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Effect of organic herbicides in weed management and cultivation of okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract
In two field experiments the effect of certain weed control treatments on weed growth and production of okra was studied at the farm of Department of Vegetable Science, College of Agriculture, Vellayani. Weed management is one of the major challenges farmers face in organic farming of okra cultivation which leads to a heavy dependence on mechanic tactics that are labour intensive and environmentally harmful. Organic products such as Vinegar made from coconut water and clove leaf oil is used in this experiment to evaluate their herbicidal properties and their effect in organic cultivation of okra along with other organic weed management strategies such as stale seed bed technique, mango leaf mulching and hand weeding. Among the different concentrations of vinegar used in the experiment, coconut vinegar herbicide (CVH) with 12.5 percent acetic acid was observed to be best for weed management and its herbicidal properties could be enhanced to maximum by mixing it with 4 percent clove leaf oil (Clove leaf oil herbicide- CLOH). In organic cultivation of okra, CLOH with 4 percent clove leaf oil recorded better growth and yield characters similar to that of hand weeding.

Keywords: Clove leaf oil, okra, organic herbicides, vinegar, weed management

Introduction
Okra is an economically important vegetable crop grown in both tropical and subtropical parts of the world. The immature fruits are used in salads, soups, strews, fried or boiled, fresh or dried vegetable. India ranks first in the production of okra.

Modern agricultural chemicals are said to have various side effects that questions the quality of protective foods especially vegetables. So the avoidance of synthetic chemicals for pest management has an important role in organic farming practices (Nazir *et al*., 2016) [12]. Among the 1.70 million MT of organic products produces in India, okra is one of the major organically cultivated and exported vegetables. (APEDA, 2018) [1].

Quality of seeds, climatic and nutritional factors and cultural practices are some of the factors that determine the growth and yield of okra (Kusvuran, 2012) [10]. Also, poor weed management causes more loss in production of okra compared to pest and disease attack (Khalil and Jan, 2002) [9]. It was observed an annual average loss of 30-45 percent with inadequate weed management and weed control policy (Usoroh, 1981) [18]. 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) [8]. Farmers have to depend on scarce and expensive manual labour to hand weed in an organic production system. The labour wages in agricultural sector are higher in Kerala than other states of India (GOI, 2017) [7].

The researchers found that 5- and 10-percent concentrations killed the weeds during their first two weeks of life. Older plants required 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 is about a 5-percent concentration. Controlling weeds with an herbicide mixture of clove oil (318 L ha^{-1}) and vinegar (636 L ha^{-1}) is quite effective (83%) for controlling weeds in crops of corn, onions and potatoes (Evans and Bellinder, 2009) [5].

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

Another organic weed management practice is the stale seed bed method in which the weed seeds just below the soil surface are allowed to germinate and then killed prior to planting. Those flushed weeds can be controlled by no disturbance techniques like herbicides, which are considered to be better than techniques that disturbed the soil. Since certain studies showed that older plants require higher concentration of acetic acid to kill them, we followed stale seed bed method for weed control in this study. Organic mulches like mango leaf mulching can also be utilised effectively for weed management in okra.

Therefore, the main objective of first part of this study is to evaluate the herbicidal properties of different concentrations of coconut vinegar and the best concentration is mixed with clove leaf oil at four different concentrations in order to standardise them as herbicides. In the second part, the objective was to study their herbicidal efficacy when integrated with stale seed bed method in organically grown okra.

Materials and Methods

The experiment was conducted at the Department of Vegetable Science, College of Agriculture, Vellayani, Thiruvananthapuram. Predominant soil type of the site was red loam texturally classified as sandy clay loam soils. Okra variety Anjitha, which is tolerant to yellow vein mosaic virus, was used for the experiment.

First part consist of 2 experiments each having 5 treatments and 5 replications laid out in Completely Randomised Block Design (CRD). Second part consist of 7 treatments and 3 replications laid out in 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 acetic acid content of coconut vinegar was enhanced from 4 percent to 5, 7.5, 10, and 12.5 percentage by freeze distillation method (acetic acid having a melting point of 16.5 °C (Eichelberger and Mer, 1933) [4] will melt faster than water with 0 °C melting point). The four concentrations of acetic acid was applied on to the weeds and compared with 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 concentrations of CLOH was applied on to the weeds and compared with unweeded control.

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- T_1 + repeated spray of CVH at 30 DAS (Days after sowing)
T_4- T_2 + repeated spray of CLOH at 30 DAS
T_5- Organic mulching with mango leaves
T_6- Hand weeding (weed free till 7th week)
T_7- Control (weedy check)

Land preparation and sowing

Land was prepared thoroughly using rotavator to produce fine tilth. Ridges and furrows were taken at a spacing of 60 cm. weeds were allowed to grow in the seed bed for 45 days. The above mentioned treatments were applied in individual plots. Seeds were sown at a spacing of 60 x 45 cm. All the cultural operations, like field preparation, fertilization, irrigation, plant protection, etc., were carried out as per the organic recommendations in order to obtain a successful crop.

Weeding

Weeding was done as per the treatments in different plots. In the seed bed organic herbicides were applied at 45 days after weed emergence in T_1 to T_4. Repeated spraying was carried out at 30 days after sowing of crop in treatments T_3 and T_4. Mango leaf mulching was carried out in T5. Hand weeding in T6 where the plot was kept weed free till 7 weeks after sowing.

Data recorded

Part 1

Observation on weeds

Absolute density of weeds was recorded before application, 15 and 45 days after application. Weed samples were collected randomly in an area of 25 cm x 25 cm in 3 sites in each plot and taking average. Weeds were classified into two groups, i.e., annual broadleaf and grassy.

Ad= total number of plants of a given species per m^2 (Philips, 1959) [14].

Weed control efficiency calculated based on formula suggested by Mani *et al*. (1973) [11].

$$WCE = \frac{WDWC - WDWT}{WDWC} \times 100$$ 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.

Part 2

Okra growth and yield characters

From each plot, 5 plants were selected at random and growth characters such as germination percentage, phytotoxicity rating, plant height, number of leaves per plant, days to 50 percent flowering and crop duration were recorded. Yield characters such as 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.

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 shows highest weed control efficiency of 70.37 percent at 15 DAS and 56.31 percent at 45 DAS (Figure 1) which proves that CVH with 12.5 percent acetic acid was the best treatment concentration for controlling weeds compared to other concentrations. Chinery (2002) [3] 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 (Figure 2). The results from the study conducted by de Oleveira *et al*. (2016) [13], proves that the major 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) [20] reported that clove oil is a post emergent, contact herbicide for controlling actively growing annual and perennial grass and broad leaved weeds. Clove oil consisted of 77.10 percent eugenol, whereas clove leaf oil consisted of 94.4 percent eugenol (Razafimamonjison *et al*., 2014) [15].

This fall in line with the findings of Brainard (2013) [2], who reported that 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.

Part 2

The best treatment of part 1, CVH with 12.5% acetic acid and CLOH with 4% clove leaf oil were sprayed on the 45 day old weeds on stale seed bed, repeated application thirty days after sowing of okra variety Anjitha seeds in comparison to organic mulching with mango leaves, hand weeding till 7th week and weedy check. Results on crop growth characters, yield attributes, weed growth characters, and economics of cultivation are discussed below.

Okra growth characters

All the treatments except unweeded control recorded significantly higher germination percentage indicating that the application of organic herbicides did not affect the germination of okra. There are several studies that found significant reduction in germination of seeds due to acetic acid treatment (Shiralipour *et al*., 1997) [16]. But this contradiction may be because of sowing okra seeds 15 days after organic herbicide treatment in the present study.

All the treatments produced taller plants and more number of leaves compared to unweeded control (Table 3). Single and repeated application of CLOH produced taller plants similar to hand weeded plot and there was no significant influence for repeated application of herbicide in plant height of okra, whereas more number of leaves similar to hand weeding was recorded with repeated application of bot organic herbicides. Increased crop weed competition cause reduced height of okra (Usman *et al*., 2005) [17]. All the treatments significantly reduced the number of days for 50 percent flowering when compared to unweeded control.

Phytotoxicity

The contact herbicidal action of vinegar was reported by Webber and Shrefler (2009a) [19] and that of clove leaf oil was reported by Webber and Shrefler (2009b) [20]. In the present study also, we observed phytotoxicity symptoms due to drifting of these contact organic herbicides while spraying in a crop stand at repeated application 30 days after sowing.

Okra yield characters

All the treatments recorded longer crop duration compared to unweeded control. Repeated spray of organic herbicides did not affect the duration of crop significantly. All treatments recorded significantly more number of flowers and fruits, higher percentage of fruit set and yield compared to unweeded control (Table 4). Among the organic herbicides, repeated application of CLOH recorded better yield attributes of okra similar to hand weeded plot. Severe weed infestation may lead to increased crop weed competition, thereby reduces the nutrient uptake of crop leading to reduced crop duration and poor yield characters in unweeded control.

Weed growth

Grasses such as *Panicum maximum*, *Cynodon dactylon*, *Digitaria sanguinalis*, *Eleusine indica*, *Setaria barbata*, sedges such as *Cyperus rotundus* and broad leaved weeds such as *Synedrella nodiflora*, *Euphorbia genniculata*, *Phyllanthus niruri*, *Alternanthera sessilis*, *Cleome viscose*, *Tridax procumbens*, *Vernonia cinerea*, and *Commelina benghalensis* were the weeds species observed in the experimental plots. With the application of herbicides, some of the weed species got reduced at the time of sowing. At 30 days after sowing and 60 days after sowing, regrowth of certain weed species was observed. It was observed that with the application of organic herbicides the regrowth of broad leaved weeds were significantly less compared to grasses and sedges (Table 5). This may be because grasses and sedges can regrow from the roots as these herbicides have contact action.

All treatments significantly recorded higher weed control efficiency at the time of sowing (Table 6), when compared to unweeded control. Single and repeated spray of CLOH and hand weeded plot consistently exhibited higher weed control efficiency upto 60 days after sowing.

Weed index is defined as the magnitude of yield reduction due to presence of weeds in comparison with weed free check (Gill and Vijayakumar, 1969) [6]. It was observed to be higher in unweeded control with weed index of 94.2 which indicates higher yield reduction in this plot as compared to hand weeded plot (Table 6). Repeated spray of CLOH recorded the lowest weed index of 8.68 and it was significantly similar to weed index of hand weeded plot.

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
T_1-5% CVH	15.55*	4.07	9.81	15.57	4.32	8.48	15.71	4.68	8.34
T_2- 7.5% CVH	15.51	3.98	10.28	15.46	4.08	9.59	15.65	4.26	9.74
T_3- 10% CVH	15.64	4.07	10.19	14.69	3.58	6.03	13.99	4.13	6.67
T_4- 12.5% CVH	15.29	4.32	10.33	12.40	3.11	5.44	12.60	4.07	5.56
T_5- 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
T_1- 1% CLOH	13.59*	8.74	12.08	7.79	5.54	7.70	7.91	5.75	8.11
T_2- 2% CLOH	13.80	7.87	12.74	7.62	5.14	6.93	7.70	5.21	6.99
T_3- 3% CLOH	13.83	8.10	12.95	5.30	4.08	4.93	5.3	3.97	4.92
T_4- 4% CLOH	13.67	7.97	12.62	3.26	2.87	2.87	3.16	2.55	2.89
T_5- 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 treatments on growth characters of okra.

Treatments	Germination %	Plant height	No. of leaves	Days to 50% flowering
T_1	87.50	102.00	16.13	49.67
T_2	91.67	114.00	18.33	49.33
T_3	92.36	101.00	19.00	50.33
T_4	90.97	114.20	20.00	49.67
T_5	90.97	102.80	14.00	49.67
T_6	93.06	124.60	19.60	48.33
T_7	81.25	61.40	11.07	53.00
CD (0.05)	3.52	14.51	1.168	0.99

Table 4: Effect of treatments on yield characters of okra

Treatments	Crop duration	No. of flowers	No. of fruits	% fruit set	Yield
T_1	104.33	5.80	4.47	77.27	5.96
T_2	106.00	7.47	6.87	92.51	8.79
T_3	105.33	5.67	3.73	65.60	4.61
T_4	105.00	8.93/10.18	7.67/8.90	87.50	9.89
T_5	103.00	5.27	4.47	84.68	6.70
T_6	105.00	9.80	9.07	92.43	10.83
T_7	75.00	3.47	0.60	16.54	0.63
CD (0.05)	2.02	1.80	1.35	16.23	1.16

Table 5: Effect of treatments on 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
T_1	12.28*	7.27	7.80	9.73	6.21	5.31	11.34	5.98	5.18	10.34	6.16	6.58
T_2	11.31	7.91	7.17	5.86	4.99	4.01	9.34	5.92	3.84	11.20	5.33	3.57
T_3	11.37	7.77	7.36	8.85	5.70	6.30	10.20	5.87	5.88	10.02	6.30	5.87
T_4	10.64	6.42	8.27	3.12	2.91	2.49	7.51	4.74	2.78	8.25	4.56	3.35
T_5	11.57	6.56	7.09	5.23	3.48	3.41	8.35	5.88	6.17	8.45	5.18	5.03
T_6	12.02	6.13	5.98	0.70	0.70	0.70	3.42	2.60	2.46	8.95	4.77	4.76
T_7	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

*square root transformed values.

Table 6: Effect of treatments on weed control efficiency and weed index

Treatments	Weed control efficiency (%)			Weed index
	At sowing	30 DAS	60 DAS	
T_1	51.13	59.84	37.89	45.15
T_2	92.26	61.28	57.34	18.77
T_3	40.08	55.46	48.25	57.18
T_4	90.89	70.04	61.89	8.68
T_5	72.65	61.51	54.14	37.75
T_6	100.00	71.99	59.17	0.00
T_7	0.00	0.00	0.00	94.20
CD (0.05)	10.51	12.30	12.57	9.82

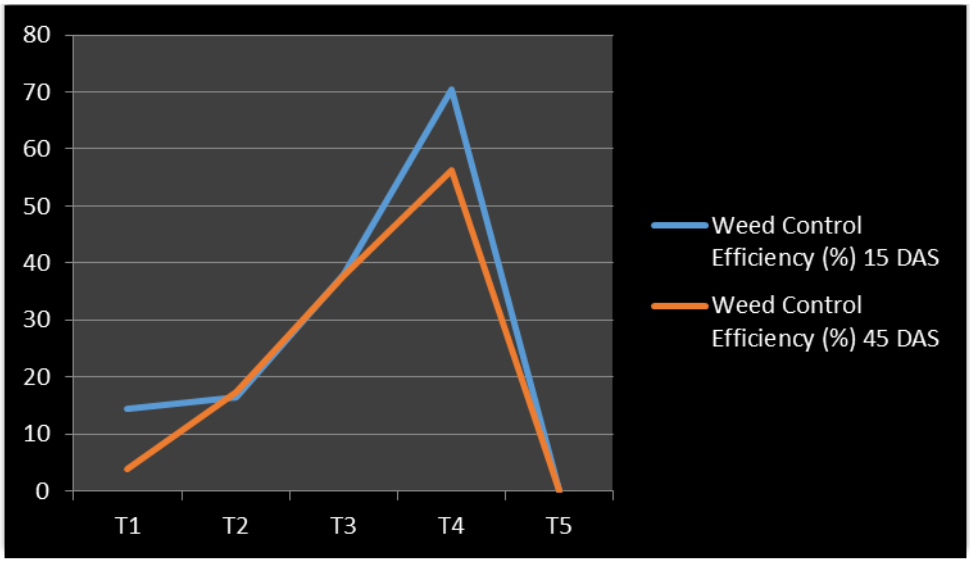

Fig 1: Effect of CVH on weed control efficiency at 15 and 45 days after spraying

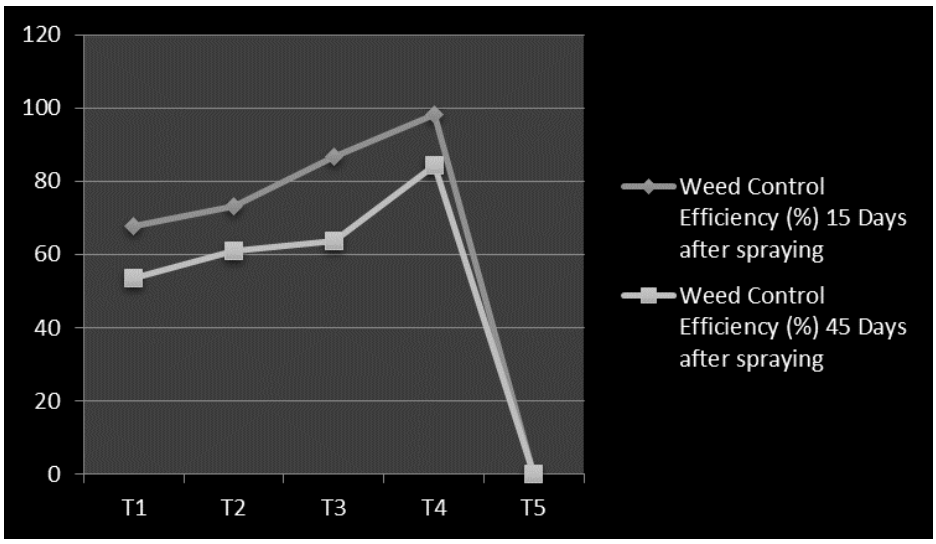

Fig 2: Effect of CLOH on weed control efficiency at 15 and 45 days after spraying.

Conclusion

Clove leaf oil herbicide (CLOH) (mixture of coconut vinegar with 12.5 percent acetic acid and 4 percent clove leaf oil) performed on par with hand weeding for improving major growth and yield parameters of organic grown okra and has better weed control efficiency till the crop growth period. This suggests the use of this herbicide in organic cultivation of crops with proper care about the phototoxic effect of these herbicides to the crop. Technologies to reduce the cost of these herbicides has to be developed and long term impact on ecosystem need to be assessed.

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