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Effect of pre and post-emergence herbicide on crop-weed competition of Indian mustard

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Abstract
The experiment was carried out in Kumarganj, Ayodhya, during the rabi season of 2021–2022 at the Agronomy Research Farm of Acharya Narendra Deva University of Agriculture and Technology to examine the effects of preand post emergence herbicides and weed control techniques on the productivity and economics of Indian mustard. In the experiment, fifteen weed management strategies were evaluated. The experiment was set up using a randomized block design with three replications. Application of pendimethalin (PE) @ 1000 g ha-1 + hand weeding at 40 DAS recorded minimum weed density over weedy check and highest weed control efficiency recorded with pendimethalin (PE) @ 1000 g ha-1 + hand weeding at 40 DAS over to other herbicide treatment, and WCI and HEI was highly correlated with WCE. The number of siliquea plants, number of siliquea seeds, length of siliqua, and seed and stover yield were all significantly increased as a result. Maximum net return values (in Rs. Pendimethalin (PE) @ 1000 g ha-1 + hand weeding at 40 DAS was found to be superior to other weed management treatments for B:C ratio (1.33 and 1.69) and B:C ratio (50537 and 64251).

Keywords: Production, herbicide, mustard, WCI and yield

Introduction
In India, mustard is a significant oil seed crop. With an amazing area next to food seeds, it secures a unique position in the Indian farming system. condiment known as mustard is created from the flavorful seeds of one of two major Brassicaceae plants. India, which ranks third in terms of area and production behind China and Canada, is a significant rapeseed-mustard producing nation. After groundnut, mustard is India's second-most significant edible oil seed crop. During the years 2021–2022, India produced 11.5 million tonnes of rapeseed–mustard on 95.77 lakh hectares of land. In contrast, the area of rapeseed-mustard in Uttar Pradesh in 2021–2022 was 1.10 mha, with a production of 1.11 mt and an average productivity of 1055 kg ha–1. Rajasthan, on the other hand, had the highest area (2.12 mha) and production (2.45 mt), with a low productivity (1152 kg ha–1) compared to Gujarat (1373 kg ha–1). In comparison to Gujrat (1373 kg ha-1) and Rajsathan (1152 kg ha-1) the production in Uttar Pradesh (1055 kg ha-1) is extremely low. Since 1980–81, area and production in Uttar Pradesh have decreased, but productivity has increased, going from 540 kg ha–1 in 1980–81 to 1055 kg ha–1 in 2021–22.

This decline may be the result of switching from growing mustard as a single crop to mixing it with other crops, notably in eastern Uttar Pradesh, competing rabi crops, particularly with wheat, and a lack of lucrative mustard-based cropping systems. If farmers have access to the right types and suggested agronomic practises, mustard production and productivity in this region may be increased by at least twofold. The Indian mustard, yellow sarson, brown sarson, raya, and toria are the main components of rapeseed mustard. Due to Indian mustard's better productivity and resilience to biotic and abiotic stressors, its acreage has recently increased at the expense of other Brassicas. Rapeseed cultivation is confined only to northern India because of late maturity and shattering of pods owing to high temperature prevailing during harvest in February-March.

Weeds have a horrifying impact on crop production, causing yield failure in the case of mustard that can range from 15 to 30 percent. For water, room, light, and nutrients, weeds compete with crop plants. In addition to lowering produce quality and posing various health and environmental risks, it reduces seed yield by up to 35–60% or even more, depending on the weed population, type of weed flora, and length of infestations. Due to the crop's slow growth in the first 4 to 8 weeks after sowing, weed competition in mustard crops is

More severe early on. However, the crucial window is between 15 and 40 days. Weed damage is severe, but it frequently goes unnoticed because it primarily has an invisible impact. Due to this, the farmer adopts a fatalistic mindset toward weeds and treats them as the least important when it comes to management. According to estimates, weeds account for up to 37 percent of all agricultural pests' combined production losses in India. According to a conservation estimate, weeds cause the annual loss of 10 to 15 percent of crop production, or well over $1, 000, 000 crore (Sharma *et al*., 2018) [9]. Weeds account for 45 percent of all annual agricultural production losses, followed by insects (30 percent), diseases (20 percent), and other causes (5 percent) (Rao 2000) [8]. Therefore, prompt and effective weed control is essential to increase the efficiency of nutrient use and, ultimately, the yield. Avena fatua, Cynodon dactylon, Cyperus rotundus, Phalaris minor, and the following monocots and dicots are the main weed flora that infest the mustard crop. Apart from this, Broomrape (Orobanche) is an alarming parasitic weed of rapeseed-mustard. The yield of Indian mustard is typically reduced by 28–30% due to broomrape weed infestation. In the Orobanche spp., One of the most unsettling parasitic weeds, aegyptiaca severely reduces the yield and quality of rapeseed-mustard (Bhanu *et al*. The traditional practice of hand or mechanical weeding once during early stages of crop growth i.e., 25-30 days after sowing (DAS) is not sufficient as new flushes of weeds appears after every mechanical weeding, irrigation and winter rainfall re-infest the crop and most importantly they take away major portion of the nutrients and moisture from the soil. Manual weeding in mustard is cumbersome, laborious, time taking and costly. For effective weed management, two hand weeding are generally required. The first should be done 25 to 30 days after sowing (i.e. at fourth leaf stage) and the second at 45-50 days after planting. Wherever hand weeding is not possible or is uneconomical, use of herbicide is recommended. Therefore, most of the mustard farmers depend on herbicides due to effective and easy application compared other method of weed control. Chemical herbicides play an important role for weed control in mustard crop where mechanical or manual weeding is difficult, costly and scare labours. With the aim of optimize the weed control efficacy and minimize the application costs, use of pre-and post-emergence herbicides, as well as herbicide mixtures, has become the alternative. It approach also represents a vital device to avoid problems related to herbicide resistance.

Considering above fact, the present experiment was planned to assess the integration of different weed management practices in mustard. Spraying of pendimethalin @ 1.25 kg a.i. ha-1 (pre-emergence) could be effective in the management of weeds. The application of isoproturon @ 1 kg a.i. ha-1 is beneficial in wheat + mustard mixed cropping. (2019).

Material Methods

At the Acharya Narendra Deva University of Agriculture and Technology, the current experiment was carried out during the Rabi season of 2021–2022. The experiment soil was a silty loam with a pH of 8 and a texture with low organic carbon (0.34) available nitrogen (138.20 kg ha-1), medium available phosphorus (15.2 kg/ha), and high potassium (251. 22 kg/ha). fifteen weed management techniques, i.e. T1-Pendimethalin (PE) @ 1000 g ha-1, T2-Isoproturon (POE) @ 1000 g ha-1 at 20DAS, T3-Pendimethalin (PE) @ 1000 g ha-1 + Hand weeding at 40DAS, T4-Isoproturon (POE) @ 1000 g ha-1 + Hand weeding at 40DAS, T5-Pendimethalin (PE) @ 1000 g ha.cv for the mustard variety. With a seed rate of 5 kg/ha, "NDR-8501" was manually sown with a row-row distance of 45 cm and a plant-plant distance of 15 cm. Under test conditions, the recommended fertilizer doses of nitrogen (90 kg ha-1), phosphorus (45 kg ha-1), potash (25 kg ha-1) and sulfur (20 kg ha-1) were used. On the other hand, full doses of phosphorus and nitrogen were applied as a base dose through single super phosphate and urea, respectively. Two equally sized doses of the remaining nitrogen were applied. Knapsack sprayers equipped with flat fan nozzles and 500 L/ha of spray volume were used to apply the herbicides. To raise the crop in accordance with the recommendations, the other set of procedures was used. After sowing, the crop received a light irrigation during the flowering and pod-formation stages March 23, 2022, saw the crop's harvest. Using an iron quadrate measuring 0.5 m2 of the net plot area, observations on the quantity of weeds and the dry matter of weeds were made in four randomly chosen locations. Prior to analysis, the weed data were transformed using square roots. Using the F-test method described by Gomez and Gomez (1984) [12], all of the collected data were statistically analyzed. To assess the significance of the difference between means, least significant differences (LSD) values at P=0.05 were used.

Result and Discussion

Effect of weed

Different weed management practices significantly reduced the weed density at 60 DAS. However, besides Hand weeding at 20 and 40 DAS (T_{14}), the lowest density and dry weight was recorded with the application of pendimethalin (PE) @ 1000 g ha^{-1} + hand weeding at 40 DAS (T_3), which was statistically at par with T_5 and T_9 as compare to remaining weed management treatment during the investigation years**.** The weed control efficiency (WCE %), weed control index and herbicide efficiency index at harvest was concerned, it was also affected due to various weed control treatments (Table 1). Beside hand weeding at 20 and 40 DAS, the higher WCE was recorded in pendimethalin (PE) @ 1000 g ha^{-1} + hand weeding at 40 DAS (98.47), and the lowest with isoproturon (POE) @ 1000 g ha^{-1} at 20 DAS (75.45). Isoproturon herbicides used to control only grassy weeds and in the experimental field density of grassy weeds was comparatively less as compared to broadleaved weeds. Thus this was a main reason of lower WCE with this treatment over rest of the herbicidal treatments. Overall the pendimethalin was found more effective to control the both types of weeds which resulted in higher WCE. It was because of the effective control of broadleaved and grassy weeds due to pendimethalin. These findings are in close conformity with those reported by Patel *et al*. 2013 [7]. As it is well known fact that the weed control index (WCI %) is directly correlated with WCE, if a particular treatment showed the highest WCE means weeds have been controlled effectively. Integrated of pendimethalin (PE) @ 1000 g ha^{-1} with hand weeding at 40 DAS recorded superior herbicide efficiency index (HEI %). It was closely *fb* by pendimethalin (PE) @ 1000 g ha^{-1} + paddy straw mulch @ 5 t ha^{-1} at 2-3 DAS and the lowest was found under alone application of isoproturon (POE) @ 1000 g ha^{-1} at

20 DAS during both the years of experimentation. Better improved control of weeds under pendimethalin (PE) @ 1000 g ha^{-1} + hand weeding at 40 DAS could be assigned the reason for superior weed indices. Similar results have also been reported by Krishnamurthy *et al*. 1975 [3] and Lal *et al*. 2017 [4].

Effect of Yield attributes and yield

Yield per plant in mustard is affected by several plant characters such as number of siliques per plant, length of siliquae, number of seeds per siliques and test weight etc. Regarding the number of siliquae $plant^{-1}$, the highest number of siliquae was recorded due to the pendimethalin (PE) @ 1000 g ha^{-1} + hand weeding at 40 DAS (285) after the hand weeding at 20 and 40 DAS. This was also statistically *at par* with T_5 and T_9. Number of siliquae was directly with number of branches, since these treatments had the more number of branches $plant^{-1}$, resulted in more number of siliqua in different treatments. Length of siliqua and number of seeds per siliqua was also followed the same trend as of number of siliquae in different treatments. To some extent, siliqua length is a genetic trait but environmental factors also affect it. As far as the 1000- seed weight or test weight was concerned, it was not affected significantly due to different weed control treatments. However, higher test weight was recorded with pendimethalin (PE) @ 1000 g ha^{-1} + hand weeding at 40 DAS (4.74) but non-significant differences were noted due to different weed control treatments. (Singh *et al.* 2002 and Nirala and Dinkar 2012) [10, 6]. Seed and stover yields were influenced significantly by applying various weed management practices. Besides hand weeding at 20 and 40 DAS, application of herbicides had significant effect on seed and stover yield. The highest grain (19.66 q ha^{-1}) and stover yield (51.93 q ha^{-1}) of mustard was also recorded under pendimethalin (PE) @ 1000 g ha^{-1} + hand weeding at 40 DAS. It was found statistically at par with T_5, T_9 and T_{11}. Significantly lowest seed and stover yields were found under weedy check. Similar results were also reported by Yadav *et al*. (2010) [11]

Effect on Economics

The Highest net return (Rs.50538 ha^{-1}) was recorded under pendimethalin (PE) @ 1000 g ha^{-1} + hand weeding at 40 DAS with maximum B: C ratio (1.34) for mustard crop. The minimum net return (Rs.27818 ha^{-1}) was recorded in the weedy check and the minimum B-C ratio (0.81) was recorded in the paddy straw mulch @ 10 t ha^{-1} at 2-3 DAS in mustard crop. Mukherjee (2014) [5] also reported similar effect of weed control on economics of mustard crop.

Table 1: Effect of weed management practices on weed density, WCE (%), WCI (%) and HEI (%) in mustard crop

Treatments	Weed population (m^{-2}) at 60 DAS	Weed control efficiency (%)	Weed control index (%)	Herbicide efficiency index (%)
T_1-Pendimethalin (PE) @ 1000 g ha^{-1}	6.62 (42.10)	82.27	69.63	0.83
T_2-Isoproturon (POE) @ 1000 g ha^{-1} at 20DAS	7.75 (58.10)	75.45	62.14	0.36
T_3-Pendimethalin (PE) @ 1000 g ha^{-1} + Hand weeding at 40DAS	4.40 (18.00)	98.47	87.47	4.12
T_4-Isoproturon (POE) @ 1000 g ha^{-1} + Hand weeding at 40DAS	5.78 (33.00)	89.89	78.01	1.28
T_5-Pendimethalin (PE) @ 1000 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	4.53 (21.00)	96.78	85.60	2.97
T_6-Isoproturon (POE) @ 1000 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	6.05 (35.10)	87.40	75.27	1.11
T_7-Metribuzin (PE) @ 175 g ha^{-1}	6.77 (44.10)	80.58	67.78	0.71
T_8-Quizalofop-ethyl (POE) @ 60 g ha^{-1} at 20DAS	7.14 (49.10)	78.02	64.95	0.56
T_9-Metribuzin (PE) @ 175 g ha^{-1} + Hand weeding at 40DAS	4.73 (21.00)	95.90	84.64	2.57
T_{10}-Quizalofop-ethyl (POE) @ 60 g ha^{-1} + Hand weeding at 40DAS	5.15 (25.00)	92.46	80.85	1.75
T_{11}-Metribuzin (PE) @ 175 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	4.95 (23.00)	94.22	82.81	2.2
T_{12}-Quizalofop-ethyl (POE) @ 60 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	5.53 (29.10)	90.77	79.00	1.45
T_{13}-Paddy straw mulch @ 10 t ha^{-1} at 2-3DAS	6.31 (38.10)	84.83	72.46	0.94
T_{14}-Hand weeding at 20 and 40DAS	4.06 (16.00)	99.13	94.97	0.00
T_{15}-Weedy check	10.02 (100.20)	0.00	0.00	0.00
SEM±	0.21	-	-	-
CD (P=0.05)	0.62	-	-	-

Table 2: Effect of weed management practices on yield attributing character of mustard crop

Treatments	No of siliquae/plant	length of siliquae(cm)	No of seeds /siliquae	Test weight (g)
T_1-Pendimethalin (PE) @ 1000 g ha^{-1}	240	6.46	10.90	4.55
T_2-Isoproturon (POE) @ 1000 g ha^{-1} at 20DAS	224	6.31	10.75	4.44
T_3-Pendimethalin (PE) @ 1000 g ha^{-1} + Hand weeding at 40DAS	285	7.26	12.35	4.74
T_4-Isoproturon (POE) @ 1000 g ha^{-1} + Hand weeding at 40DAS	260	6.61	11.20	4.55
T_5-Pendimethalin (PE) @ 1000 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	282	7.21	12.20	4.72
T_6-Isoproturon (POE) @ 1000 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	254	6.56	11.10	4.58
T_7-Metribuzin (PE) @ 175 g ha^{-1}	234	6.41	10.95	4.42
T_8-Quizalofop-ethyl (POE) @ 60 g ha^{-1} at 20DAS	229	6.36	10.85	4.46
T_9-Metribuzin (PE) @ 175 g ha^{-1} + Hand weeding at 40DAS	280	7.01	11.95	4.63
T_{10}-Quizalofop-ethyl (POE) @ 60 g ha^{-1} + Hand weeding at 40DAS	269	6.76	11.40	4.66
T_{11}-Metribuzin (PE) @ 175 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	274	6.91	11.75	4.63
T_{12}-Quizalofop-ethyl (POE) @ 60 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	266	6.71	11.40	4.66
T_{13}-Paddy straw mulch @ 10 t ha^{-1} at 2-3DAS	247	6.52	11.05	4.57

T_{14}-Hand weeding at 20 and 40DAS	291	7.31	12.40	4.83
T_{15}-Weedy check	187	5.62	9.50	4.36
SEM±	4.12	0.11	0.18	0.18
CD (P=0.05)	11.94	0.31	0.53	NS

Table 3: Effect of weed management practice on yield and economics in mustard

Treatments	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
T_1-Pendimethalin (PE) @ 1000 g ha^{-1}	16.20	44.34	41220	1.30
T_2-Isoproturon (POE) @ 1000 g ha^{-1} at 20DAS	14.70	40.39	34714	1.10
T_3-Pendimethalin (PE) @ 1000 g ha^{-1} + Hand weeding at 40DAS	19.66	51.93	50538	1.34
T_4-Isoproturon (POE) @ 1000 g ha^{-1} + Hand weeding at 40DAS	16.60	45.17	37270	1.01
T_5-Pendimethalin (PE) @ 1000 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	18.50	49.85	46522	1.27
T_6-Isoproturon (POE) @ 1000 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	16.50	44.94	37824	1.04
T_7-Metribuzin (PE) @ 175 g ha^{-1}	15.70	43.59	40765	1.32
T_8-Quizalofop-ethyl (POE) @ 60 g ha^{-1} at 20DAS	15.60	42.59	38073	1.20
T_9-Metribuzin (PE) @ 175 g ha^{-1} + Hand weeding at 40DAS	18.10	48.89	44625	1.21
T_{10}-Quizalofop-ethyl (POE) @ 60 g ha^{-1} + Hand weeding at 40DAS	17.30	46.89	40133	1.07
T_{11}-Metribuzin (PE) @ 175 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	17.70	47.83	43833	1.22
T_{12}-Quizalofop-ethyl (POE) @ 60 g ha^{-1} + Paddy straw mulch @ 5 t ha^{-1} at 2-3DAS	16.90	45.89	39333	1.07
T_{13}-Paddy straw mulch @ 10 t ha^{-1} at 2-3DAS	16.30	44.57	32748	0.81
T_{14}-Hand weeding at 20 and 40DAS	20.30	53.46	48526	1.14
T_{15}-Weedy check	12.91	35.92	27818	0.91
SEM±	0.72	1.76	-	-
CD (P=0.05)	2.09	5.09	-	-

Conclusion

Hence, it is concluded that the significantly reduced weed density with pendimethalin (PE) @ 1000 g ha^{-1} + hand weeding at 40 DAS and increased weed control efficiency. Produced maximum mustard yield and benefit cost ratio was found under pendimethalin (PE) @ 1000 g ha^{-1} + hand weeding at 40 DAS over to other.

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