:60 kg NPK ha^{-1} recorded all the growth components, yield and yield characters compared to others. Combination of 60 × 30 cm + 80:60:60 kg NPK ha^{-1} recorded higher seed yield under eastern dry zone of Karnataka.

Table 6: Influence of spacing and fertilizer levels on yield attributes and yield of chia

Treatments	No. of spikes per plant	No. of spikelets spike^{-1}	Spike length (cm)	Seed yield plant^{-1} (g)	Test weight (g)	Seed yield (Kg ha^{-1})	Haulm yield (Kg ha^{-1})	Harvest index
Spacing (S)								
S_1: 45 × 15 cm	48.69	19.60	11.00	5.06	1.34	705	2986	0.19
S_2: 45 × 30 cm	67.32	27.17	14.17	12.81	1.37	915	4140	0.18
S_3: 60 × 15 cm	60.72	21.51	13.43	7.82	1.36	814	3457	0.19
S_4: 60 × 30 cm	81.68	28.50	14.82	18.62	1.40	1015	4765	0.17
S.Em±	**0.97**	**0.84**	**0.96**	**0.21**	**0.03**	**28.78**	**152.44**	**0.01**
CD (P=0.05)	**2.85**	**2.47**	**NS**	**0.61**	**NS**	**84.42**	**447.10**	**NS**
Fertilizer levels (F)								
F_1: 40:20:20 kg NPK ha^{-1}	55.57	22.21	12.55	9.56	1.35	709	3542	0.17
F_2: 60:40:40 kg NPK ha^{-1}	65.97	24.05	12.77	11.02	1.36	857	3844	0.18
F_3: 80:60:60 kg NPK ha^{-1}	72.26	26.33	14.75	12.65	1.38	1020	4124	0.20
S.Em±	**0.84**	**0.73**	**0.84**	**0.18**	**0.02**	**24.93**	**132.02**	**0.007**
CD (P=0.05)	**2.47**	**2.14**	**NS**	**0.53**	**NS**	**73.11**	**387.20**	**0.02**
Interaction (S×F)								
S.Em±	**1.69**	**1.46**	**1.67**	**0.36**	**0.04**	**49.85**	**264.04**	**0.01**
CD (P=0.05)	**4.95**	**NS**	**NS**	**1.06**	**NS**	**146.21**	**NS**	**NS**

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