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Research Article

Effects of Aqueous Plant Leaf Extracts on Populations of *Phalaris minor* and *Anagallis arvensis* in Wheat Crop

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Abstract
This study aimed to assess the efficacy of aqueous extracts from various plant leaves in controlling two major weed species, *Phalaris minor* and *Anagallis arvensis*, in wheat crops. Excessive herbicide use in conventional weed management has raised environmental concerns and led to increased herbicide resistance. To address these issues, we tested reduced doses of herbicides in combination with aqueous leaf extracts from Eucalyptus, Guava, and Neem to evaluate their impact on weed suppression. Results showed that a 5% eucalyptus leaf extract combined with 75% of the recommended herbicide dose significantly reduced *Phalaris minor* populations. For *Anagallis arvensis*, the application of eucalyptus and neem leaf extracts was particularly effective in controlling infestation levels. The findings suggest that plant-based extracts, especially those from eucalyptus and neem, can be integrated with reduced herbicide doses as a sustainable strategy to manage weed populations in wheat cultivation. This integrated approach holds potential for enhancing crop yields while reducing herbicide reliance, contributing to more sustainable and environmentally friendly agricultural practices.

Keywords: Weed Management, Plant Leaf Extracts, Herbicide, Wheat, *Phalaris minor* and *Anagallis arvensis.*

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1. Introduction

Wheat (*Triticum aestivum* L.) is the most grown cereal crop globally and holds a significant position among the world's major food crops, especially in Asian countries. It is widely recognized as one of the staple foods that plays a crucial role in sustaining human life. According to the Food and Agriculture Organization's data for 2021, the global wheat production was approximately 770.88 million tones. This production was harvested from an estimated area of around 220.76 million hectares, resulting in a total estimated yield of 34.92 quintals (100 kg) per hectare.

In India, specifically in Punjab, wheat crop is one of the significant crops and plays a pivotal role in ensuring food security, contributing to approximately one-third of the total food grain production. On the other hand, there are several challenges faced in wheat and rice production such as soil degradation due to intensive cultivation & excessive use of chemicals to control weeds, insects and diseases, groundwater depletion, climate change, etc.

Among all these issues, weed management has also become a major concern because of their developed

resistance against herbicides & application of higher doses of herbicide is a concern. Weeds are a significant contributor to yield reduction. Weeds not only reduce the wheat yield by 25 to 30% but also increase the cost of farming, and affect crop quality (Rao *et al*., 2020). Over the period, several weed species have been observed and recorded in association with wheat cultivation (Shahzad *et al*., 2021). Weeds affects agricultural productivity by competing for essential resources and ultimately reduce crop yield by suppressing the overall growth and development of rice and wheat plants. The most frequently observed weed species in wheat are *Phalaris minor* and *Anagallis arvensis.*

Proper weed control is crucial for maintaining higher yield. Since effective weed control is essential to preventing yield losses in modern agriculture, it is imperative to modify and enhance weed management strategies in order to reduce the negative effects of weeds on the wheat-rice cropping system (Bhullar *et al.,* 2016).

Over the past 40 years, the excessive dependence and improper application of herbicides have caused several issues which cannot be ignored. A number of reports have highlighted the pollution of resources and soil degradation occurred as a direct result of herbicide misuse (Ihsan et al., 2015). The residues of herbicide chemicals tend to remain in the soil, affecting its quality and disrupting the natural habitat of soil micro flora that play vital roles in sustaining soil health and rejuvenating nutrient pool in soil (Singh et al., 2020; Łozowicka et al., 2021). When herbicides sprayed near water bodies, it contaminates both surface water and groundwater, posing serious risks to aquatic ecosystems and drinking water sources. Moreover, some herbicides evaporate into the air which contributing to air pollution and further create environment pollution. Consequently, excessive use of chemical herbicides contaminates water sources and disrupt ecosystem and also harms non-target plants and animals (Bamal *et al.,* 2024).

In recent years, chemical control method become less viable due to herbicide resistance development, environmental degradation and health concerns. As a result, there is an urgent need of sustainable & more environmentally friendly weed management strategies that not only boost agricultural productivity but also address these challenges. The negative effects of herbicides solicit the need for a more balanced and sustainable method to weed management in agriculture (Singh, 2020).

Integrating plant allelopathic extracts with reduced herbicide doses offers several advantages as a weed management strategy. By combining plant allelopathic extracts with reduced herbicide doses, the overall weed control efficacy can be improved (Pardo-Muras *et al.,* 2020). Also, it helps to decrease the concentration of herbicides applied. Utilization of plant allelopathic extracts in combination with reduced herbicide doses can lead to cost savings for farmers (Ain *et al.,* 2023). By utilizing the natural chemical compounds produced by allelopathic plants, the herbicides can work synergistically to suppress weed growth and minimize herbicide reliance (Bhowmik & Inderjit, 2004; Ray *et al*., 2022). A wide range of plant species have been identified for their allelopathic effects such as *Juglans nigra* L. (Zubay *et al*., 2021), *Eucalyptus spp.* (Silva *et al*., 2020; Ayed *et al*., 2023), *Azadirachta indica* (Nahak and Sahu 2015), *Ipomoea tricolor* (Onen *et al*., 2023) etc. Allelopathy provides a variety of useful weed management techniques for field crops, including mulching, intercropping, crop rotation, cover crops, and the use of allelopathic water extracts (Scavo & Mauromicale 2010; Khamare *et al.,* 2022).

2. Materials and Methods

Experiment was conducted during Rabi season of year 2021-22 and 2022-23 at the research field of Lovely Professional University, Kapurthala district year 2021-2023. The location of the farm is at 31022'31.81" North latitude and 75023'03.02". The experimental region comes under an area, which is having cool weather (10-15°C) in the winter season and hot weather (35-45°C) in the summer season. Rainfall has mainly happened in the month of July, August, and September if there is no delay in the southwest monsoon winds. In winter, temperature goes very low but never goes below zero degree in the month of December and January. The temperature ranges from 35-45°C in the month of April, May and June. Highest temperature normally reaches 45°C during summer months. Normally from the last week of June, monsoon rainfall starts and continues to end in September. Highest amount of rainfall normally receives in the month of July.

After the selection of the cropping site, all agricultural operations were performed in the trial field. Firstly, tillage operations were done in the trial field and then accordingly field was made with RBD design. PBW 550 wheat variety was sown in the field with a recommended dose of fertilizers and different reduced dosage of herbicide in combination with plant leaf aqueous extract. Plant population, weed population, weed intensity and weed control efficiency data were taken in different stages of the crop. Herbicide application with a combination of plant leaf aqueous extract was done 25-30 DAS. The interval between herbicide application and plant leaf aqueous extract application was 24 hours. Total treatments were 20 with 3 replications in the field. Treatments detail are; T1 (Absolute control i.e. no herbicide application), T2 (100% of recommended dose of Herbicide), T3 (Eucalyptus Leaf Aqueous Extract 5% + 50% Herbicide), T4 (Eucalyptus Leaf Aqueous Extract 5% + 75% Herbicide), T5 (Eucalyptus Leaf Aqueous Extract 10% + 50% Herbicide), T6 (Eucalyptus Leaf Aqueous Extract 10% + 75% Herbicide), T7 (Neem Leaf Aqueous Extract 10% + 50% Herbicide), T8 (Neem Leaf Aqueous Extract 10% + 75% Herbicide), T9 (Neem Leaf Aqueous Extract 15% + 50% Herbicide), T10 (Neem Leaf Aqueous Extract 15% +75% Herbicide), T11 (Guava Leaf Aqueous Extract 25% + 50% Herbicide), T12 (Guava Leaf Aqueous Extract 25% + 75% Herbicide), T13 (Guava Leaf Aqueous Extract 30% + 50% Herbicide), T14 (Guava Leaf Aqueous Extract 30% + 75% Herbicide), T15 (Eucalyptus Leaf Aqueous Extract 5%), T16 (Eucalyptus Leaf Aqueous Extract

10% Sole), T17 (Neem Leaf Aqueous Extract 10% Sole), T18 (Neem Leaf Aqueous Extract 15% Sole), T19 (Guava Leaf Aqueous Extract 25% Sole) and T20 (Guava Leaf Aqueous Extract 30% Sole). Plant population count was done in different stages of the crop growth. Furthermore, weed population count, weed intensity and weed control efficiency were measured to analyze and find out the best sustainable solution to reduce herbicidal doses. Plant & weed population was determined by quadrille method from $1m^2$ of every treatment plot. Treatments were applied in the field in foliar application. Recommended doses of fertilizer, irrigations, insecticides were applied as per the management practices. Plat population and weed population data was taken in 30, 60, 90 & 120 DAS. Weed intensity of wheat crop has been taken before and after the application of treatments and analyzed. Data collected in the study was analyzed using R Studio software using Analysis of Variance (ANOVA) at a significance threshold of $p<0.05$.

3. Results and Discussion

3.1 Effect on Population of *Phalaris minor*

The periodic Phalaris minor population data was taken at 30, 60, 90 & 120 days after sowing (DAS) (Table 1). In Wheat, at 30 DAS, *Phalaris minor* population ranged from 20.3 to 40.7 plants/m^2. Maximum weed population was recorded in T1 (40.7) followed by T15 (31.0) while minimum in T6 (20.3). As compared to T1 (40.7), treatment T6 (20.3) showed a significant reduction of 50.12 % in weed population at 30 DAS. At 60 DAS, the weed population was ranged from 8.7 to 41.3 plants/m^2. Maximum weed population was recorded in T1 (41.3) followed by T6 (21.0) while minimum in T4 (8.7). As compared to T1 (41.3), treatment T4 (8.7) showed significant reduction of 78.90 % in weed population at 60 DAS. At 90 DAS, the population of Phalaris minor ranged from 6.7 to 43.0 plants/m^2. Maximum weed population was recorded in T1 (43.0) followed by T6 (22.7) while the lowest population in T4 (6.7). As compared to T1 (43.0), treatment T4 (6.7) showed significant reduction (84.41%) in weed population at 90 DAS. At 120 DAS, the weed population ranged from 5.0 to 41.3 plants/m^2. Maximum population was recorded in T1 (41.33) followed by T6 (22.0) while the minimum weed population was recorded at T4 (5.0). As compared to T1 (41.3), treatment T4 (5.0) showed a significant reduction of 87.89% in weed population at 120 DAS.

Subsequently, during second trial the population of *Phalaris minor* at 30 DAS ranged from 23.0 to 41.3 plants/m^2. Maximum weed population was recorded in T1 (41.3) followed by T12 (36.3) while the minimum was recorded in T17 (23.0). As compared to control i.e. T1 (41.3), a significant reduction of 44.30 % was reported in T17 (23.0) at 30 DAS. At 60 DAS, weed population ranged from 9.3 to 43.6 plants/m^2. Maximum weed population was recorded in T1 (43.6) followed by T9 (20.6) while minimum was recorded in T8 (9.3). As compared to control i.e. T1 (43.6), treatment T8 (9.3) showed a significant reduction of 78.66% in Phalaris minor population at 60 DAS. At 90 DAS, the population of *Phalaris minor* was ranged from 6.3 to 42.6 plants/m^2. Maximum weed population was recorded in T1 (42.6) followed by T9 (16.0) while the minimum population was recorded in T4 (6.3). As compared to T1 (42.6), treatment T4 (6.3) showed a significant reduction of 85.2% in *Phalaris minor* population at 90 DAS. At 120 DAS, weed population was recorded in the range of 6.6 to 41.3 plants/m^2. Maximum weed population was recorded in T1 (41.3) followed by T6 (15.0) while the minimum population was recorded in T4 (6.6). As compared to T1 (41.3), a significant reduction of 84.0 % in weed population was recorded at 120 DAS.

Overall, above results clearly report that treatments T4 i.e. ELE 5% + 75% H was most effective among all the other treatments used to control the *Phalaris minor* population in field condition. Eucalyptus leaf aqueous extract contains a variety of bioactive compounds that can help to penetrate the weed cell walls and control them. Among all the compounds present in eucalyptus leaves, eucalyptol is the one, which has been shown to have strong herbicidal properties (Silva *et al*., 2020; Ayed *et al*., 2023). When eucalyptus leaves, aqueous extract is applied to *Phalaris minor* the eucalyptol can penetrate the cell wall and membrane of the weeds. As result it disrupts the cellular process of the weed and cause damage to the tissues, leading to the eventual death of the weed plant. Eucalyptol also affects the hormonal balance of plants, which can inhibit the cell elongation and cell division. This can cause stunted growth and reduce biomass production in plant. In addition to that, other bioactive compounds that present in eucalyptus leaf aqueous extract may also contribute some herbicidal effects. For, an example the presence of tannins in eucalyptus leaves extracts can reduce and inhibit the growth of weeds by disrupting their metabolism and cellular process.

3.2 Effect on population of *Anagallis arvensis*

The periodic *Anagallis arvensis* population data was taken at 30, 60, 90 & 120 days after sowing (DAS) (Table 2). In Wheat, at 30 DAS the weed population ranged from 3.0 to 52.0 plants/m^2. Maximum weed population was recorded at T1 (52.0) followed by T5 (43.7) while the minimum population was recorded at T2 (30.0). As compared to control i.e. T1 (52.0) showed significant reduction of 94.0% in T2 (3.0) at 30 DAS. At 60 DAS, the weed population ranged from 6.3 to 51.7 plants/m^2. Maximum population was recorded in T1 (51.7) followed by T4 (22.0) while the lowest population was recorded in T3 (6.3). As compared to control i.e T1 (51.7), treatment no. T3 (6.3) showed a significant reduction of 87.81% in weed population at 60 DAS. Similarly, at 90 DAS, the weed population ranged from 6.0 to 48.3 plants/m^2. Maximum population was recorded in T1 (48.3) followed by T4 (20.3) while the minimum was recorded in T3 (6.0). As compared to T1 (48.3) a significant reduction of 87.57 % in T3 (6.0) at 90 DAS. At 120 DAS, the weed population ranged from 5.3 to 47.3 plants/m^2. Maximum weed population was recorded in T1 (47.3) followed by T4 (19.3) while the minimum population was recorded in T3 (5.3). As compared to T1 (47.3), treatment T3 (5.3) showed

Table 1. Effect of treatments on *Phalaris minor* population in wheat crop

Treatments	30 DAS			60 DAS			90 DAS			120 DAS		
	2021-2022	**2022-2023**	**Pooled**	**2021-2022**	**2022-2023**	**Pooled**	**2021-2022**	**2022-2023**	**Pooled**	**2021-2022**	**2022-2023**	**Pooled**
T_1-Absolute control	$40.7^{a}\pm1.20$	$41.3^{a}\pm2.40$	41.0	$41.3^{a}\pm1.33$	$43.6^{a}\pm2.40$	42.5	$43.0^{a}\pm1.52$	$42.6^{a}\pm2.33$	42.8	$42.3^{a}\pm0.57$	$41.3^{a}\pm1.45$	41.8
T_2-100% RDH	$26.3^{cde}\pm1.85$	$28.6^{cde}\pm1.45$	27.5	$11.0^{ef}\pm1.15$	$10.0^{ef}\pm0.57$	10.5	$7.3^{gh}\pm0.88$	$8.6^{gh}\pm0.88$	8.0	$6.3^{fg}\pm0.88$	$7.0^{fg}\pm0.57$	6.7
T_3-ELE 5% + 50% H	$29.0^{bcd}\pm1.52$	$30.0^{bcd}\pm0.57$	29.5	$15.7^{bc}\pm1.20$	$17.0^{bc}\pm1.52$	16.3	$14.0^{bcdef}\pm0.57$	$13.3^{bcdef}\pm0.33$	13.7	$13.3^{cdefg}\pm0.88$	$10.0^{cdefg}\pm0.57$	11.7
T_4-ELE 5% + 75% H	$27.0^{cde}\pm3.51$	$26.3^{cde}\pm1.45$	26.7	$8.7^{ef}\pm0.88$	$10.0^{ef}\pm0.57$	9.3	$6.7^{h}\pm0.88$	$6.3^{h}\pm0.33$	6.5	$5.0^{g}\pm0.57$	$6.6^{g}\pm0.88$	5.8
T_5-ELE 10% + 50% H	$25.0^{e}\pm2.08$	$23.0^{e}\pm2.08$	24.0	$13.7^{def}\pm0.33$	$12.0^{def}\pm0.57$	12.8	$13.3^{efgh}\pm0.88$	$10.0^{efgh}\pm0.57$	11.7	$13.0^{defg}\pm0.57$	$9.0^{defg}\pm0.57$	11.0
T_6-ELE 10% + 75% H	$20.3^{de}\pm0.88$	$25.3^{de}\pm1.45$	22.8	$21.0^{bc}\pm0.57$	$16.6^{bc}\pm1.45$	18.8	$22.7^{bc}\pm1.45$	$15.3^{bc}\pm1.45$	19.0	$22.0^{b}\pm0.57$	$15.0^{b}\pm1.15$	18.5
T_7-NLE 10% + 50% H	$24.3^{cde}\pm2.40$	$27.3^{cde}\pm1.45$	25.8	$13.3^{cde}\pm1.76$	$14.3^{cde}\pm1.45$	13.8	$13.3^{bcdefg}\pm1.20$	$12.0^{bcdefg}\pm0.57$	12.7	$13.0^{bcde}\pm0.57$	$11.3^{bcde}\pm0.88$	12.2
T_8-NLE 10% + 75% H	$23.7^{cde}\pm0.88$	$26.3^{cde}\pm1.45$	25.0	$10.0^{f}\pm0.57$	$9.3^{f}\pm0.33$	9.7	$9.3^{fgh}\pm0.88$	$9.3^{fgh}\pm0.33$	9.3	$9.0^{defg}\pm0.57$	$8.6^{defg}\pm0.33$	8.8
T_9-NLE 15% + 50% H	$27.0^{cde}\pm2.08$	$28.3^{cde}\pm1.45$	27.7	$20.0^{b}\pm2.08$	$20.6^{b}\pm1.20$	20.3	$19.0^{b}\pm2.08$	$16.0^{b}\pm1.15$	17.5	$17.7^{bc}\pm1.85$	$13.6^{bc}\pm1.20$	15.7
T_{10}-NLE 15% + 75% H	$29.0^{bcd}\pm2.51$	$30.0^{bcd}\pm0.57$	29.5	$11.3^{cde}\pm1.45$	$14.3^{cde}\pm1.15$	12.8	$9.7^{efgh}\pm0.88$	$10.0^{efgh}\pm0.57$	9.8	$9.0^{efg}\pm0.57$	$8.0^{efg}\pm0.57$	8.5
T_{11}-GLE 25% + 50% H	$30.3^{bc}\pm3.84$	$33.0^{bc}\pm1.76$	31.7	17.7cd±1.20	$15.6^{cd}\pm1.20$	16.7	$17.0^{bcd}\pm1.00$	$14.3^{bcd}\pm0.88$	15.7	$16.3^{bcd}\pm1.45$	$12.3^{bcd}\pm0.88$	14.3
T_{12}-GLE 25% + 75% H	$26.3^{ab}\pm1.85$	$36.3^{ab}\pm1.45$	31.3	$13.7^{cde}\pm0.88$	$14.0^{cde}\pm0.57$	13.8	$17.0^{cdefg}\pm1.73$	$11.6^{cdefg}\pm0.33$	14.3	$16.0^{cdef}\pm1.73$	$10.6^{cdef}\pm0.66$	13.3
T_{13}-GLE 30% + 50% H	$29.7^{cde}\pm3.48$	$28.3^{cde}\pm2.08$	29.0	$16.0^{cd}\pm1.52$	$15.6^{cd}\pm0.66$	15.8	$15.3^{defg}\pm0.88$	$10.6^{defg}\pm1.20$	13.0	$15.0^{defg}\pm0.57$	$8.6^{defg}\pm0.33$	11.8
T_{14}-GLE 30% + 75% H	$27.7^{cde}\pm3.18$	$28.0^{cde}\pm1.20$	27.8	$10.7^{def}\pm1.76$	$12.0^{def}\pm0.88$	11.3	$10.0^{efgh}\pm1.52$	$10.0^{efgh}\pm0.57$	10.0	$9.7^{defg}\pm0.33$	$9.3^{defg}\pm0.33$	9.5
T_{15}-ELE 5%	$31.0^{bcd}\pm2.88$	$30.6^{bcd}\pm1.73$	30.8	$14.7^{cd}\pm1.20$	$14.6^{cd}\pm0.57$	14.7	$13.3^{defg}\pm0.66$	$11.0^{defg}\pm0.57$	12.2	$12.7^{defg}\pm1.20$	$9.3^{defg}\pm0.33$	11.0
T_{16}-ELE 10%	$29.3^{cde}\pm2.90$	$28.0^{cde}\pm1.73$	28.7	$16.7^{cdef}\pm1.85$	$13.3^{cdef}\pm0.88$	15.0	$15.0^{bcde}\pm0.57$	$13.6^{bcde}\pm0.88$	14.3	$14.0^{cdef}\pm1.15$	$10.6^{cdef}\pm0.66$	12.3
T_{17}-NLE 10%	$23.7^{e}\pm2.60$	$23.0^{e}\pm1.45$	23.3	$15.0^{cdef}\pm2.64$	$13.0^{cdef}\pm0.57$	14.0	$13.0^{defg}\pm0.57$	$11.0^{defg}\pm0.57$	12.0	$12.3^{bcde}\pm0.88$	$11.3^{bcde}\pm0.33$	11.8
T_{18}-NLE 15%	$29.7^{de}\pm2.33$	$25.6^{de}\pm0.57$	27.7	$14.0^{cd}\pm0.57$	$15.3^{cd}\pm0.88$	14.7	$13.0^{defg}\pm1.00$	$10.6^{defg}\pm1.20$	11.8	$12.0^{cde}\pm0.57$	$11.0^{cde}\pm0.57$	11.5
T_{19}-GLE 25%	$25.0^{de}\pm2.51$	$26.0^{de}\pm0.57$	25.5	$16.0^{cd}\pm1.15$	$16.0^{cd}\pm1.15$	16.0	$14.3^{bcdef}\pm1.45$	$13.3^{bcdef}\pm1.20$	13.8	$13.3^{cde}\pm0.88$	$11.0^{cde}\pm0.57$	12.2
T_{20}- GLE 30%	$24.7^{cde}\pm2.33$	$28.6^{cde}\pm1.45$	26.7	$15.7^{cde}\pm0.88$	$14.3^{cde}\pm1.20$	15.0	$13.0^{bcdefg}\pm0.57$	$12.0^{bcdefg}\pm1.15$	12.5	$12.7^{bcd}\pm0.33$	$12.0^{bcd}\pm0.57$	12.3
CD	6.95	3.72	N/A	3.926	2.397	N/A	3.227	2.272	N/A	2.651	2.03	N/A
SEM(±)	2.418	1.294	N/A	1.366	0.834	N/A	1.123	0.793	N/A	0.922	0.706	N/A

Note- The Mean value, followed by different letters are significantly different at $p<0.05$, according to LSD (Least Significant difference) for separation of means. DAS- Days after sowing, RDH-recommended dose of herbicide, ELE- eucalyptus leaf extract, NLE- neem leaf extract, GLE- guava leaf extract, SE- standard error and CD- critical difference.

Table 2. Effect of treatments on *Anagallis arvensis* population in wheat crop

TREATMENTS	30 DAS			60 DAS			90 DAS			120 DAS		
	2021-2022	2022-2023	Pooled	2021-2022	2022-2023	Pooled	2021-2022	2022-2023	Pooled	2021-2022	2022-2023	Pooled
T_1-Absolute control	52.0^{a}±2.30	43.0^{a}±1.73	47.5	51.7^{a}±3.18	43.3^{a}±2.96	47.5	48.3^{a}±3.38	45.0^{a}±2.51	46.7	47.3^{a}±2.60	45.0^{a}±2.08	47.0
T_2-100% RDH	30.0^{ef}±3.21	34.6^{d}±0.88	32.3	8.3^{g}±0.66	10.6^{g}±0.33	9.5	7.7^{g}±0.88	8.3^{g}±0.88	8.0	5.3^{g}±0.33	6.6^{g}±0.66	6.7
T_3-ELE 5% + 50% H	37.0^{bc}±1.52	39.0^{ab}±2.08	38.0	6.3^{defg}±0.88	12.0^{defg}±1.15	9.2	$6.0e^{fg}$±0.57	10.6^{efg}±0.88	8.3	5.7^{efg}±0.33	7.6^{efg}±0.66	7.0
T_4-ELE 5% + 75% H	30.7^{e}±1.20	36.6^{cd}±1.20	33.7	22.0^{b}±1.52	11.0^{fg}±0.57	16.5	20.3^{fg}±0.33	9.0^{fg}±0.57	14.7	19.3^{defg}±0.33	8.6^{defg}±0.33	17.0
T_5-ELE 10% + 50% H	43.7^{ab}±1.85	42.3^{ab}±1.45	43.0	17.7^{cdefg}±0.88	14.0^{cdefg}±1.15	15.8	17.3^{cde}±0.88	13.0^{cde}±1.15	15.2	17.0^{bcdef}±0.57	11.0^{bcdef}±0.57	16.1
T_6-ELE 10% + 75% H	37.3^{bc}±2.33	39.0^{bc}±1.15	38.2	17.3^{cd}±0.66	23.0^{b}±1.73	20.2	16.3^{b}±0.33	18.0^{b}±1.15	17.2	16.0^{b}±1.52	13.6^{b}±1.45	16.6
T_7-NLE 10% + 50% H	42.0^{abc}±1.15	39.6^{bc}±2.02	40.8	14.3^{g}±0.88	10.0^{g}±0.57	12.2	13.3^{g}±0.66	8.3^{g}±0.33	10.8	12.7^{g}±0.66	6.6^{g}±0.33	11.8
T_8-NLE 10% + 75% H	42.0^{abc}±4.58	42.0^{ab}±1.15	42.0	15.0^{efg}±3.64	13.6^{cdefg}±0.66	14.3	13.0^{efg}±1.00	10.0^{efg}±0.57	11.5	12.7^{fg}±0.88	7.3^{fg}±0.33	12.1
T_9-NLE 15% + 50% H	44.0^{ab}±1.52	38.6^{bcd}±0.88	41.3	18.3^{cd}±0.33	16.0^{cd}±1.15	17.2	16.7^{defg}±0.88	11.3^{defg}±0.88	14.0	16.0^{bcdef}±0.57	11.0^{bcdef}±0.57	15.0
T_{10}-NLE 15% + 75% H	36.7^{c}±1.33	37.6^{cd}±1.33	37.2	17.0^{c}±0.57	17.3^{c}±0.88	17.2	16.7^{cde}±0.88	13.0^{cde}±0.57	14.8	15.3^{bcde}±0.33	11.3^{bcde}±0.33	15.1
T_{11}-GLE 25% + 50% H	38.3^{bc}±3.93	36.6^{cd}±1.76	37.5	15.7^{cdef}±1.20	15.0^{cdef}±1.15	15.3	15.7^{defg}±0.88	11.3^{defg}±0.88	13.5	14.0^{bcd}±0.57	12.3^{bcd}±0.33	13.8
T_{12}-GLE 25% + 75% H	34.0^{cd}±2.51	38.6^{bc}±0.88	36.3	16.3^{cdefg}±1.20	13.3^{cdefg}±0.88	14.8	15.7^{cdef}±1.85	12.3^{cdef}±0.88	14.0	15.0^{bcd}±0.57	12.3^{bcd}±0.66	14.5
T_{13}-GLE 30% + 50% H	44.0^{ab}±5.03	38.6^{bc}±1.20	41.3	15.0^{efg}±1.00	11.6^{efg}±0.66	13.3	14.7^{efg}±0.66	10.3^{efg}±0.88	12.5	14.0^{cdefg}±1.00	9.6^{bcdefg}±0.33	13.3
T_{14}-GLE 30% + 75% H	32.0^{d}±1.52	37.3^{cd}±0.88	34.7	14.7^{cd}±2.33	16.0^{cd}±1.15	15.3	14.0^{cde}±0.57	13.0^{cde}±0.57	13.5	13.3^{bcdef}±1.45	11.0^{bcdef}±0.57	13.4
T_{15}-ELE 5%	42.7^{abc}±2.40	39.0^{bc}±0.57	40.8	13.3^{g}±1.20	10.0^{g}±0.57	11.7	12.7^{defg}±0.66	11.0^{defg}±0.57	11.8	11.7^{defg}±0.88	9.3^{defg}±0.33	11.8
T_{16}-ELE 10%	42.7^{abc}±3.38	38.6^{bcd}±0.88	40.7	$15.0e^{fg}$±2.64	11.0^{fg}±0.57	13.0	14.0^{efg}±1.52	10.3^{efg}±0.88	12.2	13.7^{bcdefg}±0.66	10.3^{bcdefg}±0.33	12.9
T_{17}-NLE 10%	42.0^{abc}±4.16	37.0^{ab}±1.15	39.5	16.7^{cd}±1.45	16.0^{cd}±0.57	16.3	16.3^{bc}±1.85	16.0^{bc}±1.15	16.2	13.7^{bc}±1.45	13.3^{bc}±0.88	14.9
T_{18}-NLE 15%	36.7^{c}±2.02	36.3^{cd}±1.20	36.5	17.7^{cd}±0.88	16.0^{cd}±1.15	16.8	17.0^{bcd}±0.57	14.6^{bcd}±0.88	15.8	16.7^{bcd}±0.88	12.3^{bcd}±0.88	16.3
T_{19}-GLE 25%	39.3^{bc}±2.60	37.3^{cd}±0.88	38.3	18.3^{cde}±0.33	15.3^{cde}±0.88	16.8	16.7^{cde}±0.33	13.0^{cde}±1.00	14.8	16.3^{bcde}±1.20	11.3^{bcde}±0.88	15.6
T_{20}- GLE 30%	42.3^{abc}±1.45	39.6^{bc}±1.45	41.0	17.0^{cdefg}±0.57	13.3^{cdefg}±0.88	15.2	16.3^{cde}±0.88	13.3^{cde}±0.33	14.8	15.7^{bcdefg}±0.88	10.3^{bcdefg}±0.88	15.3
CD	8.04	3.793	N/A	4.276	2.305	N/A	3.482	2.021	N/A	3.025	2	N/A
SEM(±)	2.798	1.32	N/A	1.488	0.802	N/A	1.212	0.703	N/A	1.053	0.696	N/A

Note- The Mean value, followed by different letters are significantly different at $p<0.05$, according to LSD (Least Significant difference) for separation of means. DAS- Days after sowing, RDH-recommended dose of herbicide, ELE- eucalyptus leaf extract, NLE- neem leaf extract, GLE- guava leaf extract, SE- standard error and CD- critical difference.

significant reduction of 88.79% in weed population at 120 DAS.

Subsequently in the second trial, similar results were reported. At 30 DAS, *Anagallis arvensis* population in wheat crop was ranged from 34.67 to 43.0 plants/m^2. At 60 DAS, the weed population ranged from 10.0 to 43.3 plants/m^2. Maximum weed population was recorded in T1 (43.3) followed by T6 (23.0) while the minimum population was recorded in T2, T7 and T15 (10.0). As compared to T1 (43.3), in treatments T2, T7 and T15 a significant reduction of 76.90 % of weed population was recorded at 60 DAS. At 90 DAS, the weed population ranged from 8.3 to 45.0 plants/m^2. Maximum weed population was recorded in control i.e. T1 (45.0) followed by T6 (18.0) while the minimum population was recorded in T2 and T7 (8.3). As compared to control i.e. T1 (45.0), the population of weed was significantly reduced upto 81.55% in T2 and T7 (8.3) at 90 DAS. At 120 DAS, the weed population was ranged from 6.6 to 45.0 plants/m^2. Maximum weed population was recorded in T1 (45.0) followed by T6 (13.6) while the minimum population was recorded in T2 and T7 (6.6). As compared to T1 (45.0), a significant reduction of 85.33% was recorded in T2 and T7 (6.6) at 1200 DAS.

As per the result, the most effective treatments were the ones with reduced dosage of herbicide in combination with eucalyptus & neem leaf aqueous extracts. Studies showed that neem leaves could be effective on controlling weeds species by effecting their growth (Nahak and Sahu 2015). The active ingredients in neem leaves, such as azadirachtin, salannin and meliantriol have been found to be toxic to weed species and can inhibit the growth of weeds (Juma et al., 2022). Other than that, eucalyptus leaves contain allelochemicals such as terpinoids, phenolics and flavonoids. These properties inhibit the weeds germination, growth and development by reducing root and shoot growth and disrupting the physiological process like photosynthesis.

Specifically, the allelochemicals present in eucalyptus leaf aqueous extract can disrupt the hormonal balance within weeds, inhibit enzymes activity and disrupt cell membrane integrity, ultimately leading to weed suppression (Silva et al., 2020; Ayed et al., 2023). Furthermore, eucalyptus leaf aqueous extract releases allelopathic compounds to the soil by the decomposition of weeds for further inhibiting weed growth and providing long lasting weed control effects.

4. Conclusion

The weed Phalaris minor poses a significant threat to wheat crops, negatively impacting yield. Population data at 30, 60, 90, and 120 days after sowing (DAS) revealed varying levels of infestation, with the highest populations consistently recorded at T1 across all time points. Notably, treatment T4, involving eucalyptus leaf aqueous extract, was most effective in reducing the *Phalaris minor* population. Eucalyptus

Maximum population was recorded in T1 (43.0) followed by T5 (42.33) while the minimum population was recorded in T2 (34.67). As compared T1 (43.0), treatment T2 (34.67) showed a significant reduction of 19.37 % in weed population at 30 DAS.

contains bioactive compounds like eucalyptol, which disrupts weed cell processes, leading to their death. Other compounds, such as tannins, also inhibit weed growth by affecting their metabolism. Similarly, the weed *Anagallis arvensis* was monitored at the same intervals, showing higher populations at T1 across trials. The combination of reduced herbicide dosages with eucalyptus and neem leaf extracts showed the best control results. Neem's active ingredients, such as azadirachtin and salannin, are toxic to weeds, while eucalyptus leaf compounds disrupt growth by affecting hormonal balance, enzyme activity, and photosynthesis. These extracts offer a sustainable solution for long-term weed suppression by releasing allelopathic compounds into the soil.

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