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**RESEARCH ARTICLE**

# Effect of pre- and post-emergence herbicides on growth and yield of chia (*Salvia hispanica* L.)

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**ABSTRACT**

A field experiment was conducted during *Rabi* seasons of 2021-22 and 2022-23 at Research Farm of Dr. B.R. Choudhary Agricultural Research Station, Mandor, Agriculture University, Jodhpur with an objective of identifying suitable weed management practices in chia crop. The treatments comprised of post-emergence application (PoE) of bentazon 500 g/ha and 750 g/ha at 30 days after seeding (DAS), fluazifop–p-butyl 100 g/ha and 200 g/ha PoE at 30 DAS, pre-emergence application (PE) of sulfentrazon 50 g/ha and 75 g/ha, pendimethalin 200 g/ha and 400 g/ha PE, weed free and weedy check. A randomized block design with three replications was used. Bentazon 750 g/ha PoE recorded significantly lower total weed density, total weeds biomass, and maximum weed control efficiency (12.4, 83.4, 79.7 and 85.4 % at 30, 60, 90 and at harvest, respectively) with minimum reduction in yield due to weed competition. Among pre-emergence herbicides, sulfentrazon 75 g/ha and pendimethalin 400 g/ha were found statistically equally effective in controlling weeds in chia. It was concluded that bentazon 750 g/ha PoE can be used for managing weeds in chia.

**Keywords**: Bentazon, Chia, Pendimethalin, Sulfentrazon and Weed management

## INTRODUCTION

Chia (*Salvia hispanica* L.) is a medicinal and edible plant from the Lamiaceae family and is native to Mexico and Guatemala (Ixtaina *et al.* 2008). Worldwide, central Mexico, Guatemala, Australia, South America and Argentina are the main producers of chia seeds. Chia seeds have become very popular nowadays due to the health benefits of eating their seeds. Chia seeds have many uses, mostly health-related. Chia seeds contain protein (15-25%), fat (30-30%), carbohydrates (26-41%) and total dietary fibre (18-30%). Chia seeds are a source of minerals (calcium, phosphorus, potassium and magnesium), vitamins (thiamine, riboflavin, niacin, folate, ascorbic acid and vitamin A) and antioxidant compounds (Anon 2022). It's seeds are considered the best source of omega-3 fatty acids and a good source of bioactive and polyphenolic compounds that help prevent inflammation, improve cognition, and reduce fat cholesterol in the human body (Punia and Dhull 2019). Cultivation of chia seeds in India began with small-scale cultivation in Madhya Pradesh, Andhra Pradesh, Gujarat, Maharashtra, Karnataka, Rajasthan, Haryana and Himachal Pradesh. The popularity of chia crop has also increased in Rajasthan and recently it has been included in the package of practices in agro-climatic zone Ia of Rajasthan. It grows in parts of Jalore, Jodhpur, Chittorgarh and Bhilwara districts in Rajasthan. Chia plants can grow up to 1.0 to 1.5 m tall, with leaves approximately 1.5 to 3.0 inches long and 1 to 2 inches wide and arranged near the stem. Chia seeds produce small white or purple flowers (3 to 4 mm) that facilitate self-pollination (Bresson *et al.* 2009). The seeds are black, brown and white, black, oval-shaped and 1 to 2 mm thick. Chia seeds can grow in many soil and climate types, but sandy loam soil is best for high yields.

There are many yield limiting factors in commercial cultivation of chia including infestation of weeds which causes yield loss due to competition in chia depending on the type, intensity and duration of competition. Competition for resources during the initial period is a major limitation to chia's productivity (Kumar *et al.* 2024). Weed interference can lead to low seed yield and subsequently lower the quality of the yields (Finch-Savage 2020). Forty-five days after Chia shoot emergence is considered the most critical period for competition (De Goes Maciel *et al.* 2019). Hand weeding 3-4 weeks after planting is often used to control weeds in chia. However, rising wages and labour shortages are forcing people to look for alternatives. Herbicides are an important tool used to control weeds in today's agriculture; they are effective against most, if not all, weeds (Mishra *et al.*

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2016, Karkanis *et al.* 2018). It would be economical for growers to choose proper crop management with effective and economical herbicides and other management methods. Currently, no recommended practices have been established for growing chia in the Western Arid Plains (Ia) region. Therefore, in order to increase chia productivity by weed control, this study was carried out to determine the effective pre- and post-emergence herbicides to manage weeds in chia crop.

## MATERIALS AND METHODS

The experiment was conducted at Research Farm of Agricultural Research Station, Mandor, Agriculture University, Jodhpur during *Rabi* season of 2021-22 and 2022-23 to find out suitable effective herbicide for chia crop. The treatments comprised of post-emergence application (PoE) of bentazon 480 G/L SL (bentazon) 500 g/ha at 30 days after seeding (DAS), bentazon 750 g/ha 30 DAS, fluazifop-p-butyl 11.1% SL (fluazifop-p-butyl) 100 g/ha at 30 DAS, fluazifop–p-butyl 200 g/ha at 30 DAS, pre-emergence application (PE) of sulfentrazon 4 SC (39.6%) (sulfentrazon) 50 g/ha, sulfentrazon 75 g/ha, pendimethalin CS (38.7%) (pendimethalin ) 200 g/ha PE, pendimethalin 400 g/ha PE, weed free and weedy check. Treatments were laid out in randomized block design with three replications. The seeds of chia genotype Jodhpur Chia 1 (JC 1) were sown in 20 and 25 October, 2021 and 2022 respectively by using *kera* method with spacing 30×10 cm and depth 3 cm. The soil of the experimental area was sandy loam in texture, neutral to slight saline in reaction (pH 8.2) having 1.3 g/kg organic carbon, 174.0 kg/ha available nitrogen, 22.2 kg/ha available phosphorus and 325.0 kg/ha available potassium. Recommended dose of 40-23-15 NPK kg/ha was applied through urea, single super phosphate and muriate of potash. 30 kg N and PK fertilisers were applied through basal dose and remain N as top dressing at 40 DAS. All the observations were recorded and recommended package of practices suggested by Agriculture University, Jodhpur were used except management of weeds. Data were analyzed using standard statistical procedures as suggested by Panse and Sukhatme (1978).

### Total weed density and weed dry weight (biomass)

Weed samples from two randomly selected spots in each plot were taken at 30, 60, 90 DAS and at harvest stages with the help of 0.25 $m^2$ (0.5 m x 0.5 m) quadrat and the average density (no./$m^2$). was calculated. The samples collected were subjected to sun drying for sufficient time and weighed to compute average dry matter (biomass) (g/$m^2$). Data were transformed ($\sqrt{x+0.5}$) as recommended by Blackman and Roberts (1950) before statistical analysis.

### Weed control efficiency (%)

In order to evaluate the weed management treatments for their efficacy, weed control efficiency of each treatment was computed by using the following formula given by Mani *et al.* (1973).

$$\text{WCE (\%)} = \frac{DM_C - DM_T}{DM_C} \times 100$$

Whereas,

DMC = Dry matter yield of weeds (weed biomass) in weedy check plot,

DMT = Dry matter yield of weeds (weed biomass) in treated plot

### Weed index (%)

Weed index is defined as the magnitude yield reduction due to presence of weeds in comparison with weed free check. In other words, weed index expresses the competition offered by weeds measured by per cent reduction in yield owing to their presence in the field. Weed index was calculated by using following formulae.

$$\text{Weed index (\%)} = \frac{X - Y}{X} \times 100$$

Whereas,

X = Total yield from the weed free check

Y = Total yield from the treatment

The statistical analysis was done using MS excel program.

## RESULTS AND DISCUSSION

The species wise relative weed density in weedy check at 30 DAS indicates the predominance of *Asphodelus tenuifolius* Cav. (40.0%), *Chenopodium album* L. (22.9%), *Chenopodium murale* (L.) S. Fuentes, Uotila & Borsch (17.1%), *Cyprus rotundas* L. (11.4%) and *Cirsium arvensis (L.) Scop.* (8.6%).

### Total weed density (no./$m^2$)

Application of sulfentrazon 50 g/ha PE recorded 72% lower weed density compared to weedy check while sulfentrazone 75 g/ha PE recorded 78.9% lower weed density than weedy check (**Table 1**). Pendimethalin 200 g/ha PE and pendimethalin 400 g/ha PE recorded 72% and 74% lower weed density respectively than weedy check at 30 DAS. Among post-emergence herbicides, bentazon 750 g/ha applied at 30 DAS recorded significantly lower total weed density at 60 DAS of chia. Fluazifop –p-butyl 200 g/ha was superior than bentazone 500 g/ha and fluazifop –p-butyl 100 g/ha. Among pre-emergence herbicides, sulfentrazone 75 g/ha and pendimethalin 400 g/ha were found equally effective and recorded significantly lower total weed density than weedy check at 60 DAS of chia. Weed free and weedy check treatment, respectively recorded minimum and maximum density of total weeds at 60 DAS of chia.

### Weed biomass

Sulfentrazon 50 g/ha and 75 g/ha PE reduced the total weed biomass by 77.7% and 84.5% (**Table 1**), respectively over weedy check. There was 76% reduction in total weeds biomass with pendimethalin 200 g/ha PE. The increased dose of pendimethalin 400 g/ha PE caused greater reduction in total weed biomass (81%), over weedy check**.** All the pre-emergence herbicides were found equally effective. Among post-emergence herbicides, bentazon 750 g/ha PoE at 30 DAS recorded significantly lower total weeds biomass in chia and was superior over rest of the treatments except weed free.

### Weed control efficiency (%)

The maximum weed control efficiency was recorded with bentazon 750 g/ha PoE which was followed by pendimethalin 400 g/ha PE and sulfentrazon 75 g/ha PE and fluazifop–p-butyl 200 g/ha PoE at 60 DAS.

### Weed index (%)

The least reduction in yield was recorded with bentazon 750 g/ha PoE followed by bentazone 500 g/ha PoE, sulfentrazone 75 g/ha PE, pendimethalin 400 g/ha PE and sulfentrazone 50 g/ha PE. Fluazifop–p-butyl 100 and 200 g/ha PoE and pendimethalin 200 g/ha PE were found lesser effective and recorded greater reduction in yield of chia in comparison to rest of the treatments.

### Chia yield

The increase in chia seed yield was more with post-emergence herbicide application compared to pre-emergence herbicide application. Bentazone 750 g/ha PoE increased yield significantly, followed by bentazone 500 g/ha PoE, sulfentrazone 75 g/ha PE and pendimethalin 400 g/ha PE (**Table 3**). These

**Table 1. Total weed density and biomass as influenced by various weed management treatments (pooled two years data)**

| Treatment | Total weed density (no./$m^2$) | | | | Total weeds biomass (g/$m^2$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | At harvest | 30 DAS | 60 DAS | 90 DAS | At harvest |
| Bentazon 500 g/ha PoE 30 DAS | (15.4)3.9 | (3.6)2.0 | (2.9)1.8 | (3.5)2.0 | (15.8)4.0 | (6.9)2.7 | (3.1)1.9 | (3.9)2.11 |
| Bentazon 750 g/ha PoE 30 DAS | (15.4)4.0 | (2.1)1.6 | (2.3)1.7 | (2.5)1.7 | (16.3)4.1 | (4.0)2.1 | (2.6)1.7 | (2.8)1.82 |
| Fluazifop-p-butyl 100 g/ha PoE 30 DAS | (16.5)4.1 | (4.0)2.1 | (4.7)2.2 | (5.0)2.3 | (17.9)4.3 | (7.8)2.9 | (5.6)2.4 | (5.9)2.51 |
| Fluazifop-p-butyl 200 g/ha PoE 30 DAS | (14.9)4.0 | (3.0)1.9 | (4.5)2.2 | (4.5)2.2 | (17.2)4.2 | (5.9)2.5 | (5.3)2.4 | (5.2)2.38 |
| Sulfentrazon 50 g/ha PE | (4.9)2.3 | (4.7)2.3 | (4.4)2.2 | (5.1)2.3 | (5.0)2.3 | (9.3)3.1 | (5.1)2.4 | (6.0)2.53 |
| Sulfentrazon 75 g/ha PE | (3.7)2.0 | (3.8)2.1 | (3.5)2.0 | (4.0)2.1 | (3.8)2.1 | (7.3)2.8 | (4.0)2.1 | (4.6)2.25 |
| Pendimethalin 200 g/ha PE | (5.3)2.3 | (4.9)2.3 | (6.2)2.5 | (6.4)2.5 | (5.3)2.4 | (9.6)3.2 | (7.6)2.8 | (7.8)2.87 |
| Pendimethalin 400 g/ha PE | (3.9)2.2 | (4.5)2.2 | (4.0)2.1 | (4.6)2.2 | (4.4)2.2 | (8.7)3.0 | (4.6)2.3 | (5.5)2.44 |
| Weed free | (0.0)0.7 | (0.0)0.7 | (0.0)0.7 | (0.0)0.7 | (0.0)0.7 | (0.0)0.7 | (0.0)0.7 | (0.0)0.71 |
| Weedy check | (17.5)4.2 | (20.4)4.5 | (11.8)3.5 | (17.8)4.2 | (18.6)4.4 | (24.2)5.0 | (12.7)3.6 | (19.4)4.46 |
| LSD (p=0.05) | 0.45 | 0.41 | 0.58 | 0.37 | 0.36 | 0.49 | 0.59 | 0.28 |

*The values in the parenthesis are square root transformed values; PoE = post-emergence application; PE = pre-emergence application; DAS = days after seeding

**Table 2. Weed control efficiency, and weed index of chia crop as influenced by different weed management treatments. (pooled two years data)**

| Treatment* | Weed control efficiency (%) | | | | Weed index (%) |
|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | At harvest | |
| Bentazon 500 g/ha PoE 30 DAS | 14.9 | 71.6 | 75.3 | 79.7 | 15.5 |
| Bentazon 750 g/ha PoE 30 DAS | 12.4 | 83.4 | 79.7 | 85.4 | 10.2 |
| Fluazifop-p-butyl 100 g/ha PoE 30 DAS | 3.7 | 67.7 | 56.1 | 69.8 | 31.8 |
| Fluazifop-p-butyl 200 g/ha PoE 30 DAS | 7.6 | 75.7 | 58.1 | 73.1 | 27.9 |
| Sulfentrazon 50 g/ha PE | 72.9 | 61.6 | 59.7 | 69.0 | 26.1 |
| Sulfentrazon 75 g/ha PE | 79.7 | 69.9 | 68.8 | 76.2 | 16.8 |
| Pendimethalin 200 g/ha PE | 71.4 | 60.2 | 40.3 | 59.9 | 38.5 |
| Pendimethalin 400 g/ha PE | 76.5 | 63.8 | 63.6 | 71.7 | 20.7 |
| Weed free | 100.0 | 100.0 | 100.0 | 100.0 | 0.0 |
| Weedy check | 0.0 | 0.0 | 0.0 | 0.0 | 53.6 |

*PoE = post-emergence application; PE = pre-emergence application; DAS = days after seeding

**Table 3. Seed yield and ancillary characters affected by different weed management treatments (pooled two years data)**

| Treatment* | Seed yield (kg/ha) | | | Straw yield (kg/ha) | Biomass yield (kg/ha) | Harvest index | Plant height (cm) |
|---|---|---|---|---|---|---|---|
| | 2022 | 2023 | Pooled | | | | |
| Bentazon 500 g/ha PoE 30 DAS | 469 | 472 | 471 | 1561 | 2031 | 0.23 | 74.1 |
| Bentazon 750 g/ha at 30 DAS | 495 | 505 | 500 | 1604 | 2104 | 0.24 | 75.2 |
| Fluazifop-p-butyl 100 g/ha PoE 30 DAS | 382 | 377 | 380 | 1316 | 1696 | 0.22 | 67.7 |
| Fluazifop-p-butyl 200 g/ha PoE 30 DAS | 417 | 385 | 401 | 1365 | 1766 | 0.23 | 68.2 |
| Sulfentrazon 50 g/ha PE | 434 | 390 | 412 | 1429 | 1840 | 0.22 | 68.5 |
| Sulfentrazon 75 g/ha as PE | 467 | 460 | 463 | 1555 | 2018 | 0.23 | 69.1 |
| Pendimethalin 200 g/ha PE | 371 | 314 | 342 | 1218 | 1560 | 0.22 | 67.8 |
| Pendimethalin 400 g/ha PE | 460 | 423 | 441 | 1511 | 1952 | 0.23 | 69.2 |
| Weed free | 554 | 560 | 557 | 1723 | 2279 | 0.24 | 76.2 |
| Weedy check | 291 | 226 | 258 | 950 | 1209 | 0.22 | 65.5 |
| LSD (p=0.05) | 76.22 | 52.66 | 89.43 | 274.53 | 311.28 | NS | 6.50 |

*PoE = post-emergence application; PE = pre-emergence application; DAS = days after seeding

treatments are comparable to each other and superior over fluazifop-p-butyl 100 g/ha PoE, fluazifop-p-butyl 200 g/ha PoE and pendimethalin 200 g/ha PE. The increase in yield and its traits may be due to reduced weed competition with the use of herbicides before crop initiation and subsequent reduced competition for nutrients and other growth factors with post-emergence herbicides. These practices reduce competition between crops and plants, thus saving more nutrients for crops and allowing crops to grow better (Maciel *et al.* 2018).

Bentazon 750 g/ha PoE and sulfentrazon 75 g/ha PE efficiently controlled the weeds and produced higher yield of chia. Hence, they can be used for weed control in chia crop.

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