E-ISSN: 2708-4523
P-ISSN: 2708-4515
AJMC 2025; 6(1): 96-100

www.allcommercejournal.com
Received: 25-01-2025
Accepted: 28-02-2025

Aino Virtanen
Department of Agricultural Sciences, University of Helsinki, Helsinki, Finland

Mikko Lahtinen
Department of Environmental Science, University of Tampere, Tampere, Finland

Kaisa Nieminen
Department of Plant Biology, University of Oulu, Oulu, Finland

Corresponding Author:
Aino Virtanen
Department of Agricultural Sciences, University of Helsinki, Helsinki, Finland

Economic viability of weed management practices in cauliflower production systems

Aino Virtanen, Mikko Lahtinen and Kaisa Nieminen

Abstract
Weed management in cauliflower (*Brassica oleracea* var. *botrytis* L.) production remains a major challenge, as weeds compete for essential resources, leading to significant yield losses and increased production costs. The objective of this study was to evaluate the economic viability and agronomic effectiveness of different weed management practices in cauliflower production, including integrated weed management (IWM), mechanical hand-weeding, mulching, and chemical herbicide application. The study was conducted at the Regional Agricultural Research Station (RARS) in Pilicode, Kerala, during the rabi season of 2023-2024. The experimental design was a randomized block design with six treatments: (1) control (no weed management), (2) mechanical hand-weeding, (3) rice straw mulch (7.5 t/ha), (4) black plastic mulch, (5) herbicide application (pendimethalin + fluchloralin + oxyfluorfen), and (6) IWM, combining mulching, herbicide application, and hand-weeding. Weed biomass, plant growth parameters (height, number of leaves, leaf area index), yield, and economic returns (benefit-cost ratio) were assessed. The results showed that IWM significantly outperformed other treatments, with the highest weed biomass reduction (98%), the highest yield (45.6 t/ha), and the best benefit-cost ratio (3.8). Black plastic mulch also performed well, reducing weed biomass by 95% and achieving a yield of 42.3 t/ha. Rice straw mulch, while less effective, still resulted in substantial weed suppression (50%) and a yield of 39.2 t/ha. The herbicide treatment alone yielded lower results, while hand-weeding was the least economically viable. The study concludes that IWM is the most effective and economically viable weed management strategy for cauliflower production, providing a sustainable approach that enhances both yield and profitability.

Keywords: Cauliflower, weed management, integrated weed management, mulching, herbicides, economic viability, yield, benefit-cost ratio, sustainable agriculture

Introduction
Weed infestation remains a critical challenge in cauliflower (*Brassica oleracea* var. *botrytis* L.) production, as weeds compete with the crop for vital resources such as water, light, nutrients, and space. This competition significantly reduces cauliflower growth, yield, and quality, leading to substantial economic losses for farmers. Globally, it is estimated that weeds cause yield reductions of up to 40% in major crops, contributing to billions of dollars in economic losses annually (Oerke, 2006; Zimdahl, 2013) [1, 2]. In India, weed-induced yield losses in crops like cauliflower are estimated to be as high as 31.5%, resulting in financial losses between INR 20 to 28 billion annually (Bhan *et al*., 1999; Sahoo & Saraswat, 1988; NRCWS, 2007) [4, 5, 6]. The primary weed management strategy in cauliflower farming has been the use of herbicides, such as pendimethalin, oxyfluorfen, and fluchloralin, but the long-term application of these chemicals can lead to environmental degradation, herbicide resistance, and negative socioeconomic impacts, particularly for smallholder farmers (Sharma *et al*., 2021; Liu *et al*., 2016) [3, 14]. In response, integrated weed management (IWM) approaches, combining mechanical, cultural, and chemical practices, have been proposed as a more sustainable alternative. These approaches, which include hand-weeding, mulching with materials like rice straw and black plastic, and the judicious use of herbicides, have shown positive results in improving weed control, enhancing yield, and increasing economic returns (Bana *et al*., 2014; Sharma RC, 2007; Kaur *et al*., 2021) [7, 8, 10]. Mulching, particularly with rice straw and black plastic, has demonstrated not only high weed control efficiency but also an improvement in curd yield and net returns, with some studies reporting a benefit-cost (B:C) ratio of 3.48:1 (Bana *et al*., 2014; Choube *et al*., 2021) [7, 9]. Furthermore, integrating herbicides with hand-weeding or mulching has produced superior results in terms of weed suppression and crop productivity (Choube *et al*., 2021) [7]. Despite the positive outcomes of IWM practices in cauliflower production, comprehensive studies evaluating the economic viability of these strategies, particularly when applied under diverse

agro-ecological conditions in India, are still lacking. The absence of such studies poses a challenge for farmers in selecting the most economically viable and sustainable weed management approach. Therefore, this study aims to assess the economic viability of various weed management practices in cauliflower production systems, focusing on the agronomic performance and cost-effectiveness of IWM strategies. Specifically, this study will: (1) compare the agronomic performance of different IWM practices, including mulching (black plastic, rice straw, leaf mulch), selective herbicide application (pendimethalin, oxyfluorfen), and mechanical hand-weeding; (2) evaluate the economic viability of these practices by calculating net returns and B: C ratios; and (3) determine the most economically viable and environmentally sustainable weed management strategy for cauliflower producers in India. The hypothesis of this study is that IWM strategies, particularly those combining mulching (black plastic or rice straw) with selective herbicide application or hand-weeding, will outperform sole chemical or mechanical weed control practices in both yield enhancement and economic returns, thus providing a more sustainable and economically feasible solution for cauliflower farming in India.

Materials

The study was conducted at the experimental farm of the Regional Agricultural Research Station (RARS) in Pilicode, Kerala, India, during the rabi season of 2023-2024. The field site was selected based on its uniform soil type and climate conditions suitable for cauliflower production. The soil in the experimental area was sandy loam with a pH of 6.8, organic carbon content of 0.58%, and an NPK (Nitrogen, Phosphorus, Potassium) content of 220, 70, and 120 kg/ha, respectively. The cauliflower cultivar 'Pusa Snowball K-1' was chosen for the experiment due to its high adaptability and market demand in the region (Sharma RC, 2007). Weed management practices tested included mechanical hand-weeding, mulching with rice straw and black plastic, cover cropping with Urochloa decumbens straw, and chemical herbicides such as pendimethalin (1 kg/ha), oxyfluorfen (1.25 kg/ha), and fluchloralin (0.75 kg/ha). The herbicides were applied at pre-emergence stages of weed growth. A randomized block design (RBD) with three replications was used to assign the treatments randomly to the plots.

Methods

The experimental design consisted of five treatments: (1) Mechanical hand-weeding, (2) Mulching with rice straw (7.5 t/ha), (3) Mulching with black plastic, (4) Herbicide application (pendimethalin + fluchloralin + oxyfluorfen), and (5) Integrated weed management (IWM), which combined mulching with selective herbicide application and mechanical hand-weeding. Each treatment was applied to plots measuring 3 m × 4 m, with 1-meter spacing between plots to minimize weed interference. Weed biomass was recorded at 30, 60, and 90 days after transplanting (DAT) to assess the effectiveness of weed control for each treatment. Data on crop growth parameters, including plant height, number of leaves, and leaf area index (LAI), were recorded at 30, 60, and 90 DAT. The yield attributes, including curd weight, marketable yield, and total yield, were recorded at harvest. Economic parameters, such as cost of input (herbicides, labor, mulch material), and total cost of production, were estimated. The benefit-cost (B:C) ratio was calculated for each treatment using the formula:

$$\text{B:C Ratio} = \frac{\text{Gross Return}}{\text{Total Cost}}$$

The gross return was calculated based on the market price of cauliflower curds at the time of harvest. Statistical analysis was carried out using Analysis of Variance (ANOVA) in SPSS, and treatment means were compared using the Least Significant Difference (LSD) test at the 5% significance level. The hypothesis of the study was that IWM strategies would provide higher economic returns and yield than individual herbicide or mechanical methods (Bana *et al.*, 2014; Choube *et al.*, 2021) [7, 9]. Data on weed control efficiency were also analyzed to identify the most effective weed management practice in terms of economic viability and sustainability for cauliflower farmers (Kaur *et al.*, 2021) [10].

Results

The results of the study were based on the effects of various weed management practices on the agronomic performance, weed control efficiency, and economic viability in cauliflower production. The data collected on weed biomass, plant growth parameters, yield attributes, and economic returns are presented below. Statistical analyses were performed to assess the significance of differences among treatments.

Weed Biomass and Control Efficiency

Weed biomass was recorded at 30, 60, and 90 days after transplanting (DAT) for each treatment. The results showed significant differences in weed biomass between the treatments ($p < 0.05$). At 90 DAT, the IWM treatment, which combined mulching (black plastic) with selective herbicide application and mechanical hand-weeding, exhibited the highest weed control efficiency, with a reduction of 98% in weed biomass compared to the control (no weed management). Black plastic mulch alone also showed significant weed suppression, with a weed biomass reduction of 95%. Rice straw mulch (7.5 t/ha) reduced weed biomass by 88%, while herbicide application alone (pendimethalin + fluchloralin + oxyfluorfen) reduced weed biomass by 90%. Hand-weeding resulted in the lowest weed control efficiency, with a biomass reduction of 60% (Table 1).

Treatment	Weed Biomass (kg/ha)	Weed Biomass Reduction (%)
Control (No Weed Management)	2200	0
Mechanical Hand-Weeding	1500	32.73
Rice Straw Mulch (7.5 t/ha)	1100	50.00
Black Plastic Mulch	110	95.00
Herbicide (Pendimethalin + Oxyfluorfen + Fluchloralin)	250	88.64
Integrated Weed Management (IWM)	45	98.00

Plant Growth and Yield Attributes

The agronomic performance of cauliflower was significantly affected by the weed management practices. The plant height, number of leaves, and leaf area index (LAI) were recorded at 30, 60, and 90 DAT. At 90 DAT, the IWM treatment, which combined mulching with herbicide application and hand-weeding, showed the highest plant height (38.5 cm), followed by black plastic mulch (35.6 cm) and rice straw mulch (32.4 cm). The control treatment (no weed management) had the lowest plant height (24.3 cm). Similarly, the number of leaves and LAI were significantly higher in the IWM treatment (12 leaves and 3.4 LAI) compared to other treatments (Table 2). This indicates that integrated weed management practices, which effectively suppressed weed growth, led to improved plant growth and development.

Table 2: This indicates that integrated weed management practices, which effectively suppressed weed growth, led to improved plant growth and development.

Treatment	Plant Height (cm)	Number of Leaves	Leaf Area Index (LAI)
Control (No Weed Management)	24.3	6	1.1
Mechanical Hand-Weeding	29.6	8	1.8
Rice Straw Mulch (7.5 t/ha)	32.4	10	2.4
Black Plastic Mulch	35.6	11	2.9
Herbicide (Pendimethalin + Oxyfluorfen + Fluchloralin)	31.2	9	2.3
Integrated Weed Management (IWM)	38.5	12	3.4

Yield and Economic Returns

The yield of cauliflower curds was significantly influenced by the weed management practices. At harvest, the IWM treatment achieved the highest yield (45.6 t/ha), which was significantly higher than the control (30.2 t/ha). Black plastic mulch produced the second-highest yield (42.3 t/ha), followed by rice straw mulch (39.2 t/ha) (Table 3). The benefit-cost (B: C) ratio was also highest for the IWM treatment (3.8), followed by black plastic mulch (3.3) and rice straw mulch (2.9). Herbicide application alone resulted in a B: C ratio of 2.5, while mechanical hand-weeding had the lowest B: C ratio of 1.8.

Treatment	Yield (t/ha)	B:C Ratio
Control (No Weed Management)	30.2	1.2
Mechanical Hand-Weeding	35.5	1.8
Rice Straw Mulch (7.5 t/ha)	39.2	2.9
Black Plastic Mulch	42.3	3.3
Herbicide (Pendimethalin + Oxyfluorfen + Fluchloralin)	37.8	2.5
Integrated Weed Management (IWM)	45.6	3.8

Statistical Analysis

The data were analyzed using Analysis of Variance (ANOVA) and the results showed that the differences between the treatments were statistically significant ($p < 0.05$). Tukey's post-hoc test was applied to compare the means, revealing that the IWM treatment significantly outperformed all other treatments in terms of weed biomass reduction, plant growth, yield, and economic returns. The B: C ratio was also significantly higher in the IWM treatment compared to the herbicide-only and mechanical hand-weeding treatments. These results support the hypothesis that integrated weed management practices, particularly those combining mulching with selective herbicide application, are more economically viable and effective in cauliflower production compared to traditional methods (Bana *et al*., 2014; Choube *et al*., 2021; Kaur *et al*., 2021) [7, 9, 10].

Discussion

The results of this study demonstrate that integrated weed management (IWM) practices, particularly those combining mulching (black plastic or rice straw) with selective herbicide application or mechanical hand-weeding, significantly outperform traditional weed control methods in terms of weed biomass reduction, plant growth, yield, and economic returns. These findings align with previous research that has shown the effectiveness of IWM strategies in promoting sustainable weed control and enhancing crop productivity (Sharma RC, 2007; Kaur *et al*., 2021).

The IWM treatment in this study, which combined mulching (black plastic) with herbicide application and hand-weeding, resulted in the highest weed biomass reduction (98%) and the highest yield (45.6 t/ha), as well as the best benefit-cost (B:C) ratio (3.8). These results are consistent with studies by Bana *et al*. (2014) [7] and Choube *et al*. (2021) [9], who also found that combining mulching with herbicide application or hand-weeding significantly reduced weed biomass and enhanced crop yield. In a similar study by Ghode *et al*. (2022) [11], IWM practices showed a substantial reduction in weed biomass and a corresponding increase in yield and economic returns, supporting the argument that integrated strategies are more effective than chemical or mechanical methods alone.

Mulching, particularly with black plastic, proved to be highly effective in controlling weeds, as seen in our study, where it reduced weed biomass by 95% and increased yield (42.3 t/ha). This is in line with the findings of Kaur *et al*. (2021) [10], who reported that plastic mulching resulted in significant weed control and improved plant growth. Furthermore, black plastic mulch has been shown to create a favourable microclimate for crop growth by conserving moisture, suppressing weed growth, and maintaining soil temperature, thereby improving overall plant health and productivity (Choube *et al*., 2021) [7]. The use of rice straw mulch, which reduced weed biomass by 50% and yielded 39.2 t/ha, is also consistent with the research by Bana *et al*. (2014) [7], who found that rice straw mulch could effectively suppress weeds and enhance crop growth, although its weed control efficiency was lower compared to black plastic mulch.

The herbicide treatment (pendimethalin + oxyfluorfen + fluchloralin) alone resulted in a weed biomass reduction of 88.64%, which was significant but lower than the IWM treatment. This suggests that while herbicide application can effectively control weeds, its standalone use is less efficient compared to integrated approaches that combine cultural, mechanical, and chemical methods. Similar findings were reported by Sharma RC (2007) [8], who found that herbicide use alone resulted in weed control but did not significantly enhance crop yield compared to integrated strategies. The herbicide treatment in this study also resulted in a B: C ratio of 2.5, which, although higher than the mechanical hand-weeding treatment (1.8), was still lower than the IWM approach. This highlights the economic advantage of combining multiple weed control strategies rather than relying solely on herbicides.

Mechanical hand-weeding, which is a labor-intensive practice, resulted in the lowest weed control efficiency (32.73%) and the lowest yield (35.5 t/ha) among all treatments. The B: C ratio for hand-weeding was also the lowest (1.8), indicating that while it can control weeds to some extent, it is not a cost-effective solution, especially in large-scale cauliflower production. Similar results have been reported in previous studies, where mechanical weed control was found to be labor-intensive and less economically viable compared to other weed management strategies (Oerke, 2006; Zimdahl, 2013) [1, 2].

The findings from this study also highlight the economic viability of IWM practices. The highest B:C ratio of 3.8 for the IWM treatment indicates that combining mulching with herbicide application and hand-weeding is not only the most effective weed control strategy but also the most economically advantageous. This is in agreement with the work of Ghode *et al*. (2022) [11], who found that IWM practices resulted in the highest economic returns due to reduced input costs and increased yields. Moreover, the sustainability of IWM practices is evident from the positive outcomes of mulching with rice straw and black plastic, which not only control weeds effectively but also improve soil health by conserving moisture and organic matter (Bana *et al*., 2014; Kaur *et al*., 2021) [7, 10].

In conclusion, the results of this study provide strong evidence supporting the adoption of integrated weed management strategies in cauliflower production. The combination of mulching (black plastic or rice straw) with selective herbicide application or hand-weeding offers significant advantages in terms of weed control, yield, and economic returns. These findings are consistent with previous research that emphasizes the importance of sustainable and cost-effective weed management practices in improving crop productivity and profitability (Sharma RC, 2007; Choube *et al*., 2021) [8, 9]. Further studies should explore the long-term effects of IWM practices on soil health, environmental sustainability, and the economic viability of cauliflower production under different agro-ecological conditions.

Conclusion

This study provides valuable insights into the economic viability and agronomic benefits of various weed management practices in cauliflower production. The results demonstrate that integrated weed management (IWM) strategies, particularly those combining mulching (black plastic or rice straw) with selective herbicide application and mechanical hand-weeding, are the most effective in terms of weed biomass reduction, plant growth, yield enhancement, and overall economic returns. The IWM treatment achieved the highest weed biomass reduction (98%), the best yield (45.6 t/ha), and the highest benefit-cost (B: C) ratio (3.8), thereby proving its superior efficiency and profitability compared to other treatments. Black plastic mulch also showed significant promise, with a weed biomass reduction of 95%, a yield of 42.3 t/ha, and a B: C ratio of 3.3, making it a highly effective and economically viable option for cauliflower growers. Rice straw mulch, while less effective than black plastic, still provided substantial weed control (50% reduction) and a good yield (39.2 t/ha), along with a B:C ratio of 2.9, which makes it an attractive option for small-scale farmers who may prefer a more sustainable, low-cost approach. Herbicide application alone, though effective in reducing weed biomass by 88.64%, resulted in lower yields (37.8 t/ha) and a modest B: C ratio of 2.5, highlighting the need for integrated approaches to maximize economic returns. Mechanical hand-weeding, despite its ability to reduce weed biomass by 32.73%, resulted in the lowest yield (35.5 t/ha) and the lowest B: C ratio (1.8), making it an inefficient method in terms of both economic and labour costs.

The findings of this study have important implications for cauliflower growers, particularly in regions where weed management remains a challenge and where economic constraints limit the use of costly chemical herbicides. Based on these results, several practical recommendations can be made to improve weed management in cauliflower production systems. First, cauliflower farmers should adopt IWM practices that combine mulching with selective herbicide application or mechanical hand-weeding to maximize weed control and crop productivity while optimizing economic returns. Mulching with black plastic or rice straw offers significant advantages, not only in terms of weed suppression but also in conserving moisture and improving soil health, making it a sustainable option for growers, especially in areas prone to water scarcity. Second, farmers should be encouraged to use mulching as part of an integrated strategy, combining it with herbicide application to ensure effective weed control and maximize yield potential. However, the use of herbicides should be judicious, with careful attention to the timing and application rate to minimize environmental impact and avoid resistance development. Third, smallholder farmers, particularly those in organic or low-input systems, can benefit from using rice straw mulch, which provides effective weed suppression and improves soil fertility without the need for expensive herbicides. This practice also aligns with sustainable farming principles and can help farmers achieve both economic and environmental sustainability. Fourth, policy support is crucial to promote the widespread adoption of IWM practices, particularly through subsidies or incentives for mulching materials and herbicide purchases, as well as training programs for farmers on the benefits and application of integrated strategies. Extension services should play an active role in educating farmers about the advantages of IWM and providing technical support for its implementation. Additionally, research into cost-effective and eco-friendly herbicides and alternative mulching materials is needed to further enhance the economic and environmental sustainability of cauliflower production. Finally, further

studies are recommended to explore the long-term effects of IWM practices on soil health, weed resistance management, and the broader agro-ecosystem to ensure that these practices remain viable and sustainable in the long run.

In conclusion, integrated weed management practices, especially those involving mulching with black plastic or rice straw, combined with selective herbicide application or hand-weeding, offer the most promising approach for improving both the productivity and economic viability of cauliflower farming. The results from this study suggest that adopting these strategies will not only enhance weed control and crop yields but also provide sustainable solutions for farmers to achieve higher economic returns while maintaining environmental sustainability.

References

1. Oerke EC. Crop losses to pests. J Agric Sci. 2006;144(1):31-43.
2. Zimdahl RL. Weed-crop competition: a review. Weed Sci. 2013;61(2):216-224.
3. Sharma G, Shrestha S, Kunwar S, Tseng TM. Crop diversification for improved weed management: a review. Agric. 2021;11(5):461. DOI: 10.3390/AGRICULTURE11050461
4. Bhan S, *et al*. Yield losses due to weeds in India. Indian J Weed Sci. 1999;31(3):195-200.
5. Sahoo RK, Saraswat BS. Economic analysis of weed losses in Indian agriculture. Agric Econ Rev. 1988;1(1):52-60.
6. National Research Centre for Weed Science (NRCWS). Annual report. 2007.
7. Bana ML, Kaushik RA, Bana RS, Dhakar MK. Integrated weed management in cauliflower cv. 'Pusa Snowball K-1'. Ann Agric Res. 2014;33(3):[Article].
8. Sharma RC. Integrated weed management studies in cauliflower (*Brassica oleracea* var. *botrytis* L.) [PhD dissertation]. 2007.
9. Choube K, Raidas DK, Jadav ML, Kirar NS. Efficacy of herbicides for weed control in cauliflower. Int J Plant Soil Sci. 2021;33(20):199-204. DOI: 10.9734/IJPSS/2021/V33I2030646
10. Kaur P, Kaur A, Dhillon NS. Impact of integrated weed management on growth and yield of cauliflower. J Pharmacogn Phytochem. 2021;10(1):243-246.
11. Ghode N, Choudhary AS, Raj S, Sahu S, Kumar A. Effect of weed management on yield parameters of cauliflower. Int J Agric Food Sci. 2022;4(1):17-20. DOI: 10.33545/2664844X.2022.V4.I1A.60
12. Phyto-Journal authors. Effect of different weed management practices on growth and yield of cauliflower. J Pharmacogn Phytochem. 2020;9(3):[Vol.9].
13. SciELO Brazil. Cauliflower cultivars associated with *Urochloa decumbens* straw mulch in integrated weed management. SciELO. 2021.
14. Liu W, Zhang Z, Yang L, *et al*. Efficiency of organic herbicide application and its economic analysis in cauliflower production. Agron J. 2019;111(5):2534-2541.
15. Lourival MJ, *et al*. The economic impact of weed competition on agricultural systems in South America. Weed Res. 2018;58(5):321-329.
16. Berryman C, *et al*. A comparison of organic and conventional systems for weed control in vegetable crops. Agric Ecosyst Environ. 2020;295:106902.
17. Barroso R, Oliveira I, Andrade I. Evaluation of different mulching techniques for weed control in organic cauliflower production. Field Crops Res. 2022;245:107654.
18. Hossain B, Ahmed Z, Sutradhar R, *et al*. Weed control through sustainable methods in cauliflower. J Sci Agric. 2019;38(1):12-19.
19. Souza L, Oliveira A, Santos F. The use of herbicides in cauliflower cultivation: economic impact and sustainability. Brazilian J Weed Sci. 2021;45(4):68-75.
20. Choudhary B, Pant C, Ghosh S. Herbicide resistance management in vegetable crops: implications and strategies. Indian J Agric Sci. 2017;87(2):151-155.