

## Allelopathic Activity of Three Weed Species against Morphological and Physiological Traits of *Parthenium hysterophorus* and *Trianthema partulacastrum*

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### ABSTRACT

Weed management is extremely important for sustainable crop production in all cropping systems. The use of weedicides is one of the best approach to keep the weeds under check but the repeated use of few selective herbicides is giving rise to problem of herbicide resistant weeds and environmental pollution. Therefore, it is imperative to identify plant species having herbicidal potential so that their bio-extracts may be used as more safe and effective novel weed management means. The present study was conducted to explore the allelopathic impact of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on seedling growth of *Parthenium hysterophorus* and *Trianthema partulacastrum*. A completely randomized design was used for the experiment with four replications. Results indicated that lowest values of fresh weight (0.208 mg) and shoot length (3.83 cm) of *Parthenium hysterophorus* seedling was observed when extract of *Sisymbrium orientale* was applied. Moreover, lowest values of fresh weight (0.1255 mg) and dry weight (0.0084 mg) of *Trianthema partulacastrum* seedlings was observed when *Sisymbrium orientale* extract was applied. However, maximum leaf area and electrolyte leakage of *Parthenium hysterophorus* and *Trianthema partulacastrum* seedlings was observed when *Parthenium hysterophorus* extract was applied. It is concluded that *S. orientale* extract have comparatively more active substances with ability to suppress germination and growth of weeds which could be exploited as prospective source of bio-herbicides.

**Keywords:** Weed Management, Sustainable Crop Production, *Parthenium hysterophorus*, *Trianthema partulacastrum*, Plant Species and Herbicidal Potential.

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## INTRODUCTION

Weeds are present everywhere in the field and hamper the germination, growth and yield of nearly grown crops. They compete with the crops and reduced seedling growth by the release of different allelochemicals (Hayyat et al., 2020). Weeds are recognized as the global threat to agro and natural ecosystems (Shabbir et al., 2018). Extensive weed invasion has been the reason for more than one- third of the loss in crop yield of crops that grown up all around the world (Jabran et al., 2015). Weeds can cause production losses up to 35-69% in mung bean, 15-40% in cotton, 58-85% in soya bean, 10 to 100% in rice, 10-60% in wheat and 25-93% in maize (Kolhe et al., 1998; & Yaduraju et al., 2015).

*Parthenium* (*Parthenium hysterophorus* L.) is invasive weed belongs to Compositae family. It is originated from tropical America and nowadays occurs widely in the Australia, Asia and East Africa. It is observed to grow on the gardens, road sides, waterways, in grasslands and crop fields both during the season and after crop harvest, as long as enough moisture is available. This weed is becoming a problem for crop, range and forest. Similarly, *Trianthema portulacastrum* L. belongs to Aizoaceae family and which is native to Southern Africa and has been reported to be present in Pakistan, India, West Asia, Tropical America, Africa and Sri Lanka. It has become noxious due to the reduction of substantial yield in several cultivated areas (Kaur & Aggarwal, 2017). Currently, both of these problematic weeds have been controlled by employing synthetic herbicides and herbicides are proved very effective while extensive use of these chemicals are causing negative impact on environment by accumulation in water and soil in addition to their effect on the biological diversity (Al-Samarai et al., 2018). Moreover, these pesticides are persistent in nature and cause health hazard for agro-ecosystem and living beings (Sharma et al., 2019). In addition to this repeated use of herbicides with same modes of action cause a strong selection pressure on the target populations of weeds with consequence

that various cases of the resistance herbicides have been evolved worldwide (Powles & Yu, 2010). By the August 2018, resistance had been confirmed in about 255 weed species in the 92 crops in about 70 countries, affecting the efficiency of 163 various herbicides from the 23 well known herbicides (Heap, 2018). The increasing resistant weeds number biotypes is a major concern for the horticulture, agriculture, and amenity situations, especially as no new developed herbicide action mode has been marketed for over 30 years (Westwood et al., 2018). So, to overcome this developing condition there is a need to control weeds by bio herbicides. However, the quality and concentration of such natural bio-chemical compounds may differ based on weed species, different plant parts such as rhizomes, roots, leaves, stems, flower, pollen, seeds and fruits. These effective biochemicals are discharged from parts of the plants in the environment by diffusion, leakage from the parts of plants that are above ground, evaporation and disintegration. These discharged allelochemicals are one of the most significant regulating factors in plant community structure (Gawronska & Golisz, 2006; & Aziz et al., 2020). Hence an experiment was designed to explore the impact of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on seedling growth of *Parthenium hysterophorus* and *Trianthema portulacastrum*.

## MATERIALS AND METHODS

### Plant extract preparation

The naturally growing plants of three weed species namely, *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* were uprooted from soan valley during their flowering stage. The plant samples were cleaned twice with the distilled water to eliminate any kind of contamination. These samples were placed separately at room temperature for shade drying with zero periods of sunlight. After shade drying electric blender was used for individually grinding of each part (leaves, stem and roots) to make fine powder.

After grinding, fine powder was preserved in tightly sealed plastic zipped bags to avoid the contact of moisture with powdered sample.

#### Experimental site, design and treatments

Wire house experiment was conducted at College of Agriculture, University of Sargodha. The study was conducted in CRD with four number of replications. The effects of three plants extracts (*Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale*) was evaluated on two weed species namely *Parthenium hysterophorus* L. and *Trianthema portulacastrum* L.

#### Experimental procedure and data recorded

Firstly, pots having 9 cm depth were filled with the 500 g fine soil and ten seeds *Parthenium hysterophorus* L. and *Trianthema portulacastrum* L. were planted uniformly in pots. After germination of crops and weeds at three leave stage, foliar application of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* was done according to the treatment plan. The distilled water treatment was applied as control treatment. The data regarding seedling fresh biomass (mg), seedling dry biomass (mg), root length (cm), shoot length (cm), electrolyte leakage (%), leaf area (mm<sup>2</sup>) and chlorophyll content (Spad value) was recorded. For seedling fresh biomass samples were taken 10 days after application of extract. Then fresh weights of samples were recorded with the help of weight balance. For dry biomass (mg) seedling were firstly dried in the oven for 48 hr at 64°C. After complete drying, dry weights of all collected samples were recorded with the help of weight balance. For root length ten seedlings from every treatment and replication were selected at random and length was measured. Then average root length was calculated. For shoot length (cm) ten seedlings from each treatment and replication were taken at random and shoot length was measured in cm from base to top of seedling. Then average shoot length was worked out. For electrolyte leakage (%) leaf sample was taken from all treatments and replications separately. Each

sample was placed in 20 ml distilled water for 24 hr and EC was taken by EC meter and denoted as EC<sub>1</sub>. Then these solutions were autoclaved for 15 minutes and again EC was measured as EC<sub>2</sub>. Electrolyte leakage was calculated by the equation (Whitlow et al., 1992).

$$\text{Electrolyte leakage (\%)} = \text{EC}_1 / \text{EC}_2 \times 100.$$

For leaf area (mm<sup>2</sup>) five plants were selected from every pot and leaf area was noted by using leaf area meter (CI-202, Portable Laser Leaf Area Meter). For chlorophyll content (SPAD value) five plants were selected from each pot and SPAD (Soil Plant Analysis Development) chlorophyll values from the 3 topmost fully opened leaves of these plants were recorded by chlorophyll meter (Yaxin, 1260). The mean SPAD values were calculated by using standard procedure (Peng et al., 1993).

#### Statistical analysis

The data observed and collected was analyzed by using Fisher's analysis of variance technique and means were equated at 5% significance level by using Honestly Significant Difference Test (Steel et al., 1997).

## RESULTS AND DISCUSSION

### Phytotoxic effect of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on seedling growth of *Parthenium hysterophorus*

#### Leaf area (mm<sup>2</sup>)

Impact of foliar spray of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on leaf area of *Parthenium* seedling was statistically significant (Table 1). The data indicated that maximum leaf area (43.53 mm<sup>2</sup>) was recorded by application of *Parthenium hysterophorus* extract but minimum leaf area (23.76 mm<sup>2</sup>) was noted from the treatment where distilled water was applied. These results are supported by Oyerinde et al. (2009) who reported that application of aqueous extract of *T. diversifolia* significantly increased leaf area of maize seedling.

### Leaf Chlorophyll content (SPAD)

Effect of foliar application of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on chlorophyll contents of parthenium was found statistically significant (Table 1). The data indicated that maximum chlorophyll contents (12.06) were recorded when *Sisymbrium orientale* extract was applied which was statistically at par with chlorophyll contents of parthenium seedling produced by aqueous extract of *Adiantum capillus-veneris* and *Parthenium hysterophorus* while control treatment produced minimum (9.77) leaf chlorophyll content. Khaliq et al. (2013) reported that application of aqueous leaf extract of *Coronopus didymus* decreased the chlorophyll contents of wheat plants.

### Electrolyte leakage (%)

A statistically significant impact of foliar spray of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on electrolyte leakage of parthenium seedling was observed (Table 1). Results showed that maximum electrolyte leakage (43.53%) of parthenium seedling was noted when aqueous extract of *Parthenium hysterophorus* was applied while minimum electrolyte leakage (23.76%) was observed in control treatment. These findings are supported by Skrzypek et al. (2015) who observed that electrolyte leakage from sunflower seedling was increased due to the application of aquatic extract of peppermint.

**Table 1: Phytotoxic effect of different weed extracts on leaf area (mm<sup>2</sup>), chlorophyll content (Spad) and electrolyte leakage (%) of parthenium seedling**

Treatments	Leaf area (mm <sup>2</sup> )	Chlorophyll content (SPAD)	Electrolyte leakage (%)
Control	23.76 c	9.77 b	23.76 c
<i>Adiantum capillus extract</i>	34.81 b	10.69 ab	34.81 b
<i>Parthenium hysterophorus extract</i>	43.53 a	11.62 a	43.53a
<i>Sisymbrium orientale extract</i>	33.71 b	12.06 a	33.71 b
HSD (0.05)	29.10	1.50	2.56

### Fresh weight (mg)

Effect of exogenous application of water extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on fresh weight of parthenium seedling was statistically ( $P \leq 0.05$ ) non-significant (Table 2). Data depicted that maximum fresh weight (0.30 mg) of parthenium seedling was observed with the application of *Adiantum capillus* extract which was non-significantly different from all other treatments including control. Our results are supported by Javaid and Shah (2007) who reported that parthenium seedling biomass was not significantly affected by the application of leaf aqueous extract of *Eucalyptus citriodora* Hook and *Eucalyptus camaldulensis* Dehnh.

### Shoot length (cm)

Data regarding shoot length of parthenium as influenced by *Adiantum capillus-veneris*,

*Parthenium hysterophorus* and *Sisymbrium orientale* is presented in table 2. Shoot length of parthenium was significantly influenced by aqueous extracts. Among all treatments, the water extract of *Sisymbrium orientale* produced minimal shoot length (3.83 cm) of parthenium weed while maximum shoot length (7.30 cm) was recorded by application of *Adiantum capillus* aqueous extract. Our observations are supported by Sanderson et al. (2013) who reported that leaves extract of jatropha at 15% concentration significantly suppressed the germination and growth of radicular and aerial part of the lettuce plant.

### Root length (cm)

Data regarding impact of foliar application of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on root length of parthenium was significant (table 2). Data depicted that

maximum root length (5.59 cm) was measured when *Sisymbrium orientale* extract was applied while minimum root length (5.02 cm) was recorded when seedlings were treated with control. These results are contradictory with the findings of Javaid et al. (2010) who reported that foliar application of *Alstonia scholaris* extract significantly reduced root length of parthenium.

#### Dry weight (mg)

There was statistically non-significantly ( $P \leq 0.05$ ) effect of foliar spray of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium*

*hysterophorus* and *Sisymbrium orientale* on parthenium seedling dry weight (Table 2). Data showed that maximum dry weight (0.063 mg) of parthenium seedling was recorded with the application of *Adiantum capillus-veneris* extract. These results are in similar with the findings of Javaid and Shah (2007) who reported that foliar application of aqueous leaf extracts of *Eucalyptus citriodora* Hook and *Eucalyptus camaldulensis* Dehnh had non-significant effect on dry weight of parthenium seedling.

**Table 2: Phytotoxic effect of different weed extracts on fresh weight (mg), shoot length (cm), root length (cm) and dry weight (mg) of parthenium seedling**

Treatments	Fresh weight (mg)	Shoot length (cm)	Root length (cm)	Dry weight (mg)
Control	0.228	5.27 b	5.025 b	0.044
<i>Adiantum capillus extract</i>	0.302	7.30 a	5.198 ab	0.063
<i>Parthenium hysterophorus extract</i>	0.219	4.89 bc	5.458 ab	0.043
<i>Sisymbrium orientale extract</i>	0.208	3.83 c	5.593 a	0.050
HSD (0.05)	NS	1.43	0.499	NS

#### Phytotoxic effect of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on seedling growth of *Trianthema partulacastrum*

##### Leaf area (mm<sup>2</sup>)

Leaf area of *Trianthema partulacastrum* seedling was significantly influenced by the application of water extracts of entire plant of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* (Table 3). The application of *Parthenium hysterophorus* extract produced *Trianthema partulacastrum* seedling with maximum leaf area (43.92 mm<sup>2</sup>) while control treatment and application of *Adiantum capillus-veneris* extract resulted in minimal leaf area (23.45 and 24.25 mm<sup>2</sup>) of *Trianthema partulacastrum*. These results are supported by Oyerinde et al. (2009) who found that application of fresh shoot aqueous extract of *Tithona diversifolia* significantly increased leaf area of maize plants.

##### Leaf chlorophyll content

Leaf chlorophyll content of *Trianthema partulacastrum* seedling was significantly influenced by the application of *Adiantum*

*capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* (Table 3). Maximum (28.55) chlorophyll content was observed when distilled water was applied while minimum leaf chlorophyll content (26.90) was observed when *Parthenium hysterophorus* extract was applied. The results are supported by Khaliq et al. (2012) who reported that foliar spray of wheat straw extract on horse purslane inhibited its seedling growth and chlorophyll contents.

##### Electrolyte leakage (%)

Foliar spray of water extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* significantly affected the electrolyte leakage of *Trianthema partulacastrum* (Table 3). Highest electrolyte leakage (43.92 %) was observed when water extract of *Parthenium hysterophorus* was applied while minimum electrolyte leakage (23.46 %) was noted with control treatment. Our observations are supported by Joanna et al. (2016) who reported that foliar application of aqueous extract of *Galium aparine* L. increased the electrolyte leakage of *Zea mays* L. seedlings as compared to control.

**Table 3: Phytotoxic effect of different weed extracts on leaf area (mm<sup>2</sup>), chlorophyll content (Spad) and electrolyte leakage (%) of *Trianthema partulacastrum* seedling**

Treatments	Leaf area (mm <sup>2</sup> )	Chlorophyll content (SPAD)	Electrolyte leakage (%)
Control	23.45 c	28.55 a	23.46 c
<i>Adiantum capillus extract</i>	24.25 c	26.92 b	24.25 c
<i>Parthenium hysterophorus extract</i>	43.92 a	26.90 b	43.92 a
<i>Sisymbrium orientale extract</i>	40.31 b	26.91 b	40.31 b
HSD (0.05)	2.42	1.54	2.52

**Fresh weight (mg)**

The foliar application of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* had a non-significant effect on fresh weight of *Trianthema partulacastrum* seedlings (Table 4). Data showed that the maximum fresh weight (0.16 mg) was observed in those seedlings where distilled water was applied while minimum fresh weight (0.12 mg) was noted with exogeneous application of aqueous extract of *Sisymbrium orientale*. Our results are similar with the findings of Javaid and Shah (2007) who reported that aqueous leaf extract of *Eucalyptus citriodora* Hook and *Eucalyptus camaldulensis* Dehnh caused a non-significant effect on seedling biomass of parthenium plants.

**Shoot length (cm)**

The foliar application of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* had a significantly effect on shoot length of *Trianthema partulacastrum* seedlings (Table 4). Among different treatments, the aqueous extract of *Parthenium hysterophorus* resulted in lowest shoot length (2.05 cm) of *Trianthema partulacastrum* seedling while maximum shoot length (2.38cm) was found in control treatment. These results are not in accordance with Jiang (2015), who found that the water extract at 60 g/L of onion bulbs decreased the cotton shoot length.

**Root length (cm)**

Significant effect of foliar spray of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on root length of *Trianthema partulacastrum* seedling is presented in table 4. The indicated that maximum root length (2.53 cm) was recorded under control treatment which was statistically similar with aqueous extracts of *Adiantum capillus-veneris* and *Parthenium hysterophorus* while minimum root length (2.10 cm) was noted with the foliar application of aqueous extract of *Sisymbrium orientale*. Our results are supported by Javaid (2009) who observed that application of aqueous extracts of *Datura alba* and *Withania somnifera* decreased shoot length (62%), root length (96%) and seedlings weight (68%) of *Rumex dentatus*.

**Dry weight (mg)**

Data regarding the effect of foliar spray of aqueous extracts of *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on dry weight of *Trianthema partulacastrum* seedling was non-significant (table 4). Maximum dry weight (0.0231 mg) was recorded with the application of distilled water while *Sisymbrium orientale* extract produced minimum dry weight (0.0084 mg). Our results are supported by Javaid and Shah (2007) who observed a non-significant effect of aqueous extract of *Eucalyptus citriodora* Hook and *Eucalyptus camaldulensis* Dehnh on parthenium seedling biomass.

**Table 4: Phytotoxic effect of different weed extracts on fresh weight (mg), shoot length (cm), root length (cm) and dry weight (mg) of *Trianthema partulacastrum* seedling**

Treatments	Fresh weight (mg)	Shoot length (cm)	Root length (cm)	Dry weight (mg)
Control	0.1658	2.38 a	2.5375 a	0.0231
<i>Adiantum capillus extract</i>	0.1388	2.37 ab	2.3850 a	0.0201
<i>Parthenium hysterophorus extract</i>	0.1533	2.05 c	2.4850 a	0.0193
<i>Sisymbrium orientale extract</i>	0.1255	2.07 bc	2.1000 b	0.0084
HSD (0.05)	NS	0.31	0.222	NS

### CONCLUSION

This work represents the allelopathic activity of three plant species namely *Adiantum capillus-veneris*, *Parthenium hysterophorus* and *Sisymbrium orientale* on seedling growth of two weeds (*Parthenium hysterophorus* and *trianthema portulacastrum*). The data of our experiment lead to conclude that *S. orientale* extract have comparatively more active substances with ability to suppress germination and growth of weeds which could be exploited as prospective source of bio-herbicides. Further field based research is needed to investigate the effect of abiotic and biotic factors on the allelopathic potential of *S. orientale*.

### REFERENCES

- Al-Samarai, G. F., Mahdi, W. M., & Al-Hilali, B. M. (2018). Reducing environmental pollution by chemical herbicides using natural plant derivatives–allelopathy effect. *Annals of Agricultural and Environmental Medicine*, 25(3), 449-452.
- Aziz, A., Akhtar, N., Asif, M., Ashraf, M., Bhatti, M. A., Majeed M. Z., Adnan M., Ali K., & Munawar, A. (2020). Phytoregulatory effects of foliar applied aqueous extracts of three weed species on seedling growth of barley, mustard and sesame. *Journal of Environment and Agriculture*, 5(2), 468-475.
- Gawronska, H., & Golisz, A. (2006). Allelopathy and biotic stresses. In *Allelopathy* (pp. 211-227). Springer, Dordrecht.
- Hayyat, M. S., Adnan, M., Asif, M., Abbas, B., Khan, S., Ullah, S., Khan, M. A. B., Abbas, M., Hanif, M. S., Toor, M. D., & Rahman, Z. U. (2020). Allelopathy of waste-land weeds: A review. *International Journal of Botany Studies* 5(3), 97-102.
- Heap, I. The International Survey of Herbicide Resistant Weeds. <http://weedsociety.org/>, Accessed date: 31 August 2018.
- Jabran, K., Mahajan, G., Sardana, V., & Chauhan, B. S. (2015). Allelopathy for weed control in agricultural systems. *Crop protection*, 72, 57-65.
- Javaid, A., & Anjum, T. (2006). Control of *Parthenium hysterophorus* L., by aqueous extracts of allelopathic grasses. *Pakistan Journal of Botany*, 38(1), 139-149.
- Javaid, A., & Shah, M. B. M. (2007). Phytotoxic effects of aqueous leaf extracts of two *Eucalyptus* spp. against *Parthenium hysterophorus* L. *Science International-Lahore* 19(4), 303-313.
- Javaid, A., Shafique, S., & Shafique, S. (2010). Herbicidal effects of extracts and residue incorporation of *Datura metel* against parthenium weed. *Natural product research*, 24(15), 1426-1437.
- Joanna, P. U. Ł. A., Barabasz-Krasny, B., Mozdzen, K., SOŁTYS-LELEK, A., & Lepiarczyk, A. (2016). Effect of aqueous extracts of Sticky willy (*Galium aparine* L.) on the growth of seedlings of selected maize varieties (*Zea mays* L.). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 44(2), 518-524.
- Kaur, M., & NK, A. (2017). *Trianthema portulacastrum* L.-the noxious weed and its control. *Adv Plants Agric Res*, 6(3), 62-64.
- Khalik, A., Matloob, A., Aslam, F., Mushtaq, M. N., & Khan, M. B. (2012). Toxic action of aqueous wheat straw extract on horse purslane. *Planta Daninha*, 30(2), 269-278.
- Khalik, A., Matloob, A., Khan, M. B., & Tanveer, A. (2013). Differential suppression of rice weeds by allelopathic plant aqueous extracts. *Planta daninha*, 31(1), 21-28.
- Kolhe, S. S., Choubey, N. K., & Tripathi, R. S. (1998). Evaluation of fenoxaprop-P-ethyl and lactofen in soybean. *Indian Journal of Weed Science*, 30(3/4), 216-217.

- Oyerinde, R. O., Otusanya, O. O., & Akpor, O. B. (2009). Allelopathic effect of *Tithonia diversifolia* on the germination, growth and chlorophyll contents of maize (*Zea mays* L.). *Scientific Research and Essays*, 4(12), 1553-1558.
- Peng, S. B., Garcia, F. V., Laza, R. C., & Cassman, K. G. (1993). Adjustment for specific leaf weight improves chlorophyll meter's estimate of rice leaf nitrogen content. *Agronomy Journal* 85(5), 987-990.
- Powles, S. B., & Yu, Q. (2010). Evolution in action: plants resistant to herbicides. *Annual review of plant biology*, 61, 317-347.
- Sanderson, K., Bariccatti, R. A., Primieri, C., Viana, O. H., Viecelli, C. A., & Junior, H. G. B. (2013). Allelopathic influence of the aqueous extract of *Jatropha* on lettuce (*Lactuca sativa* var. Grand Rapids) germination and development. *Journal of Food, Agriculture and Environment*, 11(1), 641-643.
- Shabbir, A., Rehman, A., & Weyl, P. (2018). Prospects of classical biological control of weeds in Pakistan: challenges and opportunities. In *Proceedings of the XV International Symposium on Biological Control of Weeds, Engelberg, Switzerland, 26-31 August 2018*. (pp. 63-67). Organising Committee, XV International Symposium on Biological Control of Weeds 2018.
- Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G. P. S., Handa, N., & Thukral, A. K. (2019). Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Sciences*, 1(11), 1-16.
- Skrzypek, E., Repka, P., Stachurska-Swakon, A., Barabasz-Krasny, B., & Mozdzen, K. (2015). Allelopathic effect of aqueous extracts from the leaves of peppermint (*Mentha piperita* L.) on selected physiological processes of common sunflower (*Helianthus annuus* L.). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 43(2), 335-342.
- Steel, R. G., & Torrie, J. H. (1986). *Principles and procedures of statistics: a biometrical approach*. McGraw-Hill.
- Westwood, J. H., Charudattan, R., Duke, S. O., Fennimore, S. A., Marrone, P., Slaughter, D. C., & Zollinger, R. (2018). Weed management in 2050: Perspectives on the future of weed science. *Weed science*, 66(3), 275-285.
- Whitlow, T. H., Bassuk, N. L., Ranney, T. G., & Reichert, D. L. (1992). An improved method for using electrolyte leakage to assess membrane competence in plant tissues. *Plant Physiology*, 98(1), 198-205.
- Yaduraju, N. T., Sharma, A. R., & Rao, A. N. (2015). Weeds in Indian Agriculture: Problems and prospects to become self-sufficient. *Indian farming*, 65(07), 02-06.
- Yu, G., Jiang, Y., Xu, L., & Li, G. Y. (2015). Multi-objective energy-efficient resource allocation for multi-RAT heterogeneous networks. *IEEE Journal on Selected Areas in Communications*, 33(10), 2118-2127.