Original Research Article

Effect of organics on yield and yield components of chia (*Salvia hispanica* L.)

Abstract

Chia (*Salvia hispanica* L.) is a new emerging crop as functional food. Its seeds are richest source of omega-3, antioxidant, calcium and are known to prevent heart disease, diabetes and cancer. Owing to its nutraceutical and therapeutical values, the studies on its organic production are very essential under Indian condition. Therefore, an experiment to determine the influence of organic fertilization on growth and yield of chia was done at Jabalpur, Madhya Pradesh during 2018-19 and 2019-20. The recommended fertilizers dose (RDF) 57.5:40:24 NPK kg ha^{-1} with FYM 10 t ha^{-1} was compared with fourteen treatment combinations of organic manures *viz.*, vermicompost (V), bio gas spent slurry (BSS) and Neem cake (Nc) at 25% or 50%N equivalent dose of RDF and organic supplements namely, microbial consortia (M), Jeevamrita (J) and humic acid (H).

The maximum plant height, number of branches per plant, number and weight of spikes per plant, spike weight, dry matter, seed yield per plant and seed yield per hectarewere higher under RDF which was *at par* with FYM50V25BSS25MJH, RDFM, RDFJ. During first year, RDF recorded the higher yield (835.67 kg ha^{-1}) followed by RDFMJH (680.93 kg ha^{-1}), RDFJ (665.84 kg ha^{-1}), FYM50V25BSS25H (616.19 kg ha^{-1}) and FYM50V25BSS25 (603.57 kg ha^{-1}). During first year, chia resulted in lower yield in comparison to second year in all the treatments. The reproductive phase, blooming to seed filling was found sensitive to frost. During second year RDFMJH gave higher yield (1201.65kg ha^{-1}) and was *at par* to FYM50V25BSS25M (1186.28kg ha^{-1}), FYM50V25BSS25J (1165.71 kg ha^{-1}) and RDF (1165.43kg ha^{-1}). Therefore, the RDF can be substituted by organic manures combination viz. FYM 10.7 t + vermicompost 1.07 t + biogas spent slurry 1.68 t ha^{-1}along with microbial consortia or with Jeevamrita.

Key words: Chia, Jeevamrita, Humic acid,Harvest index, Yield components.

Introduction

Chia (*Salvia hispanica* L.) is an important medicinal as well heart healthy source of dietary proteins [4] and antioxidant [1] for prevention of diseases caused by oxidative stress. The chia seed as the richest source of omega-3 fatty acids[3]are consumed in various ways as ground or as whole grain in fruit juice, with milk,refreshing drinks or as salads. Its flour is consumed as an ingredient of bakery and in beverage industries due to its fat binding and gel forming character including nutritional and functional properties[8]. Historical records revealed that chia was used by ancient Mesoamerican cultures Aztecs and Mayas in the preparation of traditional medicines and food[7]. It was the second main crop after beans in pre-Columbian communities [24]. The Aztec societies used chia as food, cosmetics and in religious functions. At present the chia is cultivated in Mexico, Guatemala, Paraguay, Australia, Bolivia, Columbia, Ecuador, Peru. Argentina, America and Europe. The largest chia producer in the world is Mexico [11].In India it can be grown as a short duration (3-4 months) crop in winter season as well as a kharif season with less irrigation for crop diversification in different states. Hence, it can be easily fit into various existing cropping patterns adopted by farmers.Chia is an annual herbaceous plant belongs to Lamiaceae family. It grows to onemeterheight with dichotomous branching.Leaves are simple, petiolated, serrated and opposite. Chia seeds are very minute oval shaped, colour vary from black, grey or black spotted to white. The nutritional values of these seeds are almost similar. The protein content of black seeds is 16.9 per cent and fibre content is 32.6 per cent while in whites seed content is 16.5 per cent and 32.4 per cent respectively [6].

This is the very first experiment conducted on chia crop with reference to assess the influence of organic manures on growth and yield of chia cultivation in Madhya Pradesh, India. It has been designed to substitute the inorganic fertilizers by use of different organic manures viz., vermicompost, biogas spent slurry, neem cake, microbial consortia, humic acid or Jeevamrita along with FYM in various combinations. These organic manures are eco-friendly having great potential to enhance the agricultural production in a sustainable manner by increasing the soil microorganisms andnutrient availability. Organic manures are cost effective, improve the plant growth, productivity and supply enough nutrients to crop. Hence, these organics can be the best alternative to the inorganic fertilizers to enhance the quality,quantity and price of the chia products.The objective of this investigation is to identify the best organics combination to substitute or minimize the use of inorganic fertilizers in chia cultivation which is responsible for the low price of the chia seeds as demand for organic chia is increased internationally.

Material and methods

Experimental site

The field experiment was conducted during 2018-19 and 2019-20 in collaboration with University of Horticultural Sciences, Bagalkot, Karnataka, India at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India at 23.185884 latitude and 79.974380 longitude with the GPS coordinates of $23^0$11'9.1824" N and $79^0$58'27.7680" E. Occasionally winter rains occur and minimum temperature may fall to 3-4^0C and generally frost was observed in the month of Decemberto January and the meteorological data prevailed during the experiment period are depicted in Table-1 as taken from Department of Agrometeorology, JNKVV, Jabalpur. Experimental field soil was sandy loam, low available nitrogen and phosphorus 198 and 9.42 kg ha^{-1} respectively, but rich in potassium 338 kg ha^{-1} with 7.2 pH, electrical conductivity 0.19ds m^{-1} and organic carbon 0.50 %.

Table 1. Monthly meteorological data during crop growth season 2018-2019 and 2019-2020.

Month	Temperature ^{0}C		Relative humidity %		Sunshine hours	Rainfall (cm)	Evaporation %
	max	min	max	min			
			2018-19				
October	32.43	17.16	86.55	54.71	8.8	0	3.59
November	29.54	10.48	84.37	33.20	8.15	0	2.44
December	23.88	6.69	80.77	36.03	6.24	0	1.89
January	23.41	7.14	79.68	39.74	6.78	0.14	1.95
February	27.63	11.45	74.79	40.29	8.30	0.23	3.03
March	31.29	13.46	80.42	36.19	8.44	0.59	3.94
			2019-20				
October	29.25	18.96	91.29	60.10	5.68	0.56	2.60
November	29.16	12.45	92.37	48.07	6.90	0	2.14
December	23.67	8.51	90.42	54.61	5.28	0.4	1.64
January	22.73	9.51	88.29	50.29	6.34	1.1	1.89
February	25.67	9.55	86.24	40.83	7.97	0.3	2.66
March	30.83	15.89	75.97	38.65	7.41	1.30	3.20

Experimental Details and methodology:

Fifteen treatments comprising of organic manures viz., farmyard manure (FYM), vermicompost (V), biogas spent slurry (BSS), neem (*Azadiracta indica* L.) kernel cake (Nc), with organic supplements microbial consortia which consist of Phosphate solubilizing bacteria (PSB), *Azotobacter chrococcum* and *Pseudomonas* each 4 kg ha^{-1}(M), humic acid (H) 5kg ha^{-1} and Jeevamrita (J) (150 lit. ha^{-1}). The nutrient content of these organic manures was estimated (Table-2). The recommended dose of fertilizer (RDF) [17]consisting of 125 kg ha^{-1} urea (57.5Kg N), 250 kg ha^{-1} single super phosphate (40kg P_2O_5), 40 kg ha^{-1} muriate of potash (24 kg ha^{-1}) and FYM 10 t ha^{-1} were used as a control treatment. It was compared with above different organic manures and supplements in different combinations (Table-3). Fifteen treatments were tested in a complete Randomized block design according toPanse andSukhatme,[15]with three replications.

Table 2. Nutrient composition of fertilizers and organic manures used for experimentation.

S. N.	Manures/ fertilizer	Nutrients composition %		
		N	P	K
1.	FYM	0.5	0.2	0.5
2.	Vermicompost	2.5	2.35	1.7
3.	Biogas spent slurry	1.6	1.55	1.05
4.	Neem cake	5.2	1.05	1.45

The plot size was 4.90 m x3.00 m having row spacing of 45 cm and plant spacing of 30 cm. Except urea and Jeevamrita all other fertilizers and organic manures were applied before transplanting of seedlings and incorporated in the soil as per treatment after layout of the experiment. Urea was applied after 10 days of transplanting.

Table 3.Details of nutrient sources and total NPK supplied under different treatments.

S.N.	Treatment	Treatment detail	Nutrient Source applied	Quantity ha^{-1}	Nutrients supplied (kg ha^{-1})		
					N	P	K
T1	RDF	Recommended fertilizers dose (RDF) 57.5:40:24 NPK kg ha^{-1} with FYM 10 t ha^{-1}	FYM	10 t	50.00	20.00	50.00
			Urea	125kg	57.50	-	-
			SSP	250kg	-	40.00	-
			MOP	40 kg	-	-	24.00
			Total		**107.50**	**60.00**	**74.00**
T2	FYM50V25BSS25	FYM 50% + Vermicompost 25% + BSS 25%	FYM	10.70 t	53.50	21.40	53.50
			Vermicompost	1.07 t	26.87	25.14	18.19
			BSS	1.68 t	26.87	26.04	17.47
			Total		**107.50**	**72.58**	**89.16**
T3	FYM50Nc50	FYM 50% + Neem cake 50%	FYM	10.7 t	53.50	21.40	53.50
			Neem cake	1.02 t	53.50	10.71	14.79
			Total		**107.50**	**32.11**	**68.29**
T4	RDFM	RDF + Microbial consortia	FYM	10 t	50.00	20.00	50.00
			Urea	125kg	57.50	-	-
			SSP	250kg	-	40.00	-
			MOP	40 kg	-	-	24
			Microbial consortia	13kg			
			Total		**107.50**	**60.00**	**74.00**
T5	RDFJ	RDF + Jeevamrita	FYM	10 t	50.00	20.00	50.00
			Urea	125kg	57.50	-	-
			SSP	250kg	-	40.00	-
			MOP	40 kg	-	-	24.00
			Jeevamrita	150Liter			
			Total		**107.50**	**60.00**	**74.00**
T6.	RDFH	RDF + Humic acid	FYM	10 t	50.00	20.00	50.00

			Urea	125kg	57.50	-	-
			SSP	250kg	-	40.00	-
			MOP	40 kg	-	-	24
			Humic acid	5kg			
			Total		**107.50**	**60.00**	**74.00**
T7	FYM50V25BSS25 M	FYM 50% + Vermicompost 25% + BSS 25% + Microbial consortia	FYM	10.70 t	53.50	21.40	53.50
			Vermicompost	1.07 t	26.87	25.14	18.19
			BSS	1.68 t	26.87	26.04	17.47
			Microbial consortia	13kg			
			Total		**107.5**	**72.58**	**89.16**
T8	FYM50V25BSS25 J	FYM50% + Vermicompost 25% +BSS 25% + Jeevamrita	FYM	10.70 t	53.50	21.40	53.50
			Vermicompost	1.07 t	26.87	25.14	18.19
			BSS	1.68 t	26.87	26.04	17.47
			Jeevamrita	150 liters			
			Total		**107.5**	**72.58**	**89.16**
T9	FYM50V25BSS25	FYM 50% + Vermicompost 25% + BSS 25%+ Humic acid	FYM	10.70 t	53.50	21.40	53.5
			Vermicompost	1.07 t	26.87	25.14	18.19
			BSS	1.68 t	26.87	26.04	17.47
			Humic acid	5kg			
			Total		**107.50**	**72.58**	**89.16**
T10	FYM50Nc50M	FYM 50% + Neem cake 50%+ Microbial consortia	FYM	10.70 t	53.50	21.40	53.50
			Neem cake	1.02 t	53.50	10.71	14.79
			Microbial consortia	13kg			
			Total		**107.50**	**32.11**	**68.29**
T11	FYM50Nc50J	FYM 50% +Neem cake 50%+ Jeevamrita	FYM	10.70 t	53.50	21.40	53.50
			Neem cake	1.02 t	53.50	10.71	14.79
			Jeevamrita	150L			
			Total		**107.50**	**32.11**	**68.29**
T12	FYM50Nc50H	FYM 50% +Neem cake 50% + Humic acid	FYM	10.70 t	53.50	21.40	53.50
			Neem cake	1.02 t	53.50	10.71	14.79
			Humic acid	5kg			
			Total		**107.5**	**32.11**	**68.29**
T13	RDFMJH	RDF+ Microbial Consortia + Jeevamrita + Humic acid	FYM	10 t	50.00	20.00	50.00
			Urea	125kg	57.50	-	-
			SSP	250kg	-	40.00	-
			MOP	40 kg	-	-	24.00
			Microbial Consortia	13kg			
			Jeevamrita	150L			
			Humic acid	5kg			
			Total		**107.50**	**60.00**	**74.00**
T14	FYM50V25BSS25 MJH	FYM 50% + Vermi compost 25% + BSS 25% + Microbial Consortia+ Jeevamrita + Humic acid	FYM	10.7 t	53.50	21.40	53.50
			Vermicompost	1.07 t	26.87	25.14	18.19
			BSS	1.68 t	26.87	26.04	17.47
			Microbial Consortia	13kg			
			Jeevamrita	150L			
			Humic acid	5kg			
			Total		**107.50**	**72.58**	**89.16**
T15	FYM50Nc50MJH	FYM 50%+ Neem	FYM	10.7 t	53.50	21.40	53.50

		cake 50%+Microbial Consortia + Jeevamrita + humic acid	Neem cake	1.02 t	53.50	10.71	14.79
			Microbial Consortia	13kg			
			Jeevamrita	150L			
			humic acid	5kg			
			Total		**107.50**	**32.11**	**68.29**

Note: FYM= Farm Yard Manure, V=vermicompost, BSS= Biogas spent slurry (Dried), M= Microbial consortia, J= Jeevamrita, H=Humic acid SSP= Single super phosphate, MOP= Muriate of Potash

Chia seeds of variety CHIAmpion B-1developed by Central Food Technological Research Institute, Mysore having blue flowered and white seeds was used for sowingat the rate of 250g ha^{-1} in nursery on raised beds during October, 2018 and 2019. The 19 days old seedlings at four true leaves stage were transplanted in fine granulated plots at 45x30cm. distance. After transplanting light irrigation was given. Subsequent two irrigations were provided at an interval of 10 days and fourlight irrigations at 15 days intervals. The crop was kept weed free by hand weeding and hoeing twice. Jeevamrita was prepared by fermentation of a mixture of 50 litre water, 10 litre cow urine, 10kg cow dung, 1kg jaggery, 1 kg Bengal gram flour, 500g soil and kept under tree shade for 10 days. This fermented product was diluted to 10 per cent with water and finalvolume made up to 500 litres. It was drenchedin soilthree timesat the rate of 500 litres ha^{-1} each time once at planting, second at 20 DAP and third at 35 DAP along with irrigation.

The data were recorded from five randomly selected plants at harvest for growth parameters *viz*., plant height(cm), number of branchesper plant, dry matter per plant(g), spike length (cm),number of spikesper plant and for yield components, *viz*., spike weight (g), seed yield per spike(g)andseed yield per plant (g). The data on seed yield and total biological yield kg per hectare were estimated based on seed yield kg per plot and total biological yield kg per plot. The harvest index (%) was computedas per Nichiporovich [14] as following:

$$HI\ (\%) = \frac{\text{Economic yield ha}^{-1}}{\text{Biological yield ha}^{-1}} \times 100$$

The data were analysed statistically to find the critical differences among the treatments. The pooled mean of year 2018-19 and 2019-20 was compared for growth and yield attributing traits. The results were discussed in the light of available literature.

Result and discussion

Growth parameters

Pooled mean of growth parameters was computed for year 2018-19 and 2019-20 and results are discussed as below.

Plant height (cm)

The influence of various organic manure treatments on plant height revealed that during first year of experimentation the initial plant growth in terms of height was more as compared to second year.Whereas, in general increase in plant height during 90 DAP stage till harvest stage was more during second year as compared to first year experiment. At harvest the plant height was higher under all the organic treatments during second year than the first-year experiment owing to extremely low temperature (1.6^{0}C) at the crop stage of 60-90 DAP. Although, the plant height increased linearly during first year. Significant variations amongst the treatment were noted at all the stages during both the years. The growth of chia in terms of plant height recorded at harvest revealed the linear increase in plant height up to 90 DAP in almost all the treatments. Further increase in plant was meagre.

At harvest stage almost similar trend was found in pooled mean of plant height (Table-4). Significantly highest plant height was recorded under RDFMJH (71.89 cm) which was *at par* with FYM50V25BSS25MJH(70.49 cm) FYM50V25BSS25H (70.56 cm) and FYM50V25BSS25M (69.55 cm). Robinet al.[18] reported the plant height of line sown chia from 102.3 cm to 117.5 cm while Karimet al.[13] reported the chia plant height up to 136 cm. The variation in plant height may be due to variation on supply of nutrients at different growth stages.

Number of branches per plant

The linear increasing trend in branching revealed that branching in chia was non-synchronous. Apical bud bears the terminal spike and after itsterminal growth was checked and side branches started. When growth of these primary branches terminated on appearance of spikes the secondary branches were emerged and terminated by appearance of tertiary spikes. Therefore, the process of development of branching, spikes, flowering, seed setting and maturity in chia were non synchronous. All these growth and developmental events were likely to be also influenced by prevailing temperature and photo period at these crop stages. The data recorded on branching in chia at various stages revealed that number of branches was increased up to 90 DAP during both the years.

At the harvest time pooled mean of both years the highest number of branches (Table-4) was found under RDFMJH (38.11) which was *at par* to FYM50V25BSS25H (37.03), FYM50V25BSS25M (36.89) RDFH (36.73), RDFM (36.54), RDF (36.29), RDFJ (36.08) and FYM50Nc50M (36.06). The lowest number of branches were found under FYM50Nc50 (26.41) followed by FYM50Nc50J (26.43).

Table-4 Influence of organics on growth and yield components at harvest(pooled mean data of two years)

Treatments		Plant height (cm)	Number of branches plant^{-1}	Dry matter plant^{-1}	Spike Length (cm)	Number of spikes plant^{-1}	Spike Weight (g)	Seed yield spike $^{-1}$ (g)	Seed yield per plant(g)
T1	RDF	65.01	36.29	39.15	**18.33**	**55.80**	0.48	0.21	**12.46**
T2	FYM50V25BSS25	66.90	30.97	30.82	18.19	50.89	0.50	0.19	8.98
T3	FYM50Nc50	62.90	26.41	23.51	14.73	38.46	0.39	0.18	6.33
T4	RDFM	66.58	36.54	35.28	16.31	45.73	0.42	0.21	9.62
T5	RDFJ	65.73	36.08	33.51	17.20	44.34	0.50	0.22	9.99
T6	RDFH	67.51	36.73	34.44	16.43	47.17	0.43	0.19	8.36
T7	FYM50V25BSS25 M	69.55	36.89	36.14	17.71	50.26	0.44	0.25	10.07
T8	FYM50V25 BSS25J	66.59	32.39	34.90	16.64	41.95	0.55	0.23	10.99
T9	FYM50V25BSS25H	70.56	37.03	39.13	16.27	45.07	0.50	0.22	9.96
T10	FYM50Nc50M	62.67	36.06	29.06	15.37	41.34	0.48	0.21	7.08
T11	FYM50Nc50J	62.54	26.43	28.82	15.58	38.53	0.44	0.21	6.58
T12	FYM50Nc50H	64.43	33.31	23.81	16.73	41.10	0.36	0.19	6.27
T13	RDFMJH	**71.89**	**38.11**	36.74	18.06	51.65	0.57	0.26	12.24
T14	FYM50V25BSS25MJH	70.49	33.62	**40.76**	16.26	47.98	**0.58**	**0.31**	8.93
T15	FYM50Nc50MJH	66.27	29.19	33.71	15.71	44.60	0.46	0.22	8.17
	Sem	0.77	0.78	0.89	0.37	1.09	0.02	0.01	0.26
	CD 5%	2.18**	2.20**	2.51**	1.05**	**3.08****	0.05**	0.02**	0.74**
	CV	2.48	4.37	7.76	4.21	5.89	10.51	10.46	9.70

(Note: Sem = Standard error from mean, CD 5%= Critical difference at 5 percent level of significance, and CV= Covariance, ** significant)

Dry matter plant^{-1}

The influence of organics on above ground dry matter accumulation rate per plant was significant at all the stages during both the years as pooled mean (table-4). The data recorded at harvest resulted in significantly higher above ground biomass per plant^{-1} under FYM50V25BSS25MJH (40.76g) followed by RDF (39.15g) and FYM50V25BSS25H (39.13g). These treatments were *at par*. The lowest dry matter was found with FYM50Nc50 (23.51g) followed by FYM50Nc50H (23.81g). The production of dry matter per plant in the present experiment was lower as compare to the finding of Karim et al.[13], who noted 305g dry matter per plant. It may be due to location effect. The variation in plant height and dry matter per plant may also be due to variation in sowing time and plant density [19].

Length of spikes

The yield contributing parameters viz., length and number of spikes varied significantly due to treatments during both the years of pooled mean. The longest spikes were recorded at harvest (table-4) under RDF (18.33cm), FYM50V25BSS25 (18.19 cm) *at par* with RDFMJH (18.06 cm) and FYM50V25BSS25M (17.71cm). The lowest spike length was in plots which were treated with FYM50Nc50 (14.73cm) and shown non-significant variations. The spike lengths of 10-15cm were also reported by Rosa et al. [20].

Number of spikes plant^{-1}

In general,the number of spikes per plant were more during the first year than second year under all the treatments. The highest number of spikes (table-4) were found in those plants supplied with RDF (55.80) as compared all other treatments. followed by RDFMJH (51.65), FYM50V25BSS25 (50.89) and FYM50V25BSS25M (50.26). The lowest number of spikes were found under FYM50Nc50 (38.46) and was *at par* to FYM50Nc50J (38.53). The results corroborated by Salman et al.[21] reported 58.89 spikes per plant.

The yield attributing traits *viz.*, the spike weight, seed weight per spike and seed yield per plant also varied significantly among the organic treatments during both the years and for pooled mean (table-4).

Spike weight

The weight per spike during second year was more in all the treatments as compared to first year in spite of a smaller number of spikes per plants than first year. The lower weight of spike during first year was due to occurrence of frost by which fertilization and development of seed was inhibited and the spikelets under blooming remained empty. The higher pooled mean of both the years spike weight (0.58g) was found in the treatments supplied with FYM50V25BSS25MJH than all the treatments and except it was *at par* with RDFMJH and FYM50V25BSS25J. The lowest spike weight (0.36g) was found under FYM50NC50H and FYM50Nc50 (0.39g).

Seed yield per spike

Corresponding to spike weight, seed yield per spike was also lower during first year of experiment than the second year. The seed yield per spike during the second year was almost double in all the treatments as compared to first year. It indicated that seed setting was more during second year due to more favourable climatic conditions particularly temperature. During first year the minimum temperature was extremely low at the maximum seed setting stage. It caused most of the spikes empty during first year resulting in low spike weight and lower seed weight per spike. As pooled mean of both years the highest seed weight per spike was found in plots treated with

FYM50V25BSS25MJH (0.31g) followed by RDFMJH (0.26) and FYM50V25BSS25M (0.25) while the treatment FYM50Nc50 (0.18) recorded lowest seed yield per spike. This treatment was also noticed with short spike length.

Seed yieldper plant

The seed weight per plant varied significantly among the treatments during both the years. The seed weight per plant was also higher in all the treatments during second year as compared to first year experiment. Pooled mean of both the years the seed weight per plant was maximum under RDF (12.46 g) and was*at par* with RDFMJH (12.24), these two treatments were significantly superior than all other treatments. The minimum seed yield per plant was obtained under FYM50Nc50H (6.27) and it was *at par* to FYM50Nc50 (6.33) and FYM50Nc50J (6.58).However, the results obtained by Salman et al. [21] showed higher seed weight per plant (24.22g) as compared to seed weight of present experiment. This may be due to macro-environmental conditions and population density.

Seed yield per hectare

The significant variations were found amongst the treatments during both the years(table-5). Chia seed yield estimated per hectare was lower during first year in all the treatments as compared to second year of experimentation. The reason would be the occurrence of frost with temperature below 5^0C during December and January during flowering and seed filling stage resulted in few empty spikelets as seed development was hampered resulting low yield. In first year the significantly higher yield was noted under RDF (835.67 kg ha^{-1}) as compared to all other treatments followed by RDFMJH (680.93 kg ha^{-1}) and RDFJ (665.84 kg ha^{-1}). These latter two were significantly superior to all other treatments except FYM50V25BSS25 (603.57 kg ha^{-1}). While the lowest was recorded in FYM50Nc50H (278.19 kg ha^{-1}). During second year the seed yield was significantly higher under RDFMJH (1201.65 kg ha^{-1}) *at par* to FYM50V25BSS25M (1186.28 kg ha^{-1}), FYM50V25BSS25J (1165.71 kg ha^{-1}) and RDF (1165.43 kg ha^{-1}). All these treatments gave significantly superior seed yields than all other treatments. The lowest yield was found under FYM50Nc50 (542.39 kg ha^{-1}) followed by FYM50Nc50MJH (628.26 kg ha^{-1}), FYM50Nc50J (631.82 kg ha^{-1}) and FYM50Nc50H (635.39 kg ha^{-1}). All these treatments with Neem seed cake combinations gave significantly lower seed yields as compared to other treatments. These results clearly evidenced that the present RDF for chia cultivation can be substituted by application of organic manures only *i.e.*, FYM50V25BSS25J without significant reduction in yield. In Argentina15-47kg N and 37 kg P ha^{-1} while in Mexico 68 kg N ha^{-1}gave higher yield of chia as reported by Ayerza and Coates [2]. While Jeenaet al. [12] reported 676.58 kg ha^{-1} seed yield with 19:60:75 NPK kg ha^{-1}.

The reason for low plant growth dry matter accumulation rate and biomass production as well as all yield attributes and seed yield during first year of experimentation would be due to slow release of nutrients from organic manures like FYM, Vermicompost, biogas spent slurry and neem seed cake. Souza et al.[23] and Dickmannet al.[9] also reported that in organic fertilization all the nutrients are not released at a time.Bordin-Rodriqueset al.[5]have reportedchia responded to both direct application of fertilizers as well as to use of residual fertilization done for previous crop. It may also be a possible reason for increased yield in second year.

Table-5 Influence of organic fertilizers on seed yield per hectare, total biological yield per hectare and harvest index (HI%)

Treatments	Seed yield kg ha^{-1}			Total Biological yield (kg ha^{-1})	Harvest index (HI%)
	2018-19	2019-20	Pooled	Pooled	Pooled

T1	RDF	**835.67**	1165.43	**1000.55**	**3373.53**	22.93
T2	FYM50V25BSS25	603.57	669.41	636.49	2032.10	23.87
T3	FYM50 Nc50	476.54	542.39	509.47	1930.73	21.62
T4	RDFM	449.66	936.35	693.00	2308.23	22.42
T5	RDFJ	665.84	955.28	810.56	2430.59	25.28
T6	RDFH	513.58	899.86	706.72	2578.05	21.59
T7	FYM50V25BSS25 M	449.38	1186.28	817.83	2109.05	**26.68**
T8	FYM50V25 BSS25 J	536.35	1165.71	851.03	2683.26	23.42
T9	FYM50V25BSS25H	616.19	856.79	736.49	2241.70	24.73
T10	FYM50Nc50M	461.45	730.32	595.88	2083.40	22.22
T11	FYM50Nc50J	354.18	631.82	493.00	2005.49	19.59
T12	FYM50Nc50H	278.19	635.39	456.79	1833.61	19.41
T13	RDF MJH	680.93	**1201.65**	941.29	3066.39	23.62
T14	FYM50V25BSS25MJH	518.52	738.00	628.26	3323.32	15.78
T15	FYM50NC50MJH	551.17	628.26	589.71	2112.35	21.91
	Sem	21.11	56.77	21.41	85.00	0.73
	CD 5%	61.16*	164.46**	60.41**	239.88**	2.05**
	CV %	7.40	12.69	9.16	7.19	5.24

(Note: Sem = Standard error from mean, CD 5%= Critical difference at 5 percent level of significance, and CV= Covariance, ** =significant)

Pooled seed yield

Pooled seed yield of both years (table-5) indicated significantly highest seed yield in RDF (1000.55 kg ha^{-1}) followed by RDFMJH (941.29 kg ha^{-1}). Next in order were FYM50V25BSS25J, FYM50V25BSS25M and RDFJ. It was found that FYM50V25BSS25 gave the average yield of 636.49 kg ha^{-1} when this treatment was superimposed separately with microbial consortia (FYM50V25BSS25M) or Jeevamrita (FYM50V25BSS25J) or humic acid (FYM50V25BSS25H), the seed yield was 817.83 kg ha^{-1}, 851.03 kg ha^{-1}, 736.49 kg ha^{-1} respectively that increased by 167.18kg ha^{-1}, 197.57kg ha^{-1} and 92.57kg ha^{-1} respectively.

It indicated that with FYM50V25BSS25 the addition of microbial consortia or Jeevamrita or humic acid had synergistic effect. Similarly, application of RDF along with humic acid, microbial consortia and Jeevamrita (RDFMJH)also resulted in higher seed yield of chia (941.29.5kg ha^{-1}) *on par* to RDF (1000.55 kg ha^{-1}). Hence, there was additional benefit of integrated use of MJH over use of microbial consortia or Jeevamrita or Humic acid alone with RDF.

The treatment FYM50Nc50H recorded the lowest seed yield (456.79 kg ha^{-1}) with other FYM50Nc50 combinations indicating neem seedcake was not much effective to increase the seed yield of chia. The application of neem cake with other organic manures like FYM or with FYM along with microbial consortia or Jeevamrita or humic acid could not result the yield *at par* to RDF or other organic manures treatments viz., FYM50V25BSS25J. Hence the neem cake may not be recommendable to chia crop due to slow release of nitrogen. According to Sosa et al. [22] inadequate nitrogen fertilization is a major cause oflower seed yield in chia. However, with neem seed cake application Eifidiyi et al. [10],Veena et al. [25] and Rajkamal et al. [16] havereported significant increase in growth and yield of okra and green gram, respectively over control.

Total biologicalyield per hectare

Total biological yield per hectare also varied significantly among the treatments as pooled mean of both the years (table-5). It was maximum in RDF (3373.53 kg ha^{-1}) and was *at par* with FYM50V25BSS25MJH (3323.32 kg ha^{-1}) and both were significantly higher than other treatments. The lower total biomass yield was found in all treatments where FYM was applied with neem seed cake and FYM50Nc50H (1833.61 kg ha^{-1}) recorded the lowest.

However, Karim et al.[13] reported 888 kg ha^{-1} husk yield. Salman et al. [21] reported total dry matter of chia up to82,200 kg ha^{-1} in response to different fertilizer applications.

Harvest index (HI%)

The higher harvest index (HI%) was noted (table-5) for pooled mean of both years under FYM50V25BSS25M (26.68 %) at par with RDFMJ (25.28) and FYM50V25BSS25H (24.73). In these treatments seed yields were also higher. The lowest harvest index was found in FYM50V25BSS25MJH (15.78%) among all the treatments though its seed yield was higher which indicates vigorous growth of above ground vegetative plant parts. The higher HI% clearly indicated that conversion of photosynthates into economic sink i.e., seed, was more as compared to diversion towards structural parts.

Conclusion:

This research experiment concluded that for organic production of chia among all treatment combination two treatments with (T_7) FYM50V25BSS25M (FYM at 50% N equivalent dose + vermicompost at 25% N equivalent dose + biogas spent slurry at 25% N equivalent dose + microbial consortia of PSB, *Pseudomonas* and *Azotobacter* and (T_8)FYM50V25BSS25J (FYM at 50% N equivalent dose + vermicompost at 25% N equivalent dose+ biogas spent slurry at 25% N equivalent dose + Jeevamrita) can be recommended as an alternative to present recommendation of inorganic fertilizer RDF. These two organics combination treatments provided the seed yield 449.38 to 536.35kg ha^{-1} in first year and during second year 1186.28 to 1165.71 kg $ha^{-1}$and as pooled mean of both years 817.83 and 851.03 kg ha^{-1} respectively.

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