Journal of Advances in Biology & Biotechnology

Volume 27, Issue 9, Page 680-688, 2024; Article no.JABB.121589
ISSN: 2394-1081

Weed Management with New Generation Herbicides in *Rabi* Lentil in Sub-mountainous Area of Reasi District

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jabb/2024/v27i91340

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121589

Original Research Article

Received: 28/06/2024
Accepted: 31/08/2024
Published: 03/09/2024

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***Cite as:** Koushal, Sanjay, Okram Ricky Devi, Bibek Laishram, Dipankar Barman, and Bhim Singh. 2024. "Weed Management With New Generation Herbicides in Rabi Lentil in Sub-Mountainous Area of Reasi District". Journal of Advances in Biology & Biotechnology 27 (9):680-88. https://doi.org/10.9734/jabb/2024/v27i91340.*

ABSTRACT

In *rabi,* 2017–18, a field study was carried out at KVK, Reasi, SKUA&T, Jammu & Kashmir to assess the effectiveness of five herbicides applied alone, in combination with mechanical weeding (MW), or in sequence to study the effects of the herbicides on weed control and production economics of lentil variety L4147 (Pusa Ageti). Three replications of the experiment were conducted using completely randomized block design having six treatments with three replications. The treatments included T1:Weedy check (control), T2: Weed free, T3: Hand Weeding at 30 DAS and 45 DAS (Khurpi), T4: Quizalofop-p-ethyl 5% EC @ 50 g ai /ha at 40 DAS, T:5 Imazethapyr 10% SL at 40 DAS @ 37.5 g ai /ha, T6: Chlorimuron ethyl 25% WP (PPI) @ 4 g ai/ha and T7: Pendimethalin 30% EC (PE) @ 1 kg ai/ha. The most successful approach for controlling weeds, after weed free, was two hand weeding (HAND WEEDING), according to the results. However, at 60 DAS, two hand weedings at 30 DAS and 45 DAS produced the dry matter accumulation and lowest density of all weed species, followed by pendimethalin and Imazethapyr (post-emergence/POE). Under two hand weeding, the highest weed control efficiency of 83% was attained, and this was followed by Imazethapyr at 40 DAS. But under weed-free conditions, the maximum yield (1365 kg /ha) as well as the highest pods per plant (66.07), seeds per pod (1.94) and nodules per plant (8.20) were observed. Two hand weeding was then applied at 25 and 40 DAS. Pendimethalin greatly lowered broad leaved weeds but only moderately controlled grasses and sedges, while it was still better than control when applied alone. In contrast, Imazethapyr significantly suppressed both broad and grasses. When it came to the economic component, two-hand weeding outperformed all other treatments, including control, with the highest net returns, benefit cost ratio (~42294.49 /ha and 2.8), and lowest weed index (2.8). It was discovered that this combined treatment was the most profitable and long-lasting weed control method for lentils.

Keywords: Integrated weed management; weed management; chemical weed control; lentil.

1. INTRODUCTION

Legumes (*Lens culinaris* Medik.) are among the world's first domesticated crops. A basic meal that is frequently consumed with cereal grains is lentil, commonly referred to as red dhal, masur, or split peas (Reddy and Reddy 2010). In addition to providing fiber, potassium, iron, B vitamins, and vitamin A, it is a great source of vitamin A. Aside from its potential to fix free nitrogen upto 107 kg/ha, it also plays a significant role in crop rotations, improving soil fertility and other environmental factors in the production systems [1]. One such use is the promotion of sustainable cereal based production systems. 53 nations cultivate lentils, and in 2018. Estimates from FAOSTAT [2] place the global lentil cultivation area at 6.10 mha, with an annual yield of 1038 kg/ha and 6.33 MT of production. Lentils are produce and consumed most in India. It accounts for 23.40 million metric tons (6.67%) of India's total pulse production in 2018–19 and is cultivated on 29.03 million hectares, or 5.21% of the country's total pulse area. On 1.42 million hectares of land, India produced 1.28 million tons of lentils in 2022, generating 904 kg/ha of yield. India's lentil crop is primarily farmed by small-holder farmers, who are known for their inconsistent yields. It has been found that biotic stressors cause 25% decrease in productivity of lentil in India [1]. Among the Rabi pulses, lentils are a significant crop that are typically produced unmanaged on marginal and sub-marginal lands in the Jammu region's mid-hills and kandi (rainfed) areas. Not only are production and productivity currently declining, but the area planted to this crop is also getting smaller. The most significant reasons limiting productivity are the lack of promising cultivars, inadequate fertilizer, pest and disease problems, hungry and abandoned soil, and poor weed management. 73% less lentils are produced when weeds are present [3]. Mechanical and hand weeding is typically more expensive, labor-intensive, and tiresome. In lentil crops, weed control—which involves using herbicides and a variety of planting techniques—can be more advantageous and cost-effective. Hand weeding is said to be the most efficient way to control weeds. However, according to Sharma et al. [4], this approach is only practical for small family farms and is not cost-effective for larger farms. Hand hoeing could not be as cost-effective as using a variety of integrated control techniques or potent pesticides. To find the most suitable and efficient weed control technique for winter lentils, this study assessed alternatives to hand weeding. Hand weeding is said to be the most efficient way to control weeds. However, according to Eyupoglu et al. (1995), this approach is only practical for small family farms and is not cost-effective for larger farms. Hand hoeing could not be as cost-efficient as using a variety of integrated control techniques or potent herbicides. To find the most suitable and efficient weed control technique for winter lentils, this study assessed alternatives to hand weeding.

2. MATERIALS AND METHODS

In order to determine the most effective herbicide-based weed management techniques for lentil, Krishi Vigya Kendra, Reasi, SKUAS&T-Jammu conducted a field experiment in 2022 titled "Weed management with new generation herbicides in *rabi* lentil (*Lens culinaris* Medik.)" at various locations in the district Reasi as an on Farm Trial (OFT). The pH of the sandy loam soil in the experimental field was 7.2. The experimental site is located in the Reasi district of Jammu and Kashmir (UT) and is situated physically in the Northern Western Hill Zone (Zone - 1) of India. It is situated between 32.97° North latitude and 74.91° East longitude. The location is 790 meters above MSL. The sandy loam soil at the experimental location had a neutral pH of 7.02, a high organic carbon content of 0.82, an EC of 0.77, medium in vailable nitrogen (362.95 kg/ha), medium in available phosphorus (25.68 kg/ha), and medium in potassium (263.52 kg/ha). Three replications of the experiment were conducted using a randomized block design (RBD) with six treatments. During the growth season of the lentil crop in 2017–18, 110 mm of rain fell overall. The weekly mean maximum and minimum temperatures were, respectively, 15 to 39°C and 7 to 19°C. Fertilizers that were advised for each plot were applied consistently. On November 15, 2017, the lentil variety L 4717 (Pusa Ageti) was sown. Three replications of the experiment were conducted using a randomized block design with six treatments and replicated thrice. The treatments included T1:Weedy check (control), T2: Weed free, T3: Hand Weeding at 30 and 45 DAS (Khurpi), T4: Quizalofop-p-ethyl 5% EC @ 50 g ai /ha at 40 DAS, T:5 Imazethapyr 10% SL at 40 DAS @ 37.5 g ai /ha, T6: Chlorimuron ethyl 25% WP (PPI) @ 4 g ai/ha and T7: Pendimethalin 30% EC (PE) @ 1 kg ai/ha. At 30, 60, and harvest, weed samples were gathered by randomly inserting a quadrate (0.50×0.50 m^2) in each plot, which was then translated to a square meter basis. The data on weed dry weight and weed count were transformed using square x + 0.5 (Chandel, root transformation by applying formula 1984) for consistency in order to increase the validity of the analysis of variance. At the five percent significance level, the critical difference for the significant source of variation was computed. RCBD data analysis were performed utilizing OPSTAT software. The market prices for inputs and outputs at current rates were calculated in order to do the economic analysis.

3. RESULTS AND DISCUSSION

Effect on biomass and weed density: The most commonly found weed species in the experimental field were *Chenopodium album, Cyperus esculentus* (sedge) and *Solanum nigrum*. During the trial, *Cynodon dactylon* was the only member of the grass family that was hardly noticeable (Table 1). A critical examination of the data collected at 30 DAS revealed that Pendimethalin had much lower broadleaved weed density and dry matter buildup. Grass and sedges were not significantly affected by pre-emergence herbicides. The lowest density (sedge 48%, BLWs 33% and grass 18%) was found at 60 DAS, despite the fact that dry matter buildup of all the weed species was observed during two-hand weeding at 30 and 45 DAS (Table 2). After that, Imazethapyr (POE) and Pendimethalin (PE) were used continuously. Later-emerging weeds were hidden by the crop canopy, which reduced their negative effects on the crop when treated with PE herbicides. As a result, the weeds that did emerge were not very problematic. Singh and Joshi [5] also reported a similar outcome. The season-long weed suppression under two HAND WEEDING (83%) produced the noticeably the highest weed control efficiency, which was subsequently followed by imazethapyr (Table 2). According to Khope et al. [6], two-hand weeding of chickpeas produced the highest WCE. While it was considerably better than the weedy check, the single application of chlorimuron ethyl resulted in the significantly the lowest weed count and dry matter with a low WCE. While studies have shown that post-emergence administration of chlorimuron ethyl is an efficient method of controlling weeds, the low efficacy of chlorimuron ethyl may have been caused by timing of the application [7]. These pre-emergence herbicides efficiently eliminated broadleaved weeds at both 30 and 60 DAS, although pendimethalin was less effective on grasses and sedges.

Table 1. Impact of weed management strategies on dry matter accumulation and weed density

Treatments	Weed density (m^{-2}) at 30 DAS			Dry matter accumulation (g m^{-2}) at 30 DAS			Weed density (m^{-2}) at 60 DAS			Dry matter accumulation (g m^{-2}) at 60 DAS		
	BLW	**Sedge**	**Grass**	**BLW**	**Sedge**	**Grass**	**BLW**	**Sedge**	**Grass**	**BLW**	**Sedge**	**Grass**
T1	7.55 (56.50)	7.49 (55.67)	2.48 (5.67)	2.22 (4.45)	2.75 (7.08)	1.46 (1.67)	9.65 (92.67)	10.05 (100.50)	3.52 (12.00)	5.97 (35.20)	4.76 (22.13)	3.07 (8.97)
T2	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T3	7.30 (52.83)	6.49 (41.67)	2.44 (5.47)	2.18 (4.23)	2.47 (5.60)	1.30 (1.20)	1.92 (3.20)	2.68 (6.67)	1.32 (1.33)	2.09 (3.85)	2.08 (3.83)	1.30 (1.25)
T4	7.45 (55.00)	6.63 (43.50)	2.45 (5.50)	2.06 (3.73)	2.57 (6.10)	1.15 (0.82)	4.17 (16.87)	5.90 (34.33)	1.63 (2.17)	3.58 (12.35)	2.87 (7.72)	1.66 (2.28)
T5	7.35 (53.58)	6.89 (47.00)	2.42 (5.33)	2.11 (3.94)	2.53 (5.90)	1.05 (0.60)	3.81 (14.00)	3.72 (13.33)	1.68 (2.33)	2.89 (7.85)	2.77 (7.18)	1.57 (2.00)
T6	6.07 (36.33)	6.87 (46.67)	2.12 (4.00)	2.03 (3.62)	2.40 (5.25)	1.17 (0.88)	7.31 (53.00)	6.61 (43.17)	2.27 (4.67)	4.27 (17.75)	3.34 (10.65)	1.97 (3.40)
T7	1.29 (1.17)	6.66 (43.83)	2.35 (5.00)	1.06 (0.62)	2.60 (6.27)	1.06 (0.63)	2.65 (6.50)	8.37 (69.50)	2.74 (7.00)	2.81 (7.38)	3.74 (13.50)	1.83 (2.88)
SEm±	0.14	0.20	0.06	0.06	0.21	0.04	0.12	0.17	0.07	0.13	0.11	0.06
CD (p=0.05)	0.42	0.58	0.17	0.18	0.61	0.10	0.34	0.49	0.21	0.38	0.33	0.16

Table 2. Effect of weed control treatments on relative density, WCE and NPK depletion at harvest

Treatments	Relative density at 30 DAS (%)			Relative density at 60 DAS (%)			WCE (%)	Nutrient depleted at harvest (kg /ha)		
	BLWs	Sedges	Grasses	BLWs	Sedges	Grasses		N	P	K
T1	49	47	4	51	43	7	-	5.98 (35.32)	2.38 (5.15)	4.76(22.13)
T2	0	0	0	0	0	0	100	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T3	43	52	5	48	33	18	83	2.65 (6.54)	1.24 (1.05)	2.19 (4.29)
T4	39	55	5	62	34	4	57	3.76 (13.67)	1.71 (2.42)	3.12 (9.22)
T5	47	49	5	45	48	7	67	3.31 (10.46)	1.53 (1.83)	2.88 (7.78)
T6	52	45	4	47	49	4	50	4.10 (16.33)	1.80 (2.73)	3.32 (10.55)
T7	89	2	9	80	10	11	63	3.66 (12.89)	1.61 (2.10)	3.00 (8.52)
SEm±	-	-	-	-	-	-	-	0.15	0.04	0.09
CD (p=0.05)	-	-	-	-	-	-	-	0.44	0.10	0.27

Table 3. Economic effects of weed control interventions on nodule count (60 DAS), yield characteristics, grain yield and phytotoxicity

Treatments	No. of Nodules (per plant)	No. of Pods (per Plant)	No. of Seeds (per Pod)	Yield (kg /ha)	Net returns	B:R	Weed Index (%)
T1	3.69	24.48	1.70	625.91	13352.61	1.71	56.21
T2	10.83	68.88	1.98	1429.67	41416.62	2.32	0.00
T3	9.20	65.07	1.95	1389.47	42294.49	2.48	2.81
T4	4.62	42.33	1.75	1018.55	31185.54	2.49	28.76
T5	4.42	50.93	1.72	1115.90	37083.61	2.86	21.95
T6	4.08	37.25	1.78	1010.10	32160.99	2.65	29.35
T7	5.98	58.35	1.88	1045.76	32725.47	2.58	26.86
SEm±	0.45	2.94	0.09	36.84	-	-	-
CD (p=0.05)	1.32	8.53	NS	106.80	-	-	-

Effect on NPK depletion: Table 2 shows the amount of nutrients (nitrogen, phosphorus, and potassium) decreased as a result of the influence of different weed management strategies. Significantly higher depletion by weeds was observed under Chlorimuron ethyl applied as PPI, but was significantly superior to weedy check. There were considerable differences in the amount of nitrogen, phosphorus, and potassium that weeds removed when weed-free and two-hand weeding were followed by Imazethapyr. The significant nutrient depletion by weeds under this treatment could have been caused by a number of factors, including high weed intensity, low weed control effectiveness, application time (PPI), and lower efficiency of the herbicides on the complete weed spectrum. In terms of total NPK removal, Imazethapyr and two hand weeding at 30 DAS and 45 DAS were the least nutrient-depleting treatments overall. The enhanced effectiveness of these treatments may have resulted from improvements in the quantity of weeds present, the accumulation of dry matter, and the crop's capacity to absorb nutrients.

Weed data undergo (x+0.5) modification; original values are enclosed in parenthesis. DAS: Days following seeding; Weedy Check (T1), Weed Free (T2); T4: (Quizalofop-p-ethyl @ 50 g a.i./ha at 40 DAS); T5: (Imazethapyr @ 37.5 g ai/ha at 40 DAS); T6: (Chlorimuron ethyl @ 4 g ai/ha as PPI); T7: (Pendimethalin @ 1 kg a.i./ha) as PE (P); T3: (Two Hand Weeding 30 and 45 DAS); T4 (PE stands for pre-emergence).

Effect on yield attributes: The various treatments, either alone or in combination, had a major impact on the yield attributes (Table 3). After weed free, two HAND WEEDING were linked to a significantly larger number of pods per plant and seeds per pod. Pendimethalin (PE) @ 1 kg ai /ha was next. Pendimethalin (PE) at 1 kg ai /ha and mechanical weeding at 40 DAS. With the exception of single Chlorimuron and Quizalofop-p-ethyl, which were found to have significantly lower values and to exhibit statistically non-significant differences between them, the other treatments did not exhibit any significant variations in the yield qualities. The results of Muhammad et al. [8]. corroborate the outcome. Improved yield qualities may have resulted from pre-emergence Pendimethalin spraying, mechanical weeding, and reduced weed density and dry matter buildup during the early stages of weed growth. Additionally, hoeing-related treatments shown improved yield attributes performance in chickpea, according to Muhammad et al. [9].

Impact on yield: When compared to weed-free, hand weeding at 30 DAS and 45 DAS (khurpi) demonstrated a noticeably better result. The similar outcome was also verified by Kaur et al. [10] when hand weeding in lentil was carried out at 25 DAS and 45 DAS. Of all the treatments, hand weeding produced the highest yield by a large margin, followed by imazethapyr, which was statistically comparable to the other weedicides used, namely quizalofop-p-ethyl, chlorimuron ethyl, and pendimethalin. There was no discernible differences between weed-free and twice-hand weeding. Applied alone, chlorimuron ethyl produced a yield that was higher than the weedy control but noticeably lower than the other treatments. Sharma and Sharma [5] also observed a similar outcome of a superior effect of chlorimuron ethyl in soybean yield over control).

Weed index: Table 3's weed index showed that weedy checks caused a 56% reduction in yield. The higher intensity of weeds that depleted crop's supply of nutrients, water and sunlight in addition to providing insufficient room for the crops to grow and develop comfortably may have contributed to the output drop. The treatments with the biggest yield loss relative to the control were Chlorimuron ethyl (29%) applied alone as a PPI and Quizalofop-p-ethyl (28.76%) administered alone as a post-emergence. Both weed-free and two-hand weeding resulted in little to no loss. The results are consistent with those of Adak [11], who reported a 60% yield decrease in lentils without weeding. Following weed-free, two-hand weeding and hoeing showed the least yield drop. The improved ability to prevent crop loss may be linked to effective weed control with decreased biomass and weed flora. T5 exhibited the least amount of yield decline among the herbicides treated alone.

Economic implication: Economic analysis (Table 3) showed that while the cost of using herbicides alone was relatively lower, the low biological yield also led to a low net return and BCR. The best grain production and gross return were achieved with weed-free and two-hand weeding; however, because of the higher cultivation costs, the corresponding net return and BCR were lower. When individual herbicides were compared, it was found that imazamethazard at 37.5 g ai /ha at 40 DAS was found to be the most profitable one. Among the herbicide application, pendimethalin (PE) was the second best due to its high BCR and good net return. The best option for integrated weed management may be to use Imazethapyr, as it reported the highest BCR despite two-hand weeding at 30 DAS and 45 DAS showing the highest net returns. Similar profitability was also found by Kalpana [12] using the treatment in lentils. Every treatment showed a greater BCR than the control [13-18].

4. CONCLUSION

According to the study, the optimum alternative for using a single weedicide to control weeds in lentil under rainfed circumstances in the Shivalik foothills of Jammu could be Imazethapyr @ 37.5 g ai /ha at 40 DAS. Because the data only represents a single year of observation, more long-term experiment data should be available to inform future recommendations.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s) certify that during the drafting or editing of manuscripts, NO generative AI tools, such as large language models (COPILOT, ChatGPT, etc.), were employed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/121589