**Influence of Weed Management Practices on Lentil Productivity and Weed Dynamics**

**Abstract**

Weeds are a major constraint in lentil production, competing for nutrients, light, and water, which ultimately reduces yield and its quality. A series of field experiments were conducted to assess how different weed management approaches affect yield and yield components of lentil and weeds’ dry weight over four consecutive years at the Grain Legumes Research Program, Khajura, Banke, Nepal. The study tested various pre-emergence (Pendimethalin, Metribuzin and Oxadiargyl) and post-emergence herbicides (Quizolofop-ethyl), their combinations, and manual weeding practices. Results indicated that weed management had a significant impact on 100-seed weight and seed yield, whereas its effect on traits like days to flowering and maturity, number of pods per plant, and plant height was not significant. The combined results showed that Two-hand weeding (1015 kg ha–1) and One-hand weeding (936 kg ha–1) produced the highest seed yields, while Pendimethalin and Metribuzin-based combinations effectively reduced weed biomass. The herbicide Quizolofop-ethyl alone and un-weeded control plots consistently performed poorly in all parameters. These findings suggest that combining chemical herbicides, particularly pre-emergence, with manual weeding can effectively control weeds and improve lentil productivity.

*Keywords: Lentil; herbicides; weeds; management; yield.*

**1. INTRODUCTION**

Lentil (*Lens culinaris* Medik.) is an important winter legume crop widely grown across Nepal because of its high nutritional value, soil improvement benefits, and significant economic advantages for smallholder farmers. As a protein-rich pulse, 100 grams of lentil seeds contain about 25 grams of protein (Alexander *et al.*, 2024), along with essential vitamins, minerals, dietary fiber (~11%), carbohydrates (~63%), lipids (0.5–4.3%), and healthy fats (USDA, 2015). Lentils dominate Nepal’s pulse sector, covering roughly 60% of the total legume cultivation area and accounting for 59% of legume production nationwide (Pokhrel & Poudel, 2025). Globally, Nepal ranks among the top five lentil-producing countries, contributing approximately 5% to global production (FAOSTAT, 2025).

In Nepal’s primary rice-based cropping systems, lentils are grown in relay or rotation, significantly improving soil health through biological nitrogen fixation. This process reduces reliance on synthetic nitrogen fertilizers for subsequent cereal crops (Rijal *et al*., 2021). Research shows that lentils can fix up to 107 kg of nitrogen per hectare, enhancing soil fertility (Ghimire *et al*., 2022).

Despite these advantages, weed infestation remains a major obstacle to lentil productivity due to the plant’s short stature and slow early growth, especially during the initial stages when lentil plants are less competitive (Shivani *et al*., 2022; Koushal *et al*., 2024). Weeds compete fiercely for nutrients, water, and sunlight, hinder harvesting, and degrade seed quality, leading to substantial yield losses (Birla *et al*., 2023). Unmanaged weed pressure can reduce lentil yields by as much as 80% (Balech *et al*., 2022)

Manual weeding is a common traditional practice, but is labor-intensive, time-consuming, and often delayed because of labor shortages and rising costs (Pokhrel *et al*., 2025). Chemical weed control using herbicides provides a practical and cost-effective alternative, with pre-emergence herbicides like Pendimethalin and Metribuzin successfully reducing weed biomass and increasing lentil yields (Gurjar *et al*., 2024). However, herbicide effectiveness depends on application timing, weed species, and environmental conditions (Delchev *et al*., 2022).

Combining pre- and post-emergence herbicides with cultural practices such as crop rotation, intercropping, and timely manual weeding in integrated weed management strategies has shown promising results for suppressing weeds, maintaining productivity, and minimizing environmental impacts (Kumar *et al*., 2024). These integrated approaches offer sustainable solutions to challenges like labour shortages and herbicide resistance in lentil cultivation.

This study aims to assess how different weed management practices, including individual herbicides, their combinations, and manual weeding, impact weed biomass, yield, and yield components of lentil under multi-year field conditions in Nepal.

**2. MATERIALS AND METHODS**

**2.1 Treatment Details**

A multi-year field experiment was conducted at the Grain Legumes Research Program (GLRP), Khajura, Banke, Nepal, situated at 28° 06'' 45' N latitude, 81° 35'' 58' E longitude and 182 masl, during the winter growing seasons of the year 2018/19 (Year I), 2019/20 (Year II), 2020/21(Year II), and 2021/22(Year IV). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in the individual plot size of 4 m2. The seeds of lentil were sown continuously in rows spaced at 25 cm, and the fertilizers were applied at the rate of 20:40:20 kg N:P2O5 and K2O per hectare.

The weed management practices were (i) Pendimethalin, (ii) Pendimethalin and Quizolofop-ethyl, (iii) Metribuzin, (iv) Metribuzin and Quizolofop-ethyl, (v) Oxadiargyl, (vi) Oxadiargyl and Quizolofop-ethyl, (vii) Quizolofop-ethyl, (viii) Two-hand weeding, (ix) One-hand weeding and (x) Unweeded. In this experiment, pre-emergence herbicides were applied through Penda 30% (Pendimethalin), Anchor (Metribuzin) and Top Star (Oxadiargyl) at the rate of 4 ml, 1 g and 0.2 g per liter of water, respectively, at a day after seed sowing while post-emergence herbicide Quizolofop-ethyl was used through Terga Super at the rate of 2 ml per liter of water at 25 days after seeding (DAS). The treatments of hand weeding were performed at 25 DAS for one hand weeding, and at 25 and 45 DAS in the case of two hand weeding treatments.

**2.2 Soil Characteristics**

The soils of the experimental plots were found sandy loam with 6.6 to 7.1 pH value that had low amount of organic matter (1.76 to 1.82%) and nitrogen (0.07 to 0.09%) but a high level of phosphorous (98.4 to 123.7 kg ha–1) and potassium (291.1 to 283.3 kg ha–1) (Pokhrel *et al*., 2022).

**2.3 Climatic Conditions of the Study Time**

The experimental site received 201.5 mm of rainfall during the crop period, from October to April. December and January were noted as the coolest months, while April was the hottest month. The mean minimum and maximum temperatures and rainfall of the study area are presented in Table 1.

**Table 1. Average temperatures and rainfall during the study periods of the year 2018/19 to 2021/22**

|  |  |  |  |
| --- | --- | --- | --- |
| **Month** | **Min. Tem. (ºC)** | **Max. Tem. (ºC)** | **Rainfall (mm)** |
| October | 18.8 | 31.6 | 133.9 |
| November | 13.2 | 27.7 | 0.0 |
| December | 9.1 | 23.7 | 1.7 |
| January | 8.9 | 19.3 | 18.1 |
| February | 10.7 | 23.6 | 12.8 |
| March | 15.0 | 31.8 | 12.6 |
| April | 19.9 | 39.5 | 22.4 |

**2.4 Statistical Analysis**

All the data on growth, development, and yield were analyzed statistically at a probability level of *P* ≤ 0.05 by using the statistical software RStudio.

**3. RESULTS AND DISCUSSIONS**

* 1. **Effects on Growth and Yield Attributes of Lentil**

Two-way ANOVA analysis was done to evaluate the effect of different weed management practices and four different planting seasons on the yield attributes in lentil. The yield attributes evaluated in this study are days to flowering, days to maturity, plant height, number of pods/plant and 100 seed weight. Among these traits, only the number of pods per plant was significantly different for the interaction effect (Table 2). However, there was a significant difference between years for days to maturity, plant height, and 100-seed weight. Only the 100-seed weight was significantly different between the weed management practices used.

The days to flowering ranged from 89 to 92 days, while maturity consistently occurred between 136 and 137 days across all treatments. This suggests that weed management practices did not influence the phenological development of lentil. These findings are consistent with Saskatchewan (2023), who reported no significant effect on days to flowering and days to maturity. The plant height ranged from 21 cm to 23.5 cm, but the differences were statistically nonsignificant. The tallest plants were recorded in the Two-hand weeding treatment (23.5 cm), possibly due to better weed control and reduced competition for resources. However, due to high variability (CV = 13.2%), the differences could not be considered statistically significant. Similarly, there was no statistically significant effect of weed management on the number of pods per plant, although a significant interaction between year and management practices was observed. The number of pods ranged from 16 to 21, with the highest in One-hand weeding (21 pods) and Two-hand weeding (20 pods). The un-weeded control also produced 20 pods, indicating that pod count alone may not fully reflect the impact of weed competition without considering other yield attributes. Unlike our finding, a study by Pokharel et al. (2022) showed number of pod per plant were significantly affected by management practices (Pokhrel *et al*., 2022; Koushal *et al*., 2024).

In contrast, the 100-seed weight was significantly affected (*P* < 0.01) by weed management practices. The highest 100-seed weight was recorded in the One-hand weeding treatment (1.50 g), which was statistically at par with Oxadiargyl (1.49 g). These were closely followed by Metribuzin-Quizolofop-ethyl (1.43 g) and Pendimethalin, Pendimethalin-Quizolofop-ethyl, and Metribuzin, all producing similar weights around 1.41–1.42 g. The lowest seed weight was observed with Quizolofop-ethyl alone (1.29 g), suggesting that this herbicide alone may not effectively control a broad spectrum of weeds, ultimately affecting seed filling and development. The unweeded control also had a relatively low seed weight (1.32 g), reinforcing the importance of effective weed control for better seed quality. The results of the study are in line with the findings of Chandrakar *et al*., (2015), that weed management notably influenced test weight.

This result indicates that using any weeding practices is better than no weeding to increase the yield-related trait, which ultimately contributes to yield. However, one time weeding performed better than others. The choice of weeding method can be done based on the cost involved in different weeding methods. The present study showed that weed management practices significantly affect the yield-related traits in lentil, with notable differences observed across four different planting seasons. The implementation of weeding strategies, whether manual or chemical resulted in higher yield performance compared to un-weeded control, highlighting the importance of reducing weed competition for increasing lentil productivity. Yield attributes such as 100-seed weight were responsive to the weed management practice, and the number of pods per plant was responsive to the interaction of treatment and year. This means that the soil, rainfall, and environmental conditions also have an impact on the lentil yield. The lower values of 100-seed weight in un-weeded plot showed that the weed interacts with lentil at the critical growth stage by competing for nutrients, water, and sunlight.

**Table 2. Effects of different weed management practices on the yield attributes of lentil (combined of four years)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatment | Days to flowering | Days to maturity | Plant height, cm | Number of pods plant–1 | 100 seed weight, g |
| Pendimethalin | 91 | 136 | 22.4 | 20 | 1.41ab |
| Pendimethalin - Quizolofop-ethyl | 90 | 137 | 22.9 | 20 | 1.41ab |
| Metribuzin | 89 | 136 | 21.7 | 17 | 1.42ab |
| Metribuzin-Quizolofop-ethyl | 92 | 136 | 21.6 | 17 | 1.43ab |
| Oxadiargyl | 90 | 136 | 21.6 | 18 | 1.49a |
| Oxadiargyl-Quizolofop-ethyl | 90 | 136 | 22.1 | 18 | 1.36bc |
| Quizolofop-ethyl | 90 | 136 | 21.2 | 16 | 1.29c |
| Two-handd weeding | 89 | 136 | 23.5 | 20 | 1.40abc |
| One-hand weeding | 90 | 136 | 22.4 | 21 | 1.50a |
| Un-weeded | 90 | 136 | 21.0 | 20 | 1.32bc |
| SEm (±) | 2.66 | 0.83 | 2.91 | 5.08 | 0.13 |
| F-test |  |  |  |  |  |
| Year | ns | \*\* | \* | ns | \* |
| Management practices | ns | ns | ns | ns | \*\* |
| Interaction | ns | ns | ns | \*\* | ns |
| LSD (0.05) | 2.17 | 0.680 | 2.36 | 4.14 | 0.10 |
| CV% | 2.9 | 0.7 | 13.2 | 15.6 | 9.6 |

**3.2 Effect on Seed Yield of Lentil**

Two-way ANOVA analysis was done to evaluate the ten different weed management practices and four different planting seasons to observe their effect on the seed yield of lentil (Table 4). The ANOVA analysis resulted significant difference at *P* < 0.05 between the weeding treatments in each year as well as for the combined mean across the years, indicating the critical role of weed control methods in the lentil productivity.

Across the four years, the highest seed yield was observed in the hand weeding treatments with Two-hand weeding yielding the highest mean yield (1015 kg ha–1), and significantly higher than all herbicidal treatments. Overall, all weeding treatments increased the yield as compared to unweeding, which showed the importance of weeding practices on reducing weed competition for resources with lentil. Among herbicide treatments, Pendimethalin applied resulted in the highest yield (911 kg ha–1), which was statistically comparable to the One-hand weeding treatment. The addition of Quizalofop-ethyl to Pendimethalin did not improve the yield, suggesting no synergistic benefit of this combination.

Comparing the seed yield between ten different treatments for four different years, One-hand weeding (1054 kg ha–1) had the highest yield in the first year, where Two-hand weeding and Pendimethalin had statistically comparable yields. Similarly, in the second year, Two-hand weeding had the highest yield (998 kg ha–1) with One-hand weeding being statistically similar. Also, in the third year of the experiment, Two-Hand Weeding had the highest seed yield (990 kg ha–1) and One-hand weeding (830 kg ha–1), and Pendimethalin had a comparable yield (824 kg ha–1). Similarly, in the fourth year, Two-hand weeding (1042 kg ha–1) had the highest seed yield with One-hand weeding and Pendimethalin and Pendimethalin-Quizolofop-ethyl having statistically similar yields.

Manual weeding, especially Two-hand weeding, proved to be the most effective weed management approach for increasing lentil yield, likely because of its ability to reduce both early and late-season weed competition. One-hand weeding and Pendimethalin also provided effective weed suppression and higher productivity. Conversely, Quizolofop-ethyl alone and the Un-weeded control consistently yielded the lowest, indicating poor weed control efficiency and high crop-weed competition.

Regarding overall seed yield, Two-hand weeding consistently produced the highest yield across all years, which supports the earlier reports that manual weeding remains the most effective method of weed suppression and yield maximization (Kumar *et al*., 2018). However, Kumar *et al*., (2018) reported that, though complete removal of weeds through hand weeding may maximize the yield, it was not cost-effective than mixing the hand weeding with herbicide application as complete weed removal requires big amount of manual labor. Though it is labor-intensive, hand weeding can be particularly advantageous where herbicide supply is limited and expensive especially in small-holder farming condition.

Among the applied herbicides, Pendimethalin as a pre-emergence herbicide produced yields statistically comparable to hand weeding in multiple years. This result is by Singh *et al*., (2018), who reported that the use of Pendimethalin as pre-emergence increased the lentil yield. This suggests that herbicide application can be cost-effective and labor-saving. Herbicide application is beneficial especially in large scale production where manual weeding is not possible due to expensive labor the addition of Quizalofop-ethyl to Pendimethalin did not increase the lentil yield in our case however the study by Singh *et al*., (2018) using combination of Pendimethalin as pre-emergence and Quizalofop-ethyl as post emergence increased the yield. In Singh’s study, there was infestation of annual and grassy weeds on the later part of crop growth, where Quizalofop-ethyl might have played a role in weed suppression.

Though not investigated in this research, it can be hypothesized that mixing herbicide application and One-hand weeding may increase the seed yield as well as reduce the cost of weeding (Priya *et al*., 2023). So integrated method of weed management could be another alternative for sustainable weed management. Sustainable weed management not only increases profitability but also helps in reducing the occurrences of herbicide resistance.

Table 3. Effects of different weed management practices on yield of lentil

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatment | Seed yield, kg ha–1 (Year I) | Seed yield, kg ha–1 (Year II) | Seed yield, kg ha–1 (Year III) | Seed yield, kg ha–1 (Year IV) | Seed yield, kg ha–1 (Combined of four years ) |
| Pendimethalin | 982ab | 818bc | 824b | 1021a | 911bc |
| Pendimethalin - Quizolofop-ethyl | 915b | 825abc | 740bc | 933a | 853cd |
| Metribuzin | 541de | 842abc | 745bc | 737b | 716fg |
| Metribuzin - Quizolofop-ethyl | 729c | 957ab | 788bc | 790b | 816de |
| Oxadiargyl | 618cd | 894abc | 792bc | 780b | 771ef |
| Oxadiargyl - Quizolofop-ethyl | 736c | 822bc | 664c | 778b | 750f |
| Quizolofop-ethyl | 503de | 749c | 693bc | 765b | 678g |
| Two-hand weeding | 1030ab | 998a | 990a | 1042a | 1015a |
| One-hand weeding | 1054a | 837abc | 830b | 1023a | 936b |
| Unweeded | 481e | 557d | 395d | 418c | 463h |
| SEm (±) | 74.12 | 101.6 | 82.68 | 71.28 | 36.52 |
| F-test | \*\* | \*\* | \*\* | \*\* | \*\* |
| LSD (0.05) | 127.06 | 174.43 | 141.77 | 122.29 | 62.65 |
| CV % | 9.8 | 12.25 | 11.07 | 8.60 | 4.61 |

* 1. **Effects on Weed Dry Weight**

The data for weed dry weight was taken at 25 DAS or just before implementing hand weeding practices from all the experimental plots. Weeds were collected from the 0.5 m2 area and dried in an oven to measure their dry weights. The weed such as: *Cyperus rotundus, Chenopodium album, Oxalis corniculata, Vicia sativa, Solanum nigrum,* and *Cynodon dactylon* were found as the major weeds in the lentil field.

In the first year of the experiment, significant differences (*P* < 0.05) were observed in weed dry weight due to different weed management practices. The lowest weed dry weight was recorded in Pendimethalin-Quizolofop-ethyl (1.6 g), followed closely by Metribuzin, Metribuzin-Quizolofop-ethyl, and Pendimethalin (1.6–2.5 g), indicating strong early weed suppression by pre-emergence herbicides or their combinations. The highest weed dry weight was found in One-hand weeding (6.1 g) and Un-weeded control (6.0 g), both statistically similar and significantly higher than most herbicide treatments. This suggests that manual weeding performed once was insufficient to control weeds effectively throughout the entire crop growth period. In the second year, the differences in weed dry weight among treatments were statistically non-significant. Variations ranged from 2.6 g (One-hand weeding) to 5.5 g (Pendimethalin-Quizolofop-ethyl), indicating inconsistent performance or weed regrowth influenced by seasonal or climatic variations. The combined analysis also showed no significant differences among treatments. However, numerically lower weed biomass was still observed in Metribuzin-Quizolofop-ethyl (2.6 g) and Metribuzin (2.7 g), while Unweeded (5.3 g) and Quizolofop-ethyl alone (4.7 g) had the highest weed dry weights. The high coefficient of variation (CV = 31.48%) in the combined data indicates variability in weed populations and treatment efficacy across years.

The results highlight that pre-emergence herbicides, especially Metribuzin-based treatments, were more effective in suppressing weed biomass during the initial growth stages. These findings align with a study conducted at North Dakota State University in 2021, which showed that pre-emergent treatments demonstrate near-total weed control without compromising lentil vigor or yield (Dally, 2021). Quizolofop-ethyl alone, a post-emergence herbicide, was less effective, possibly due to late application. Similar results have been reported by Pokhrel *et al*., (2022), who emphasized that Quizalofop-ethyl, regardless of its dose, was ineffective against broadleaf weeds.

Interestingly, manual methods like One-hand weeding and even Two-hand weeding did not result in the lowest weed biomass. This could be due to the timing of weed removal or rapid weed regrowth after manual removal. Despite higher weed biomass, manual weeding still led to higher seed yield (as shown in Table 4), possibly because it removed critical weed pressure during sensitive crop stages. This supports the finding that even with higher measured biomass in manual weeding, yield remained high because critical weed competition during sensitive lentil growth stages was effectively minimized (Pokhrel *et al*., 2022). The Un-weeded treatment consistently recorded the highest weed dry weight, reaffirming the need for active weed control strategies to reduce biomass competition and improve lentil yield.

**Table 4. Effects of different weed management practices on weeds dry weight**

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Weed dry weight in g/0.5 m2 | | |
| Year I | Year II | Combined |
| Pendimethalin | 2.5bc | 3.1 | 2.8 |
| Pendimethalin-Quizolofop-ethyl | 1.6c | 5.5 | 3.5 |
| Metribuzin | 1.7c | 3.6 | 2.7 |
| Metribuzin-Quizolofop-ethyl | 1.7c | 3.4 | 2.6 |
| Oxadiargyl | 3.0abc | 3.3 | 3.2 |
| Oxadiargyl-Quizolofop-ethyl | 2.3bc | 4.4 | 3.3 |
| Quizolofop-ethyl | 5.2ab | 4.1 | 4.7 |
| Two-hand weeding | 3.5abc | 5.0 | 4.2 |
| One-hand weeding | 6.1a | 2.6 | 4.3 |
| Un-weeded | 6.0a | 4.6 | 5.3 |
| SEm (±) | 1.91 | 1.522 | 1.16 |
| F-test | \* | ns | ns |
| LSD (0.05) | 3.29 | 2.61 | 2.0 |
| CV% | 55.58 | 38.46 | 31.48 |

**4. CONCLUSION**

The study revealed that weed management significantly influenced lentil growth, yield, and weed biomass. Manual methods like Two-hand weeding consistently produced the highest yields, while Pendimethalin and Metribuzin-based combinations were effective in reducing weed biomass. Quizolofop-ethyl alone and Unweeded plots resulted in the poorest performance across all parameters. An integrated approach combining pre-emergence herbicides with timely manual weeding appears most effective for enhancing lentil productivity and suppressing weed competition, and is better to reduce the use of herbicides for better environmental health.

**Disclaimer (artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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