Effects of Weed Control Methods on Indian Mustard (Brassica Juncea L.) Performance

Rajneesh Bhardaj

Asst. Professor, School of Agriculture, Graphic Era Hill University,

Dehradun Uttarakhand India

Abstract

Rai, raya, laha, and raiya are local names for mustard (Brassica juncea L.), whereas sarson, toria, and yellow toria are names for rapeseed. Vegetable named "Sarson Ka Saag" is made from its young, fragile plants. The oil is used by people all throughout northern India, where it is used for frying and other culinary purposes. Pickles, curries, and savoury vegetables all benefit from using the entire seed as a condiment. Mustard oil has further use in the cosmetics, pharmaceuticals, personal care, automotive, and leather goods manufacturing sectors. This study investigates how different approaches to weed management affect the productivity of indian mustard (brassica juncea l.).

Keywords: *Indian mustard, Tanning Industries, Weed, Vegetable.*

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1. Introduction

In terms of market size, India's edible oil industry ranks behind only the United States, China, and Brazil. In 2016–17, India accounted for around 7% of global edible oil output, 12% of global edible oil consumption, and 20% of global edible oils imports (USDA 2020). From 2000-2001, when importing 4.3 mt of edible oil cost around Rs. 4320 crores, to 2015-16, when importing 15 mt of edible oil cost roughly Rs. 65,000 crores (Renjini and Girish 2019), an increase of more than 400%. When compared to Canada and China, India is the world's third-largest oilseed producer. [1-2]

The global rapeseed-mustard crop area in 2019-18 was over 36.68 million hectares, yielding 70.42 million metric tonnes at productivity of 1919 kilogrammes per hectare (ha-1) (DRMR, 2020). After peanuts, mustard is India's most valuable crop for edible oil seed production. It's crucial to the country's oil seed industry. The productivity per hectare in India for rapeseed-mustard in 2019-18 was 1,304 kilogrammes per hectare (kg ha-1), with a total output of 7.92 million metric tonnes (mt) (DRMR, 2020). When compared to Rajasthan's 2.12 million hectares (ma) and 2.45 million metric tonnes (mt) of production with low productivity (1,152 kg ha-1), Gujarat's 0.22 million hectares (ma) of area with 0.30 million metric tonnes (mt) of production was far more productive, with a productivity of 1,373 kilogrammes per hectare (kg ha-1). Area at 0.053 mha, output at 0.077 mt, and productivity at 1453 kg ha-1 were best in the Mathura district in Uttar Pradesh in 2020 (SEA).[3-4]

More than 70% of oilseeds production takes place in drylands and rainfed environments, which is a major contributor to output changes. Despite the fact that coarse cereals and pulses lost ground to oilseeds in the 1980s, the former were nevertheless able to expand their acreage. Farmers were not enticed to grow oilseeds because of this (Ramasamy and Selvaraj, 2002).[5-6]

There is a pressing need now to boost output in order to keep up with the rising demand for edible oils. Because expanding farmland is unlikely, boosting crop yields and reducing weed infestation are the most viable options for producing an extra 30 million metric tonnes in the next decade. Weeds have a direct impact on the development and growth of crops, resulting in lower seed and oil yields. The aggressive use of herbicides to control weed populations has grown in favour in recent years because of the chemicals' efficacy, cheap cost, and ease of application. Using modern herbicides, we can determine which ones are safest and most effective for a certain crop. [7-8]

Reducing crop-weed competition over the long term requires testing of broad-spectrum herbicides. In the agricultural ecosystem, weed is the primary factor in decreased crop yields and production. Weeds are responsible for an estimated yearly loss of Rs. 1980 million in India. Weeds have invaded the crop and are suffocating it at every stage of development by competing with it for water, nutrients, sunlight, and space. A large portion of both natural and added nutrients are taken up by them. Under moisture stress conditions, when the fast-growing weeds' lush foliage consumes most of the soil moisture in the root zone, the situation worsens dramatically. [9-10]

2. Material And Method

Experimental site and climate

Narendra Deva University of Agriculture and Technology's Agronomy Research Farm in Lucknow. The monsoon often begins in the third week of June and continues until the end of September or perhaps the first week of October. South-west monsoons bring in around 80% of the year's precipitation total (1073 mm), whereas the average annual potential evapo-transpiration is about 1667 mm. Therefore, there is a lack of soil moisture in the region. The temperature rises gradually during the month of February, peaking in March. The experiment was set up in a controlled environment with homogeneous terrain and well-drained soil that was always low in fertility and very acidic.

Soil of the experimental field

Plants can't flourish in any other environment except soil. Plant development and expansion are directly linked to the soil's fertility and production. Therefore, an effort was undertaken to evaluate the soil's chemical and physical composition in the experimental area. Using a core sampler, soil samples were taken at random from all across the area to determine the level of natural fertility. Physical and chemical tests were performed on these treated materials. The gathered data is then compared to a standard rating system for soil tests, and the findings are shown in table.

Table 1: Soil chemistry and physics in the lab

Particulars	**Value**	
	2019-18	**2020-19**
Mechanical properties		
(A)Soil separates		
Sand (%)	25.17	24.85
Silt (%)	49.53	49.10
Clay (%)	25.30	25.05

Texture	Silt loam	
(B) Chemical properties		
Soil reaction (pH) 1:2.5 soil water suspension	8.30	8.20
Electrical conductivity (EC) (dSm^{-1} at 25^{0}C) 1:2.5 soil water suspension	0.25	0.24
Organic carbon (%)	0.33	0.32
Available nitrogen (kg ha^{-1})	137.20	136.82
Available phosphorus (kg ha^{-1})	15.20	14.50
Available potassium (kg ha^{-1})	249.22	248.32
Available sulphur (kg ha^{-1})	15.78	15.92

Studies on weed

Weed samples were taken using a quadrate m-2 at 30, 60, and 90 days after sowing, as well as during harvest.

- **Weed population**

We recorded the overall weed population by counting the number of grasses, wide leaf weeds, and sedges within each quadrate.

For the purpose of reducing the considerable variation in the observation under various treatment conditions, the collected data was square-root-transformed plus 0.5.

- **Studies on mustard**

For the purpose of biometric observation, five plants were chosen at random from each plot and labelled so that their growth could be tracked at regular intervals. From day 30 from sowing until harvest, observations on growth indicators were kept monthly. At harvest, both yield characteristics and total yield were analysed.

Growth parameters

- **Initial plant population (m^{-2})**

One metre of row was picked out of each plot at random after the final thinning. Later, the total number of plants in each chosen row was tallied, and the average was determined.

- **Plant height (cm)**

After the final thinning, one metre of row was chosen at random from each plot. The average number of plants in each selected row was then calculated.

- **Leaf area index**

To determine the leaf area index, measurements were taken 30, 60, and 90 days after seeding. The surface area of the green leaves of the plant was measured using an automated leaf area metre. The whole collection of leaves was divided into three categories: little, medium, and massive. Five leaves were collected from each set to determine the total surface area. The total leaf area was calculated by adding the areas of all the leaves in a given group together. The leaf area index may be calculated using The ratio of leaf area to ground area.

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Yield attributes and yield

- **Number of siliquae plant^{-1}**

Five randomly selected plants were tagged in each experimental plot, and the total number of siliquae was tallied.

- **Number of seeds siliqua^{-1}**

The number of seeds per siliqua was expressed as the mean of counts performed on 10 siliquae used for length measurement.

- **Test weight (g)**

A thousand seeds were counted and weighed at random from each net plot to eliminate bias.

- **Seed and stover yield (q ha^{-1})**

The net harvest of both seed and stover was reported. Plants were collected, labelled, and bagged from the net plot area wise. Sun drying the crop to a constant moisture content allowed for accurate bundle weight measurement. Seed and Stover were separated from the harvest. Stover productivity was determined by deducting seed productivity from bundle weight. Seed and stover yields per plot (kg plot-1) were multiplied by a conversion factor to get yields per hectare (kg ha-

- **Harvest index (HI)**

Following the method outlined by Donald and Hamblin (1976), the harvest index was determined.

$$\text{Harvest index (\%)} = \frac{\text{Economical yield}}{\text{Biological yield}} \text{ x } 100$$

Statistical analysis

The "f" test was used to examine whether or not the aggregate differences between treatments were statistically significant. The degree of confidence used in drawing this conclusion was 5%. In order to determine whether or not the difference between the means of the two treatment groups was statistically significant, the critical difference (CD) was calculated when the "F" value in the analysis of variance table was significant (Fisher and Yates, 1).

3. Results

Studies on weed

“Weed control efficiency, weed control index, and herbicide efficiency index were measured at 30, 60, and 90 DAS, as well as at harvest, to show how various weed management treatments affected weed density and dry weight.” Experiment data from 2019 and 2020 were collected for weed index, nutritional content, and nutrient absorption by weed at harvest stage.

- **Weed flora**

Grass, sedge and broadleaf weed samples were gathered from the experimental field and identified. Eight different weed species from six different families were found in the experimental field. Cynodon dactylon L. and Phalaris minor were the two most common unwanted grasses. When it came to sedges, Cyperus rotundas L. ruled the roost. After Chenopodium album L., Anagallis arvensis, Melilotus alba, Vicia hirsuta L., and Lathyrus aphaca L. were the most common broadleaf weeds.

- **Total weed population (m^{-2})**

Table exhibit data on the total weed population at 30, 60, and 90 DAS and at harvest, respectively, and show how different weed control treatments affected the weed population in a noticeable way across all time points.Results of Experiments.

Table 2: Total weed population as a function of weed control practises (m-2)

Treatments	30 DAS		60DAS		90 DAS		At Harvest	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T1-	7.08 (49.8)	6.95 (47.90)	6.52 (42.10)	6.41 (40.70)	5.70 (32.10)	5.48 (29.60)	4.96 (24.20)	4.82 (22.80)
T2-	7.97 (63.20)	7.82 (60.80)	7.65 (58.10)	7.54 (56.50)	6.96 (48.10)	6.78 (45.60)	5.83 (33.50)	5.68 (31.80)
T3-	7.00 (48.70)	6.87 (46.80)	4.30 (18.00)	4.20 (17.20)	2.91 (8.00)	2.45 (5.50)	1.61 (2.10)	1.38 (1.40)
T4-	7.93 (62.50)	7.76 59.90)	5.78 (33.00)	5.69 (32.00)	4.84 (23.00)	4.58 (20.50)	3.78 (13.80)	3.62 (12.60)
T5-	6.03 (35.9	5.89 (34.3	4.63 (21.00)	4.54 (20.20)	3.39 (11.00)	3.00 (8.50)	2.21 (4.40)	2.02 (3.60)

	0)	0)						
T6	6.70 (44.50)	6.57 (42.80)	5.96 (35.10)	5.87 (34.00)	5.05 (25.10)	4.80 (22.60)	4.20 (17.20)	4.06 (16.00)
T7-	7.32 (53.20)	7.17 (51.10)	6.67 (44.10)	6.58 (42.90)	5.88 (34.10)	5.66 (31.60)	5.19 (26.50)	5.05 (25.10)
T8-	7.45 (55.20)	7.31 (53.10)	7.04 (49.10)	6.95 (47.80)	6.29 (39.10)	6.08 (36.60)	5.52 (30.00)	5.37 (28.40)
T9-	7.24 (52.00)	7.10 (50.00)	4.63 (21.00)	4.55 (20.20)	3.39 (11.00)	3.00 (8.50)	2.47 (5.60)	2.30 (4.80)
T10-	7.37 (54.00)	7.24 (52.00)	5.05 (25.00)	4.95 (24.10)	3.93 (15.00)	3.60 (12.50)	3.28 (10.30)	3.13 (9.30)
T11-	6.29 (39.20)	6.16 (37.50)	4.85 (23.00)	4.75 (22.10)	3.67 (13.00)	3.31 (10.50)	2.90 (7.90)	2.74 (7.00)
T12-	6.45 (41.20)	6.31 (39.50)	5.43 (29.10)	5.34 (28.10)	4.42 (19.10)	4.13 (16.60)	3.61 (12.60)	3.46 (11.50)
T13-	6.99 (48.50)	6.85 (46.50)	6.21 (38.10)	6.10 (36.80)	5.34 (28.10)	5.10 (25.60)	4.60 (20.70)	4.43 (19.20)
T14-	5.91 (34.50)	5.79 (33.00)	4.06 (16.00)	3.96 (15.20)	2.74 (7.00)	2.21 (4.40)	1.30 (1.20)	1.14 (0.80)
T15-	8.18 (66.50)	8.30 (68.60)	10.02 (100.20)	10.14 (102.60)	11.41 (130.20)	11.54 (132.70)	11.68 (136.40)	11.95 (142.70)
CD	0.69	0.67	0.62	0.62	0.56	0.49	0.49	0.48

(P=0.05)								
SEM±	0.24	0.23	0.21	0.21	0.19	0.17	0.17	0.17

over both years. In most cases, weed density grew until the crop reached 30 DAS, and then it gradually reduced.

Table shows that, at 30 DAS, the weed density was lowest in the T5 treatment, which consisted of applying pendimethalin (PE) @ 1000 g ha-1 + paddy straw mulch at 5 t ha-1 at 2-3 DAS. This treatment was statistically on par with T6, T11, and T12 for 2019–20 and 2020–21. When comparing the herbicide treatments, manual weeding at 20 and 40 DAS (T14) had the lowest overall weed density (34.50 and 33.00 m-2), whereas the weedy check (T15) plot had the highest (66.50 and 68.60 m-2).

Pendimethalin (PE) @ 1000 g ha-1 + hand weeding at 40 DAS (T3) was the most successful treatment, reducing overall weed density by 18.00 and 17.20 m-2 at 60 DAS, respectively, compared to the other two treatments. At 60 DAS in both years, this was on par with T5, T9, T11, and T14 while being far better to the other herbicidal treatments. Hand weeding at 20 and 40 DAS (T14) resulted in a considerably decreased weed population, similar to the herbicidal treatments. At 60 DAS, weedy check (T15) plots had the greatest weed population (100.20 m-2 from the first cropping season and 102.60 m-2 from the second), although this was not statistically significant.

Pendimethalin (PE) @ 1000 g ha-1 + hand weeding at 40 DAS (T3) equaled T5, T9, and T14 and was significantly higher to remaining of treatments at 90 DAS during 2019-20, where the lowest weed density weed (8.00 m-2) was recorded after application of hand weeding at 20 and 40 DAS (T14). Pendimethalin (PE) @ 1000 g ha-1 plus hand weeding at 40 DAS (T3) was just as effective as hand weeding at 20 and 40 DAS (T14) in 2020-19 for achieving the lowest overall weed density (5.50 m-2). In addition to the herbicide treatments, manual weeding at 20 and 40 DAS (T14) greatly decreased the weed population (4.40 m-2). In spite of this, weedy check (T15) plots at 90 DAS during 2020-19 showed the highest weed population (132.70).

Except for the weedy check (T14) plot, all weed control practises led to a considerable decrease in weed population at harvest. Pendimethalin (PE) @ 1000 g ha-1 + hand weeding at 40 DAS

(T3) significantly outperformed the rest of the treatments and was statistically on par with hand weeding at 20 and 40 DAS (T14), followed by pendimethalin (PE) @ 1000 g ha-1 + paddy straw mulch @ 5 t ha-1 (T5) in terms of weed population (2.10 and 1.40 m-2). Under weedy check (T14) at harvest time, the densest weed population was found to be 136.40 m-2 in the first year and 142.70 m-2 in the second..

- **Total weeds dry weight (g m^{-2})**

Table visually depicts information on the impact of different weed control treatments on the total dry weight of weeds at different growth stages. With the exception of the weedy check, total weed dry weight rose up to 90 DAS before declining somewhat at harvest time. The total dry weight of weeds was observed to be reduced by most of the weed control treatments at 30 DAS, with the exception of the weedy check treatment.

Table 3: Total weed dry weight (g m-2) as a function of weed control practises

Treatments	30 DAS		60DAS		90 DAS		At Harvest	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T1-	5.68 (31.80)	5.55 (30.40)	7.61 (57.65)	7.50 (55.90)	8.25 (67.65)	8.09 (65.15)	7.97 (63.25)	7.82 (60.80)
T2-	6.39 (40.40)	6.25 (38.70)	8.93 (79.55)	8.82 (77.50)	9.48 (89.55)	9.35 (87.05)	8.90 (78.85)	8.73 (76.00)
T3-	5.58 (30.70)	5.44 (29.20)	5.01 (24.65)	4.92 (23.75)	5.92 (34.65)	5.71 (32.15)	5.15 (26.10)	5.04 (24.95)
T4-	6.32 (39.50)	6.16 (37.60)	6.75 (45.20)	6.67 (44.05)	7.45 (55.20)	7.29 (52.70)	6.79 (45.80)	6.65 (43.75)
T5-	4.84 (22.9	4.71 (21.7	5.41 (28.75)	5.32 (27.85)	6.26 (38.75)	6.05 (36.25)	5.52 (30.00)	5.39 (28.65)

	5)	5)						
T6	5.38 (28.50)	5.26 (27.20)	6.97 (48.10)	6.87 (46.75)	7.65 (58.10)	7.48 (55.60)	7.21 (51.50)	7.07 (49.50)
T7-	5.86 (34.00)	5.74 (32.50)	7.79 (60.40)	7.70 (58.95)	8.41 (70.40)	8.26 (67.90)	8.21 (67.10)	8.07 (64.70)
T8-	5.98 (35.30)	5.85 (33.80)	8.22 (67.25)	8.12 (65.65)	8.81 (77.25)	8.66 (74.75)	8.57 (73.00)	8.40 (70.30)
T9-	5.78 (32.90)	5.62 (31.20)	5.40 (28.70)	5.32 (27.85)	6.26 (38.70)	6.05 (36.20)	5.70 (32.00)	5.57 (30.65)
T10-	5.88 (34.20)	5.75 (32.70)	5.89 (34.25)	5.80 (33.20)	6.68 (44.25)	6.50 (41.75)	6.35 (39.90)	6.21 (38.20)
T11-	5.05 (25.00)	4.92 (23.80)	5.65 (31.50)	5.55 (30.40)	6.48 (41.50)	6.28 (39.00)	6.02 (35.80)	5.89 (34.30)
T12-	5.17 (26.35)	5.05 (25.10)	6.34 (39.80)	6.26 (38.70)	7.09 (49.80)	6.91 (47.30)	6.64 (43.75)	6.50 (41.90)
T13-	5.69 (32.00)	5.36 (28.30)	7.25 (52.20)	7.14 (50.60)	7.91 (62.20)	7.75 (59.70)	7.60 (57.35)	7.43 (54.80)
T14-	4.74 (22.00)	4.62 (20.90)	4.73 (21.90)	4.63 (21.00)	4.17 (16.90)	3.86 (14.40)	3.31 (10.50)	3.20 (9.80)
T15-	6.76 (45.30)	6.95 (47.90)	12.14 (147.30)	12.22 (148.90)	13.32 (177.30)	13.41 (179.80)	14.43 (208.20)	14.52 (210.60)
CD	0.59	0.56	0.76	0.67	0.80	0.79	0.78	0.71

(P=0.05)								
SEM±	0.20	0.19	0.26	0.23	0.28	0.27	0.27	0.25

T14, which had manual weeding at 20 and 40 DAS, had weed dry weights much lower than those of T15, the weedy check plot (45.30 and 47.90 g m-2), and on par with T5, T11, and T12. Total weed dry weight was highest during treatment (T15).

"The total dry weight of weeds at 60 DAS was considerably affected by various weed control strategies. Total weed dry weight was reduced across all treatments against the weedy control. Pendimethalin (PE) @ 1000 g ha-1 + hand weeding at 40 DAS (T3) reduced total weed dry weight (24.65 and 23.75 g m-2 during both years, respectively) more than T1, T2, T4, T6, T7, T8, T10, T12, T13, and T15, and was statistically on par with T5, T9, 11 and 14. However, at 60 DAS, the weedy check (T15) treatment had the greatest weed dry weight."

Treatment 3 significantly reduced total weed dry weight at 90 DAS, which was on par with T5, T9, T10, T11, and T14 treatments and significantly superior to remaining treatments. Total weed dry weight at 60 DAS was greatest under weedy check (T15) plots.

Different weed control practises lowered total weed dry weight at harvest time in addition to weedy check. By far the lowest figure was reported for hand weeding at 20 and 40 DAS (T14). Treatment 3 (Pendimethalin (PE) @ 1000 g ha-1) and hand weeding at 40 days after sowing (DAS) considerably decreased total weed dry weight and was comparable to Treatments 5, 9, and 14.

- **Nutrients uptake by weeds (kg ha^{-1})**

Nutrient intake by weeds is shown to be altered by manual weeding, mulching, and pesticides. The amount of nitrogen, phosphorus, and potassium that weeds absorbed in either year was profoundly affected by the use of hand weeding, mulch, and pesticides. The absorption of nitrogen (37.04 and 35.60%), phosphorus (7.23% and 6.99%), and potassium (31.56 and 30.30%) by weeds was significantly higher when weedy check was used instead of pendimethalin (PE) @ 1000 g ha-1 + manual weeding at 40 days after sowing (T3).

Table 4: Uptake of nitrogen, phosphorus, and potassium due to weed control practices

Treatments	N uptake in weed		P uptake in weed		K uptake in weed	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T1-	12.33	11.85	2.38	2.30	10.47	10.05
T2-	15.00	14.44	2.97	2.78	12.76	12.27
T3-	5.68	5.46	1.11	1.08	4.82	4.64
T4-	9.26	8.87	1.82	1.75	7.84	7.56
T5-	6.36	6.11	1.23	1.19	5.41	5.19
T6	10.25	9.86	1.94	1.88	8.69	8.35
T7-	12.89	12.41	2.58	2.42	10.93	10.52
T8-	13.94	13.41	2.69	2.60	11.84	11.38
T9-	6.62	6.37	1.29	1.25	5.63	5.41
T10-	8.19	7.87	1.58	1.53	6.97	6.69
T11-	7.35	7.07	1.45	1.36	6.22	6.02
T12-	8.87	8.52	1.70	1.64	7.56	7.25
T13-	11.35	10.86	2.19	2.11	9.64	9.21
T14-	3.27	3.14	0.62	0.60	2.77	2.66
T15-	37.04	35.60	7.23	6.99	31.56	30.30
CD (P=0.05)	2.58	1.28	0.48	0.26	2.28	1.47
SEM±	0.89	0.44	0.16	0.09	0.79	0.51

N (5.68%), P (1.11%), and K (4.82%) were increased by hand weeding at 20 and 40 DAS (T14) compared to all other treatments.

Crop growth studies

- **Initial plant population (m^{-2})**

Table offer information on the initial plant population and how it is affected by various weed control strategies.

There was no significant difference in the initial plant population at 30 DAS across weed control practises. Pendimethalin (PE) at 1000 g ha-1 + paddy straw mulch @ 5 t ha-1 at 2-3 DAS (T5) had the largest initial plant population (15.00 and 15.70 m-2) of any of the herbicidal treatments. While weedy check (T15) plots had the lowest initial plant population.

- **Plant height (cm)**

Table provide information on plant height as affected by different treatments. The height of the plants rose as the crop aged and peaked at maturity, regardless of the experimental factors. Although the fastest growth in plant height was seen between 30 and 90 DAS.

Table shows that there was no significant difference in plant height amongst weed management practises at 30 DAS. On days 2 and 3, after spraying with pendimethalin (PE) @ 1000 g ha-1 + paddy straw mulch @ 5 t ha-1 (T5), plants reached a height of 23.30 and 24.25 cm, respectively, among the herbicidal treatments. In weedy check (T15), the shortest plant measured 21.20 and 22.20 centimetres in 2019 and 2020, respectively.

Table 5: Mustard seedling density (m-2) at 30 days after sowing as a function of weed control methods

Treatments	**Initial Plant population**	
	2019-20	**2020-21**
T1-	13.30	13.90
T2-	13.00	13.60
T3-	14.60	15.30
T4-	13.60	14.30
T5-	15.00	15.70
T6	13.80	14.50
T7-	13.30	13.90
T8-	13.00	13.60
T9-	14.30	15.00

T10-	14.00	14.60
T11-	14.30	15.00
T12-	14.00	14.70
T13-	13.60	14.30
T14-	15.00	15.60
T15-	12.80	13.20
CD (P=0.05)	NS	NS
SEM±	0.63	0.64

- **Leaf area index (LAI)**

The table data show that the leaf area index (LAI) of Indian mustard was considerably impacted by several treatments over the crop's development phase at 30, 60, and 90 DAS. The LAI values were lower in the first year compared to the second. The leaf area index continued to rise until the 60-day mark. The rate of growth slowed considerably after that. In both the first and second cropping seasons, the maximum leaf area index was measured at 60 DAS.

The greatest LAI (1.66) and yield (1.79) were found in the hand-weeded plots at 20 and 40 DAS (T14) in 2019 and 2020, respectively. Nonetheless, at 2-3 DAS (T5), it was on par with pendimethalin (PE) at 1000 g ha-1 + paddy straw mulch @ 5 t ha-1 (1.63 and 1.75 throughout both seasons, respectively). Both spring and autumn found the weedy check (T14) plots to have the lowest leaf area index (1.25 and 1.37 respectively).

Table 6: Changes in leaf area index (LAI) due to weed control methods

Treatments	**30 DAS**		**60DAS**		**90 DAS**	
	2019-20	**2020-21**	**2019-20**	**2020-21**	**2019-20**	**2020-21**
T1-	1.33	1.44	3.74	3.86	3.38	3.50
T2-	1.27	1.39	3.65	3.77	3.30	3.42
T3-	1.56	1.67	4.25	4.38	3.85	3.97

T4-	1.36	1.47	3.85	3.98	3.48	3.61
T5-	1.63	1.75	4.21	4.33	3.81	3.93
T6	1.38	1.49	3.81	3.92	3.45	3.56
T7-	1.30	1.42	3.71	3.82	3.36	3.47
T8-	1.29	1.4	3.68	3.80	3.33	3.45
T9-	1.49	1.61	4.15	4.27	3.76	3.87
T10-	1.41	1.53	4.00	4.12	3.62	3.75
T11-	1.52	1.65	4.05	4.18	3.66	3.80
T12-	1.46	1.57	3.90	4.02	3.53	3.65
T13-	1.34	1.45	3.78	3.90	3.42	3.54
T14-	1.66	1.79	4.52	4.65	4.10	4.22
T15-	1.25	1.37	3.10	3.23	2.80	2.93
CD (P=0.05)	0.18	0.18	0.48	0.51	0.36	0.48
SEM±	0.06	0.06	0.16	0.18	0.13	0.17

Yield attributes and yields

Tables detail the attributes and yield of Indian mustard in 2019 and 2020, respectively, as a result of different weed management practises. "Attributes and yield include the number of siliquae per plant, siliqua length in centimetres, siliqua seeds per plant, test weight in grammes, seed yield per hectare, stover yield per hectare, and harvest index in percentage."

- **Number of siliquae plant^{-1}**

The highest number of siliquae plants per hectare was observed in the T3 chemical treatment, which consisted of pendimethalin (PE) @ 1000 g ha-1 + hand weeding at 40 days after sowing (DAS) and was statistically equivalent to T5, T9, and T14 in both study years. In contrast, the equivalent values were 186 and 189 in weedy check plots throughout the spring and summer.

Table 7: Mustard crop weed management's effect on siliquae density, siliquae length, seeds per siliqua, and test weight.

Treatments	No. of siliquae/ plant		No. of seeds/ siliquae		Test weight (g)	
	2019-20	**2020-21**	**2019-20**	**2020-21**	**2019-20**	**2020-21**
T1-	239	244	10.95	11.70	4.51	5.02
T2-	223	227	10.70	11.40	4.42	4.94
T3-	284	290	12.30	13.10	4.75	5.27
T4-	259	264	11.20	11.90	4.58	5.10
T5-	281	287	12.25	13.00	4.70	5.22
T6	253	258	11.15	11.85	4.56	5.06
T7-	232	237	10.90	11.60	4.48	5.00
T8-	228	232	10.80	11.50	4.46	4.95
T9-	278	283	11.90	12.65	4.68	5.20
T10-	268	274	11.45	12.20	4.64	5.15
T11-	273	278	11.75	12.50	4.66	5.17
T12-	265	271	11.40	12.10	4.60	5.13
T13-	246	251	11.05	11.80	4.53	5.05
T14-	290	296	12.40	13.15	4.80	5.32
T15-	186	189	9.50	10.30	4.35	4.88
CD (P=0.05)	11.94	11.89	0.53	0.58	NS	NS
SEM±	4.12	4.10	0.18	0.20	0.18	0.20

- **Number of seeds siliqua^{-1}**

Pendimethalin (PE) @ 1000 g ha-1 + hand weeding at 40 DAS (T3) yielded a substantially larger number of seeds siliquae-1 (12.30 and 13.10) compared to T5, T9, and T14 after hand weeding at 20 and 40 DAS. Under weedy check, however, the siliqua-1 seed yield was considerably lower throughout both growing seasons (9.50 and 10.30), respectively.

- **Test weight (g)**

The 1000-seed weight (g) was not substantially affected by the use of manual weeding, mulching, or herbicides. The highest 1000 seed weight (between 4.75 and 5.27 g) was reported for pendimethalin (PE) @ 1000 g ha-1 + manual weeding at 40 DAS (T3), which was among the herbicidal treatments. The greatest values of 1000 seed weight (4.80 and 5.32 g) were obtained in the years 2012 and 2013 when manual weeding was performed at 20 and 40 DAS instead of chemical treatments. This was in comparison to the weedy check (4.35 and 4.88 g).

4. Conclusion

The following inferences may be made from the aforementioned experimental results and the discussion in the preceding pages. The weed population (viz. grassy, wide leaved, and sedges) was reduced most effectively by pendimethalin (PE) @ 1000 g ha-1 + manual weeding at 40 DAS, in addition to hand weeding at 20 and 40 DAS.It was discovered that hand weeding at 20 and 40 days after sowing (DAS) and integrated application of pendimethalin (PE) @ 1000 g ha-1 with the hand weeding at 40 DAS were notable in improving the growth and yield characteristics and yield of mustard crop in both seasons of sowing. In both years of the experiment, the weeds in the weedy check plots absorbed more nutrients than the crop did when treated with pendimethalin (PE) at 1000 g ha-1 + manual weeding at 40 DAS. Maximum net return and B:C ratio (Rs. 57394 ha-1 and 1.51, respectively) were observed following pre-emergence application of pendimethalin @ 1000 g ha-1 coupled with manual weeding at 40 DAS in both years of experiment, according to economic assessment of the treatments.

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