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RESEARCH ARTICLE

EFFECT OF DIFFERENT WEED MANAGEMENT PRACTICES ON GROWTH AND YIELD OF INDIAN MUSTARD (*BRASSICA JUNCEA*)

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ABSTRACT

Indian mustard (*Brassica juncea*) is an economically significant oilseed crop cultivated widely in India with versatile applications in various industries. However, weed infestation poses a major challenge to successful mustard cultivation, leading to reduced crop productivity and growth. To address these challenges, farmers and researchers have employed various weed management practices encompassing cultural, mechanical, chemical, and biological approaches. Understanding the effectiveness of these weed control strategies is essential for optimizing mustard cultivation and enhancing overall crop productivity. In this study, an experiment was conducted at the Experimental Research Farm Rampur of Doon (P.G) College of Agriculture Science & Technology in Uttarakhand, India. The experiment followed a Randomized Block Design (R.B.D) with eight weed management treatments and three replications, resulting in 24 experimental plots. The treatments included weed check, hand weeding, and various herbicides (Pendimethalin, Oxyfluorfen, Isoproturon, Quizalofop, Oxadiaryzl, and Clodinoflop). Data on growth attributes (plant height and number of branches per plant) and yield attributes (number of siliqua per plant, siliqua length, number of seeds per siliqua, and 1000-seed weight) were collected at different growth stages. The results showed that hand weeding and Pendimethalin @ 1.25 kg/ha were effective in promoting plant growth and yield attributes, while Clodinoflop @ 0.75 kg/ha had adverse effects on growth and yield. In terms of yield, hand weeding resulted in the highest seed yield, Stover yield, and biological yield, while the weed check treatment exhibited the lowest values. Economically, hand weeding demonstrated the highest gross return, net return, and benefit-to-cost ratio, emphasizing its economic superiority. However, herbicidal treatments like Pendimethalin also showed competitive economic benefits.

KEYWORDS

Brassica Juncea, Herbicides, Weed control, Yield, Economics

1. INTRODUCTION

Indian mustard, also known as Brassica juncea is a crop that holds economic value in India. It finds use, across industries such as food, pharmaceuticals and bio-fuels (Dwivedi et al. 2020). However the cultivation of mustard faces challenges due to the presence of weeds that compete with the crop for resources like nutrients, water, light and space (Pandey et al., 2016). These weeds not decrease crop productivity. Also have an impact on the microenvironment of the crop, which affects its growth and development (Chauhan et al., 2017). Indian mustard is particularly susceptible to weed competition leading to varying degrees of yield loss depending on factors, like weed species, density and the growth stage of the mustard crop (Kumar et al., 2019). Farmers and researchers have become aware of the impact that weed infestation can have on mustard. To address this issue they have implemented strategies, for managing weeds. These strategies involve approaches such as mechanical, chemical and biological methods (Bajwa et al., 2021). Each method has its advantages and disadvantages. Their effectiveness may differ based on factors, like agro climatic conditions the types of weeds present and the growth stage of the crops. To ensure sustainable and profitable mustard cultivation, it is essential to evaluate and compare the effects of different weed management practices on the growth, yield attributes, and economic aspects of Indian mustard. This study aims to provide valuable insights into the impact of various weed control strategies, helping optimize weed management practices and enhance overall crop productivity (Singh et al., 2020). Additionally, the research seeks to contribute to the development of sustainable agricultural practices that minimize the environmental impact of weed control measures (Kaur et al., 2022).

2. MATERIALS AND METHODS

2.1 Experimental Sites

The experimental study was conducted at the Experimental Research Farm Rampur of Doon (P.G) College of Agriculture Science & Technology, located in the sub-temperate mid-hill zone of Uttarakhand, India. The site's latitude ranged from 29º58' N to 31º2' N and longitude from 77º34' E to 78º18' E, with an elevation of approximately 450 meters above sea level. The soil at the experimental site was characterized as sandy loam in texture with a pH of 7.8. Before the layout of the experimental plots, a composite soil sample (0-15 cm depth) was collected and its physical and chemical characteristics were determined as follows:

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Table 1: Physical characteristics of the experimental field soil		
Properties	**Composition**	**Method employed**
Soil separates %		International pipette method (Piper,1966)
% Sand	64.5	
% Silt	13.4	
% Clay	12.1	
Texture class	Sandy loam	
Chemical characteristics of the experimental field soil		
Particulars	**values**	**Method employed**
EC (d Sm^{-1})	0.29	Conductivity bridge (Jackson, 1973)
pH	7.8	Glass electrode pH meter (Jackson, 1973)
Organic carbon (%)	0.52	Walkley and Black method (1934)
Available Nitrogen (kg/ha)	98	Alkaline $KMnO_4$ method (Subbiah & Asija,1956)
Available Phosphorus (kg/ha)	33.8	Olsen's method (Olsen et al.,1954)
Available Potassium (kg/ha)	94	Flame photometer method (Jackson, 1973)

2.2 Experimental Details

The study followed a Randomized Block Design (R.B.D) to reduce the effect of variability within the experimental site. Eight weed management treatments were evaluated, and each treatment was replicated three times. This resulted in a total of 24 experimental plots. The net plot size was 4×3 m2, with a row spacing of 30 cm and a plant spacing of 10 cm (Table 2).

Table 2: Treatments and layout details	
Treatments Symbol	**Name of the Treatments**
T_1	Weed check
T_2	Hand weeding at 30 and 60 DAS
T_3	Pendimethalin 1.25 kg/ha (pre-emergence)
T_4	Oxyfluorfen 1.5 kg/ha (pre-emergence)
T_5	Isoproturon 0.75 kg/ha (post-emergence)
T_6	Quizalofop 1 kg/ha (post-emergence)
T_7	Oxadiaryzl 0.75 kg/ha (pre-emergence)
T_8	Clodinoflop 0.75 kg/ha (post-emergence)
Details of the layout	
Experimental design	**R.B.D.**
Total treatments	8
Replication	3
Total no of plots	8×3=24
Plot size	
a. Gross plot size	5×3.5m^{-2}
b. Net plot size	4×3 m^{-2}
Row spacing	30 cm
Plant spacing	10 cm

2.3 Fertilizer Application

The recommended doses of fertilizers, including 80 kg N, 60 kg P_2O_5, 40 kg K_2O, and 25 kg S per hectare, were applied. Nitrogen was applied in two split doses, with half as a basal application and the remaining half as top-dressing after the first irrigation.

2.4 Herbicides Application

The herbicides Pendimethalin, Oxyfluorfen, Isoproturon, Quizalofop, Oxadiaryzl, and Clodinoflop were applied at recommended rates as pre-emergence or post-emergence herbicides according to the manufacturer's instructions and local regulations. The applications were made in a solution with 600 liters of water per hectare at specified stages after sowing.

2.5 Data Collection and Analysis

Observations on various growth and yield attributes, including plant height, number of branches per plant, number of siliqua per plant, siliqua length, number of seeds per siliqua, and 1000-seed weight, were recorded at 25, 50, 75 days after sowing (DAS), and at the harvest stage. The data were analyzed using standard analysis of variance (ANOVA) for Randomized Block Design, and significant differences between treatment means were determined using the Least Significance Difference (LSD) test at a 5% level of significance.

2.5.1 Analysis

2.5.1.1 Gross return (G.R)

The yield of the mustard crop (grain + straw) was converted into gross return in rupees per hectare based on the prevalent price of the produce in the market.

2.5.1.2 Net returns (N.R.)

Net return was calculated by subtracting the total cost of production from the gross return expressed in rupee per hectare.

2.5.1.3 Benefit-cost ratio (B: C)

Benefit: cost ratio was worked out by dividing the net return by the respective cost of cultivation.

2.5.1.4 Harvest index

The ratio of economic yield (seed) to the total biological yield (seed plus stover) was computed and presented in percent by using the formula given below:

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

3. Result & Discussion

3.1 Growth attributes

3.1.1 Plant height

Table 3 displays the impact of different weed management practices on the plant height of Indian mustard at various growth stages (25 DAS, 50 DAS, 75 DAS, and harvest). The treatment of Pendimethalin @ 1.25 kg/ha (PE) resulted in the tallest plants at 25 DAS, with an average height of 13.907 cm. Conversely, the Clodinoflop @ 0.75 kg/ha (PoE) treatment caused significantly shorter plants, measuring 11.747 cm. At 50 DAS, the plants that had been treated with 1.25 kg/ha of Pendimethalin (PE) reached their maximum height of 51.513 cm. This height was significantly taller than the plants that had been treated with 0.75 kg/ha of Clodinoflop (PoE), which only grew to a height of 48.08 cm. As the crop continued to grow and mature to 75 DAS, the difference in height between the two treatments became less pronounced. However, the plants treated with 1.25 kg/ha of Pendimethalin (PE) still remained the tallest, with an average height of 109.19 cm. At 0.75 kg/ha (PoE), the Clodinoflop treatment managed to keep plants short, measuring an average height of 98.593 cm. Surprisingly, the Pendimethalin treatment at 1.25 kg/ha (PE) led to significantly taller plants during harvest, reaching heights of 152.8 cm, outperforming all other weed management methods. Even at the time of harvest, the Clodinoflop treatment at 0.75 kg/ha (PoE) upheld its reputation for resulting in shorter plants, with an average height of 120.363 cm.

Table 3: Plant height as influenced by weed management practices in Indian mustard				
Treatments	**Plant height 25 DAS (cm)**	**Plant height 50 DAS (cm)**	**Plant height 75 DAS (cm)**	**Plant height harvest (cm)**
Weed check	11.183	45.54	90.513	110.603
Hand weeding	15.897	53.61	112.67	158.153
Pendimethalin @ 1.25 kg/ha (PE)	13.907	51.513	109.19	152.8
Oxyfluorfen @1.5 kg/ha (PE)	13.35	49.433	106.737	139.583
Isoproturon @0.75 kg/ha (PoE)	13.72	50.583	104.637	136.137
Quizalofop @1.0 kg/ha (PoE)	13.227	48.667	103.913	129.293
Oxadiaryzl @0.75 kg/ha (PE)	12.7	48.117	101.207	124.433
Clodinoflop @ 0.75 kg/ha (PoE)	11.747	48.08	98.593	120.363
SEm (±)	**0.32**	**0.58**	**0.41**	**0.32**
CD 5%	**1.45**	**2.15**	**1.73**	**1.47**

Standard error of the mean (SEm) and the critical difference at a 5% significance level (CD 5%)

3.1.2 Number of branches per plant

The various weed management techniques had a significant impact on the number of branches per plant in Indian mustard, as shown in Table 4. The Weed check treatment had the fewest branches per plant at 50 DAS, with an average of 2.333 branches. At 75 DAS, this number increased to 4 branches, and by harvest time, it had grown to 5.333 branches. Thus, there were fewer branches in the Weed check treatment, indicating that weed competition had a detrimental effect on branch development. However, when compared to the Weed check treatment, the Hand weeding treatment revealed a significant increase in the number of branches. An average of 5.667 branches was present on each plant at 50 DAS; this number rose to 7.667 branches at 75 DAS; and finally, 8 branches were present at harvest. This implies that weed removal by hand had a positive impact on branch development, leading to more branched plants. Similar results were obtained with the Pendimethalin @ 1.25 kg/ha (PE) treatment, which produced a fair number of branches. Average branches per plant were 5 at 50 DAS, 6.667 at 75 DAS, and 7.333 at harvest. Although it wasn't as efficient as hand weeding, the herbicide treatment had a favorable impact on branch development. The Clodinoflop @ 0.75 kg/ha (PoE) treatment, on the other hand, displayed the least amount of branches throughout all three stages. The average number of branches per plant was 2.667 at 50 DAS, grew to 4.667 branches at 75 DAS, and finally reached 6 branches at harvest. This suggests that, in contrast to other herbicide treatments, this particular treatment had a negative effect on branch development, resulting in fewer branches.

Table 4: Number of branches per plant as influenced by weed management practices in Indian mustard			
Treatments	**Number of branches at 50 DAS**	**Number of branches at 75 DAS**	**Number of branches at harvest**
Weed check	2.33	4	5.33
Hand weeding	5.67	7.67	8
Pendimethalin @ 1.25 kg/ha (PE)	5	6.67	7.33
Oxyfluorfen @1.5 kg/ha (PE)	4.33	5.67	6.33
Isoproturon @0.75 kg/ha (PoE)	4	6.67	7
Quizalofop @1.0 kg/ha (PoE)	3.33	6.33	7
Oxadiaryzl @0.75 kg/ha (PE)	3	5.66	6
Clodinoflop @ 0.75 kg/ha (PoE)	2.66	4.67	6
SEm (±)	**0.48**	**0.33**	**0.38**
CD 5%	**2.13**	**1.41**	**1.62**

Standard error of the mean (SEm) and the critical difference at a 5% significance level (CD 5%)

3.2 Yield Attributes

According to Table 5, various weed management techniques had a significant impact on the yield attributes of Indian mustard, including the number of siliqua per plant, the length of siliqua, the number of seeds per siliqua, and the weight of 1000 seeds. The treatment that involved hand weeding had the highest number of siliqua per plant (225.67), demonstrating that manual weeding had a beneficial effect on siliqua development. Pendimethalin was applied at a rate of 1.25 kg/ha, and this resulted in 225 siliqua per plant, indicating that this herbicide treatment was successful in fostering the growth of siliqua. However, the Clodinoflop treatment had the fewest siliqua per plant (171.33), indicating that this particular herbicide treatment had an adverse effect on siliqua formation, leading to fewer siliqua. The longest siliqua (5.65 cm) was produced by the Hand weeding treatment, while the shortest (4.53 cm) was produced by Clodinoflop. The fact that longer siliqua may contain more seeds and increase yield further supports the positive effects of hand weeding on yield characteristics. The hand weeding and oxadiaryll treatments had the highest values, averaging 7.67 seeds per siliqua. This implies that these two treatments were more effective at promoting seed development within the siliqua. The 1000-seed weight varied slightly between treatments, with values between 5.22 g and 5.55 g. The differences in 1000-seed weight between treatments were not significant, implying that the herbicide treatments had no effect on seed weight.

Table 5: Yield attributes of Indian mustard as influenced by weed management practice				
Treatments	**Number of siliqua plant^{-1}**	**Length of siliqua (cm)**	**Number of seeds siliquae^{-1}**	**1000-seeds weight (g)**
Weed check	139.67	4.44	7	5.22
Hand weeding	225.67	5.65	8.67	5.55
Pendimethalin @ 1.25 kg/ha (PE)	225	5.44	8.33	5.47
Oxyfluorfen @1.5 kg/ha (PE)	206	4.82	7.67	5.42
Isoproturon @ 0.75 kg/ha (PoE)	209.33	5.04	8	5.42
Quizalofop @ 1.0 kg/ha (PoE)	197	4.61	7.67	5.39
Oxadiaryzl @ 0.75 kg/ha (PE)	187.33	4.55	8.67	5.34
Clodinoflop @ 0.75 kg/ha (PoE)	171.33	4.53	7.67	5.32
SEm (±)	**15.68**	**0.25**	**0.38**	**0.06**
CD 5%	**49.75**	**0.81**	**1.22**	**0.16**

Standard error of the mean (SEm) and the critical difference at a 5% significance level (CD 5%)

3.3 Seed Yield, Stover Yield, Biological Yield

3.3.1 Seed Yield

The "Hand weeding" treatment had the highest seed yield of 2,008 kg/ha, proving that hand weeding produced the most grain. The lowest seed yield, 983 kg/ha, was found in the "Weed check" treatment, a poor weed control method, indicating that weed competition adversely affected grain production. The other herbicide treatments yielded intermediate seed yields ranging from 1,530 kg/ha to 1,675 kg/ha.

3.3.2 Stover Yield

The highest Stover yield (5,644 kg/ha) was also achieved with the "Hand weeding" treatment, demonstrating effective weed control and increased biomass production. However, the "Weed check" treatment had the lowest Stover yield (3,748 kg/ha), indicating that insufficient weed control hampered the growth of above-ground biomass. The other herbicide applications revealed Stover yields ranging from 4,962 kg/ha to 5,518 kg/ha, which were typically higher than the "Weed check" treatment but lower than the "Hand weeding" treatment.

3.3.3 Biological Yield

The highest biological yield of 7,652 kg/ha was observed in the "Hand weeding" treatment, which indicates a combined effect of higher grain and Stover yields. In contrast, the "Weed check" treatment had the lowest biological yield of 4,731 kg/ha, indicating reduced overall biomass production due to inadequate weed control. The other herbicide treatments showed intermediate biological yields ranging from 6,516 kg/ha to 7,193 kg/ha.

Table 6: Grain yield, Stover yield, biological yield and harvest index as influenced by weed management practices in Indian mustard

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvesting Index (%)
Weed check	983	3,748	4,731	20.77
Hand weeding	2,008	5,644	7,652	26.24
Pendimethalin @ 1.25 kg/ha (PE)	1,675	5,518	7,193	23.28
Oxyfluorfen @1.5 kg/ha (PE)	1,655	5,250	6,805	24.32
Isoproturon @0.75 kg/ha (PoE)	1,670	5,325	6,995	23.87
Quizalofop @1.0 kg/ha (PoE)	1,605	4,968	6,573	24.41
Oxadiaryzl @0.75 kg/ha (PE)	1,585	4,962	6,547	24.2
Clodinoflop @ 0.75 kg/ha (PoE)	1,530	4,986	6,516	23.48
SEm (±)	**15.75**	**69.54**	**94.43**	**0.34**
CD 5%	**44.66**	**198.26**	**269.67**	**0.97**

Standard error of the mean (SEm) and the critical difference at a 5% significance level (CD 5%)

3.4 Economics

Significant differences in gross returns, net returns, and benefit-to-cost ratios were found in the economic analysis of various weed management techniques in Indian mustard. Pendimethalin @ 1.25 kg/ha showed the highest gross return of Rs. 91,929/ha among the treatments, demonstrating its economic superiority in terms of yield and market value. The Clodinoflop @ 0.75 kg/ha treatment, however, produced the lowest gross return of Rs. 83,808/ha, indicating its limited efficacy in boosting crop productivity and profitability. After taking cultivation expenses into account, the net return is a critical gauge of overall profitability. The hand weeding treatment produced the highest net return of Rs. 68,382/ha, highlighting the financial advantages of doing manual weeding. Contrarily, the Clodinoflop @ 0.75 kg/ha treatment had the noticeably lowest net return of Rs. 47,198/ha, indicating its inadequate success in producing profits. A crucial metric for assessing the economic effectiveness of weed management strategies is the benefit-to-cost ratio. The hand-weeding-performed method had the highest benefit-to-cost ratio of 1.75, meaning that for every rupee spent on it, a return of 1.75 rupees was made. This demonstrates the profitability and efficiency of manual weed control. Additionally, Pendimethalin @ 1.25 kg/ha treatment showed a competitive benefit-to-cost ratio of 1.58, highlighting its financial advantages as a herbicidal option. Although hand weeding was found to be the most economically advantageous method, herbicidal treatments such as Pendimethalin, Oxyfluorfen, Isoproturon, Quizalofop, and Oxadiaryzl also demonstrated competitive economic benefits with varying levels of gross returns, costs, net returns, and benefit-to-cost ratios. Based on their particular budget restrictions and weed control needs, farmers can take these herbicides into consideration as viable alternatives.

Table 7: Economics as influenced by herbicidal control of weed in Indian mustard

Treatments	Gross return (Rs ha-1)	Cost of cultivation (Rs ha^{-1})	Net return (Rs ha^{-1})	Benefit: Cost ratio
Weed check	55,479	33,910	21,569	0.63
Hand weeding	1,07,292	38,910	68,382	1.75
Pendimethalin @ 1.25 kg/ha (PE)	91,929	35,530	56,399	1.58
Oxyfluorfen @1.5 kg/ha (PE)	90,225	35,890	54,335	1.51
Isoproturon @0.75 kg/ha (PoE)	91,125	35,710	55,415	1.55
Quizalofop @1.0 kg/ha (PoE)	87,129	350,710	51,419	1.43
Oxadiaryzl @0.75 kg/ha (PE)	86,211	36,007	50,204	1.39
Clodinoflop @ 0.75 kg/ha (PoE)	830,808	360,610	47,198	1.29

4. Conclusion

In conclusion, the study highlights the importance of effective weed management practices in Indian mustard cultivation. Weeds pose a significant threat to crop yield and can result in economic losses for farmers. The research demonstrates that a combination of manual methods such as hand weeding, along with the appropriate use of herbicides, can provide the most successful weed control and increase overall crop productivity. Hand weeding was found to be the most economically beneficial method, followed closely by the application of Pendimethalin herbicide. However, careful consideration should be given to the selection of herbicides, as some may have adverse effects on crop growth and yield. The findings underscore the need for continuous research and adaptation of weed management strategies to address evolving weed species and herbicide resistance. By adopting the best practices outlined in this study, farmers can optimize their yields, reduce production costs, and promote sustainable agriculture. Ultimately, effective weed management not only contributes to food security but also supports the livelihoods of farming communities. As agriculture continues to play a vital role in providing for a growing global population, it is essential to prioritize weed management as a fundamental aspect of modern farming practices.

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