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Response of chia (*Salvia hispanica* L.) to spacing and organic nutrient levels under Southern dry zone of Karnataka

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Abstract
A field experiment was conducted at Zonal Agricultural Research Station, V. C. Farm, Mandya to determine the response of chia to spacing and organic nutrient levels during *kharif* 2020-21 and 2021-22. The experiment was laid out in Factorial Randomized Complete Block Design with three replications. The spacing had non-significant influence with respect to soil available nutrients and soil microbial population. The pooled data indicated that among different organic nutrient levels, application of 100% RDN equivalent compost + application of jeevamrutha at the time of sowing and 30 DAS recorded significantly superior values of soil chemical properties *viz.*, available nitrogen (256.95 kg/ha), available phosphorus (29.53 kg/ha) and available potassium (189.72 kg/ha) and soil microbial population at 30 DAS *viz.*, bacteria (52.20×10^5 cfu/g of soil), fungi (11.39×10^4 cfu/g of soil) and actinomycetes (6.17×10^3 cfu/g of soil). Among spacing, 45 cm × 15 cm spacing registered statistically higher soil available nutrients (245.51, 28.35 and 184.08 NPK kg/ha, respectively) and soil microbial population at 30 DAS (46.82×10^5, 9.48×10^4 and 5.30×10^3 cfu/g of soil, respectively) compared to the spacing of 60 cm × 15 cm. The correlation and multiple regression analysis was done for quality parameters using R software.

Keywords: Chia, spacing, organic nutrient levels, quality parameters and microbial population

Introduction

Chia, scientifically known as *Salvia hispanica* (L.), is an herbaceous plant that completes its life cycle within a year and belongs to the *Lamiaceae* family. It can reach a height of up to one meter and features leaves arranged in pairs, along with small flowers in shades of purple or white, measuring 3 to 4 mm. These flowers have a smaller corolla and a fused flower part. The color of the chia seeds varies from grey, black, black pointed to white, with an oval shape and a size ranging from 1 to 2 mm (Bresson *et al*., 2009) [2].

Its cultivation 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 as an alternative crop to tobacco and also offered technical support for its cultivation in rain-fed areas of Mysore and Chamarajanagar districts of Karnataka. Though this crop is not acquainted by all the farming community, there is bright scope in the Indian market to address malnutrition problem in the country (Mary *et al*., 2018) [7]. Chia is used as a medicinal food crop from three decades in order to prevent diseases like diabetes, obesity and cardiovascular problems (Ayerza and Coates, 2006) [1] and it is gaining more importance among public due to its nutritional properties such as high protein (16.5 g), low carbohydrates (42.1 g), dietary fiber (34.4 g), fat (31 g) and also rich in minerals like potassium (407 mg), phosphorus (860 mg), magnesium (335 mg), calcium (631 mg), zinc (4.58 mg) and iron (7.72 mg).

Since chia is a recently introduced crop, it is essential to explore various aspects of spacing and organic nutrient management practices to optimize its potential yield. Therefore, the current study was conducted to examine how chia responds to different spacing and organic nutrient levels, specifically focusing on soil chemical properties, quality parameters, and soil microbial population.

Materials and Methods

The study was carried out during the *kharif* seasons of 2020-21 and 2021-22 at Zonal Agricultural Research Station, V. C. Farm, Mandya. Its purpose was to assess how chia responds to varying spacing and organic nutrient levels, focusing on soil chemical properties, quality parameters, and soil microbial population. Geographically, the experimental site is positioned between 11° 30' to 13° 05' North latitude and 76° 05' to 77° 45' East longitude, with an altitude of 695 meters above mean sea level. The soil at the site has a red sandy loam texture, a neutral pH of 7.71, and a low electrical conductivity of 0.35 dS/m. Additionally, the soil has 0.66% organic carbon content, low available nitrogen (278.24 kg/ha), medium available phosphorus (32.3 kg/ha), and medium available potassium (291.56 kg/ha).

Table 1: Experimental details

1.	Season	*kharif* season: 2020-21 and 2021-22
2.	Experimental design	Factorial Randomized Complete Block Design (FRCBD)
3.	Factor 1	Spacing (S) – 02
4.	Factor 2	Organic nutrient management practices (N) - 06
5.	No. of Replications	3
6.	Total No. of treatment combinations	12
7.	Total No. of plots	12 × 3 = 36
8.	Gross plot size	23.76 m^2 (7.2 m × 3.3 m)
9.	Net plot size	60 cm × 15 cm = 12.96 m^2 (4.8 m × 2.7 m) 45 cm × 15 cm = 14.58 m^2 (5.4 m × 2.7 m)
10.	RDF	40:20:20 NPK kg/ha
11.	Seed rate	600-800 g/ha
12.	Location	ZARS, V. C. Farm, Mandya

Table 2: Treatment details and symbols

Sl. No	Treatments	Symbols
Factor 1: Spacing (S)		
1.	45 cm × 15 cm	S_1
2.	60 cm × 15 cm	S_2
Factor 2: Organic nutrient management practices (N)		
1.	75% RDN equivalent compost	N_1
2.	100% RDN equivalent compost	N_2
3.	N_1 + application of jeevamrutha at the time of sowing	N_3
4.	N_2 + application of jeevamrutha at the time of sowing	N_4
5.	N_1 + application of jeevamrutha at the time of sowing and 30 DAS	N_5
6.	N_2 + application of jeevamrutha at the time of sowing and 30 DAS	N_6

The compost and jeevamrutha was applied to the respective experimental plots as per the treatments. The compost was applied @ 8 t/ha prior to 15 days of sowing and jeevamrutha @ 500 L/ha.

Observations recorded

Available nitrogen (kg/ha)

The available nitrogen content of soil was determined by alkaline potassium permanganate method as outlined by Subbaiah and Asija (1956) [9].

Available phosphorus (kg/ha)

The available phosphorus content of soil was determined by chlorostannous reduced molybdophosphoric blue colour method in hydrochloric acid system by using Bray-I extractant (Jackson, 1973) [5].

Available potassium (kg/ha)

The available potassium in soil was determined by using neutral normal ammonium acetate extractant using a flame photometer (Jackson, 1973) [5].

Enumeration of soil microbial population at 30 DAS

Microbial populations were enumerated from the soil samples collected at 0-15 cm depth. The samples were mixed thoroughly and were subjected to serial dilution using 10 g of soil in 100 ml of sterile water. The enumeration of microorganisms was done after culturing these organisms using different media by standard dilution plate technique. The media used were soil extract agar for bacteria, Martin's Rose Bengal Agar with streptomycin sulphate for fungi and Kusters agar for actinomycetes. The number of colonies appeared on agar medium in plate were counted and multiplied by the representative dilution factor for each group of microorganisms and expressed as number of colonies per gram of oven dry soil.

Statistical analysis

The data collected from the experiment's diverse observations were subjected to statistical analysis, utilizing Fisher's "Analysis of variance (ANOVA)" method, as described by Gomez and Gomez (1984) [4]. The 'F' test's significance level was tested at 5%. Critical difference (CD) values, at a 5% significance level, are provided in the table where the 'F' test showed significance. To facilitate a comparative examination of various parameters, correlation and multiple regression analyses were performed using R software for a comprehensive analysis.

Results and Discussion

Effect on soil chemical properties

The results of the investigation were presented using pooled data, considering the consistency in outcomes across individual years. Notably, organic nutrient levels had a significant impact on soil chemical properties (Table 1). However, available nitrogen, available phosphorus, and available potassium did not show significant variations in both years concerning spacing and the interaction between spacing and organic nutrient levels. The application of 100% RDN equivalent compost, combined with jeevamrutha at sowing and 30 DAS, resulted in significantly higher levels of available nitrogen (256.95 kg/ha), available phosphorus (29.53 kg/ha), and available potassium (189.72 kg/ha). Conversely, lower nutrient availability in the soil was observed with 75% RDN equivalent compost (231.02, 25.69, and 172.79 NPK kg/ha, respectively). The treatment involving 100% RDN equivalent compost, along with jeevamrutha application at sowing and 30 DAS, demonstrated superiority due to increased microbial activity resulting from the use of organic nutrient sources like compost and jeevamrutha. This enhances the conversion of organically bound nutrients into inorganic forms, making nutrients more accessible to plants. These findings align with the results reported by Upendranaik (2017) [10] and Yogananda *et al*. (2019) [11].

Table 3: Influence of spacing and organic nutrient levels on soil available nutrient status in chia at harvest

Treatment	Soil available nutrients (kg/ha)								
	Available N			Available P_2O_5			Available K_2O		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Factor 1: Spacing (S)									
S_1	245.02	246.00	245.51	28.24	28.46	28.35	183.91	184.25	184.08
S_2	237.82	238.57	238.20	27.29	27.45	27.37	181.08	181.48	181.28
S.Em ±	2.84	2.82	2.83	0.44	0.44	0.44	1.93	1.94	1.94
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factor 2: Organic Nutrient levels (N)									
N_1	230.62	231.42	231.02	25.57	25.81	25.69	172.57	173.02	172.79
N_2	236.48	237.32	236.90	27.56	27.69	27.62	182.20	182.46	182.33
N_3	234.15	235.23	234.69	26.83	27.04	26.94	180.11	180.42	180.26
N_4	248.77	249.71	249.24	28.90	29.11	29.00	186.49	186.86	186.68
N_5	241.94	242.72	242.33	28.29	28.50	28.40	184.15	184.48	184.31
N_6	256.56	257.34	256.95	29.46	29.59	29.53	189.46	189.98	189.72
S.Em ±	4.92	4.89	4.90	0.76	0.76	0.76	3.35	3.36	3.36
C.D. (p=0.05)	14.42	14.34	14.38	2.24	2.24	2.24	9.83	9.87	9.85
Interaction (S × N)									
S.Em ±	6.95	6.91	6.93	1.08	1.08	1.08	4.74	4.76	4.75
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Jeevamrutha was applied @ 500 L/ha

Table 4: Influence of spacing and organic nutrient levels on soil microbial population in chia at 30 DAS

Treatment	Soil microbial population								
	Bacteria (10^5 cfu/g soil)			Fungi (10^4 cfu/g soil)			Actinomycetes (10^3 cfu/g soil)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Factor 1: Spacing (S)									
S_1	46.75	46.90	46.82	9.42	9.55	9.48	5.23	5.38	5.30
S_2	43.21	43.35	43.28	8.74	8.89	8.81	4.80	4.95	4.88
S.Em ±	1.73	1.73	1.73	0.28	0.28	0.28	0.33	0.33	0.33
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factor 2: Organic Nutrient levels (N)									
N_1	38.00	38.08	38.04	5.72	5.89	5.80	3.21	3.36	3.29
N_2	42.16	42.34	42.25	9.02	9.14	9.08	4.98	5.13	5.05
N_3	42.92	43.05	42.99	8.59	8.75	8.67	4.65	4.82	4.74
N_4	49.80	49.97	49.88	10.29	10.42	10.35	5.82	5.93	5.87
N_5	44.87	45.03	44.95	9.54	9.65	9.60	5.35	5.50	5.42
N_6	52.12	52.28	52.20	11.32	11.45	11.39	6.10	6.24	6.17
S.Em ±	3.00	3.00	3.00	0.49	0.49	0.49	0.58	0.58	0.58
C.D. (p=0.05)	8.79	8.81	8.80	1.44	1.43	1.44	1.70	1.69	1.69
Interaction (S × N)									
S.Em ±	4.24	4.25	4.24	0.70	0.69	0.69	0.82	0.81	0.82
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Jeevamrutha was applied @ 500 L/ha

Effect on soil microbial population

Among various organic nutrient levels, the use of 100% RDN equivalent compost combined with the application of jeevamrutha at sowing and 30 DAS resulted in a notably higher bacterial population (52.20×10^5 cfu/g of soil at 30 DAS), fungal population (11.39×10^4 cfu/g of soil), and actinomycetes population (6.17×10^3 cfu/g of soil). Conversely, applying 75% RDN equivalent compost led to lower bacterial population (38.04×10^5 cfu/g of soil at 30 DAS), fungal population (5.80×10^4 cfu/g of soil), and actinomycetes population (3.29×10^3 cfu/g of soil). The increased soil microbial population can be attributed to the use of jeevamrutha, a vital organic liquid formulation that creates a favorable environment for microorganisms when applied to soil. This, in turn, aids in making essential nutrients available for plant growth, ultimately ensuring an enhanced soil microbial population. These findings are consistent with the results reported by Meti *et al*. (2019) [8], Gangadhar *et al*. (2020) [3], and Jagadeesha *et al*. (2020) [6]. There were no significant differences in soil microbial population based on spacing and interaction at 30 DAS.

Correlation between different quality parameters: For comparative study of different quality parameters like protein content, oil content, zinc content and iron content, correlation was performed using R software for effective study. Zinc content, nitrogen content and protein content is highly significantly and highly positive correlated with oil content (0.86, 0.69 and 0.69, respectively). Protein content is having highly significant and perfect positive correlation with nitrogen content (1.00).

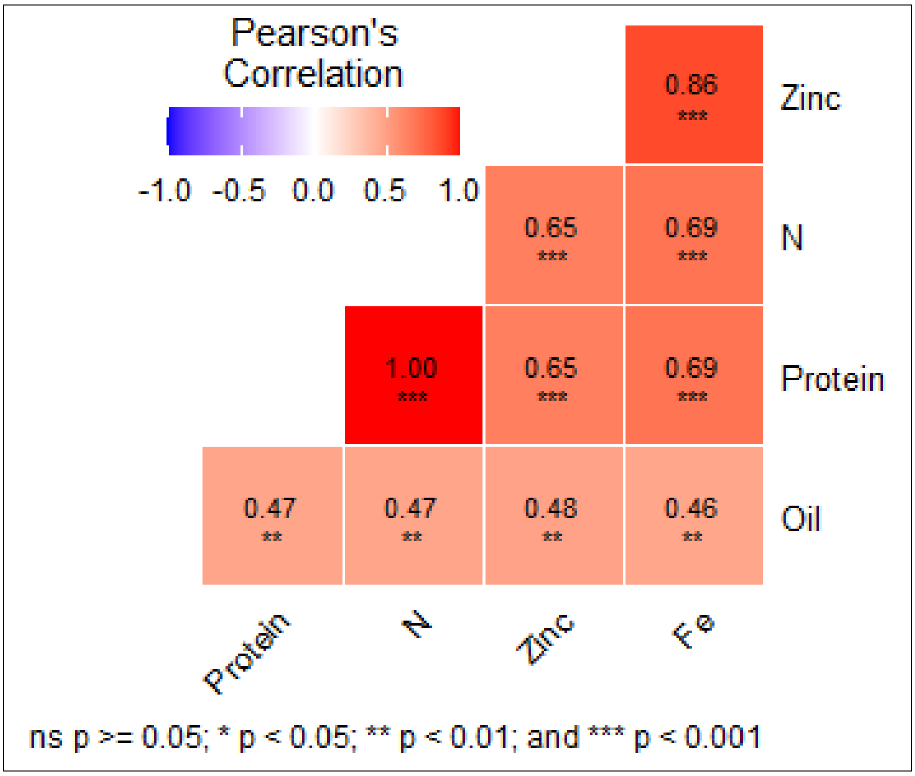

Fig 1: Correlation analysis between different quality parameters (pooled mean of two years)

Regression models

Regression analysis of seed yield with quality parameters

$$\mathbf{Y = -1317.27 + b_1\ 66.23 + b_2\ 17.95 - b_3\ 17.42 + b_4\ 27.24}$$

Multiple regression analysis was done using R software for effective study. Regression coefficient b_1 indicates protein content, b_2 - oil content, b_3 - zinc content and b_4 – iron content. For every 1 kg increase in yield per hectare, protein content increases by 66.23%, oil content increases by 17.95%, zinc content decreases by 17.42 mg and iron content increases by 27.24 mg (R^2 = 66.4%). Fig. 2a indicates that all the actual and predicted values of independent variables are linearly related.

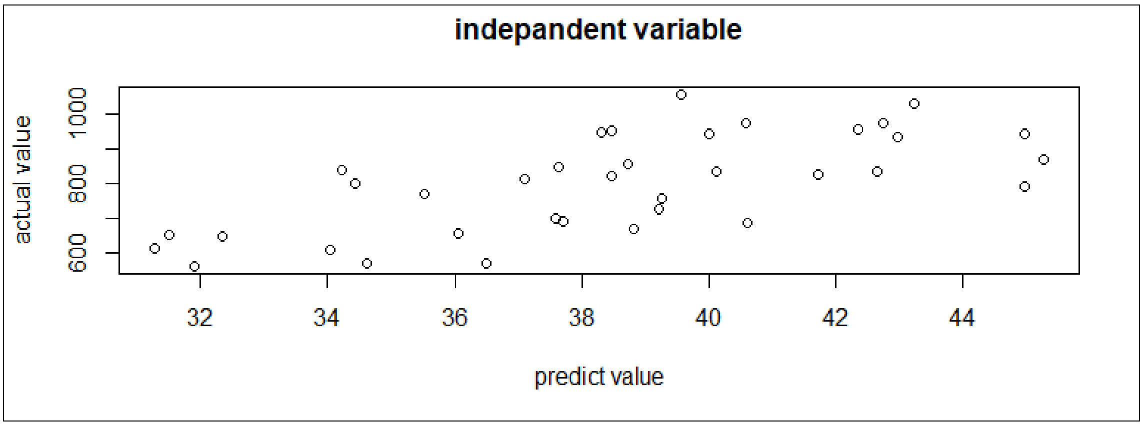

Fig 2a: Linear regression curve (quality parameters)

Regression analysis of seed yield with growth parameters

$$\mathbf{Y = -532.02 + b_1\ 1.85 + b_2\ 0.18 + b_3\ 5.11 - b_4\ 0.29 + b_5\ 370.20 + b_6\ 9.94}$$

Regression coefficient b_1 indicates plant height, b_2 - number of leaves per plant, b_3 - number of branches per plant, b_4 – leaf area, b_5 – leaf area index and b_6 – total dry matter production. For every 1 kg increase in yield per hectare, plant height increases by 1.85 cm, number of leaves per plant increases by 0.18, number of branches per plant increases by 5.11, leaf area decreases by 0.29 cm^2/plant, leaf area index increases by 370.20 and total dry matter production increases by 9.94 (R^2 = 85.8%). Fig. 2b indicates that all the actual and predicted values of independent variables are linearly related.

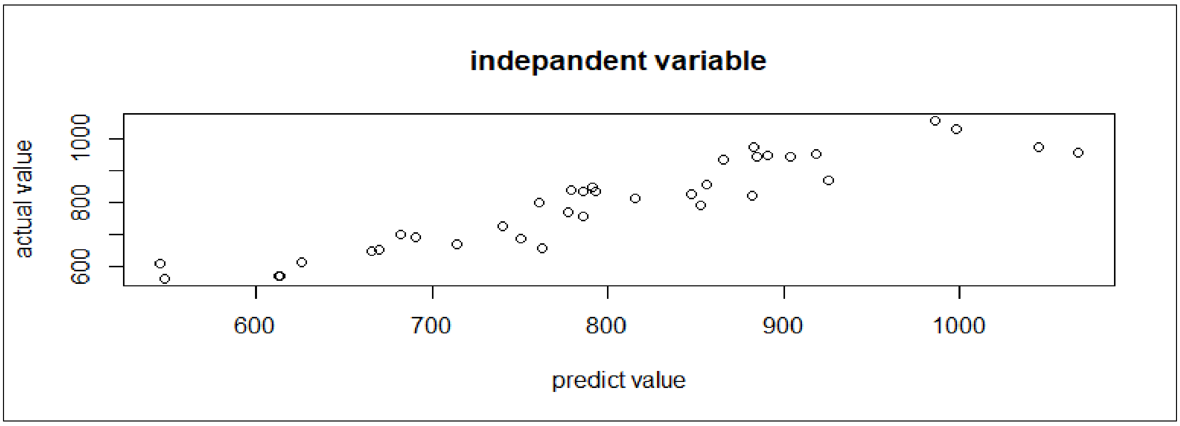

Fig 2b: Linear regression curve (growth parameters)

Conclusion

From the results obtained over the pooled data of two years, it was concluded that 45 cm × 15 cm spacing and 100% RDN equivalent compost + application of jeevamrutha at the time of sowing and 30 DAS was found economically viable and registered higher soil available nutrients and soil microbial population.

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