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## WEED MANAGEMENT STRATEGIES FOR ENHANCED MUSTARD (*BRASSICA JUNCEA* L. VAR. GIRRAJ) PRODUCTIVITY UNDER OROBANCHE AND OTHER WEEDS INFESTATION IN GIRD REGION OF MADHYA PRADESH, INDIA

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### ABSTRACT

A field study was conducted during *Rabi* 2024–25 at Gwalior, Madhya Pradesh, to evaluate the effectiveness of twelve weed management practices on mustard (*Brassica juncea* L. var. Girraj) under Orobanche infestation. The experiment was laid out in a randomized block design with three replications. Observations on plant growth, branching, leaf area, dry matter accumulation, yield attributes, seed yield, stover yield, biological yield, and harvest index were recorded. Results revealed significant differences among treatments. Pre-emergence application of Pendimethalin 38.4% + Pyrazosulfuron 0.85% ZC at 785 g ha<sup>-1</sup> PPI (T<sub>2</sub>) was the most effective, significantly enhancing plant population, growth parameters, biomass accumulation, yield attributes, and seed yield (2238 kg ha<sup>-1</sup>), followed by Pyroxasulfone 100 g ha<sup>-1</sup> PoE (T<sub>6</sub>) and manual removal of Orobanche shoots (T<sub>11</sub>). Treatments using organic amendments (T<sub>8</sub>–T<sub>10</sub>) moderately improved growth and yield but were less effective in weed control. Unweeded plots (T<sub>12</sub>) recorded the lowest growth, yield, and harvest index, highlighting the detrimental effect of Orobanche and other weeds. These findings suggest that integrated herbicidal management is the most efficient strategy for enhancing mustard productivity under Orobanche infestation.

**Key words:** Growth, Herbicides, Mustard, Orobanche, Weed management, Yield

### Introduction

Mustard (*Brassica juncea*) is a crucial oilseed crop contributing substantially to India's agricultural economy and ensuring edible oil availability to rural populations (Gupta *et al.*, 2024). Mustard seeds are processed for edible oil, while the residual meal serves as a protein-rich animal feed and organic soil amendment, reflecting its multifunctional use in agriculture, food processing, and livestock nutrition (Taak *et al.*, 2022). India's diverse agro-ecological conditions support the cultivation of nine annual oilseed crops, including groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower, niger seed, castor, and linseed (Suresh and Mathur, 2025). Among these, rapeseed-mustard is a key crop, grown across 24 states.

Madhya Pradesh is one of India's key mustard-producing states, contributing over 13% of national output with around 1.08 million ha under cultivation, production exceeding 1.66 million tonnes, and an average productivity of about 1,530 kg ha<sup>-1</sup> in recent crop years (Kumar *et al.*, 2025).

India's mustard seed and oil export performance shows a positive trend, with a growing share in global oilseed trade. Mustard seed export grew by nearly 18% over the last decade, indicating an expanding role in international markets (Tyndel *et al.*, 2025). Mustard seed has enjoyed consistent demand due to its versatility and the growing health-consciousness surrounding mustard oil (Aslan, 2023).

**Table 1:** Effect of Different Weed Management Practices on Plant Population and Growth of Mustard (*Brassica juncea* L. var. Girraj) under Orobanche Infestation.

Treatments	Plant population/m row length at		Plant height (cm) at		
	Initial	Harvest	30	60	Har-
			DAS	DAS	vest
T <sub>1</sub> -Pyrazosulfuron 10% WP 20 g ha <sup>-1</sup> PPI	11.55	10.91	22.68	118.73	190.06
T <sub>2</sub> -Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC 785 g ha <sup>-1</sup> PPI	12.05	11.95	25.92	125.16	211.86
T <sub>3</sub> -Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC 588.75 g ha <sup>-1</sup> PPI	11.25	11.14	24.78	120.42	195.66
T <sub>4</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 615 g ha <sup>-1</sup> PPI	12.11	10.48	22.24	108.73	179.02
T <sub>5</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 461.25 g ha <sup>-1</sup> PPI	11.59	10.53	22.56	117.54	183.16
T <sub>6</sub> -Pyroxasulfone 100 g ha <sup>-1</sup> PoE	11.98	11.48	25.52	124.32	208.66
T <sub>7</sub> -Pendimethalin 3000 ml ha <sup>-1</sup> CS + Metsulfuron SC 4 g ha <sup>-1</sup> PE	11.72	10.88	22.91	118.81	191.79
T <sub>8</sub> -Neem cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	11.61	10.74	20.63	118.44	187.59
T <sub>9</sub> -Poultry manure 2.0 t ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	11.47	11.01	23.89	119.27	192.86
T <sub>10</sub> -Karanj Cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	11.92	11.08	23.90	119.45	193.86
T <sub>11</sub> -Manual removal of <i>Orobanche</i> shoots	12.21	11.22	25.08	123.54	197.93
T <sub>12</sub> -Unweeded	11.54	10.42	20.96	107.73	165.36
<b>SE(m)±</b>	<b>0.25</b>	<b>0.19</b>	<b>2.28</b>	<b>1.09</b>	<b>1.51</b>
<b>CD (5%)</b>	<b>NS</b>	<b>0.56</b>	<b>NS</b>	<b>3.20</b>	<b>4.46</b>

Weed competition in mustard crops is particularly severe during the early stages because the crop exhibits slow growth during the first 4–8 weeks after sowing. The critical period for crop-weed competition, however, is 15–40 days (Sharma *et al.*, 2018). Weeds emerge alongside the crop and compete for light, nutrients, space, and moisture, leading to yield reductions of 10–58% (Banga and Yadav, 2001). Beyond direct competition,

weeds can also act as alternate hosts for insect pests and plant pathogens, increasing biotic stress and further reducing crop performance (Oerke, 2006). High competitive ability of mustard with weeds, weed control strategies should be devised to target reducing weed competition during seedling emergence using mechanical or chemical means. Weed infestation by species of the Brassicaceae and Poaceae is one of the most important

**Table 2:** Effect of Weed Management Practices on Branching, Leaf Number and Leaf Area of Mustard (*Brassica juncea* L. var. Girraj) under Orobanche Infestation.

Treatments	NBP		NLP		LPP	
	60 DAS	Har-vest	30 DAS	60 DAS	30 DAS	60 DAS
T <sub>1</sub> -Pyrazosulfuron 10% WP 20 g ha <sup>-1</sup> PPI	3.69	5.25	7.01	40.12	19.79	51.42
T <sub>2</sub> -Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC 785 g ha <sup>-1</sup> PPI	5.27	8.24	8.61	42.72	22.56	71.18
T <sub>3</sub> -Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC 588.75 g ha <sup>-1</sup> PPI	4.54	5.65	7.38	40.49	21.02	52.65
T <sub>4</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 615 g ha <sup>-1</sup> PPI	3.28	4.45	6.28	39.39	19.06	47.36
T <sub>5</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 461.25 g ha <sup>-1</sup> PPI	3.41	4.92	6.71	39.82	19.49	47.79
T <sub>6</sub> -Pyroxasulfone 100 g ha <sup>-1</sup> PoE	4.71	7.18	8.03	41.14	22.34	62.30
T <sub>7</sub> -Pendimethalin 3000 ml ha <sup>-1</sup> CS + Metsulfuron SC 4 g ha <sup>-1</sup> PE	3.85	5.28	7.02	40.13	19.80	51.43
T <sub>8</sub> -Neem cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	3.46	5.08	6.75	39.86	19.53	51.16
T <sub>9</sub> -Poultry manure 2.0 t ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	4.02	5.32	7.08	40.19	19.86	51.49
T <sub>10</sub> -Karanj Cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	4.43	5.59	7.25	40.36	20.03	51.66
T <sub>11</sub> -Manual removal of <i>Orobanche</i> shoots	4.58	6.65	7.68	40.79	21.13	53.76
T <sub>12</sub> -Unweeded	3.16	4.01	6.04	39.15	18.82	47.12
<b>SE(m)±</b>	<b>0.25</b>	<b>0.15</b>	<b>0.15</b>	<b>0.36</b>	<b>0.40</b>	<b>0.35</b>
<b>CD (5%)</b>	<b>0.75</b>	<b>0.45</b>	<b>0.44</b>	<b>1.06</b>	<b>1.19</b>	<b>1.03</b>
<b>NBP: Number of branches/plant at; NLP: Number of leaves/plant at; LPP: Leaf area per plant (cm<sup>2</sup>) at</b>						

**Table 3:** Effect of Weed Management Practices on Dry Weight of Infested and Non-Infested Mustard Plants (*Brassica juncea* L. var. Girraj).

Treatments	DWIP			DWNIP		
	60 DAS	90 DAS	Har-vest	60 DAS	90 DAS	Har-vest
T <sub>1</sub> -Pyrazosulfuron 10% WP 20 g ha <sup>-1</sup> PPI	11.01	31.85	38.88	13.78	30.00	45.01
T <sub>2</sub> -Pendimethalin 38.4%+ pyrazosulfuron ethyl 0.85% ZC 785 g ha <sup>-1</sup> PPI	12.94	34.99	47.22	15.75	35.75	47.70
T <sub>3</sub> -Pendimethalin 38.4%+ pyrazosulfuron ethyl 0.85% ZC 588.75 g ha <sup>-1</sup> PPI	12.06	34.23	45.26	14.83	32.23	45.55
T <sub>4</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 615 g ha <sup>-1</sup> PPI	10.20	23.37	34.40	11.97	28.70	41.25
T <sub>5</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 461.25 g ha <sup>-1</sup> PPI	10.74	25.58	36.61	13.51	29.58	41.55
T <sub>6</sub> -Pyroxasulfone 100 g ha <sup>-1</sup> PoE	12.86	34.37	47.11	15.63	35.70	47.55
T <sub>7</sub> -Pendimethalin 3000 ml ha <sup>-1</sup> CS + Metsulfuron SC 4 g ha <sup>-1</sup> PE	11.22	32.39	43.42	13.99	30.52	45.20
T <sub>8</sub> -Neem cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	10.81	29.65	38.68	13.58	29.65	41.52
T <sub>9</sub> -Poultry manure 2.0 t ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	11.48	33.65	44.68	14.25	32.05	45.25
T <sub>10</sub> -Karanj Cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	11.63	33.80	44.83	14.40	32.13	45.35
T <sub>11</sub> -Manual removal of <i>Orobanche</i> shoots	12.15	34.32	45.35	14.92	35.65	47.45
T <sub>12</sub> -Unweeded	9.68	22.12	34.15	11.45	28.65	39.88
SE(m)±	<b>0.34</b>	<b>0.51</b>	<b>0.50</b>	<b>0.58</b>	<b>0.56</b>	<b>0.59</b>
CD (5%)	<b>0.99</b>	<b>1.49</b>	<b>1.46</b>	<b>1.70</b>	<b>1.66</b>	<b>1.73</b>
<b>DWIP: Dry weight of infested plant (g) at; DWNIP: Dry weight of non-infested plant (g) at</b>						

challenges for mustard growers in India as a result of the lack of efficient selective herbicides. Competition by weeds at initial stages is a major limiting factor to its productivity. Manual weeding at 3–4 weeks after sowing is the most common practice to control weeds in Indian mustard. Controlling total weed populations, including both competitive weeds and parasitic broomrape (*Orobanche* spp.), not only improves resource availability for the crop but also minimizes yield losses caused by parasitic nutrient withdrawal, resulting in significant increases in mustard seed yield (Sheoran *et al.*, 2014).

Keeping these challenges in mind, the present study aims to evaluate the effectiveness of different weed management practices on weed dynamics, growth, yield, and productivity of mustard under *Orobanche* infestation.

### Materials and Methods

An investigation was carried out during the *rabi* season of 2024–25 at the Research Farm, Department of Agronomy, College of Agriculture, Gwalior (M.P.), India (26°13' N latitude, 78°14' E longitude, 206 m above MSL). Gwalior experiences a subtropical climate with extreme summer temperature up to 48°C and winter minimum of 4°C, receiving an annual rainfall of 750–800 mm, mostly during June–September. During the crop season, the average maximum and minimum temperatures were 28.6°C and 10.0°C, respectively. The experimental field had uniform topography with proper

drainage and sandy clay loam soil. Soil analysis indicated medium organic carbon content (0.31%), low available nitrogen (169.10 kg ha<sup>-1</sup>), medium phosphorus (10.89 kg ha<sup>-1</sup>), high potash (165.2 kg ha<sup>-1</sup>), slightly alkaline pH (7.71) and normal electrical conductivity (0.233 dS/m).

The experiment was laid out in a randomized block design with three replications comprising twelve treatments, each plot measuring 4.0 m × 2.8 m with 40 cm row spacing and 1 m plot-to-plot distance. Mustard variety Girraj was sown on 25<sup>th</sup> November 2024 at a seed rate of 5 kg ha<sup>-1</sup>, with recommended fertilizers (N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O – 80:40:20 kg ha<sup>-1</sup>) applied, and harvested on 1<sup>st</sup> April 2025. Treatments included various herbicides, organic amendments, and manual weeding practices.

Observations on crop growth included plant population per meter row at initial and harvest stages, plant height, number of branches, and number of leaves per plant at 30, 60 DAS and at harvest, recorded from five randomly selected tagged plants per plot. Leaf area per plant was measured using a LICOR leaf area meter. Dry weight of both *Orobanche*-infested and non-infested plants was recorded at 30, 60, 90 DAS and at harvest after oven drying at 65–70°C to a constant weight. Yield and yield components such as number of siliqua per plant, length of siliqua, number of seeds per siliqua, seed weight per plant, and 1000-seed weight were measured from tagged plants. Seed yield, stover yield, biological yield,

**Table 4:** Effect of Weed Management Practices on Yield Attributes of Mustard (*Brassica juncea* L. var. Girraj).

Treatments	NSP	LS	NSS	SW	TW
T <sub>1</sub> -Pyrazosulfuron 10% WP 20 g ha <sup>-1</sup> PPI	190.11	5.18	15.84	19.16	5.30
T <sub>2</sub> -Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC 785 g ha <sup>-1</sup> PPI	296.11	6.61	19.68	36.62	5.60
T <sub>3</sub> -Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC 588.75 g ha <sup>-1</sup> PPI	269.22	5.71	16.77	34.07	5.47
T <sub>4</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 615 g ha <sup>-1</sup> PPI	176.25	5.08	15.36	16.79	4.60
T <sub>5</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 461.25 g ha <sup>-1</sup> PPI	182.21	5.09	15.43	16.92	4.62
T <sub>6</sub> -Pyroxasulfone 100 g ha <sup>-1</sup> PoE	293.11	6.03	17.60	35.67	5.59
T <sub>7</sub> -Pendimethalin 3000 ml ha <sup>-1</sup> CS + Metsulfuron SC 4 g ha <sup>-1</sup> PE	194.44	5.37	16.10	21.01	5.32
T <sub>8</sub> -Neem cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	184.34	5.12	15.63	18.34	5.22
T <sub>9</sub> -Poultry manure 2.0 t ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	200.36	5.58	16.15	22.13	5.39
T <sub>10</sub> -Karanj Cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	222.44	5.67	16.25	24.42	5.42
T <sub>11</sub> -Manual removal of <i>Orobanche</i> shoots	290.11	5.91	17.48	34.85	5.50
T <sub>12</sub> -Unweeded	165.56	5.00	14.63	16.03	4.50
<b>SE(m)±</b>	<b>1.29</b>	<b>0.14</b>	<b>0.57</b>	<b>1.26</b>	<b>0.14</b>
<b>CD (5%)</b>	<b>3.81</b>	<b>0.40</b>	<b>1.69</b>	<b>3.71</b>	<b>0.41</b>

NSP: No. of siliqua /plant; LS: Length of siliqua (cm); NSS: No. of seeds/ siliqua; SW: Seed weight (g/plant); TW: Test weight (g)

and The harvest index was calculated by using following formula and expressed as percentage (Singh and Stoskoff, 1971).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

All data were subjected to analysis of variance (ANOVA) following Fisher (1958). Significant treatment differences were compared using critical difference (CD) at 5% probability. Mean values along with CD are presented in Tables.

## Results and Discussion

The results indicated significant variations among the different weed management practices in influencing plant

growth, yield attributes, and yield of mustard under *Orobanche* infestation.

### Plant Population and Growth

It is very clear in Table 1 that plant population at harvest was highest under T<sub>2</sub> (Pendimethalin 38.4% + Pyrazosulfuron 0.85% ZC 785 g ha<sup>-1</sup> PPI) (11.95 plants/m row) and lowest in the unweeded control (T<sub>12</sub>, 10.42 plants/m). Pre-emergence herbicides and integrated treatments helped maintain higher plant population by effectively suppressing *Orobanche* and other weeds, minimizing competition for nutrients, light, and moisture (Shekhawat *et al.*, 2012). Similarly, plant height at harvest was maximum in T<sub>2</sub> (211.86 cm), followed by T<sub>6</sub> (Pyroxasulfone 100 g ha<sup>-1</sup> PoE, 208.66 cm) and manual

**Table 5:** Effect of Weed Management Practices on Seed Yield, Stover, Biological Yield and Harvest Index of Mustard (*Brassica juncea* L. var. Girraj).

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest Index (%)
T <sub>1</sub> -Pyrazosulfuron 10% WP 20 g ha <sup>-1</sup> PPI	1306	5391	6697	19.56
T <sub>2</sub> -Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC 785 g ha <sup>-1</sup> PPI	2238	8318	10556	21.19
T <sub>3</sub> -Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC 588.75 g ha <sup>-1</sup> PPI	1874	7580	9454	19.79
T <sub>4</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 615 g ha <sup>-1</sup> PPI	1100	4720	5820	18.90
T <sub>5</sub> -Pretilachlor 30% + pyrazosulfuron 0.75% WG 461.25 g ha <sup>-1</sup> PPI	1114	4689	5803	19.21
T <sub>6</sub> -Pyroxasulfone 100 g ha <sup>-1</sup> PoE	2110	8182	10292	20.49
T <sub>7</sub> -Pendimethalin 3000 ml ha <sup>-1</sup> CS + Metsulfuron SC 4 g ha <sup>-1</sup> PE	1428	6208	7636	18.72
T <sub>8</sub> -Neem cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	1231	4954	6185	19.92
T <sub>9</sub> -Poultry manure 2.0 t ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	1522	6405	7927	19.26
T <sub>10</sub> -Karanj Cake 200 kg ha <sup>-1</sup> fb pendimethalin 30% EC 500 g ha <sup>-1</sup> herbigation at 35 DAS	1692	6892	8584	19.71
T <sub>11</sub> -Manual removal of <i>Orobanche</i> shoots	2017	8017	10034	20.19
T <sub>12</sub> -Unweeded	1044	4658	5702	18.32
<b>SE(m)±</b>	<b>69.52</b>	<b>158.72</b>	<b>170.78</b>	<b>0.79</b>
<b>CD (5%)</b>	<b>205.20</b>	<b>468.51</b>	<b>504.11</b>	<b>NS</b>

Orobanche removal ( $T_{11}$ , 197.93 cm), whereas unweeded plots exhibited significantly lower height (165.36 cm), indicating strong inhibitory effect of weeds on vegetative growth (Table 1).

### Branching, Leaf Number and Leaf Area

Branch number and leaf area per plant were significantly influenced by the treatments. Maximum branching and leaf area at 60 DAS and harvest were observed in  $T_2$  and  $T_6$ , indicating better photosynthetic efficiency and growth under effective weed management (Table 2). Unweeded plots showed minimum branching and leaf area, reflecting suppression by weeds. The integrated use of pre-emergence herbicides with organic amendments ( $T_8$ – $T_{10}$ ) also improved leaf area and branch number, highlighting the role of nutrient-enriched organic matter in promoting crop vigor (Singh *et al.*, 2024).

### Dry Weight of Infested and Non-Infested Plants

Dry matter accumulation was higher in plants under  $T_2$  (47.22 g at harvest, infested; 47.70 g non-infested) and  $T_6$  (47.11 g, infested; 47.55 g, non-infested), showing the effectiveness of herbicidal treatment in reducing Orobanche parasitism (Table 3). Unweeded plots had lowest dry weight (34.15 g, infested; 39.88 g, non-infested), confirming the negative impact of Orobanche and weed competition on biomass production (Patel *et al.*, 2017).

### Yield Attributes

Seed-bearing siliqua, seed number per siliqua, seed weight per plant, and test weight were significantly influenced by weed management practices.  $T_2$  recorded highest number of siliqua per plant (296.11), siliqua length (6.61 cm), seeds per siliqua (19.68), and seed weight (36.62 g/plant). Manual removal ( $T_{11}$ ) and Pyroxasulfone ( $T_6$ ) were also effective (Table 4). Unweeded plots consistently had lower yield attributes, confirming yield reduction under Orobanche and weed pressure (Pal *et al.*, 2021).

### Seed Yield, Stover, Biological Yield and Harvest Index

Seed yield was significantly higher in  $T_2$  (2238 kg ha<sup>-1</sup>), followed by  $T_6$  (2110 kg ha<sup>-1</sup>) and  $T_{11}$  (2017 kg ha<sup>-1</sup>). Stover and biological yield followed similar trends. Harvest index was highest in  $T_2$  (21.19%), indicating better partitioning of biomass into economic yield. Unweeded plots recorded minimum seed yield (1044 kg ha<sup>-1</sup>) and harvest index (18.32%), reflecting severe yield losses due to competition and Orobanche infestation (Table 5). Integrated weed management using herbicides or combination with organic amendments proved more

effective than manual weeding alone (Patel *et al.*, 2025). Overall, pre-emergence herbicides combined with Pyrazosulfuron ( $T_2$ ) proved to be the most effective treatment for controlling Orobanche and other weeds, improving growth, yield attributes, and final seed yield, followed by Pyroxasulfone ( $T_6$ ) and manual Orobanche removal ( $T_{11}$ ). Treatments using organic amendments ( $T_8$ – $T_{10}$ ) showed moderate improvement, suggesting that nutrient enrichment helps in better crop performance but cannot fully replace effective herbicidal control.

## Conclusion

Among the twelve treatments,  $T_2$  (Pendimethalin 38.4% + Pyrazosulfuron 0.85% ZC 785 g ha<sup>-1</sup> PPI) was found to be the most effective in controlling Orobanche and other weeds, resulting in higher plant population, growth parameters, biomass accumulation, yield attributes, and seed yield. This was followed by  $T_6$  (Pyroxasulfone 100 g ha<sup>-1</sup>PoE) and  $T_{11}$  (manual removal of Orobanche shoots), which also significantly improved crop performance compared to other treatments. Treatments involving organic amendments ( $T_8$ – $T_{10}$ ) provided moderate benefits by enhancing growth and yield, but were less effective in weed control than herbicidal treatments. The unweeded control ( $T_{12}$ ) recorded the lowest growth, yield, and harvest index, confirming the critical impact of weeds, particularly Orobanche, on mustard productivity.

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