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Screening of Herbicides for Weed Control in Chia Crop (*Salvia hispanica* L.)

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ABSTRACT

A field experiment was conducted at Zonal Agricultural Research Station on Weed Management in Chia crop at University of Agricultural Sciences, GKVK, Bengaluru during *rabi* 2022 to screen pre and post-emergent herbicides in chia crop (*Salvia hispanica* L.). The experiment was laid out in randomized complete block design with three replications. The treatments comprised of different pre-emergence and post-emergence herbicides. Among the pre-emergent herbicides, oxyflurofen 23.5 EC@ 70.5 g a.i. ha^{-1} and flumoxiozin 50 SC @125 g a.i. ha^{-1} adversely affected germination, led to injury and poor crop stand. The post-emergent herbicides propaquizafop 10 EC @ 50 g a.i. ha^{-1}, ethoxysulfuron15WD 12.5 g a.i. ha^{-1} and penoxsulam 21.7SC@ 22.5 g a.i. ha^{-1}can be recommended for effective weed control without crop toxicity.

Keywords : Chia, Pre-emergent herbicide, Post-emergent herbicide, Phytotoxicity, Screening of herbicides, Chia crop

CHIA (*Salvia hispanica* L.), a member of the Lamiaceae family, originates from the mountainous areas of Guatemala and Mexico (Baginsky *et al*., 2016). The seeds of Chia exhibit a variation in color, ranging from grey and black to a black pointed and white color, with an oval shape and sizes ranging from 1-2 mm (Migliavacca *et al*., 2014). Although predominantly cultivated in countries like Argentina, Australia, Bolivia, Colombia, Guatemala, Mexico and Peru, Chia is gaining recognition globally (Azerya, 2011, Chaitanya *et al.,* 2022).

Chia seeds have garnered attention for their medicinal properties, particularly in preventing diseases such as diabetes, obesity and cardiovascular problems (Azerya and Coates, 2009). A Chia seed contains 15-25 per cent protein, 30-33 per cent fats, 18-30 per cent high dietary fiber, 26-41 per cent carbohydrates, 4-5 per cent ash along with vitamins, minerals and 90-93 per cent dry matter. Notably, Chia seeds boast a higher amount of antioxidants (Sindhu and Ravindra, 2022).

Currently, chia crop and seeds are imported from Australia, Bolivia and the US and sold in India (Azerya, 2011). The immense potential of Chia seeds in various industries, including health, food, animal feed, nutraceuticals and pharmaceuticals is attributed to its functional components. But still not yet familiar to all farming communities, Chia cultivation holds a bright future in the Indian market to address malnutrition (Coates, 2012). Recently, farmers in Karnataka, particularly in Mysore and Chamarajanagar districts have embarked on Chia cultivation. The cultivation of this new crop is motivated by its ease of cultivation in the face of scarce labor and water availability, coupled with the superior nutritional status of its seeds ensuring nutritional security (Peiretti and Gai, 2009).

Additionally, the impact of climate change favors the cultivation of such new crops that require less water and thrive under adverse climatic conditions. (Reyes-Caudillo *et al*., 2011). The incentive of remunerative prices for the crop and a well-structured buy-back arrangement further motivates its cultivation in the region (Bochicchio *et al*., 2015).

Addressing weed management during the early seedling stage of Chia, presents a challenge, particularly with mechanical/manual weeding. To mitigate yield loss, timely weed management is essential to minimize weed infestation in Chia. While hand weeding is a conventional method, the increase in wages and labor unavailability necessitate a more effective and economical approach. A main choice for controlling weeds would be through herbicides at appropriate stage of crop (Nagarajun, 2019). Lately, many new molecules have been synthesized for different time of application, that needs to be screened for selectivity of crop. Hence, screening of herbicide for its selectivity, plays significant role while recommending for a new crop (Kamala Bai *et al*, 2021). Hence, with this background new herbicides characterized by broad spectrum weed control with broad window of application were screened for chai crop to know its selectivity.

Material and Methods

The investigations related to the experiment entitled 'Bio efficacy of pre and post emergent herbicides on chia crop' was undertaken in the field of Zonal Agricultural Research Station (ZARS), UAS, GKVK, Bengaluru. The main objective of the study was to screen the suitable herbicide for controlling weeds in chia crop and to study the bio efficacy, phytotoxicity of herbicides against complex weed flora and their effect on growth and yield of Chia crop. The details of the materials used, techniques and procedures adopted during the course of investigation are described.

Experimental Site

The experimental site is situated at an altitude of 924 m above Mean Sea level (MSL) between a latitude of 13° 05' North and longitude of 77° 34' East.

Soil Status

Soil of the experimental plot was red laterite. Composite soil samples from 0 to 30 cm depth were collected randomly from the experimental area before imposing treatment. The various physico-chemical properties of the soil were analyzed.

Experiment details

The experiment was laid out in Randomised block design with three replications. The treatments comprised of four pre-emergence herbicides and nine post-emergent herbicides at varying levels. *viz.,*

T_1 - Pendimethalin 38.7 CS @750g a.i.ha^{-1} (PE),

T_2 - Oxyfluorofen 23.5 EC@70.5g a.i.ha^{-1} (PE),

T_3 - Metribuzin 70WP@210g a.i. ha^{-1} (PE),

T_4 - Flumioxazin 50 SC @125 g a.i. ha^{-1} (PE),

T_5 - Fenoxprop-p-ethyl 9.3EC@50g a.i.ha^{-1} (PoE),

T_6 - Fenoxprop-p-ethyl 9.3EC @75g a.i.ha^{-1} (PoE),

T_7 - Propaquizafop 10EC @50 g a.i. ha^{-1} (PoE),

T_8 - Propaquizafop 10EC@75g a.i. ha^{-1} (PoE),

T_9 - Ethoxysulfuron 15WDG @12.5 g a.i.ha^{-1} (PoE),

T_{10} - Ethoxysulfuron 15WDG @15g a.i.ha^{-1} (PoE),

T_{11} - Benatzone 48 SL @60g a.i. ha^{-1} (PoE),

T_{12} - Penoxsulam 21.7 SC@22.5 g a.i. ha^{-1} (PoE),

T_{13} - Metasulfuron methyl + chloromeon ethyl 20WP @4 g a.i. ha^{-1} (PoE),

T_{14} - Fluazifop-p-butyl+fomesafen 22.2 SL@250 g a.i. ha^{-1} (PoE),

T_{15} - Fluazifop-p-butyl+fomesafen 22.2 SL @500 g a.i. ha^{-1} (PoE),

T_{16} - Propaquizafop+ imazethapyr 6.2 ME @ 75 g a.i ha^{-1} (PoE),

T_{17} - Propaquizafop+imazethapyr 6.2 ME @125g a.i.ha^{-1} (PoE),

T_{18} - Sodium acifluorfen + clodinafoppropargyl 24.5 EC@245g a.i. ha^{-1} (PoE), T_{19}- control.

(PE - Pre Emeregent, POE - Post Emeregent)

Chia (local) was sown at a common spacing of 60 cm x 30 cm Recommended dose of fertilizers 20 kg N,

20 kg P_2O_5 and 20 kg K_2O were applied in the form of urea, SSP and MOP, respectively, Entire quantity of phosphorus, potassium and half of nitrogen was applied as basal. The remaining nitrogen was applied as top dressing at 35 days after sowing. Bold and healthy seeds were hand dibbled. Seed rate 10 kg ha^{-1}. Crop was grown as per package the outcome of Research studies refered by Anand 2024. All the biometric observation like emergence count (per cent), weed control and crop toxicity ratings were recorded computed and analyzed. The following weed control ratings and crop toxicity ratings (Rao and Rao, 1986) Table 1, were adopted with reference to control plots.

The study provides scientists base to arrive on the selectivity of herbicide in the chia crop. The results obtained helps to recommend or not to recommend the evaluated herbicides for chai crop.

Results and Discussion

Major weed flora observed in experiment plots during investigation were, *Echinochloa colona, Echinochloa crusgalli, Dactyloctenium aegyptium, Setaria glauca, Bracheria repans, Echinochloa indica, Chlori barbata* and *Cyanodon dactylon* among grasses; *Cyperus rotundus* among sedges. Whereas, in Broad leaf weeds, *Borreria hispida, Spilanthus acmella, Ageratum conyzoides, Acanthospermum hispidium*.

Phytotoxicity Results

Crop Toxicity Ratings

Herbicide application exhibited profound influence on germination and plant stand of the chia crop. Among the various herbicides applied, pre-emergent application of Pendimethalin 38.7 CS @750g a.i. ha^{-1} showed slight crop toxicity and persisted till 15 days after herbicide application (DAHA) and later recovered. Metribuzin 70 WP @ 210 g a.i. ha^{-1} showed slightly discoloration at initial days after herbicide application (5 DAHA), which was persistent and later crop recovered from the toxicity. Oxyfluorofen 23.5 EC @ 70.5 g a.i. ha^{-1} (PE) and Flumioxazin 50 SC @ 125 g a.i. ha^{-1} (PE) showed severe phytotoxicity by inhibiting germination with very few plants alive. (Plate 1).

T_2: Oxyflurofen 23.5EC @70.5 g a.i. ha^{-1}(PE)

T_4: Flumioxazin 50%SC @125 g a.i. ha^{-1}(PE)

T_{14}: Fluazifop-p-butyl+fomesafen 22.2% @ 250 g a.i. ha^{-1} (PoE)

T_{18}: Sodium acifluorfen+clodinafoppropargyl 24.5% @245g a.i. ha^{-1} (PoE)

Plate 1 : Phytotoxicity of the herbicides in chia crop

TABLE 1

Qualitative description of treatment effect on weed and crop in the visual scoring scale of 0-10 (Rao, 1986)

Effect	Score	Weed control rating	Phytotoxicity symptoms (crop)
None	0	No control	No injury, normal
Slight	1	Very poor control	Slight stand loss, stunting or discoloration
	2	Poor control	Some stand loss, stunting or discoloration
	3	Poor to deficient control	Injury more pronounced but not persistent
Moderate	4	Deficient control	Moderate injury, recovery not possible
	5	Deficient control to moderate control	Injury more persistent, recovery possible
	6	Moderate control	Near sever injury, no recovery possible
Severe	7	Satisfactory control	Sever injury, stand loss
	8	Good control	Almost destroyed, a few plants surviving
	9	Good to excellent control	Very few plants alive
Complete	10	Complete control	Complete destruction

Among the post emergent Fenoxprop-p-ethyl 9.3 EC @50g a.i. ha^{-1} (PoE), Propaquizafop 10EC @50g a.i. ha^{-1}, Ethoxysulfuron 15WDG @12.5 g a.i. ha^{-1} and Penoxosulam 21.7SC @22.5g a.i. ha^{-1} showed no crop toxicity and normal crop stand was noted. While all the other PoE herbicides showed moderate to severe phytotoxicity on the crop (Plate 1) (Table 2).

Weed Control Rating

All the Pre and post emergent herbicides were effective in controlling weeds (Table 3).

Total Weed Count Observation

Observation on weed count was recorded at 15, 30 and 45 Days After Sowing (DAS). All the pre and post emergent herbicides were effective in controlling the weeds at all the stage of the crop (Table 4). All the pre-emergent herbicides tried though controlled weeds effectively, could not be recommended as it caused crop toxicity (Table 2). Among the post emergent herbicides screened, Fenoxprop-p-ethyl 9.3% EC @50g a.i. ha^{-1} (PoE), Propaquizafop 10%EC @50 g a.i. ha^{-1} (PoE), Ethoxysulfuron 15%WD @12.5 g a.i. ha^{-1} and 15 g a.i. ha^{-1} (PoE) and Penoxsulam 21.7% @ 22.5 g a.i. ha^{-1} (PoE) did not show any crop toxicity and hence can be recommended at the dosage evaluated.

TABLE 2

Crop toxicity rating as influenced by different herbicides in chia crop

	Treatment	Crop toxicity rating (DAHA)*							
		0	1	3	5	7	10	13	15
T_1	Pemdimethalin 38.7% CS @750g a.i. ha^{-1} (PE)	0	0	1	1	1	1	1	1
T_2	Oxyfluorfen 23.5 EC@70.5g a.i. ha^{-1} (PE)	0	0	9	10	10	10	10	10
T_3	Metribuzin 70wp@210g a.i. ha^{-1}(PE)	0	0	0	1	0	0	0	0
T_4	Flumioxazin 50 % SC @125g a.i. ha^{-1} (PE)	0	0	9	10	10	10	10	10

Continued....

TABLE 2 Continued....

	Treatment	Crop toxicity rating (DAHA)*							
		0	1	3	5	7	10	13	15
T_5	Fenoxprop-p-ethyl 9.3%EC @50g a.i. ha^{-1} (PoE)	0	0	0	0	0	0	0	0
T_6	Fenoxprop-p-ethyl 9.3%EC @75g a.i. ha^{-1} (PoE)	0	1	1	1	0	0	0	0
T_7	Propaquizafop 10%EC @50 g a.i. ha^{-1} (PoE)	0	0	0	0	0	0	0	0
T_8	Propaquizafop 10%EC @75g a.i. ha^{-1} (PoE)	0	0	0	1	0	0	0	0
T_9	Ethoxysulfuron 15%WD @12.5 g a.i. ha^{-1} (PoE)	0	0	0	0	0	0	0	0
T_{10}	Ethoxysulfuron 15%WD @15g a.i. ha^{-1} (PoE)	0	0	0	1	0	0	0	0
T_{11}	Benatzone 48% @60g a.i. ha^{-1} (PoE)	0	0	0	2	2	1	0	0
T_{12}	Penoxsulam 21.7% @22.5 g a.i. ha^{-1} (PoE)	0	0	0	0	0	0	0	0
T_{13}	Metasulfuron methyl +chloromeon ethyl 20% @4 g a.i. ha^{-1} (PoE)	0	0	0	2	0	0	0	0
T_{14}	Fluazifop-p-butyl+fomesafen 22.2% @ 250 g a.i. ha^{-1} (PoE)	0	3	4	4	4	3	3	0
T_{15}	Fluazifop-p-butyl+fomesafen 22.2% @ 500 g a.i. ha^{-1} (PoE)	0	3	4	4	4	4	4	0
T_{16}	Propaquizafop+imazethapyr 6.2% @75g a.i.ha^{-1} (PoE)	0	0	0	1	0	0	0	0
T_{17}	Propaquizafop+imazethapyr 6.2% @125g a.i. ha^{-1} (PoE)	0	0	0	1	0	0	0	0
T_{18}	Sodium acifluorfen+clodinafoppropargyi 24.5% @245g a.i. ha^{-1} (PoE)	0	4	8	8	8	8	0	0

TABLE 3

Weed control rating as influenced by different herbicides in chia crop

	Treatment	Weed control rating (DAHA)*			
		10	15	30	45
T_1	Pendimethalin 38.7%CS @750g a.i. ha^{-1} (PE)	8	8	8	7
T_2	Oxyfluorofen 23.5 EC@70.5g a.i. ha^{-1} (PE)	6	6	5	5
T_3	Metribuzin 70wp@210g a.i. ha^{-1} (PE)	8	8	9	8
T_4	Flumioxazin 50 % SC @125g a.i. ha^{-1} (PE)	8	9	9	7
T_5	Fenoxprop-p-ethyl 9.3%EC @50g a.i. ha^{-1} (PoE)	8	8	8	8
T_6	Fenoxprop-p-ethyl 9.3%EC @75g a.i. ha^{-1} (PoE)	8	9	9	9
T_7	Propaquizafop 10%EC @50 g a.i. ha^{-1} (PoE)	8	8	8	8
T_8	Propaquizafop 10%EC @75g a.i. ha^{-1} (PoE)	8	8	8	8
T_9	Ethoxysulfuron 15%WD @12.5 g a.i. ha^{-1} (PoE)	8	8	9	8
T_{10}	Ethoxysulfuron 15%WD @15g a.i. ha^{-1} (PoE)	8	8	9	9
T_{11}	Benatzone 48% @60g a.i. ha^{-1} (PoE)	7	7	7	7
T_{12}	Penoxsulam 21.7% @22.5 g a.i. ha^{-1} (PoE)	9	9	8	8
T_{13}	Metasulfuron methyl +chloromeon ethyl 20% @4 g a.i. ha^{-1} (PoE)	9	9	10	9

Continued....

TABLE 3 Continued....

	Treatment	Weed control rating (DAHA)*			
		10	15	30	45
T_{14}	Fluazifop-p-butyl+fomesafen 22.2% @250 g a.i. ha^{-1} (PoE)	8	8	9	9
T_{15}	Fluazifop-p-butyl+fomesafen 22.2% @500 g a.i. ha^{-1} (PoE)	8	9	9	9
T_{16}	Propaquizafop+imazethapyr 6.2% @75g a.i. ha^{-1} (PoE)	8	8	8	8
T_{17}	Propaquizafop+imazethapyr 6.2% @125g a.i. ha^{-1} (PoE)	9	9	10	10
T_{18}	Sodium acifluorfen+clodinafoppropargyi 24.5% @245g a.i. ha^{-1} (PoE)	8	9	9	9
T_{19}	Control	0	0	0	0

*DAHS – Days after herbicides spray 0- no control; 10 – complete control

TABLE 4

Total weed count (no.m^2) as influenced by different pre-emergent and post emergent herbicides in chia crop

	Treatment	Total Weed Control (no.m^2)		
		15 DAS	30 DAS	45 DAS
T_1	Pemdimethalin 38.7 % CS @750g a.i. ha^{-1} (PE)	1.17(0.86)	2.23(4.47)	2.97(8.32)
T_2	Oxyfluorofen 23.5 EC@70.5g a.i. ha^{-1} (PE)	0.79(0.12)	1.09(0.68)	1.92(3.18)
T_3	Metribuzin 70wp@210g a.i. ha^{-1} (PE)	1.00(0.5)	2.27(4.65)	2.82(7.45)
T_4	Flumioxazin 50 % SC @125g a.i. ha^{-1} (PE)	0.70(0.00)	0.70(0.00)	0.70(0.00)
T_5	Fenoxprop-p-ethyl 9.3%EC @50g a.i. ha^{-1} (PoE)	1.30(1.19)	2.50(5.75)	3.18(9.61)
T_6	Fenoxprop-p-ethyl 9.3%EC @75g a.i. ha^{-1} (PoE)	1.43(1.54)	2.09(3.86)	2.82(7.45)
T_7	Propaquizafop 10%EC @50 g a.i. ha^{-1} (PoE)	1.53(1.84)	2.09(3.86)	2.87(7.73)
T_8	Propaquizafop 10%EC @75g a.i. ha^{-1} (PoE)	1.00(0.5)	2.45(5.50)	3.04(8.74)
T_9	Ethoxysulfuron 15%WD @12.5 g a.i. ha^{-1} (PoE)	1.47(1.66)	2.56(6.05)	3.10(9.11)
T_{10}	Ethoxysulfuron 15%WD @15g a.i. ha^{-1} (PoE)	1.41(1.48)	2.46(5.55)	3.00(8.50)
T_{11}	Benatzone 48% @60g a.i. ha^{-1} (PoE)	1.88(3.03)	2.33(4.92)	3.08(8.98)
T_{12}	Penoxsulam 21.7% @22.5 g a.i. ha^{-1} (PoE)	1.18(0.89)	2.02(3.58)	2.48(5.65)
T_{13}	Metasulfuron methyl +chloromeon ethyl 20% @4 g a.i. ha^{-1} (PoE)	1.18(0.89)	1.78(2.66)	1.90(3.11)
T_{14}	Fluazifop-p-butyl+fomesafen 22.2% @250 g a.i. ha^{-1} (PoE)	1.11(0.73)	0.70(0.00)	0.73(0.03)
T_{15}	Fluazifop-p-butyl+fomesafen 22.2% @500 g a.i. ha^{-1} (PoE)	1.23(1.01)	1.48(1.69)	1.51(1.78)
T_{16}	Propaquizafop+imazethapyr 6.2% @75g a.i.ha^{-1} (PoE)	1.73(2.49)	1.51(1.78)	1.65(2.22)
T_{17}	Propaquizafop+imazethapyr 6.2% @125g a.i.ha^{-1} (PoE)	1.52(1.81)	1.32(1.24)	1.43(1.54)
T_{18}	sodium acifluorfen+clodinafoppropargyi 24.5% @245g a.i. ha^{-1} (PoE)	1.79(2.70)	0.70(0.00)	0.70(0.00)
T_{19}	Control (unweeded)	2.34(4.97)	3.14(9.35)	3.45(11.40)
	S.Em±	0.04	0.06	0.08
	LSD	0.13	0.20	0.24

Original figures in parenthesis indicate original values; Data were subjected to square-root transformation before statistical analysis- ($\sqrt{x} + 0$)

TABLE 5

Effect of pre and post emergent herbicides on yield of chia crop

	Treatment	Yield (kg ha^{-1})
T_1	Pemdimethalin 38.7% CS @750g a.i. ha^{-1} (PE)	654
T_2	Oxyfluorofen 23.5 EC@70.5g a.i. ha^{-1} (PE)	0.0
T_3	Metribuzin 70wp@210g a.i. ha^{-1}(PE)	809
T_4	Flumioxazin 50 % SC @125g a.i. ha^{-1}(PE)	0.0
T_5	Fenoxprop-p-ethyl 9.3%EC @50g a.i. ha^{-1} (PoE)	958
T_6	Fenoxprop-p-ethyl 9.3%EC @75g a.i. ha^{-1} (PoE)	764
T_7	Propaquizafop 10%EC @50 g a.i. ha^{-1} (PoE)	974
T_8	Propaquizafop 10%EC @75g a.i. ha^{-1} (PoE)	812
T_9	Ethoxysulfuron 15%WD @12.5 g a.i. ha^{-1} (PoE)	947
T_{10}	Ethoxysulfuron 15%WD @15g a.i. ha^{-1} (PoE)	843
T_{11}	Benatzone 48% @60g a.i. ha^{-1} (PoE)	684
T_{12}	Penoxsulam 21.7% @22.5 g a.i. ha^{-1} (PoE)	987
T_{13}	Metasulfuron methyl +chloromeon ethyl 20% @4 g a.i. ha^{-1} (PoE)	654
T_{14}	fluazifop-p-butyl+fomesafen 22.2% @250 g a.i. ha^{-1} (PoE)	432
T_{15}	fluazifop-p-butyl+fomesafen 22.2% @500 g a.i. ha^{-1} (PoE)	353
T_{16}	propaquizafop+imazethapyr 6.2% @75g a.i. ha^{-1} (PoE)	524
T_{17}	propaquizafop+imazethapyr 6.2% @125g a.i. ha^{-1} (PoE)	589
T_{18}	sodium acifluorfen+clodinafoppropargyi 24.5% @245g a.i. ha^{-1} (PoE)	342
T_{19}	Control (unweeded)	385
	S.Em±	24.64
	LSD	70.68

Yield

Among the pre-emergent herbicides Pendimethalin 38.7CS @750g a.i. ha^{-1} and Metribuzin 70 WP @ 210 g a.i. ha^{-1} recorded yield 654 and 809 kg/ha. While no yield was recorded in Oxyflurofen 23.5 EC @ 70.5 g a.i. ha^{-1} (PE) and Flumioxazin 50 SC @ 125 g a.i. ha^{-1} (PE) due to severe phytotoxicity and complete destruction of crop.

Among post emergent herbicides Fenoxprop-p-ethyl 9.3 EC @50g a.i. ha^{-1} (PoE), Propaquizafop 10EC @ 50 g a.i. ha^{-1}, Ethoxysulfuron 15WDG @15g a.i. ha^{-1} and Penoxsulam 21.7 SC @22.5 g a.i. ha^{-1} recorded highest yield (958, 974, 947 and 987 kg ha^{-1}, respectively) over control (385 kg ha^{-1}). While other Post emergent treatments recorded lower yield due to crop injury caused by herbicides at the respective dosage (Table 5).

Among the pre-emergent herbicides Metribuzin 70 WP can be recommended only after further evaluation at much lower dose than @ 210 g a.i. ha^{-1}. For post emergent herbicides Fenoxprop-p-ethyl 9.3EC @50g a.i. ha^{-1} (PoE), Propaquizafop 10EC @50g a.i. ha^{-1}, Ethoxysulfuron 15WDG @15g a.i. ha^{-1} and Penoxsulam 21.7 SC @ 22.5 g a.i. ha^{-1}. Can be recommended for effective weed control.

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