GMR
The Original

PHYTOTOXIC AND BIOHERBICIDAL POTENTIAL OF FIVE WILD PLANT EXTRACTS AGAINST *EUPHORBIA HETEROPHYLLA* L.: EFFECTS ON SEED GERMINATION, PLANT GROWTH AND POLLEN GERMINATION

Mohammed Khalid[1*], Rifath Tanzeem Y[1], Ayesha Tabassum[2], Nandashree E[1], Geethanjali A[1], Khadir Ulla Shariff[1]**

[1]Department of Botany, Suvarna Gange Campus, Bengaluru North University, Mangasandra, Kolar, India.
[2]Department of Botany, Government First Grade College, K R Pura, Bengaluru, India.
*Corresponding Author: Mohammed Khalid (mohd.khalid.research@gmail.com)
** Co-corresponding Author: Rifath Tanzeem Y (rifath.research@gmail.com)

ABSTRACT
Euphorbia heterophylla is a problematic weed, necessitating the development of effective and sustainable alternatives to conventional weed-management practices. The present study evaluated the phytotoxic potential of aqueous extracts of *Achyranthes aspera*, *Jatropha gossypiifolia*, *Lantana camara*, *Leucas aspera*, and *Mesosphaerum suaveolens* against *E. heterophylla* at different developmental stages. Seed germination and seedling growth were assessed at 3, 6, 9, and 12% extract concentrations, while inhibition of established plants was monitored for 15 days. Pollen germination was evaluated using 2% aqueous extracts. All extracts inhibited seed germination, with stronger inhibition generally observed at higher concentrations. Seed viability was markedly reduced at 9 and 12% concentrations, particularly following treatment with *A. aspera*, *J. gossypiifolia*, *L. aspera*, and *M. suaveolens*. All extracts caused complete (100%) mortality of established *E. heterophylla* plants within 10–15 days. Among the extracts, *L. aspera* showed comparatively strong early activity, producing 62.5–87.5% mortality during days 5–10. Furthermore, all five extracts completely inhibited pollen germination at 2%, compared with 22.72% germination in the untreated control. Overall, the extracts exhibited broad phytotoxic activity against *E. heterophylla*, affecting seed germination, vegetative growth, survival, and pollen germination. These findings highlight their potential as sources of natural phytotoxic compounds for bioherbicide development and integrated weed management. Further studies are required to identify the active compounds and validate their efficacy, selectivity, and environmental safety under greenhouse and field conditions.

KEYWORDS: *Euphorbia heterophylla*; allelopathy; phytotoxicity; aqueous extracts; seed germination; pollen germination; bioherbicide

INTRODUCTION
Weeds are among the major constraints to agricultural productivity, reducing crop yield, food production, and farm profitability through competition for nutrients, light, water, and space (Ali et al., 2017; Guglielmini et al., 2017). Conventional weed management relies heavily on synthetic herbicides because of their rapid and effective action (Harrington & Ghani Zadeh, 2017; Tang et al., 2010). However, their excessive and repeated use has raised concerns regarding environmental pollution and the sustainability of chemical-based weed management. In this context, allelopathy, in which plants release biologically active phytochemicals that influence the growth and development of neighboring plants, represents a promising natural approach for weed suppression. Allelochemicals, including phenolic compounds, flavonoids, terpenoids, and glucosinolates, can interfere with seed germination, seedling growth, nutrient uptake, and other physiological processes (Dutta & Sinha-Roy, 1974; Mushtaq et al., 2020; Jmii et al., 2020). Despite extensive research on allelopathic interactions, their practical integration into crop production and weed-management systems remains limited. Greater utilization of plant-derived phytochemicals could potentially reduce dependence on synthetic herbicides and contribute to more sustainable agricultural practices (Khush, 1996; Duke et al., 2001). Therefore, the present study explored five wild plant species as potential sources of natural bioherbicidal agents for the management of *Euphorbia heterophylla*. *Euphorbia heterophylla* L., commonly known as wild poinsettia, is a highly competitive weed occurring in several agricultural systems, including maize, soybean, groundnut, and mulberry cultivation areas in South India. Calero et al., 2023 Its competitive ability is associated with vigorous growth, rapid seed germination, and its capacity to establish under a broad range of soil and climatic conditions. (Wilson, 1981). *Euphorbia heterophylla* is characterized by a rounded stem in cross-section, with the stems, petioles, and capsules being more or less hairy. The foliage leaves are dull green, while the bracteal leaves are green and may sometimes exhibit whitish or purplish coloration at the base. The cyathial gland is funnel-shaped with a rounded opening. The seeds are angular in cross-section and possess a course, bluntly tuberculate seed coat. These characteristics provide useful morphological features for the identification of *E. heterophylla* (Turner, 1999)

The effective management of *E. heterophylla* is particularly challenging because of its rapid growth, prolific seed production, and reported resistance to several herbicidal modes of action (Trezzi et al., 2009). These characteristics emphasize the need for alternative weed-management strategies that are effective, economical, and environmentally compatible. Plant-derived extracts containing allelochemicals may provide such an alternative by interfering with different stages of weed development.

Accordingly, the present study aimed to evaluate the phytotoxic effects of aqueous extracts of *Achyranthes aspera*, *Jatropha gossypiifolia*, *Lantana camara*, *Leucas aspera*, and *Mesosphaerum suaveolens* against *E. heterophylla*. The study specifically assessed their effects on seed germination, seedling development, established plant survival, and pollen germination. The ultimate objective was to identify promising plant-derived extracts that could serve as simple, cost-effective, and potentially sustainable bioherbicidal resources for the management of *E. heterophylla* and contribute to the development of environmentally compatible weed-management strategies.

MATERIALS AND METHODS

The present research is constructed in such a way that, it is simple, so that farmers can understand and prepare their own plant extract by collecting plants without depending on any industrial manufactured product. In the present research aqueous extract is used because preparation of plant extract from other solvents will be expensive for large area application.

Collection of plants for the preparation of extract

Plant materials *A. aspera, J. gossypiifolia, M. suaveolens, L. camara, and L. aspera* were collected near BNU, PG centre campus Mangasandra, Kolar. Collected material was first cleaned to remove dust, soil and debris. After cleaning the plant material is shade dried. Once the material was completely dried, it was grinded into a fine powder. The powder was stored in airtight containers to prevent moisture adsorption.

Preparation of Aqueous Plant Extracts

Aqueous extracts were prepared from both dried plant powder and fresh plant material using sterile distilled water as the extraction solvent. For the powdered method, the respective plant materials were collected, thoroughly washed, dried under sunlight until completely free from moisture, and powdered. The powdered materials were stored in airtight containers until further use. Extract concentrations of 3%, 6%, 9%, and 12% (w/v) were prepared by suspending 30, 60, 90, and 120 g of plant powder, respectively, in 1000 mL of sterile distilled water. Sterile water was prepared by autoclaving or boiling to minimize microbial contamination. The plant–water suspensions were maintained at room temperature for 2–3 h to facilitate the extraction of water-soluble constituents and were subsequently filtered through a sieve to obtain the aqueous extracts. No heat-assisted extraction was employed during the extraction process to minimize the degradation of heat-sensitive phytochemical constituents. The powdered material could be stored in airtight containers, allowing extracts to be prepared when fresh plant material was unavailable, including during the off-season.

For the fresh plant extraction method, freshly collected plant materials were thoroughly washed and used directly without drying. Since fresh plant tissues contain varying amounts of inherent water, the concentrations established for the powdered extracts could not be directly applied to fresh plant material. Therefore, the fresh weight–dry weight ratio (FDR) was determined for each plant species to obtain a fresh plant weight equivalent to the dry weight used in the powdered extraction method. For FDR determination, a known quantity of fresh plant material (**X g**) was weighed and subsequently dried completely, after which the corresponding dry weight (**Y g**) was recorded. The quantity of fresh plant material equivalent to 1 g of dry material was calculated from the relationship between the fresh and dry weights. The resulting FDR was then used to calculate, by cross-multiplication, the quantities of fresh plant material required to prepare extracts equivalent to the 3%, 6%, 9%, and 12% concentrations used in the powdered method. The calculated fresh material was homogenized with sterile distilled water and the homogenate was incubated at room temperature for 60 min to facilitate extraction of water-soluble constituents. The homogenate was subsequently passed through a sieve to remove plant debris and obtain the aqueous extract. Fresh extracts were prepared immediately before use. Thus, the FDR method enabled fresh plant material to be used directly while maintaining concentration equivalence with the corresponding powdered extracts. The FDR of the five extracts are as follows:

PLANT NAME	FRESH WEIGHT	DRY WEIGHT
Achyranthus aspera	3.1 g	1 g
Jatropha gossypiifolia	4.3 g	1 g
Lantana camara	3.9 g	1 g
Lucas aspera	4.9 g	1 g
Mesosphaerum suaveolens	3.2 g	1 g

Preparation of Nutrient Solution

Commercial Hydro Grow A and B, a two-part liquid fertilizer (Hydro farm technologies Pvt. Ltd), was used as the nutrient source because the experimental medium consisted of cocopeat without the incorporation of soil. The

fertilizer is formulated for hydroponic and soilless cultivation. The nutrient solution was prepared by separately diluting equal volumes of Part A and Part B stock solutions in water. Approximately 5 mL of Part A was added to 1 L of water and mixed thoroughly, followed by an equal volume of Part B. The resulting solution was mixed well, and the pH was adjusted to 5.5–6.5 to ensure optimal nutrient availability. Part A and Part B were not mixed directly in their concentrated forms to prevent precipitation and nutrient incompatibility. The essential macronutrients and micronutrients, including chelated metals, present in the nutrient solution are listed in the below Table.

Nutrient Type	Element Name	Found in Bottle A	Found in Bottle B
Primary Macronutrients	Nitrogen (N)	2%	1%
		Phosphorus (P)	-
		Potassium (K)	2%
Secondary Macronutrients	Calcium (Ca)	2%	-
	Magnesium (Mg)	-	0.8%
Micronutrients (Chelated)	Iron (Fe)	0.8%	-
	Zinc (Zn)	-	0.003%
	Boron (B)	-	0.004%
	Manganese (Mn)	-	0.004%
	Copper (Cu)	-	0.0008%

Seed Germination Inhibition Test

Seeds of *E. heterophylla* were collected from mature fruits near the BNU P.G. Centre, Suvarna Gange Campus, Mangasandra, Kolar, Karnataka. Seed germination inhibition was evaluated using pot method under greenhouse condition. Cocopeat supplemented with macro- and micronutrients was used as the growth substrate. Forty-five nursery trays, each containing 16 wells, were prepared, comprising five control trays and two trays for each concentration (3, 6, 9, and 12%) of five plant extracts: *A. aspera*, *J. gossypiifolia*, *L. aspera*, *L. camara*, and *M. suaveolens*. The respective plant extracts were thoroughly incorporated into the cocopeat before sowing the weed seeds.

Control trays received no plant extract and were maintained in extract-free cocopeat under identical experimental conditions. All trays were maintained under greenhouse conditions with regular watering and nutrient supplementation for 30 days. Germination and seedling growth parameters were recorded throughout the experimental period, including the number of germinated seeds, number of leaves and shoot length were measured during the 30-day experimental period.

Plant Inhibition Test (PIT)

The bioherbicidal activity of aqueous extracts of five plants, *A. aspera*, *J. gossypiifolia*, *L. aspera*, *L. camara*, and *M. suaveolens*, was evaluated against *Euphorbia heterophylla* at 3, 6, 9, and 12% concentrations. Mature seeds of *E. heterophylla* were collected from healthy plants growing near the BNU P.G. Centre, Suvarna Gange Campus, Mangasandra, Kolar, Karnataka, India.

Seeds were sown in autoclaved cocopeat-filled nursery trays (16 wells per tray) and maintained under greenhouse conditions for 20–25 days to obtain uniform seedlings. Water was supplied twice daily, and nutrient solution was applied on alternate days. Uniform 25-day-old seedlings were treated with approximately 1 mL of the respective aqueous extract at the base of the stem near the root–stem transition. Each concentration was applied to three replicate trays, while untreated plants maintained under identical conditions served as controls. Fresh extracts were prepared daily and applied twice daily throughout the treatment period.

The effects of the extracts were assessed based on visible phytotoxic symptoms, including growth inhibition, leaf discoloration, chlorosis, necrosis, and stem abnormalities, and leaf or another organ abscission. Changes in seedling growth and development were recorded and compared with the untreated control.

Pollen germination inhibition (PGI)

Matured pollens are collected from plant *E. heterophylla* during stage of anthesis. A standard concentration of 2% extract was prepared from selected plant materials of *A. aspera, J. gossypiifolia, L. camara, L. aspera* and *M. suaveolens*. For PGI all the different plant extracts concentrations of all the respective plants are prepared from Brew Baker's medium and not from water as used in (PIT) and (SGIT). Then the control is studied without incorporation of plant extracts into the Brew Baker's medium, where normal growth and behaviour of pollen tube is noted. Hanging Drop method was employed for the observation and investigation of pollen tube growth and development. Observations regarding pollen viability, pollen tube initiation, length of the pollen tube and other pollen tube deformities were noted down systematically with the comparison to control pollen tube.

RESULTS AND DISCUSSION

The present study demonstrated that aqueous extracts of *A. aspera*, *J. gossypiifolia*, *L. camara*, *L. aspera*, and *M. suaveolens* exhibited pronounced phytotoxic effects against *E. heterophylla* at the seed germination, vegetative, and reproductive stages. The magnitude of inhibition varied among plant species and extract concentrations, indicating differences in their phytotoxic potential.

Under untreated conditions, *E. heterophylla* showed progressive germination and seedling development during the three-week observation period. Germination increased from 67% in the first week to 70% and 80% in the second and third weeks, respectively. Shoot length similarly increased from 0.2–3 cm during the first week to 0.2–7 cm and 7–17 cm during the second and third weeks, respectively, whereas two leaves were consistently observed in the seedlings. These observations confirmed normal germination and early seedling development under control conditions.

All five plant extracts suppressed seed germination, with the magnitude of inhibition generally increasing with extract concentration. *A. aspera* and *J. gossypiifolia* exhibited particularly strong inhibition at 9% and 12%, with germination reduced to approximately 0–15% at the highest concentrations. Similarly, *L. camara*, *L. aspera*, and *M. suaveolens* showed progressively reduced germination at higher concentrations, although the magnitude of inhibition differed among extracts. At the third week, germination ranged from 18.75–45% for *L. camara*, 10–50% for *L. aspera*, and approximately 9–63.75% for *M. suaveolens* across the tested concentrations. These findings indicate a predominantly concentration-dependent inhibition of *E. heterophylla* germination and early seedling establishment (Table 1 and Figure 1-5).

Table 1. Effect of different concentrations of plant extracts on seed germination and seedling growth of *Euphorbia heterophylla.*

Plant extracts	Concentration (%)	Approximate seeds sown	Time frame	No. of seeds germination	Seed viability (%)	Avg. length of germinated seedlings (cm)	No. of leaves
A. aspera (AC)	3	80	1st week	8	10	0.2-3	2
			2nd week	20	25	0.2-7	2
			3rd week	51	63.75	7-17	2
	6	80	1st week	6	7.5	0.2-3	2
			2nd week	17	21.25	0.2-7	2
			3rd week	47	58.75	7-17	2
	9	80	1st week	5	6.25	0.2-3	2
			2nd week	21	26.25	0.2-7	2
			3rd week	58	75.5	7-17	2
	12	80	1st week	0	0	0.2-3	2
			2nd week	8	10	0.2-7	2
			3rd week	30	37.5	7-17	2
J. gossypiifolia (JA)	3	80	1st week	11	13.75	0.2-3	4
			2nd week	32	40	0.2-7	4
			3rd week	64	80	7-17	4
	6	80	1st week	6	7.5	0.2-3	2
			2nd week	24	30	0.2-7	2
			3rd week	60	75	7-17	2
	9	80	1st week	4	5	0.2-3	2
			2nd week	16	20	0.2-7	2
			3rd week	46	57.5	7-17	2
	12	80	1st week	0	0	0.2-3	0
			2nd week	12	15	0.2-7	2
			3rd week	41	51.25	7-17	2
L. camara (LA)	3	80	1st week	1	1.25	0.2-3	2
			2nd week	10	12.5	0.2-7	2
			3rd week	34	42.5	7-17	2

	6	80	1st week	3	3.75	0.2-3	2
			2nd week	16	20	0.2-7	2
			3rd week	36	45	7-17	2
	9	80	1st week	3	3.75	0.2-3	2
			2nd week	15	18.75	0.2-7	2
			3rd week	37	46.25	7-17	2
	12	80	1st week	3	3.75	0.2-3	2
			2nd week	14	17.5	0.2-7	2
			3rd week	34	42.5	7-17	2
L. aspera (LU)	3	80	1st week	3	3.75	0.2-3	2
			2nd week	8	10	0.2-7	2
			3rd week	39	48.75	7-17	2
	6	80	1st week	3	3.75	0.2-3	2
			2nd week	11	13.75	0.2-7	2
			3rd week	40	50	7-17	2
	9	80	1st week	2	2.5	0.2-3	2
			2nd week	8	10	0.2-7	2
			3rd week	28	35	7-17	2
	12	80	1st week	3	3.75	0.2-3	2
			2nd week	8	10	0.2-7	2
			3rd week	30	37.5	7-17	2
M. suaveolens (ME)	3	80	1st week	6	7.5	0.2-3	4
			2nd week	25	31.25	0.2-7	4
			3rd week	49	61.25	7-17	4
	6	80	1st week	4	5	0.2-3	4
			2nd week	21	26.25	0.2-7	4
			3rd week	51	63.75	7-17	4
	9	80	1st week	4	5	0.2-3	2
			2nd week	17	21.25	0.2-7	2
			3rd week	39	48.75	7-17	2
	12	80	1st week	1	1.25	0.2-3	2
			2nd week	8	10	0.2-7	2
			3rd week	32	40	7-17	2

The observed inhibition is consistent with previous reports of allelopathic suppression of *E. heterophylla*. Novakoski et al. reported significant inhibition of *E. heterophylla* germination and seedling growth by aqueous mixtures of *Urochloa ruziziensis* and *Sorghum bicolor*, which was associated with allelopathic activity and oxidative stress. Similarly, Silva et al. demonstrated inhibitory effects of *Ilex paraguariensis* aqueous extracts on *E. heterophylla* seed germination and seedling establishment. The present findings extend these observations by demonstrating inhibitory activity from five additional plant species across multiple developmental stages.

The plant inhibition assay further confirmed the phytotoxic effects of the extracts on established *E. heterophylla* plants. No mortality was observed during the first five days; however, mortality increased substantially between days 5 and 10. During this period, *A. aspera*, *J. gossypiifolia*, *L. camara*, *L. aspera*, and *M. suaveolens* produced mortality ranges of 31.25–81.25%, 43.75–56.25%, 12.50–75.00%, 62.50–87.50%, and 18.75–81.25%, respectively. Notably, all five extracts resulted in 100% mortality of treated plants by 10–15 days at all tested concentrations. The comparatively rapid mortality observed with *L. aspera* suggests stronger or faster phytotoxic activity, whereas the variable response of *M. suaveolens* indicates that phytotoxicity was not strictly concentration-dependent during the initial treatment period (Table 2).

Table 2. Mortality of *Euphorbia heterophylla* following treatment with different concentrations of aqueous plant extracts at different exposure periods.

Plant extract	**Concentration (%)**	**1–5 days (%)**	**5–10 days (%)**	**10–15 days (%)**
	3	–	43.75	100

A. aspera (AC)	6	–	31.25	100
	9	–	68.75	100
	12	–	81.25	100
J. gossypiifolia (JA)	3	–	43.75	100
	6	–	43.75	100
	9	–	50	100
	12	–	56.25	100
L. camara (LA)	3	–	43.75	100
	6	–	75	100
	9	–	12.5	100
	12	–	68.75	100
L. aspera (LU)	3	–	87.5	100
	6	–	68.75	100
	9	–	62.5	100
	12	–	62.5	100
M. suaveolens (ME)	3	–	81.25	100
	6	–	50	100
	9	–	25	100
	12	–	18.75	100

The extracts also showed pronounced effects on the reproductive stage. In the untreated control, five of 22 pollen grains germinated (22.72%), whereas none of the pollen grains treated with 2% aqueous extracts of the five test plants germinated. Complete inhibition of pollen germination suggests that these extracts may interfere not only with vegetative growth but also with the reproductive potential of *E. heterophylla*, potentially reducing successful fertilization and subsequent seed production (Table 3 and Figure 6).

Table 3. Effect of different plant extracts on pollen germination

Plant extract	Concentration of extract (%)	Number of Observation	Total Number of Pollen	Number of Pollen Germinated	% of Pollen Germination
Control	0	1	22	5	22.72
A. aspera (AC)	2	1	20	0	0
J. gossypiifolia (JA)	2	1	12	0	0
L. camara (LA)	2	1	22	0	0
L. aspera (LU	2	1	10	0	0
M. suaveolens (ME)	2	1	25	0	0

The inhibitory effects observed across developmental stages may be associated with secondary metabolites present in the tested plants. Phenolics, flavonoids, terpenoids, alkaloids, and related phytochemicals have been reported to influence seed germination, cell division, membrane integrity, enzymatic activity, and seedling growth through allelopathic interactions. However, the present study demonstrates phytotoxic activity rather than establishing the specific compounds or mechanisms responsible for the observed effects. Phytochemical profiling and mechanistic investigations are therefore required to identify the active constituents underlying these responses.

The strong activity against both germinating and established plants indicates the potential of these aqueous extracts as sources of natural bioherbicidal agents. Although synthetic herbicides remain widely used for the management of *E. heterophylla*, the complete mortality of established plants and inhibition of pollen germination observed in the present study suggest that these extracts may have broader phytotoxic effects than those restricted to seed germination. Nevertheless, their practical application requires further evaluation of active constituents, dose optimization, crop selectivity, phytotoxicity to non-target plants, and efficacy under greenhouse and field conditions.

Overall, aqueous extracts of *A. aspera*, *J. gossypiifolia*, *L. camara*, *L. aspera*, and *M. suaveolens* exhibited substantial phytotoxic activity against *E. heterophylla* at different developmental stages. Increasing extract concentrations generally enhanced inhibition of seed germination, while all extracts ultimately caused complete mortality of established plants within 10–15 days. Complete inhibition of pollen germination was also observed at 2% extract concentration. These findings highlight the bioherbicidal potential of the tested plant extracts and provide a basis for further investigation of their active phytochemicals and application in sustainable weed management.

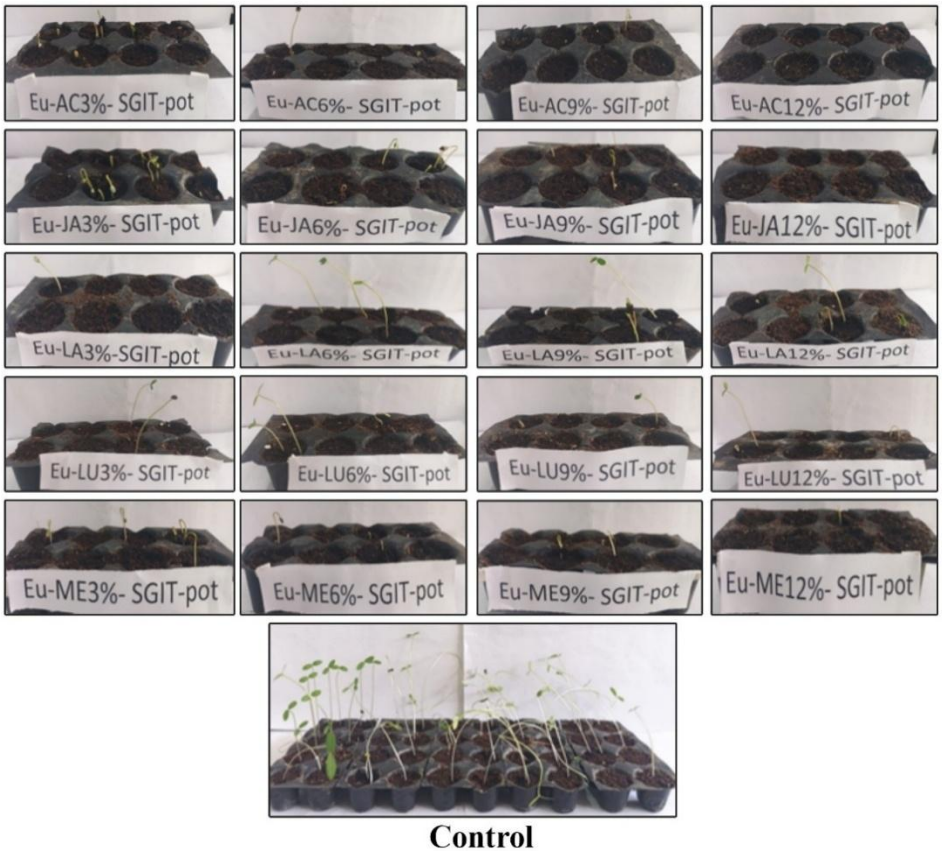

Figure 1. Effect of plant extracts on seedling growth during the first week of treatment

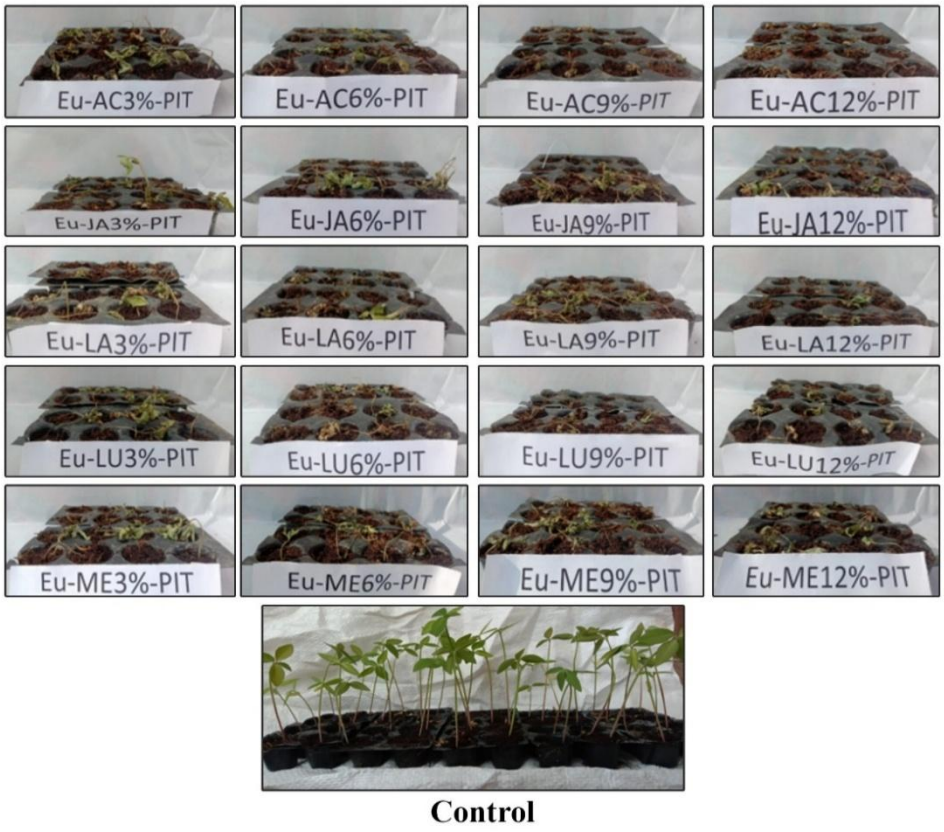

Figure 2. Effect of plant extracts on seedling growth during the second week of treatment.

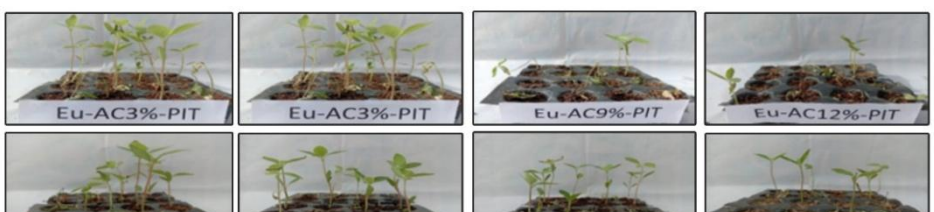

Figure 3. Effect of plant extracts on seed germination after one week of treatment.

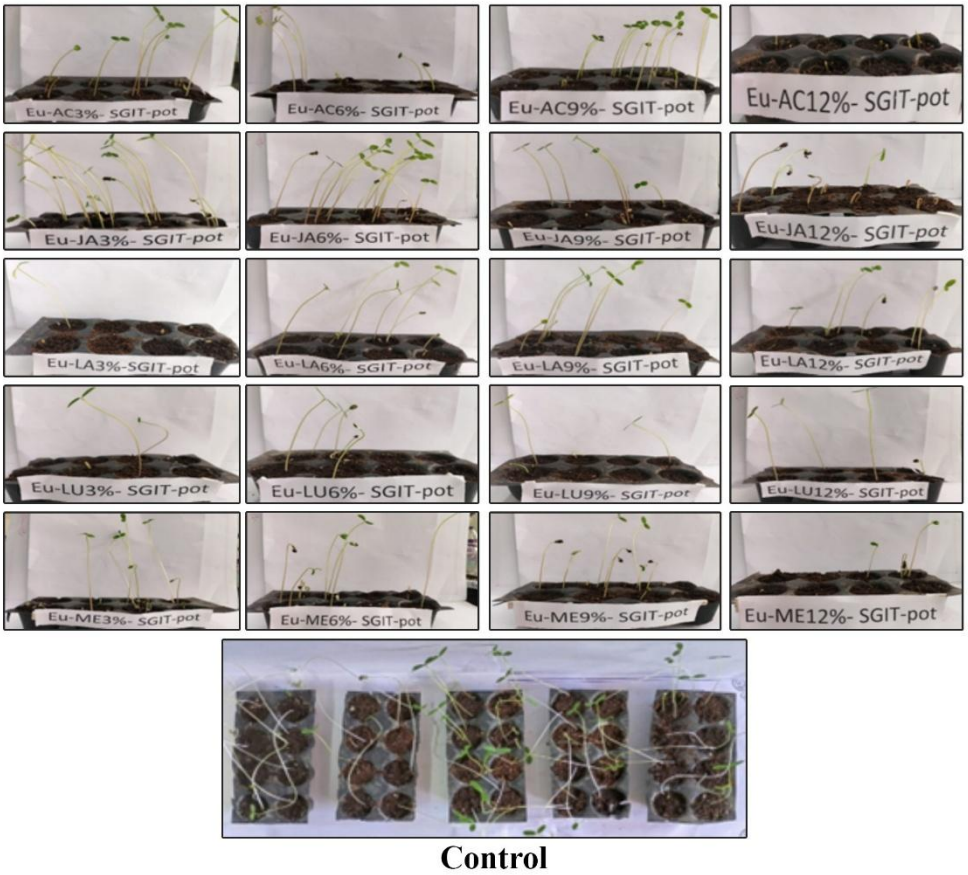

Figure 4. Effect of plant extracts on seed germination after two weeks of treatment.

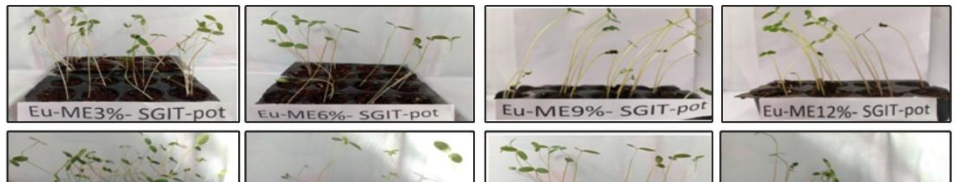

Figure 5. Effect of plant extracts on seed germination after three weeks of treatment.

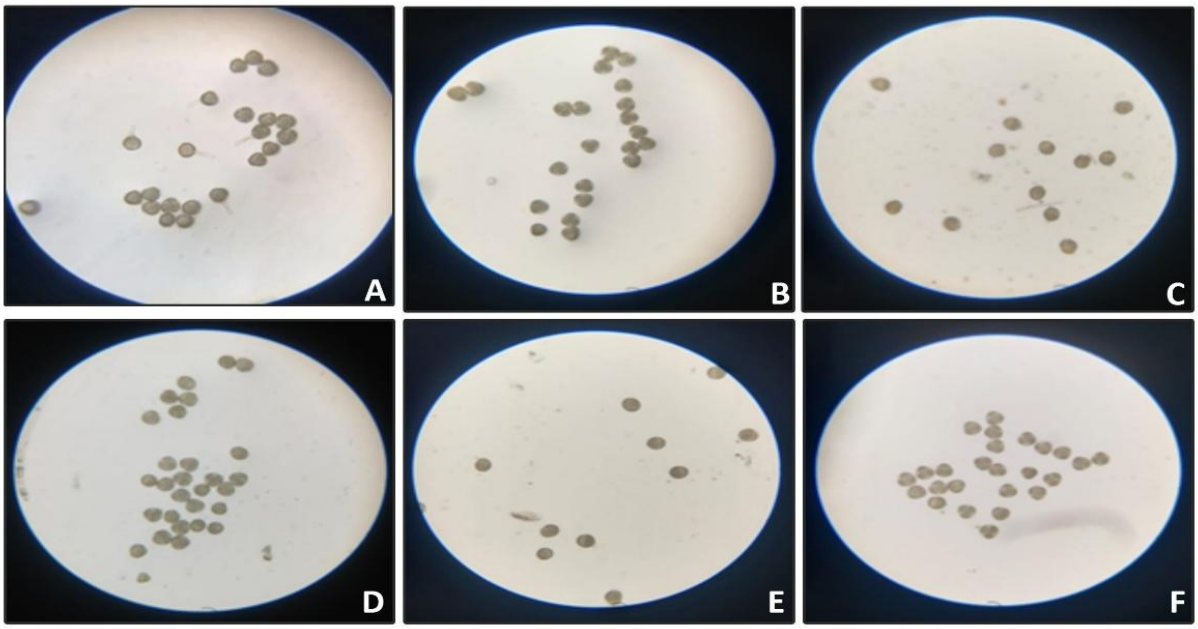

Figure 6. Pollen germination inhibition assay showing the effects of different plant extracts at 2% concentration. A. Control B. *A. aspera* C. *J. gossypiifolia* D. *L. camara* E. *L. aspera* F. *M. suaveolens.*

CONCLUSION

The present study demonstrated that aqueous extracts of *A. aspera*, *J. gossypiifolia*, *L. camara*, *L. aspera*, and *M. suaveolens* possess pronounced phytotoxic activity against *E. heterophylla*. The extracts significantly inhibited seed germination and seedling establishment, with inhibition generally becoming more pronounced at higher concentrations. Furthermore, all tested extracts caused complete mortality of established *E. heterophylla* plants within 10–15 days, demonstrating their potential to suppress both early and established stages of weed growth. The complete inhibition of pollen germination at a 2% concentration further indicates that the extracts may interfere with the reproductive potential of the weed. Collectively, the inhibition of seed germination, vegetative growth, plant survival, and pollen germination demonstrates the broad-spectrum phytotoxic potential of these plant extracts against *E. heterophylla*. Among the tested extracts, *L. aspera* exhibited comparatively strong early

activity against established plants, while *A. aspera* and *J. gossypiifolia* showed pronounced concentration-dependent inhibition of seed germination. The simple water-based extraction using powdered or fresh plant material also offers a cost-effective, environmentally friendly, and farmer-friendly approach compared with synthetic herbicides. These findings support the potential use of these plant extracts as sources of natural phytotoxic compounds and promising candidates for bioherbicide development. However, further studies are required to identify the active allelochemicals, determine their mechanisms of action, evaluate crop selectivity and environmental safety, and validate their efficacy under greenhouse and field conditions before practical application in integrated weed management.

Acknowledgments

The authors would like to express their gratitude to the Director, Suvarna Gange Campus, Bengaluru North University, Kolar, India for providing facilities.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

REFERENCES

1. Abbasvand, E., Hassannejad, S., Zehtab-Salmasi, S., & Alizadeh-Salteh, S. (2020). Physiological and biochemical responses of basil to some allelopathic plant residues and dodder infestation. *Acta Physiologiae Plantarum*, *42*(1), 1.
2. Afridi, R. A., & Khan, M. A. (2015). Comparative effect of water extract of Parthenium hysterophorus, Datura alba, Phragmites australis and Oryza sativa on weeds and wheat. *Sains Malaysiana*, *44*(5), 693-699.
3. Akshada Kakade, A. K., Madhuri Pawar, M. P., Kiran Wadkar, K. W., Sandip Patil, S. P., Magdum, C. S., & Naikwade, N. S. (2008). A comprehensive review of Jatropha gossypifolia Linn.
4. Allan, S. M., & Adkins, S. W. (2011). The effect of Phyllanthus virgatus extract on common weed species.
5. Anese, S., Gualtieri, S. C. J., Grisi, P. U., Jatobá, L. D. J., & Arduin, M. (2015). Phytotoxic potential of Drimys brasiliensis Miers for use in weed control. *Acta Scientiarum. Agronomy*, *37*(4), 505-516.
6. Awan, F. K., Rasheed, M., Ashraf, M., & Khurshid, M. Y. (2012). Efficacy of brassica sorghum and sunflower aqueous extracts to control wheat weeds under rainfed conditions of Pothwar, Pakistan.
7. Bannon, J. S., Baker, J. B., & Rogers, R. L. (1978). Germination of wild poinsettia (Euphorbia heterophylla). *Weed Science*, *26*(3), 221-225.
8. Bashar, H. K., Juraimi, A. S., Ahmad-Hamdani, M. S., Uddin, M. K., Asib, N., Anwar, M. P., & Rahaman, F. (2021). A mystic weed, Parthenium hysterophorus: threats, potentials and management. *Agronomy*, *11*(8), 1514.
9. Bhadoria, P. B. S. (2011). Allelopathy: a natural way towards weed management.
10. Brecke, B. J. (1995). Wild poinsettia (Euphorbia heterophylla) germination and emergence. *Weed Science*, *43*(1), 103-106.
11. Brecke, B. J., & Tobola, P. (1996). Growth and development of wild poinsettia (Euphorbia heterophylla) selections in peanut (Arachis hypogaea). *Weed science*, *44*(3), 575-578.
12. Calero, C. A. M., Rodríguez, J. R. Y., Fernández, Y. A., Marrero, D. F., & Fernandes, P. (2023). Euphorbia heterophylla Linn.(Wild poinsettia), a weed that deserves to be tamed and not eliminated. *Horticulture International Journal*, *7*(2), 70-71.
13. Carrubba, A., Labruzzo, A., Comparato, A., Muccilli, S., & Spina, A. (2020). Use of plant water extracts for weed control in durum wheat (Triticum turgidum L. Subsp. durum Desf.). *Agronomy*, *10*(3), 364.
14. Carvalho, F. T., Pereira, F. A. R., Peruchi, M., & Palazzo, R. R. B. (2003). Chemical management of the weeds Euphorbia heterophylla and Bidens pilosa under no-tillage system of soybean (Glycine max). *Planta Daninha*, *21*, 145-150.
15. Catanzaro, C., Kamake, H., & Bhatti, S. (2004). Performance of Poinsettia Cultivars Evaluated in 2003. *HortScience*, *39*(4), 835A-835.
16. Cheema, Z. A., Luqman, M., & Khaliq, A. (1997). Use of allelopathic extracts of sorghum and sunflower herbage for weed control in wheat. *Journal of Animal and Plant Sciences (Pakistan)*, *7*(3).
17. da Silva, T. A., Bashir, I., Giacomin, A. C., Barth, J. A., Chiapperin, M., de Oliveira, F. Z., ... & de Freitas, E. M. (2026). Toxicity of aqueous extracts of Ilex paraguariensis A. St.-Hil. about Euphorbia heterophylla L. *Pest Management Science*, *82*(7), 6196-6206.
18. De Mastro, G., El Mahdi, J., & Ruta, C. (2021). Bioherbicidal potential of the essential oils from Mediterranean Lamiaceae for weed control in organic farming. *Plants*, *10*(4), 818.
19. Dola, N. A., Sarker, U. K., Ahmed, M. T., Upama, S. A., Rashid, M. H. O., & Uddin, M. R. (2024). Comparative advantages of aqueous extract of mustard crop residues with herbicide to weed control and crop performance of wheat. *Archives of Agriculture and Environmental Science*, *9*(2), 294-301.
20. dos Santos Novakoski, A., Coelho, É. M. P., Ravagnani, G. T., da Costa, A. C. P. R., Rocha, S. A., Zucareli, V., & Lopes, A. D. (2020). Allelopathic Potential of Plant Aqueous Mixtures on Euphorbia heterophylla. *Agriculture*, *10*(10), 1-14.

21. El-Metwally, I. M., & El-Rokiek, K. G. (2019). Eucalyptus citriodora leaf extract as a source of allelochemicals for weed control in pea fields compared with some chemical herbicides. *Journal of Plant Protection Research*, *59*(3).
22. El-Rokiek, K. G., Dawood, M. G., Sadak, M. S., & El-Awadi, M. E. S. (2019). The effect of the natural extracts of garlic or Eucalyptus on the growth, yield and some chemical constituents in quinoa plants. *Bulletin of the National Research Centre*, *43*(1), 119.
23. Fay, P. K., & Duke, W. B. (1977). An assessment of allelopathic potential in Avena germ plasm. *Weed science*, *25*(3), 224-228.
24. Gella, D., Ashagre, H., & Negewo, T. (2013). Allelopathic effect of aqueous extracts of major weed species plant parts on germination and growth of wheat. *Journal of Agricultural and Crop Research*, *1*(3), 30-35.
25. Gindri, D. M., Coelho, C. M. M., & Uarrota, V. G. (2020). Physiological and biochemical effects of Lantana camara L. allelochemicals on the seed germination of Avena sativa L. *Pesquisa Agropecuária Tropical*, *50*, e62546.
26. Grisi, P. U., Gualtieri, S. C. J., Anese, S., Pereira, V. C., & Forim, M. R. (2013). Effect of Serjania lethalis ethanolic extract on weed control. *Planta Daninha*, *31*, 239-248.
27. Gurmani, A. R., Khan, S. U., Mehmood, T., Ahmed, W., & Rafique, M. (2021). Exploring the allelopathic potential of plant extracts for weed suppression and productivity in wheat (Triticum aestivum L.). *Gesunde pflanzen*, *73*(1), 29-37.
28. Hussain, W. S. (2020). Effects of spraying aqueous extracts of some crop plants on growth of four types of weeds. *Plant Archives*, *20*(1), 1460-1464.
29. Iqbal, J., Cheema, Z. A., & Mushtaq, M. N. (2009). Allelopathic crop water extracts reduce the herbicide dose for weed control in cotton (Gossypium hirsutum). *Int J Agric Biol*, *11*(4), 360-366.
30. Islam, A. M., & Kato-Noguchi, H. (2013). Isolation and characterization of allelopathic substance from Leucas aspera
31. Jabran, K., Mahajan, G., Sardana, V., & Chauhan, B. S. (2015). Allelopathy for weed control in agricultural systems. *Crop protection*, *72*, 57-65.
32. Jowers, H. E., Breman, J. W., & Fletcher, J. W. (1986). Effects of several herbicide treatments on wild poinsettia (Euphorbia heterophylla L.) control in soybean.
33. Khamare, Y., Chen, J., & Marble, S. C. (2022). Allelopathy and its application as a weed management tool: A review. *Frontiers in Plant Science*, *13*, 1034649.
34. Khan, A. A., Awan, I. U., Mansoor, M., Khan, E. A., Khakwani, A. A., Baloch, M. S., & Khan, N. (2012). Use of concentrated aqueous plant exudates as weed control measure in wheat crop. *Pakistan Journal of Weed Science Research*, *18*(1).
35. Khan, I. A., Marwat, K. B., Hassan, G., Khan, R., & Ullah, Z. (2012). Suppresive capability of herbicides and plant extracts against chickpea weeds.
36. Khan, M. B., Ahmad, M., Hussain, M., Jabran, K., Farooq, S., & Waqas-Ul-Haq, M. (2012). Allelopathic plant water extracts tank mixed with reduced doses of atrazine efficiently control Trianthema portulacastrum L. *Zea mays*, 339-346.
37. Kundra, V., Aulakh, C. S., & Bhullar, M. S. (2023). Integration of allelopathic water extracts with cultural practices for weed management in organic wheat.
38. Lati, R. N., Goldwasser, Y., Horesh, A., & Igbariya, K. (2019). Wild poinsettia biology and management–determining optimal control with herbicides and propane flaming. *Crop Protection*, *115*, 20-26.
39. Mamun, M. S. A., & Ahmed, M. (2011). Prospect of indigenous plant extracts in tea pest management. *International Journal of Agricultural Research, Innovation and Technology (IJARIT)*, *1*, 16-23.
40. May, F. E., & Ash, J. E. (1990). An assessment of the allelopathic potential of Eucalyptus. *Australian journal of botany*, *38*(3), 245-254.
41. Moore, J. D., Banks, P. A., & Pinnell-Alison, C. L. (1990). Wild poinsettia (Euphorbia heterophylla) control in peanut (Arachis hypogaea). *Weed Science*, *38*(6), 536-540.
42. Moyer, J. R., & Huang, H. C. (1997). Effect of aqueous extracts of crop residues on germination and seedling growth of ten weed species. *Botanical Bulletin of Academia Sinica*, *38*.
43. Nester, P. R., Harger, T. R., & McCormick, L. L. (1979). Weed watch-wild poinsettia.
44. Novakoski, A. D. S., Coelho, É. M. P., Ravagnani, G. T., Costa, A. C. P. R. D., Rocha, S. A., Zucareli, V., & Lopes, A. D. (2020). Allelopathic potential of plant aqueous mixtures on Euphorbia heterophylla. *Agriculture*, *10*(10), 449.
45. Putnam, A. R., & DeFrank, J. (1983). Use of phytotoxic plant residues for selective weed control. *Crop protection*, *2*(2), 173-181.
46. Razzaq, A., Cheema, Z. A., Jabran, K., Farooq, M., Khaliq, A., Haider, G., & Basra, S. M. A. (2010). Weed management in wheat through combination of allelopathic water extract with reduced doses of herbicides. *Pakistan Journal of Weed Science Research*, *16*(3).
47. Romagni, J. G., Duke, S., & Dayan, F. E. (2000). Allelochemicals as leads for new herbicides and agrochemicals. *Plant Physiol*, *123*, 725-732.
48. Saini, R., & Singh, S. (2018). Use of natural products for weed management in high-value crops: An Overview.

49. Sasikumar, K., Vijayalakshmi, C., & Parthiban, K. T. (2002). Allelopathic effects of Eucalyptus on black gram (Phaseolus mungo L.).
50. Shahid, M., Ahmad, B., Khattak, R. A., Hassan, G., & Khan, H. (2006). Response of wheat and its weeds to different allelopathic plant water extracts. *Pak. J. Weed Sci. Res*, *12*(1-2), 61-68.
51. Shirgapure, K. H., & Ghosh, P. (2020). Allelopathy a tool for sustainable weed management. *Arch. Curr. Res. Int*, *20*(3), 17-25.
52. Singh, H. P., Batish, D. R., & Kohli, R. K. (2003). Allelopathic interactions and allelochemicals: new possibilities for sustainable weed management. *Critical reviews in plant sciences*, *22*(3-4), 239-311.
53. Solymosi, P. (1994). Crude plant extracts as weed biocontrol agents.
54. Srikrishnah, S., & Begam, U. J. (2019). Review on use of plant extracts in weed control. *Curr. Trends Biomedical. Eng. Biosci*, *18*, 309-317.
55. Steinsiek, J. W., Oliver, L. R., & Collins, F. C. (1982). Allelopathic potential of wheat (Triticum aestivum) straw on selected weed species. *Weed science*, *30*(5), 495-497.
56. Tanveer, A., Safdar, M. E., Farooq, N., Sudozai, M. I., Nadeem, M. A., & Abbas, T. (2019). Exploring the Herbicidal Potential of Achyranthes aspera Against Some Weeds. *Planta Daninha*, *37*, e019188205.
57. Turner I. M.,Euphorbia heteroplylla and E. cyathophora(Euphorbiaceae) in the Malay Peninsula., "The Garden's Bulletin Singapore."VoL.51(part1)July 1999, Page no.(99-102)
58. Weston, L. A. (2005). History and current trends in the use of allelopathy for weed management. *HortTechnology.*, *15*(3), 529.
59. Willard, T. S., Griffin, J. L., Reynolds, D. B., & Saxton, A. M. (1994). Interference of wild poinsettia (Euphorbia heterophylla) with soybean (Glycine max). *Weed technology*, *8*(4), 679-683.
60. Willis, R. J. (2007). *The history of allelopathy*. Dordrecht: Springer Netherlands.
61. Wilson, A. K. (1981). Euphorbia heterophylla: a review of distribution, importance and control. *International Journal of Pest Management*, *27*(1), 32-38.
62. Won, O. J., Uddin, M. R., Park, K. W., Pyon, J. Y., & Park, S. U. (2013). Phenolic compounds in sorghum leaf extracts and their effects on weed control. *Allelopathy Journal*, *31*(1), 147.
63. Zhou, B., Kong, C. H., Li, Y. H., Wang, P., & Xu, X. H. (2013). Crabgrass (Digitaria sanguinalis) allelochemicals that interfere with crop growth and the soil microbial community. *Journal of agricultural and food chemistry*, *61*(22), 5310-5317.