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Economics of chia (*Salvia hispanica*) cultivation as influenced by foliar application of different elicitors

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Abstract
Chia is an important super food crop with lot of medicinal value getting more popularity in recent days because of heart healthy omega-3 fatty acid content. The cultivation of chia in India was started by few farmers near Mysuru which is a finger millet growing area and now the cultivation has spread to other parts of the state and also neighboring states due to high returns than the traditional crops. For production of residue free quality chia seeds, elicitation is one promising strategy which also saves the cost of chemicals by strengthening the defense system in plants. The present investigation on economics of chia cultivation revealed that the highest gross returns (Rs. 2,06,301 and Rs. 2,00,541), net returns (Rs. 1,58,588 and Rs. 1,53,064) and B: C ratio (4.32 and 4.22) was obtained from plants sprayed with foliar spray of chitosan at 200 ppm and potassium silicate at 100 ppm in black while chia respectively.

Keywords: Chia, elicitor, chitosan, potassium silicate

Introduction
Chia (*Salvia hispanica*) a new introduction to India from Mexico introduced by Central Food Technological Research Institute, (CFTRI) Mysuru and initially grown by farmers in few areas near Mysuru and presently the cultivation has spread to other areas of Karnataka and also to the neighboring states. There are two types, *viz.* black seeded with some mottling and white seeded. The white type is priced at a premium as it blends well with Indian food products. CFTRI has developed chia-blended products such as ice creams, chocolates and jams, which are being commercialized by various companies (Anonymous, 2016) [1]. Generally for chia, the cultivation costs are around 15,000/acre, which is similar to other traditional cereal crops like finger millet and maize. The average yield of chia is 500-600 kg seed/acre (Cahill, 2003) [5] but under appropriate agronomic conditions the yield of 2120 kg/hectare has also been reported (Ayerza and Coates, 2005) [3]. The increased awareness about functional food had created more demand for the chia seeds in market globally. Short duration (90-105 days), lower cultivation costs coupled with less water demand, largely untouched by pests, diseases, animals and high returns are the primary reasons for its acceptance among Indian farmers. Since it is a new crop, the information on agronomic practices is meager and the technologies with less use of fertilizers and plant protection chemicals are much needed since the demand is more for the seeds produced without any chemicals usage.

The elicitors are the substances which induce physiological changes in the plant. Application of these elicitors activates an array of mechanisms by creating stress to plants similar to the defense responses to pathogen infections or environmental stimuli which affects the plant metabolism and enhances the synthesis of phytochemicals (Baenas *et al*., 2014) [4]. These phytochemicals fight against external invaders and strengthen the plant defense system by avoiding pest and disease infestation (Garcia-Brugger *et al*., 2006) [6]. Since the chia is a new crop to India and the infestation by pest and diseases are less for now, but, as the cultivation of chia progresses new pest and diseases may emerge and therefore, elicitation may be a promising strategy to get higher yield with quality seeds and also to avoid use of plant protection chemicals to produce residue free food. These elicitors are also cost effective and reduce the overall cultivation cost by reducing use of chemicals.

Material and Methods
The study was carried out in randomized complete block design with 11 treatments and 3

replications for both black and white chia at Department of Plantation, Spices, Medicinal and Aromatic crops, College of Horticulture, University of Horticultural Sciences campus, Gandhi Krishi Vignana Kendra, Bengaluru during rabi season of 2018-19 and 2019-20. The chia seeds were procured from Raitha Mithra farmer producer organization *via* CFTRI, Mysuru. The seeds were sowed on 26th November, 2018 in the first season and on 28th October in the second season. The spacing followed was 60cm between the rows and 45 cm between the plants. The plots were watered immediately after sowing and the irrigation was given at alternate days through drip (discharge capacity - 2 liters/hour) for one hour throughout the cropping period. The fertilizers are applied based on recommendation of the study conducted by Mary *et al*., 2018.

The elicitors treatment was done twice at 25 and 50 days after sowing through foliar spray. The various treatments includes T_1: Chitosan 200 ppm, T_2: Salicylic acid 100 ppm, T_3: Dry yeast 5000 ppm, T_4: Methyl jasmonic acid 100 ppm, T_5: Potassium silicate 100 ppm, T_6: Gibberellic acid 100 ppm, T_7: Kinetin 100 ppm, T_8: Humic acid 200 ppm, T_9: Boric acid 200 ppm, T_{10}: Plant growth promoting rhizobacteria (PGPR) 5000 ppm and T_{11}: Control. The chitosan was added to distilled water three days prior to application for complete solubilization. Similarly dry yeast was added to distilled water five days prior to application for the multiplication of beneficial microbes. The PGPR consortia contain *Azospirllum*, P-solubilizer (*Bacillus megaterium*) and *Pseudomonas fluorescens* in the proportion of 1:1:1.

The harvesting was done based on the maturity and the spikes were separated and dried. Threshing of seeds was done by beating the spikes placed in a tarpaulin with sticks gently. The threshed seeds were winnowed in air, cleaned and packed in a gunny bags.

Cost of cultivation

The cost incurred towards inputs and farm labours charges that were prevailed during the study period in Bengaluru region are considered while computed per hectare cultivation cost and presented in Table 1. The quantity of elicitors used and their respective cost are presented in Table 2. While, the total cost of cultivation (in rupees) incurred towards cultivation of black and white chia are presented in Table 3 and Table 4.

Gross returns and net returns

Gross income was calculated based on the market price of seeds prevailed at the time of harvest *i.e.*, rupees 160 per kg which was offered by the food industry NutriPlanet to the farmer (Rs. 160 kg^{-1}) in an MOU signed between University of Horticultural Sciences, Bagalkot. The net income per hectare was calculated by subtracting total costs from the gross income.

Benefit: Cost ratio (B: C ratio)

The benefit cost ratio was worked out by using the following formulae.

$$\text{Benefit : Cost ratio} = \frac{\text{Gross income (Rs. ha}^{-1})}{\text{Total cost (Rs. ha}^{-1})}$$

Table 1: Cost of inputs and labour used for raising chia for one hectare

Particulars		Quantity per ha	Rate (Rs/unit)	Cost (Rs.)
Land preparation (Tractor)		8 hours	Rs 600/hour	4,800
FYM		10 t/ha	Rs 1850/t	18,850
Seeds		250 g/ha	Rs 500/kg	125
Fertilizers (40:20:20 kg NPK/ha)				
Urea		195 kg	Rs 6.4/kg	1248
SSP		375 kg	Rs 8.4/kg	3150
MOP		125 kg	Rs 16/kg	2000
Sowing		5 labours	Rs 275/labour	1,375
Weeding		15 labours	Rs 275/labour	4,125
Plant protection chemicals:	Carbendazim	0.5 kg	Rs 1340/kg	670
	Chloropyriphos 20 EC	500 ml	Rs 600/L	300
Application of plant protection chemicals		2 labours	Rs 275/labour	550
Harvesting and processing		30 labours	Rs 275/labour	8,250
Packaging material		50 gunny bags	Rs 20/bag	1,000
Miscellaneous		Transportation and others	Rs 1500	1,500
Total				47,943

Table 2: Quantity required and cost of elicitors used per ha

Particulars	Quantity required (g or kg)	Rate (Rs / g or ml)	Total cost (Rs.)
Chitosan 200 ppm	266.4 g	0.60	160
Salicylic acid 100 ppm	40 g	1.2 Rs./g	48
Dry yeast 5000 ppm	2 kg	3668 Rs./kg	7,336
Methyl jasmonic acid 100 ppm	42 ml	780	32,760
Potassium silicate 100 ppm	117.6 ml	0.35 Rs./l	42
GA_3 100 ppm	40 g	180 Rs./g	7,200
Kinetin 100 ppm	40 g	566.6 Rs./g	22,656
Humic acid 200 ppm	88 g	0.30 Rs./g	26
Boric acid	80 g	0.90 Rs./g	72
PGPR 5000 ppm	6 kg	0.15 Rs./kg	900

Note: Spray solution required for one ha is 200 and 600 litres per hectare at 25 and 50 days after sowing respectively.

Table 3: Cost of cultivation of black chia as influenced by different elicitors (Rs/ha)

Treatments	FYM	Land preparation	Seeds	Sowing	Fertilizers	Elicitors	Weeding	Plant protection	Harvesting and processing	Packaging material	Miscellaneous	Total (Rs/ha)
T_1	18,850	4,800	125	1,375	6398	160	4,125	970	8,250	1,000	1,500	47,553
T_2	18,850	4,800	125	1,375	6398	48	4,125	970	8,250	1,000	1,500	47,441
T_3	18,850	4,800	125	1,375	6398	7,336	4,125	970	8,250	1,000	1,500	54,729
T_4	18,850	4,800	125	1,375	6398	32,760	4,125	970	8,250	1,000	1,500	80,153
T_5	18,850	4,800	125	1,375	6398	42	4,125	970	8,250	1,000	1,500	47,435
T_6	18,850	4,800	125	1,375	6398	7200	4,125	970	8,250	1,000	1,500	54,593
T_7	18,850	4,800	125	1,375	6398	22,656	4,125	970	8,250	1,000	1,500	70,049
T_8	18,850	4,800	125	1,375	6398	26	4,125	970	8,250	1,000	1,500	47,419
T_9	18,850	4,800	125	1,375	6398	72	4,125	970	8,250	1,000	1,500	47,465
T_{10}	18,850	4,800	125	1,375	6398	900	4,125	970	8,250	1,000	1,500	48,293
T_{11}	18,850	4,800	125	1,375	6398	0	4,125	970	8,250	1,000	1,500	47,393

T_1: Chitosan 200 ppm **T_2:** Salicylic acid 100 ppm **T_3:** Dry yeast 5000 ppm
T_4: Methyl Jasmonic acid 100 ppm **T_5:** Potassium silicate 100 ppm **T_6:** Gibberellic acid 100 ppm
T_7: Kinetin 100 ppm **T_8:** Humic acid 200 ppm **T_9:** Boric acid 200 ppm
T_{10}: PGPR 5000 ppm **T_{11}:** Control

Table 4: Cost of cultivation of white chia as influenced by different elicitors (Rs/ha)

Treatments	FYM	Land preparation	Seeds	Sowing	Fertilizers	Elicitors	Weeding	Plant protection	Harvesting and processing	Packaging material	Miscellaneous	Total (Rs/ha)
T_1	18,850	4,800	225	1,375	6398	160	4,125	970	8,250	1,000	1,500	47,653
T_2	18,850	4,800	225	1,375	6398	48	4,125	970	8,250	1,000	1,500	47,541
T_3	18,850	4,800	225	1,375	6398	7,336	4,125	970	8,250	1,000	1,500	54,829
T_4	18,850	4,800	225	1,375	6398	32,760	4,125	970	8,250	1,000	1,500	80,253
T_5	18,850	4,800	225	1,375	6398	42	4,125	970	8,250	1,000	1,500	47,535
T_6	18,850	4,800	225	1,375	6398	7200	4,125	970	8,250	1,000	1,500	54,693
T_7	18,850	4,800	225	1,375	6398	22,656	4,125	970	8,250	1,000	1,500	70,149
T_8	18,850	4,800	225	1,375	6398	26	4,125	970	8,250	1,000	1,500	47,519
T_9	18,850	4,800	225	1,375	6398	72	4,125	970	8,250	1,000	1,500	47,565
T_{10}	18,850	4,800	225	1,375	6398	900	4,125	970	8,250	1,000	1,500	48,393
T_{11}	18,850	4,800	225	1,375	6398	0	4,125	970	8,250	1,000	1,500	47,493

T_1: Chitosan 200 ppm **T_2:** Salicylic acid 100 ppm **T_3:** Dry yeast 5000 ppm
T_4: Methyl Jasmonic acid 100 ppm **T_5:** Potassium silicate 100 ppm **T_6:** Gibberellic acid 100 ppm
T_7: Kinetin 100 ppm **T_8:** Humic acid 200 ppm **T_9:** Boric acid 200 ppm
T_{10}: PGPR 5000 ppm **T_{11}:** Control

Results and Discussion

In black chia, the perusal of data (Table 5) indicates that the cost of cultivation as affected by different elicitor treatments was maximum (Rs. 1,12,913) towards the application of methyl jasmonate 100 ppm followed by kinetin 100 ppm treatment (Rs. 92,705). While, the least expenditure was incurred in control (Rs. 47,393) followed by humic acid (Rs. 47,445), potassium silicate (Rs. 47,477), salicylic acid (Rs. 47, 489), boric acid (Rs. 47, 537) and chitosan (Rs. 47,713). The gross returns was maximum (Rs. 2,06,301) in chitosan treatment followed by dry yeast (Rs. 2,04,363) and the least returns(Rs. 1,64.419) was seen in case of gibberlic acid. The net returns was also highest from chitosan (Rs. 1,58,588) followed by dry yeast (Rs. 1,42,298), boric acid (Rs. 1,41,855) and humic acid (Rs. 1,41,430). The B: C ratio also was more in chitosan (4.32) followed by boric acid (3.98), humic acid (3.98) and salicylic acid (3.76) while the least B: C ratio was observed in methyl jasmonic acid (1.65) and kinetin (1.78).

Table 5: Economics of black chia as influenced by elicitors application

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
T_1:Chitosan 200 ppm	47,713	2,06,301	1,58,588	4.32
T_2: Salicylic acid 100 ppm	47,489	1,78,726	1,31,237	3.76
T_3: Dry yeast 5000 ppm	62,065	2,04,363	1,42,298	3.29
T_4: Methyl Jasmonic acid 100 ppm	112,913	1,86,611	73,698	1.65
T_5: Potassium silicate 100 ppm	47,477	1,66,592	1,19,115	3.51
T_6: Gibberellic acid 100 ppm	61,793	1,64,419	1,02,626	2.66
T_7: Kinetic 100 ppm	92,705	1,65,454	72,749	1.78
T_8: Humic acid 200 ppm	47,445	1,88,875	1,41,430	3.98
T_9: Boric acid 200 ppm	47,537	1,89,392	1,41,855	3.98
T_{10}: PGPR 5000 ppm	49,193	1,79,746	1,30,553	3.65
T_{11}: Control	47,393	1,74,195	1,26,802	3.68

Similarly for white chia cultivation also, the cost incurred was maximum (Rs. 1,12,913) towards methyl jasmonate at 100 ppm treatment followed by kinetin 100 ppm (Rs. 92,705). While, the least expenditure was incurred in control (Rs. 47,393) followed by humic acid (Rs. 47,445), potassium silicate (Rs. 47,477), salicylic acid (Rs. 47,489), boric acid

(Rs. 47,537) and chitosan (Rs. 47,713). Whereas, Maximum gross returns of rupees 2,00,541 was obtained from potassium silicate applied plots followed by boric acid (Rs. 1,85,048), methyl jasmonic acid (Rs. 1,84,414), dry yeast (Rs. 1,82,875) and PGPR (Rs. 1,80,581) treated plots. The net returns was also more from potassium silicate (Rs. 1,53,064) treated plots followed by boric acid (Rs. 1,37,511), PGPR (Rs. 1,31,388), chitosan (Rs. 1,29,060) and humic acid (Rs. 1,25,793). Similarly B: C ratio was also maximum in potassium silicate (4.22) treated plots followed by boric acid (3.89), chitosan (3.70), PGPR (3.67), humic acid (3.65) and salicylic acid (3.51). Whereas the least B: C ratio was recorded in methyl jasmonic acid (1.63) followed by kinetin (1.87).

Table 6: Economics of white chia as influenced by elicitors application

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
T_1:Chitosan 200 ppm	47,713	1,76,773	1,29,060	3.70
T_2: Salicylic acid 100 ppm	47,489	1,66,573	1,19,084	3.51
T_3: Dry yeast 5000 ppm	62,065	1,82,875	1,20,810	2.95
T_4: Methyl Jasmonic acid 100 ppm	1,12,913	1,84,414	71,501	1.63
T_5: Potassium silicate 100 ppm	47,477	2,00,541	1,53,064	4.22
T_6: Gibberellic acid 100 ppm	61,793	1,59,445	97,652	2.58
T_7: Kinetin 100 ppm	92,705	1,73,218	80,513	1.87
T_8: Humic acid 200 ppm	47,445	1,73,238	1,25,793	3.65
T_9: Boric acid 200 ppm	47,537	1,85,048	1,37,511	3.89
T_{10}: PGPR 5000 ppm	49,193	1,80,581	1,31,388	3.67
T_{11}: Control	47,393	1,61,219	1,13,826	3.40

Maximum cultivation cost associated with the high cost of chemicals in methyl jasmonic acid and kinetin treatments which also resulted in least B: C ratio (Figure 1). Similar results were reported in black cumin where negative B: C ration was found in methyl jasmonic acid treatment due to its high cost (Arpitha, 2019) [2]. Similarly Anil *et al*. (2021) reported high cultivation cost in kinetin treatment even he used it in small concentration (25 ppm). The low returns in GA_3 treatment was due less seed yield (data not presented). Whereas, the increased gross returns, net returns and B: C ratio in chitosan (100 ppm) sprayed plants in black chia may be attributed to higher seed yield (1289.38 kg ha^{-1}) coupled with lower cultivation costs and zero infestation of pest and diseases (data not presented) compared to all other treatments. Spraying of potassium silicate at 100 ppm to white chia plants resulted in getting 1.25 times higher yield than of control in white chia and the cost incurred toward cultivation was also least *i.e*. only 84 more rupees than control. Hence, the B: C ratio, gross returns and net returns computed per hectare was 2.26, 1.26 and 2.14 times greater than kinetin, GA_3 and methyl jasmonic acid treatment respectively.

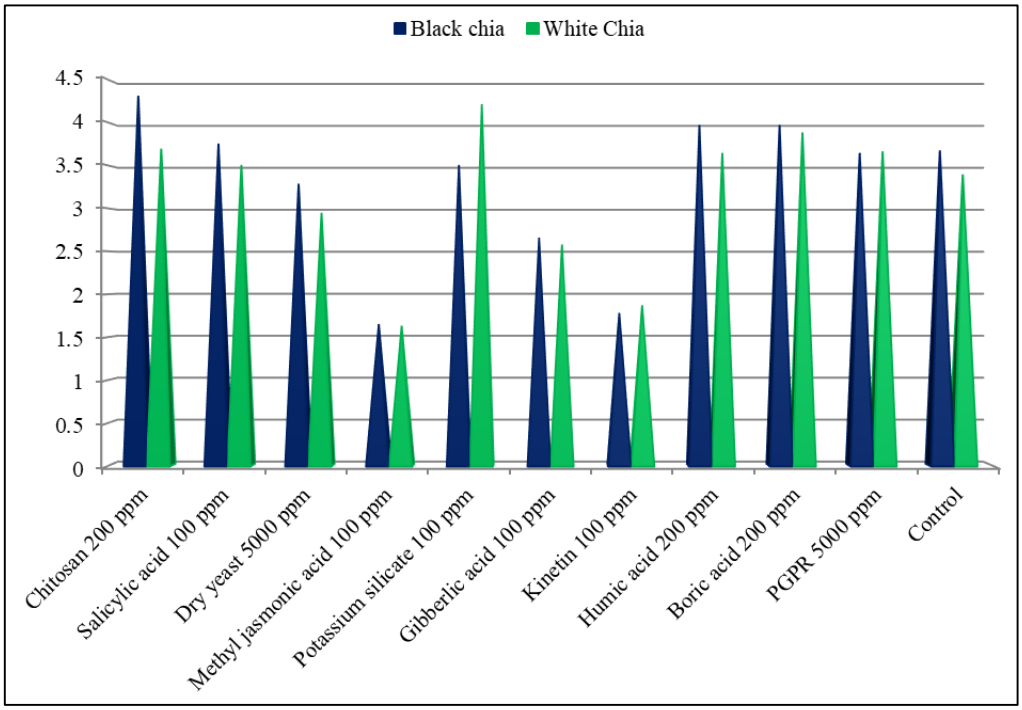

Fig 1: Benefit: Cost ratio of black and white chia as affected by different elicitor application

Conclusion

The cost incurred towards the cultivation of black chia was maximum for methyl jasmonic acid at 100 ppm and kinetin at 100 ppm sprayed plants in both black and white chia. Whereas, the highest gross returns, net returns and B: C ratio was obtained from plants treated with chitosan at 200 ppm and potassium silicate at 100 ppm treatment in black and white chia respectively. Hence, foliar spraying of chitosan at 200 ppm for black chia and potassium silicate at 100 ppm for white chia at 25 and 50 DAS can be recommended for

commercial cultivation for getting maximum yield coupled with superior quality seed and higher returns.

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