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Comparative evaluation of organic herbicides for okra weed management

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Abstract

Two field experiments were conducted at the Department of Vegetable Science, College of Agriculture, Vellayani, to investigate the impact of various weed control treatments on weed growth and okra production. Weed management is a significant challenge in organic okra farming, often relying on labour-intensive and environmentally harmful mechanical methods. This study explored the herbicidal properties of organic products, including coconut vinegar made from coconut water, cashew nut shell liquid and clove leaf oil. These products were evaluated in conjunction with other organic weed management strategies, including the stale seedbed technique, mango leaf mulching, and hand-weeding. The results showed that coconut vinegar herbicide (CVH) with 12.5% acetic acid was the most effective concentration for weed management. Its herbicidal properties were further enhanced when mixed with 4% clove leaf oil (Clove leaf oil herbicide - CLOH). In organic okra cultivation, CLOH with 4% clove leaf oil showed better growth and yield characteristics than those achieved through hand-weeding. The most cost-effective option among the treatments was single-spray CLOH, which achieved the highest benefit-cost (B:C) ratio of 1.54, providing a financially viable alternative to labour-intensive hand-weeding.

Key words: Weed control, organic okra farming, herbicidal properties, coconut vinegar, clove leaf oil, benefit-cost ratio

Introduction

Okra is a significant vegetable crop widely cultivated in tropical and subtropical regions. The immature okra fruits are a culinary delight, used in diverse preparations such as salads, soups, stews, and as a fried, boiled, or dried vegetable. India stands out as the world's largest producer of okra. Modern agricultural chemicals have various side effects that question the quality of protective foods, especially vegetables. So, avoiding synthetic chemicals for pest management has an important role in organic farming practices (Nazir *et al.*, 2016). Among India's 1.70 million MT of organic products, okra is one of the major organically cultivated and exported vegetables (APEDA, 2018).

Quality of seeds, climatic and nutritional factors and cultural practices determine the growth and yield of okra (Kusvuran, 2012). Also, poor weed management causes more loss in the production of okra compared to pest and disease attacks (Khalil and Jan, 2002). An annual average loss of 30-45 percent with inadequate weed management and weed control policy has been reported (Usoroh, 1981). Moreover, weeds acts as a reservoir of pathogens. In okra, destruction of weeds like *Croton sparsiflora* and *Ageratum* sp. is very necessary to control yellow vein mosaic disease (KAU, 2017). Farmers have to depend on scarce and expensive manual labour to hand weed in an organic production system. The labour wages in the agricultural sector are higher in Kerala than other states of India (GOI, 2017).

The researchers found that 5 and 10 percent concentrations of vinegar killed the weeds during their first two weeks of life. Older plants require higher concentrations of vinegar to kill them. At the higher concentrations, vinegar had an 85 to 100 percent kill rate at all growth stages. A bottle of household vinegar in about a 5 percent concentration. Controlling weeds with an herbicide mixture of clove oil (318 L ha^{-1}) and vinegar (636 L ha^{-1}) was quite effective (83%) for controlling weeds in crops of corn, onions and potatoes (Evans and Bellinder, 2009).

Since synthetic herbicides are completely ruled out in an organic production system, they can be replaced with certain horticultural crop products and by-products with contact herbicidal properties. Products such as coconut vinegar that can be cheaply manufactured from waste coconut water, clove leaf oil can be extracted from clove leaves, and can be utilised as alternatives for synthetic herbicides.

Although hand weeding is considered the most effective weed management method, its financial viability is hindered by the high labor costs prevalent in Kerala, making manual weeding an economically unsustainable option. Also, with labor costs constituting up to 40% of total production expenses in organic farming, there is a pressing need for economically viable alternatives (GOI, 2017).

A viable organic approach to managing weeds is the stale seedbed method. This method involves permitting weed seeds to germinate and then eliminating them before planting. The germinated weeds can be controlled using non-invasive techniques, such as herbicides, which are considered superior to methods that disturb the soil. Studies have demonstrated that older plants require higher concentrations of acetic acid to be killed, prompting the use of the stale seed bed method in this study. Organic mulches, including mango leaf mulch, can also be effectively employed for weed management in okra.

The primary objectives of this study were to: (1) investigate the herbicidal properties of various coconut vinegar concentrations and standardize the optimal concentration in combination with clove leaf oil; and (2) evaluate the herbicidal efficacy of these integrated methods in organically grown okra.

Materials and methods

The experiment was carried out at the Department of Vegetable Science, College of Agriculture, Vellayani, Thiruvananthapuram, on a site characterized by red loam soil with a sandy clay loam texture. The okra variety 'Anjitha', known for its yellow vein mosaic virus tolerance, was utilized for this study. The investigation was divided into two parts: the first part encompassed three experiments, each comprising five treatments with five replications, arranged in a Completely Randomised Block Design (CRD). The second part consisted of nine treatments with three replications, laid out in a Randomised Block Design (RBD).

Part 1

Experiment 1: Coconut vinegar herbicide (CVH)- 5 treatments (4 different concentrations of coconut vinegar (5, 7.5, 10, 12.5 percent acetic acid equivalent) and control in CRD design replicated 5 times.

Commercially available coconut water vinegar was purchased and the acetic acid content of coconut vinegar was enhanced from 4 percent to 5, 7.5, 10, and 12.5 percent by freeze distillation method (acetic acid having a melting point of 16.5 °C (Eichelberger and Mer, 1933) will melt faster than water with 0 °C melting point). The four concentrations of acetic acid were applied to the weeds and compared with the unweeded control.

Experiment 2: Coconut vinegar- clove leaf oil mixture herbicide (CLOH)- 5 treatments (best treatment of experiment 1+ 1, 2, 3, 4 percent clove leaf oil) and control in CRD design replicated 5 times.

The herbicidal property of best treatment of experiment 1 (CVH) was enhanced by mixing it with 1, 2, 3 and 4 percent clove leaf oil purchased from Synthite Industries Ltd. The four CLOH concentrations were applied to the weeds and compared with the unweeded control.

Experiment 3: Cashew Nut Shell Liquid Herbicide (CNSLH)- 5 treatments (4 different concentrations of Cashew Nut Shell Liquid (5, 10, 15, 20 percent CNSL) and control in CRD design replicated 5 times.

Industrial-grade cashew nut shell liquid (CNSL) was sourced from a cashew factory in the Kollam district. To create a sprayable solution, the CNSL was emulsified to 5%, 10%, 15%, and 20% using a combination of soap and alcohol.

These four CNSL concentrations were then applied to weeds and their effects compared to an unweeded control, allowing for an assessment of the herbicidal efficacy of CNSL at varying concentrations.

Land preparation: Seed beds were prepared in a weedy area by tilling using a rotavator, and weeds were flushed out. After 45 days, the emerged weeds were smothered by value-added extracts at tested concentrations in randomly selected mini-plots.

The best treatment of each experiment in part 1 was selected based on weed control efficiency and carried over to field experiment in part 2.

Part 2

Treatments:

T_1- Stale seed bed with coconut vinegar herbicide (CVH)
T_2- Stale seed bed with coconut vinegar- clove leaf oil herbicide (CLOH)
T_3- Stale seed bed with cashew nut shell liquid herbicide (CNSLH)
T_4- T_1 + repeated spray of CVH at 30 DAS (Days after sowing)
T_5- T_2 + repeated spray of CLOH at 30 DAS
T_6- T_3 + repeated spray of CNSLH at 30 DAS
T_7- Organic mulching with mango leaves
T_8- Hand weeding (weed-free till 7th week)
T_9- Control (weedy check)

Land preparation and sowing: The experimental site was prepared by thoroughly rotavating the land to achieve a fine tilth. Ridges and furrows were created at 60 cm intervals, and weeds were allowed to germinate in the seedbed for 45 days. Following this, the designated treatments were applied to individual plots. Okra seeds were sown at a spacing of 60 x 45 cm. To ensure a successful crop, all cultural practices, including field preparation, fertilization, irrigation, and plant protection, were carried out following organic recommendations.

Weeding: Weeding was performed according to the specified treatments in each plot. In the seedbed, organic herbicides were applied 45 days after weed emergence in treatments T_1 to T_6. Additionally, repeated spraying was conducted 30 days after crop sowing in treatments T_4, T_5 and T_6. In treatment T_7, mango leaf mulching was implemented. For treatment T_8, hand weeding was employed, maintaining a weed-free plot for 7 weeks after sowing.

Observation on weeds: The absolute density of weeds was recorded at three distinct time points: before application and 15 and 45 days after application. Weed samples were collected randomly from a 25 cm x 25 cm area at three sites within each plot, and the average value was calculated. Weeds were categorized into two primary groups: annual broadleaf and grassy weeds. Absolute density (Ad) was calculated as the total number of plants of a given species per square meter (Philips, 1959). Weed control efficiency was determined using the formula proposed by Mani *et al.* (1973).

$$WCE = WDWC - WDWT / WDWC \times 100$$

where, WCE= weed control efficiency, WDWC= weed dry weight in unweeded plot (control), WDWT= weed dry weight in treated plot

Dry weight of weeds was recorded after drying in a forced draft oven at 70 °C for 72 h.

Okra growth and yield characters: From each plot, five plants were randomly selected to assess various growth characteristics, including germination percentage, phytotoxicity rating, plant height, number of leaves per plant, days to 50% flowering, and crop duration. Additionally, yield parameters such as the number of flowers and fruits per plant, percent fruit set, and yield were recorded.

Observation on weeds were also taken in 2nd part similar to that of first part.

Economic Analysis: To calculate the economic viability of the treatments, the total costs, including local labor charges, input costs, and additional treatment expenses, were summed and expressed as gross expenditure per hectare. The total receipts were determined by multiplying the okra yield by the current local market price, also expressed per hectare. The benefit-cost ratio (BCR) was then calculated using the following formula:

BCR = Gross returns/Cost of cultivation

Results and discussion

Part 1

Weed growth : CVH with 12.5 percent acetic acid consistently recorded the lowest absolute density of grasses, sedges and broad leaved weeds upto 45 days after spraying (DAS) (Table 1). The same treatment also showed the highest weed control efficiency of 70.37 percent at 15 DAS and 56.31 percent at 45 DAS (Fig. 1), proving that CVH with 12.5 percent acetic acid was the best treatment concentration for controlling weeds compared to other concentrations. Chinery (2002) observed that acetic acid treatments cause a quick discoloration and browning of plant foliage, later turned into water soaked and blackened in a few hours, which was also observed in this study.

The weed control efficiency of CVH 12.5 percent acetic acid could be enhanced by mixing clove leaf oil at the rate of 4 percent which recorded the lowest absolute density of grasses and broad leaved weeds, accounted for 95.25 percent reduction in absolute density of grasses, 92.46 percent in sedges and 95.58 percent reduction in broad-leaved weeds compared to unweeded control and highest weed control efficiency (Table 2). The weed control efficiency could be enhanced upto 98.11 percent at 15 DAS and to 84.37 percent at 45 DAS with CLOH 4 percent concentration (Fig. 3). The results from the study conducted by de Oleveira *et al.* (2016), prove that the significant phytotoxic activity-promoting agent in clove oil is eugenol, which inhibits the seed germination and elongation of hypocotyls and radical part of seedlings. Webber and Shrefler (2009b) reported that clove oil is a post-emergent, contact herbicide for controlling actively growing annual and perennial grass and broad-leaved weeds. Clove oil comprised 77.10 percent eugenol, whereas clove leaf oil comprised 94.4 percent eugenol (Razafimamonjison *et al.*, 2014).

This aligns with the findings of Brainard (2013), who reported that a combination of 15 percent vinegar and 7.5 percent clove leaf oil was best for control of mustard.

Sedges can re-establish from remaining roots, which was observed to be difficult to control using these organic herbicides as they have contact action.

Among the different concentrations of CNSL, 20 percent CNSL (T4) consistently reduced the absolute density of weeds up to 45 days after spraying (Table 3). Five percent CNSL (T1) did not significantly reduce the absolute density of grasses, sedges and broadleaved weeds consistently upto 45 days of spraying than unweeded control, whereas 10 percent CNSL (T2) significantly reduced the absolute density of grasses and broad-leaved weeds at 15 days after spraying. This falls in line with the inference of Anadayanie *et al.* (2019) that less than six percent of CNSL acts only as an insecticide, and more than six percent of CNSL causes symptoms of phytotoxicity.

All treatments except 5 and 10 percent CNSL recorded higher weed control efficiency than that of unweeded control, wherein 20 percent CNSL (T4) recorded the highest weed control efficiency of 54.39 percent at 45 days after spraying (Figure 2). The weed control efficiency reduced from 15 to 45 days after spraying, possibly due to certain perennial weeds' regrowth.

Table 1. Effect of CVH on absolute density of grasses, sedges and broad-leaved weeds at before spraying, 15 DAS and 45 DAS

Treatments	Absolute density (no. m-2)								
	Before spraying			15 DAS			45 DAS		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T1-5% CVH	15.55*	4.07	9.81	15.57	4.32	8.48	15.71	4.68	8.34
T2- 7.5% CVH	15.51	3.98	10.28	15.46	4.08	9.59	15.65	4.26	9.74
T3- 10% CVH	15.64	4.07	10.19	14.69	3.58	6.03	13.99	4.13	6.67
T4- 12.5% CVH	15.29	4.32	10.33	12.40	3.11	5.44	12.60	4.07	5.56
T5- control	15.34	4.26	10.48	15.53	4.66	10.75	15.77	4.99	11.38
CD (0.05)	NS	NS	NS	0.98	0.34	1.95	1.47	0.66	1.38

*Square root transformed values.

Table 2. Effect of CLOH on absolute density of grasses, sedges and broad leaved weeds at before spraying, 15 DAS and 45 DAS

Treatments	Absolute density (no. m^{-2})								
	Before spraying			15 DAS			45 DAS		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T1- 1% CLOH	13.59*	8.74	12.08	7.79	5.54	7.70	7.91	5.75	8.11
T2- 2% CLOH	13.80	7.87	12.74	7.62	5.14	6.93	7.70	5.21	6.99
T3- 3% CLOH	13.83	8.10	12.95	5.30	4.08	4.93	5.3	3.97	4.92
T4- 4% CLOH	13.67	7.97	12.62	3.26	2.87	2.87	3.16	2.55	2.89
T5- control	13.92	8.08	12.81	14.29	8.80	8.80	14.48	8.95	13.35
CD (0.05)	NS	NS	NS	0.45	0.63	0.38	0.72	0.78	0.61

*Square root transformed values.

Table 3. Effect of CNSLH on absolute density of grasses, sedges and broad leaved weeds at before spraying, 15 DAS and 45 DAS

Treatments	Absolute density (no. m^{-2})								
	Before spraying			15 DAS			45 DAS		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T1- 5% CNSLH	12.80*	4.57	10.21	12.93	4.78	10.43	14.15	6.72	11.46
T2- 10% CNSLH	12.74	4.34	10.31	10.92	4.65	9.61	13.76	6.16	10.92
T3- 15% CNSLH	13.04	4.54	10.43	7.48	4.49	8.60	10.76	5.27	8.18
T4- 20% CNSLH	12.85	4.10	10.14	3.91	2.42	3.27	7.12	4.30	5.50
T5- control	12.89	4.31	10.53	13.25	4.93	10.75	14.28	6.72	11.48
CD (0.05)	NS	NS	NS	0.73	0.39	0.55	0.88	0.77	0.77

*Square root transformed values.

Part 2

The most effective treatments from part 1 involved spraying CVH with 12.5% acetic acid, CLOH with 4% clove leaf oil and CNSLH with 20% CNSL on 45-day-old weeds in a stale seedbed, with a repeat application 30 days after sowing of okra variety Anjitha. These treatments were compared to organic mulching with mango leaves, hand weeding until the 7th week, and a weedy check. The results, including crop growth parameters, yield attributes, weed growth characteristics, soil health parameters and the economics of cultivation, are discussed.

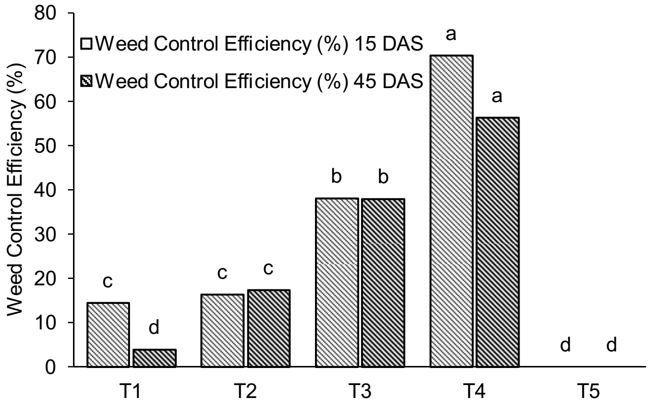

Fig 1. Effect of CVH on weed control efficiency at 15 and 45 days after spraying. T1- 5 percent, T2-7.5 percent, T3-10 percent, T4-12.5 percent acetic acid equivalent and T5- control

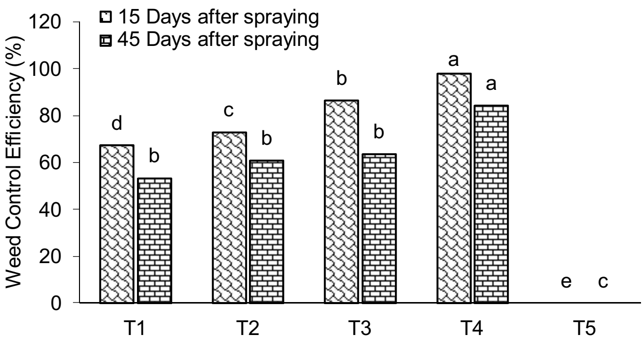

Fig 2. Effect of CLOH on weed control efficiency at 15 and 45 days after spraying. T1- 1 percent, T2-2 percent, T3-3 percent, T4-4 percent Clove leaf oil and T5- control

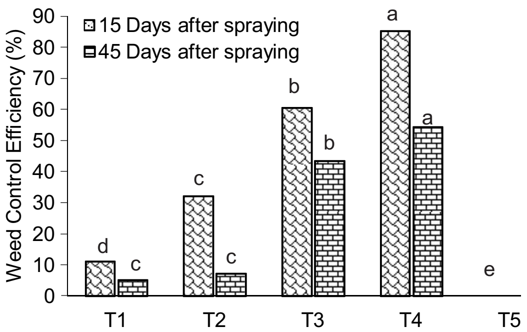

Fig 3. Effect of CNSLH on weed control efficiency at 15 and 45 days after spraying. T1- 5 percent, T2-10 percent, T3-15 percent, T4-20 percent CNSL and T5- control

Okra growth characters: All treatments, excluding the unweeded control, demonstrated significantly higher germination percentages. This suggests that the application of organic herbicides had no adverse effect on okra seed germination. Previous studies have reported significant reductions in seed germination following acetic acid treatment (Shiralipour *et al.*, 1997). However, this discrepancy may be attributed to the delayed sowing of okra seeds 15 days after organic herbicide application in the present study.

All treatments yielded taller plants with more leaves than the unweeded control (Table 3). Both single and repeated applications of CLOH resulted in plant heights similar to those achieved through hand weeding, with no significant difference observed between single and repeated herbicide applications. However, repeated applications of both organic herbicides led to a higher leaf count than hand weeding. As Usman *et al.* (2005) reported, increased competition from weeds can stunt okra plant growth, leading to reduced height.

Furthermore, all treatments significantly reduced the number of days required for 50% flowering compared to the unweeded control.

Table 4. Effect of treatments on growth characters of okra

Treatments	Germination %	Plant height	Number of leaves	Days to 50% flowering
T1	87.50	102.00	16.13	49.67
T2	91.67	114.00	18.33	49.33
T3	88.89	85.80	13.33	50.67
T4	92.36	101.00	19.00	50.33
T5	90.97	114.20	20.00	49.67
T6	89.58	87.40	13.60	49.67
T7	90.97	102.80	14.00	49.67
T8	93.06	124.60	19.60	48.33
T9	81.25	61.40	11.07	53.00
CD (0.05)	3.52	14.51	1.168	0.99

Phytotoxicity: Previous studies have documented the contact herbicidal properties of vinegar (Webber and Shrefler, 2009a) and clove leaf oil (Webber and Shrefler, 2009b). Consistent with these findings, our study observed phytotoxicity symptoms resulting from drift-related exposure to these contact organic herbicides during repeated spraying applications, specifically 30 days after sowing in a crop stand.

Okra yield characters: All treatments demonstrated a longer crop duration than the unweeded control. Notably, repeated spraying of organic herbicides did not significantly impact crop duration. Furthermore, all treatments recorded substantially more flowers and fruits, higher fruit set percentages, and increased yields compared to the unweeded control (Table 5).

Among the organic herbicides, repeated applications of CLOH yielded superior okra yield attributes, comparable to those achieved through hand weeding. As observed in the unweeded control, severe weed infestation can lead to intensified crop-weed

Table 6. Effect of treatments on the absolute density of weeds before sowing, at the time of sowing, 30 DAS and 60 DAS

Treatments	Before			At sowing			30 DAS			60 DAS		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T1	12.28*	7.27	7.80	9.73	6.21	5.31	11.34	5.98	5.18	10.34	6.16	6.58
T2	11.31	7.91	7.17	5.86	4.99	4.01	9.34	5.92	3.84	11.20	5.33	3.57
T3	11.89	6.63	8.52	8.11	5.71	5.21	9.11	5.21	3.15	10.20	5.41	5.92
T4	11.37	7.77	7.36	8.85	5.70	6.30	10.20	5.87	5.88	10.02	6.30	5.87
T5	10.64	6.42	8.27	3.12	2.91	2.49	7.51	4.74	2.78	8.25	4.56	3.35
T6	10.79	7.05	6.86	8.26	5.46	5.05	9.41	5.80	4.37	9.80	6.73	8.06
T7	11.57	6.56	7.09	5.23	3.48	3.41	8.35	5.88	6.17	8.45	5.18	5.03
T8	12.02	6.13	5.98	0.70	0.70	0.70	3.42	2.60	2.46	8.95	4.77	4.76
T9	11.78	7.40	6.79	12.18	9.18	10.18	12.13	9.67	9.70	13.44	7.95	8.05
CD (0.05)	NS	NS	NS	1.89	1.86	1.96	1.85	1.76	2.37	1.79	1.60	1.53

Table 7. Effect of treatments on weed control efficiency and weed index

Treatments	Weed control efficiency (%)			Weed index
	At sowing	30 DAS	60 DAS	
T1	51.13	59.84	37.89	45.15
T2	92.26	61.28	57.34	18.77
T3	40.36	25.81	46.53	62.05
T4	40.08	55.46	48.25	57.18
T5	90.89	70.04	61.89	8.68
T6	53.53	38.07	38.53	58.38
T7	72.65	61.51	54.14	37.75
T8	100.00	71.99	59.17	0.00
T9	0.00	0.00	0.00	94.20

competition. This competition can reduce crop nutrient uptake, resulting in shorter crop durations and poor yield characteristics.

Table 5. Effect of treatments on yield characters of okra

Treatments	Crop duration	No. of flowers	No. of fruits	Fruit set (%)	Yield
T1	104.33	5.80	4.47	77.27	5.96
T2	106.00	7.47	6.87	92.51	8.79
T3	106.00	4.20	3.27	78.34	4.10
T4	105.33	5.67	3.73	65.60	4.61
T5	105.00	10.18	8.90	87.42	9.89
T6	105.33	4.40	3.60	85.26	4.44
T7	103.00	5.27	4.47	84.68	6.70
T8	105.00	9.80	9.07	92.43	10.83
T9	75.00	3.47	0.60	16.54	0.63
CD (0.05)	2.02	1.80	1.35	16.23	1.16

Weed growth: The experimental plots were infested with various weed species, including grasses like *Panicum maximum, Cynodon dactylon, Digitaria sanguinalis, Eleusine indica*, and *Setaria barbata*. Sedges, such as *Cyperus rotundu*s, and broad-leaved weeds like *Synedrella nodiflora, Euphorbia genniculata, Phyllanthus niruri, Alternanthera sessilis, Cleome viscose, Tridax procumbens, Vernonia cinerea*, and *Commelina benghalensis,* were also present.

Upon herbicide application, a reduction in particular weed species was observed at the time of sowing. However, regrowth of specific weed species occurred 30 and 60 days after sowing. Notably, the application of organic herbicides resulted in significantly less regrowth of broad-leaved weeds compared to grasses and sedges (Table 6). This disparity may be attributed to the contact action of these herbicides, which are less effective against grasses and sedges that can regrow from their roots.

All treatments demonstrated significantly higher weed control efficiency at the time of sowing (Table 7) compared to the unweeded control. Single and repeated sprays of CLOH and hand weeding consistently maintained higher weed control efficiency up to 60 days after sowing.

The weed index, a yield reduction caused by weed presence, is calculated by comparing yields in weedy conditions to those in weed-free environments (Gill and Vijayakumar, 1969). In this study, the unweeded control exhibited the highest weed index of 94.2, indicating substantial yield reduction compared to the hand-weeded plot (Table 7).

In contrast, repeated applications of CLOH resulted in the lowest weed index of 8.68. Notably, this value was statistically similar to the weed index of the hand-weeded plot, suggesting that repeated CLOH applications provided comparable weed control and yield protection to hand-weeding.

Economic analysis: The benefit-cost (B:C) ratio ranged from 0.18 in unweeded control to 1.54 in single-spray CLOH (Table 8). Although hand weeding provided the highest benefit, its labor costs made cultivation more expensive. Repeated CLOH sprays offered higher benefits than single sprays, but increased herbicide costs reduced the B:C ratio, making single-spray CLOH the most cost-effective option. Adopting CLOH reduces reliance on manual labor, promoting sustainable agricultural practices that mitigate labor shortages and high wage rates, and common challenges in organic farming systems.

Furthermore, farmers can produce coconut water vinegar locally using readily available resources, such as household waste coconut water, through fermentation and subsequent acetic acid concentration via freeze distillation. This DIY approach enables farmers to significantly reduce costs and enhance accessibility to this organic herbicide.

Table 8. Effect of treatments on B:C ratio

Treatments	Benefit (Rs/ha)	Cost (Rs/ha)	B:C ratio
T1	178800	150468	1.19
T2	263700	170867	1.54
T3	123000	130489	0.94
T4	138300	175623	0.79
T5	296700	215447	1.38
T6	133200	135729	0.98
T7	201000	140722	1.43
T8	324900	297236	1.09
T9	18900	105889	0.18

Clove leaf oil herbicide (CLOH), a mixture of coconut vinegar, 12.5% acetic acid, and 4% clove leaf oil, proved a highly effective alternative to hand weeding for promoting growth and yield in organic okra cultivation. CLOH demonstrated superior weed control efficiency throughout the crop growth, comparable to hand weeding.

This study reveals that CLOH provides a cost-effective and economically viable alternative to hand weeding, boasting a high benefit-cost ratio (1.54) while minimizing labor dependence, thereby enhancing the financial sustainability of small-scale organic farming operations.

These findings suggest that CLOH can be a valuable tool in organic farming, provided care is taken to minimize potential phototoxic effects on crops. However, to make this herbicide more accessible, technologies that reduce its cost need to be developed. Furthermore, long-term ecosystem impact assessments are necessary to ensure the sustainability of CLOH in organic agriculture.

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