Pure Appl. Biol., 12(1):3365-377, March, 2023
http://dx.doi.org/10.19045/bspab.2023.120039

Research Article

Effect of leaf aqueous extracts of acacia, brassica, eucalyptus and sorghum on germination and growth of *Avena fatua* L. and *Phalaris minor* Retz.

Muhammad Ayaz Shahzad[1*], Rana Muhammad Ikram[1], Muhammad Aslam[1], Muhammad Roman[2], Jaffar Iqbal[3] and Ali Raza Shah[4]
1. University College of Agriculture & Environmental Science, The Islamia University of Bahawalpur, Pakistan
2. College of Plant Science and Technology, Huazhong Agricultural University, China
3. School of Soil and Water Conservation, Beijing Forestry University, China
4. Department of Horticulture, Sindh Agriculture University, Tandojam, Pakistan
**Corresponding author's email:* raoayaz999@gmail.com

Citation
Muhammad Ayaz Shahzad, Rana Muhammad Ikram, Muhammad Aslam, Muhammad Roman, Jaffar Iqbal and Ali Raza Shah. Effect of leaf aqueous extracts of acacia, brassica, eucalyptus and sorghum on germination and growth of *Avena fatua* L. and *Phalaris minor* Retz. Pure and Applied Biology. Vol. 12, Issue 1, pp365-377. http://dx.doi.org/10.19045/bspab.2023.120039

Received: 11/08/2022 Revised: 15/10/2022 Accepted: 25/10/2022 Online First: 05/11/2022

Abstract

The aggrieving unhealthy consequences of manmade chemicals towards environment have left no option for researchers to detect and develop the weed suppressant which may be more close to nature. Nature has bestowed the plants with inhibitory chemicals, name as "allelochemicals", acknowledged to deter the nourishment of nearby organisms. So, keeping the environmental hazards of herbicides in view to save the environment, the present study is designed to observe the allelopathic effect of plant species, i.e. *Acacia nilotica* L., *Brassica napus* L., *Eucalyptus camaldulensis* L. and *Sorghum bicolor* L. against narrow leaf weeds i.e. *Avena fatua* L. and *Phalaris minor* Retz. of winter season in Pakistan. Different concentrations (1%, 2%, 3%, 4% and 5%) of above mentioned allelopathic plant species were tested in the form of aqueous leaf extracts for germination and seedling growth along with its related attributes of the weeds, in laboratory conditions in Completely Randomized Design (CRD). Result revealed that except 1% of *A. nilotica* L., leaf aqueous extracts of *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. affected the germination and related attributes at significant level. Maximum obstruction towards *Avena fatua* L. and *Phalaris minor* Retz. was noted in case of 5% of *B. napus* L. along with *S. bicolor* L., those inhibited the germination and seedling development of the weed completely.

Keywords: Acacia; Allelopathy; Brassica; Eucalyptus; Little seed canary grass; Sorghum; Wild oat

Introduction

Weeds are naturally sprouted, but unwanted plants, which curtail the production of different crops drastically. Soybean production is believed to be lessened by 27-84% because of weeds, based on the severity of the interference, including the weed intensity and interval of competition with the crop [1]. Weeds substantially reduce plant productive potential and have negative effects on plant growth. Weeds and plants compete for resources necessary for plant growth, such as nutrients, water, light, and space. As a result, crops' productivity is reduced [2]. Crop productivity is reduced by a large number of weeds that are present. Different weed species are associated with differing levels of competitive ability, and they compete in certain environments [3].

Avena fatua L. and *Phalaris minor* Retz. are unavoidable weeds of the winter season in Pakistan which grievously threaten the persistence and potential of crops [4]. The weed, *Avena fatua* L. is famous for its allelopathic attributes, which are depicted by the release of deleterious chemicals, which subdue the normal nourishment pattern of targeted species. Based on the facts, this weed has been ranked as the top-most hazard for the cropping system of under-developed states i.e Pakistan, where its dominant distribution throughout the country has ranked it as the most intimidating weed [5].

Phalaris minor Retz., the most troublesome weed of wheat crop has developed resistance against the herbicide (isoprotoron), in India. The subsequent usage of weedicides, especially with the parallel behavior, has been the prime factor contributing to the rapid adaptation of resistance against herbicides [6]. Similarly, [7]. outlined that *P. minor* Retz. is a concerning and native weed specie in India, expanding towards the fields, irrespective of the cropping pattern. For effective control of weeds, allelopathy is recognized as an ecofriendly, sustainable strategy and mostly it involves material of farm production [8]. Different crops have phytotoxic abilities in their different parts, including stems, roots, seeds, flowers, and leaves in various concentrations [9]. A range of crop plants, possessing identical and unidentical allelopathic attributes, including brassica, mulberry, sorghum, rice, moringa, acacia, sesame, sunflower, and tobacco are being utilized, by the matter of choice, to abridge the deleterious weeds from arable lands [10, 4].

Alike to other plant species, acacia also pose threats to the nourishment of underneath, treated, or target species having the rivalry for nature-provided and human-supplied inputs. Moreover, its allelopathic litter disturbs the establishment and growth of other plants, when applied deliberately or happened naturally [11]. The released deleterious chemicals include phenolic compounds, which behave as novel exudates to reduce other plants' invasiveness' and act as growth stimulatory agents (for crop plants) when applied intentionally and in controlled concentrations [12]. Similarly, [13]. report ed that canola (*Brassica napus* L.) inhibits the germination, growth, length, and dry matter of weeds and crop seedlings including soybean (*Glycine max* L). Glucosinolates are exudates exhibited by the associates of the Brassicaceae family, which are brought about as auxiliary metabolites and prevailed in the leaves and roots of *Brassica napus* L. to a remarkable extend [14]. At the next step, the myrosinase enzyme degrades these metabolites into diversified molecules (isothiocyanate and nitrile) having certain allelopathic behavior [15].

The drastic effect of Eucalyptus species is well researched, acknowledged, and admired against other crops [16]. Alike to numerous tree species leaves, bark, and roots of *E. camaldulensis* L. retain and part specific phenolics compounds and volatile oils that bring allelopathic effects on the plants, growing nearby [17]. Among the researched 16 associates of *E. camaldulensis* L. essential oil, five (p-cymene, 1-8 cineole, β -phellandrene, 3Δ -carene, andα -pinene), possess grievous allelopathic features. The well-observed allelopathic behavior of eucalyptus can actively be used as nature tailored and ecofriendly tactic for meaningful weed management [18].

Leaf exudates of eucalyptus have been reported to remarkably curtail the germination and seedling development of cucumbers [19]. Similarly, the leachates of *Eucalyptus globules* L. were detected to obstruct the nourishment of *Oryza Sativa* L., *Vigna radiata* L., and *S. bicolor* L. [20]. *E. camaldulensis* L. has also been proved allelopathic towards *Solanum lycopersicum* L. where remarkable reduction in sprouting along with the growth of plumule and redical is reported [21]. *Sorghum* *bicolor* L. and *Helianthus annus* L. are recognized allelopathic crops, which retain numerous allelochemicals that are destructive toward weeds **[4]**. *Sorghum bicolor* L. is reputed for the allelopathic attributes, which it poses toward other crop plants. Fully grown and approximate to harvest sorghum plants possess nine inhibitory allelochemicals, towards the sprouting and blooming of the weeds i.e. Bathu, little seed canary grass, toothed dock, and lehli.

The present study is focused on the allelopathic behavior of *Acacia nilotica* L., *Brassica napus* L., *Eucalyptus camaldulensis* L., and *Sorghum bicolor* L. against the germination and seedling growth of *Avena fatua* L. and *Phalaris minor* Retz., with the possible supposition that these allelopathic plant species will stunt the germination and reduce the growth of mentioned weed species.

Materials and Methods

The study was carried out in the laboratory of the Department of Agronomy, University College of Agriculture and Environmental Sciences (UCA & ES), The Islamia University of Bahawalpur, (Pakistan) in 2019. The fresh leaves of *S. bicolor* L. and *B. napus* L. were randomly collected from healthy plants at Agronomic Research Area of The Islamia University of Bahawalpur. *A. nilotica* L. and *E. camaldulensis* L. leaves were collected from the botanical garden of the University. The seeds of *A. fatua* L and *P. minors* Retz. were collected from "Ayyub Agricultural Research Institute Faisalabad".

The collected leaves of mentioned test species were washed with distilled water to remove dust particles. The leaves were later dried with blotting paper, powdered and then mixed with distilled water at the ratio of 1:10 to prepare stock solution of 10% concentration. To obtain this, 10 g of dry material (powdered) of each test specie was mixed in 100 ml of distilled water for 36 hours at 25 C **[22]**. The solution was filtered and further diluted to obtain 1%, 2%, 3%, 4% and 5% using parallel dilution technique. Randomly selected 10 healthy seeds of *A. fatua* L. and *P. minor* Retz. were sterilized with 5% sodium hypochlorite solution for five minutes and later kept on Whattman No. 10 filter paper moistened with aqueous extracts (4 ml) of Acacia (*Acacia nilotica* L.), Brassica (*Brassica napus* L.), Eucalyptus (*Eucalyptus camaldulensis* L.) and Sorghum (*Sorghum bicolor* L.) in covered and sterilized 9 cm petri dishes. The distilled water was used in control treatments. The experiment was laid out in completely randomized design (CRD) with three repeats. The data was collected daily for 10 days and at the end of this period regarding final germination (%), mean germination time (days), time to 50% germination (days), promptness index, emergence index, germination energy, seedling length (cm), seed vigor index, seedling fresh weight (g) and seedling dry weight (g). The collected data was analyzed statistically by using Fisher‘s Analysis of Variance Techniques and Least Significantly Difference (LSD) test at 5% probability level was applied to compare the treatment means **[23]**.

Results

It is observed, by the data, regarding the effect of leaf aqueous extract of *A. nilotica* L., *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. in different concentrations on germination of *A. fatua* L. and *Phalaris minor* Retz., is presented in (Fig. 1). Data indicates that except 1% of *A. nilotica* L., all the tested concentrations of all the tested species decreased the germination percentage of *A. fatua* L. and *P. minor* Retz. significantly, when equated with control. Leaf aqueous extract of 1% concentration of *A. nilotica* L. had non-significant effect on germination percentage of both weeds. Furthermore, germination percentage of the weed species was found gradually decreasing with increasing concentrations of the test species. Maximum germination % age of *A. fatua* L. (93.33%) and *P. minor* Retz. (83.333%) was spotted in case of control (where only distilled water was applied) and it was significantly similar to

1% concentrations of *A. nilotica* L. Lowest germination (6.667%) was found when *A. fatua* L. was treated with the highest concentration (5%) of *B. napus* L. and *S. bicolor* L. similarly, lowest germination (6.667%) was found when *P. minor* Retz. was treated with the highest concentration (5%) of *B. napus* L.

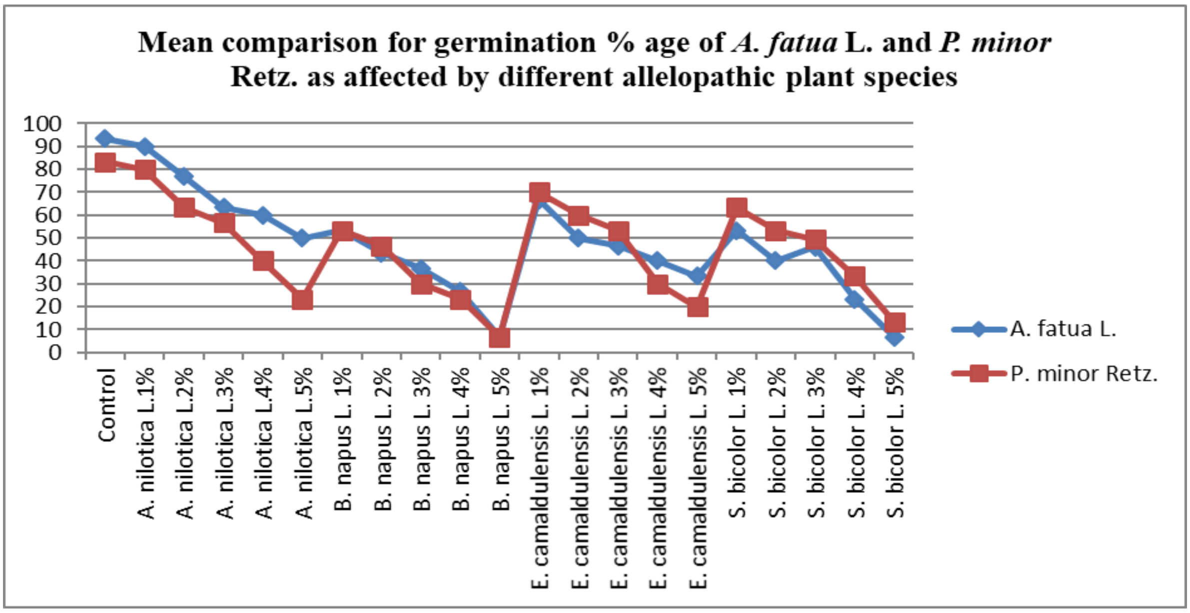

Figure 1: Effect of germination % age of *A. fatua L.* and *P. minor* Retz affected by different allelopathic plant species

Data regarding the effect of leaf aqueous extract of *A. nilotica* L., *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. in different concentrations on promptness index (PI) of *A. fatua* L. and *Phalaris minor* Retz., is presented in (Fig. 2). Data indicates that except 1% and 2% of *A. nilotica* L. and 1% of *P. minor* Retz., all the tested concentrations of the tested species decreased PI of *A. fatua* L. significantly, when equated with control. Furthermore, promptness index of the weed specie was found gradually decreasing with increasing concentrations of the test species. Highest promptness index of *A. fatua* L. (2.2500) and *P. minor* Retz. (2.5000) was observed in case of control and 1% of *A. nilotica* L. respectively. It was significantly resembled to the treatments where leaf aqueous extracts of 1% and 2% concentrations of *A. nilotica* L was used. Lowest PI (0.0833) was found when *A. fatua* L. was treated with the leaf aqueous extract containing maximum concentration (5%) of *B. napus* L. and *S. bicolor* L. similarly, lowest PI (0.0833) was found when *P. minor* Retz. was treated with the leaf aqueous extract containing top most concentration (5%) of *B. napus* L.

Data regarding the effect of leaf aqueous extract of *A. nilotica* L., *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. in different concentrations on MET of *A. fatua* L. and *P. minor* Retz., is presented in (Fig. 3). Data indicates that except 1% and 2% of *A. nilotica* L. (along with 1% of *E. camaldulensis* L. in case of *P. minor* Retz.) all the tested concentrations of the tested species increased the MET of both the weeds significantly, when equated with control. Furthermore, MET of the weed specie was found gradually increasing with increasing concentrations of the test species. Lowest MET of *A. fatua* L. (2.1499 days) and *P. minor* Retz. (1.9530 days) was observed in case of control and it resembled significantly to the treatments where leaf aqueous extracts of 1% and 2% concentrations of *A. nilotica* L. (along with 1% of *E. camaldulensis* L. in case of *P.*

minor Retz.) were used. Highest MET of *A. fatua* L. and *P. minor* Retz. (6.6667 days) and (7.0085 days) was found when *A. fatua* L. was treated with the leaf aqueous extract containing top most concentration (5%) of *B. napus* L.and (5%) of *S. bicolor* L. respectively.

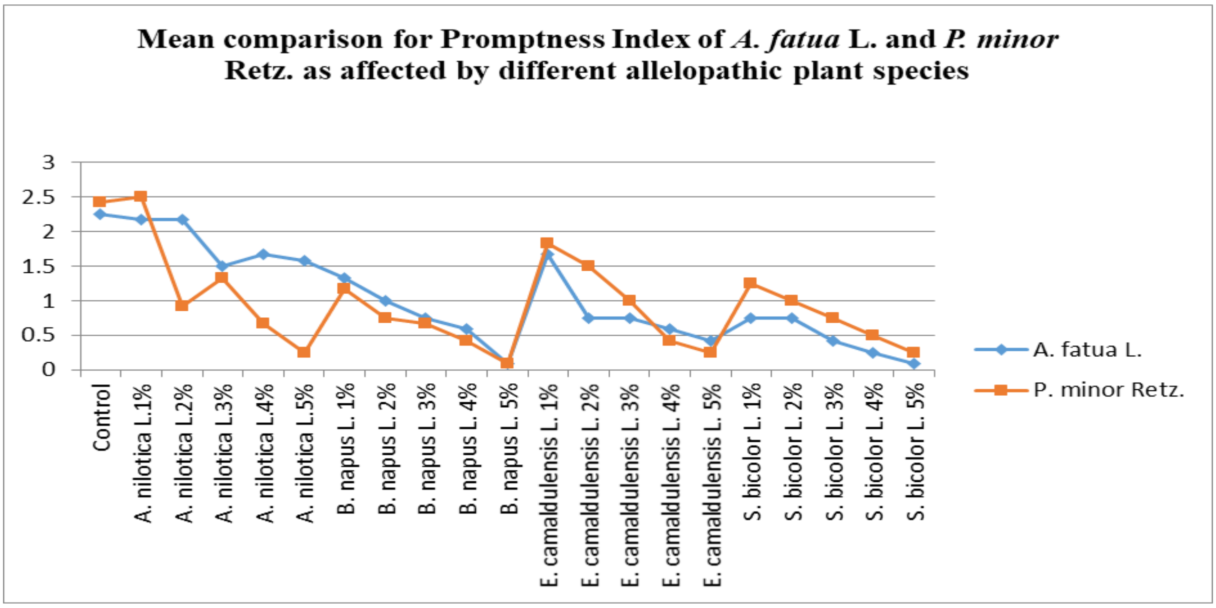

Figure 2: Effect of Promptness Index of *A. fatua L*. and *P. minor* Retz affected by different allelopathic plant species

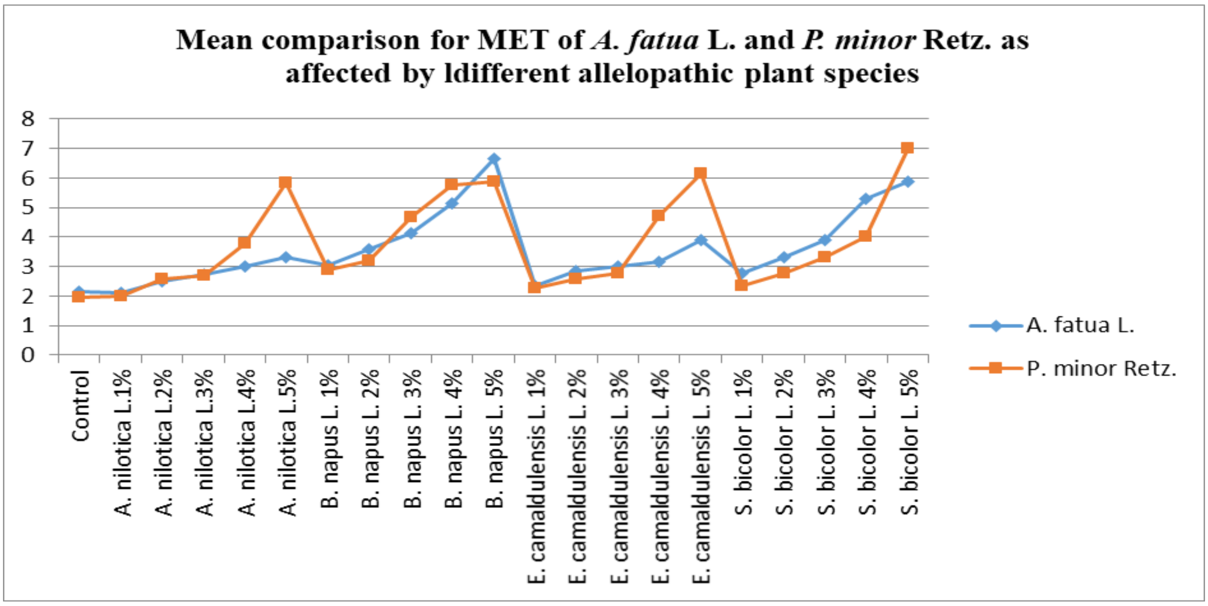

Figure 3: Effect of MET of A. *fatua L*. and *P. minor* Retz affected by different allelopathic plant species

Data regarding the effect of leaf aqueous extract of *A. nilotica* L., *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. in different concentrations on emergence index of *A. fatua* L. and *P. minor* Retz., is presented in (Fig. 4). Data indicates that except 1% of *A. nilotica* L., all the tested concentrations of all the tested species decreased the emergence index of *A. fatua* L. and *P. minor* Retz. significantly, when equated with control. Leaf aqueous extract of 1% concentration of *A. nilotica* L. had non-significant effect upon emergence index of both the weeds. Furthermore, emergence index of the weed specie was found gradually decreasing with increasing concentrations of the test species. Maximum emergence index of *A. fatua* L. (2.0933) and *P. minor* Retz. (1.4631) was observed in case of control and it was significantly parallel to the treatment, where leaf aqueous extract of 1% concentration of *A. nilotica* L was used. Lowest emergence index (0.0787) was found when *A. fatua* L. was treated with the highest concentration (5%) of *S. bicolor* L., which was significantly resembled to the highest concentration (5%) of *B. napus* L. whereas least emergence index (0.0787) was found when *P. minor* Retz. treated with the highest concentration (5%) of *E. camaldulensis* L.

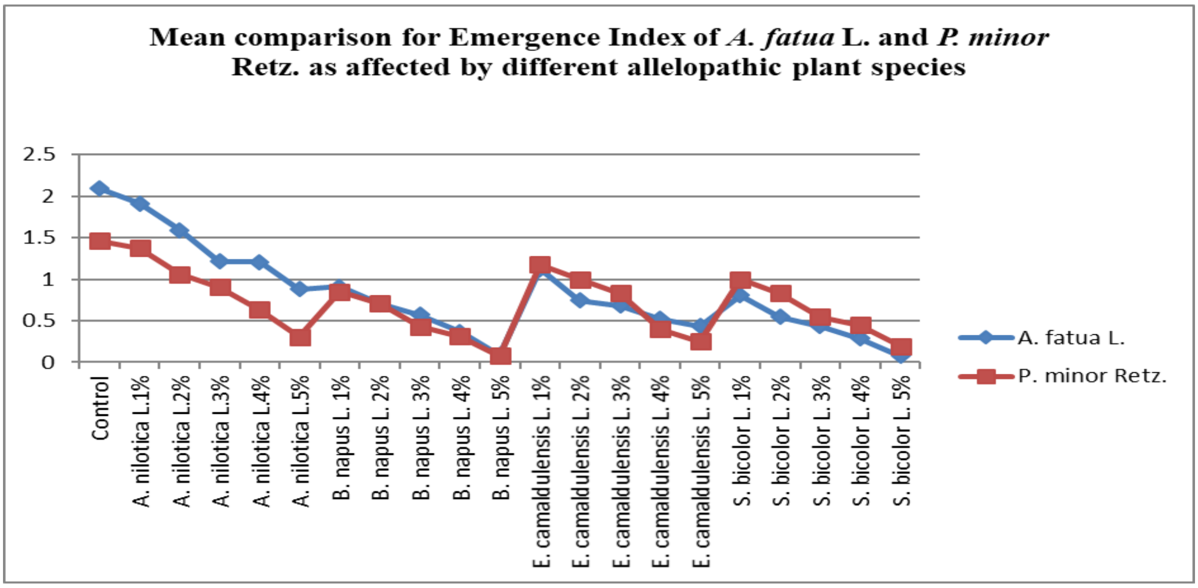

Figure 4: Effect of emergence Index of *A. fatua L.* and *P. minor* Retz affected by different allelopathic plant species

Data regarding the effect of leaf aqueous extract of *A. nilotica* L., *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. in different concentrations on seedling length of *A. fatua* L. and *P. minor* Retz., is presented in (Fig. 5). Data indicates that except 1% of *A. nilotica* L., all the tested concentrations of all the tested species decreased the seedling length of *A. fatua* L. and *P. minor* Retz. significantly, when equated with control. Leaf aqueous extract of 1% concentration of *A. nilotica* L. had non-significant effect upon seedling length of both the weeds. Furthermore, seedling length was found to be decreased gradually with increasing concentrations in leaf aqueous extracts. Maximum seedling length of *A. fatua* L. (7.4667 cm) and *P. minor* Retz. (6.6667 cm) was observed in case of control and it was significantly parallel to the treatment, where leaf aqueous extract of 1% concentration of *A. nilotica* L was used. Lowest seedling length (0.3000 cm) was found when *A. fatua* L. was treated with the highest concentration (5%) of *S. bicolor* L. whereas the lowest seedling length (0.47333 cm) was found when *P. minor* Retz. was treated with the highest concentration (5%) of *B. napus* L.

Data regarding the effect of leaf aqueous extract of *A. nilotica* L., *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. in different concentrations on seed vigor index (SVI) of *A. fatua* L. and *P. minor* Retz., is presented in (Fig. 6). Data indicates that except 1% of *A. nilotica* L., all the tested concentrations of all the tested species decreased the SVI of *A. fatua* L. and *P. minor* Retz., significantly, when equated with control. Leaf aqueous extract of 1% concentration of *A. nilotica* L. had non-significant effect upon SVI of *A. fatua* L.

Pure Appl. Biol., 12(1):3365-377, March, 2023
http://dx.doi.org/10.19045/bspab.2023.120039

Furthermore, SVI was found to be decreased gradually with increasing concentrations in leaf aqueous extracts. Highest SVI (699.33) and (557.33) was observed in case of control and it was significantly similar to the treatment where leaf aqueous extract of 1% concentration of *A. nilotica* L was used. Lowest SVI (6.00) was found when *A. fatua* L. was treated with highest concentration (5%) of *S. bicolor* L. and lowest SVI (9.47) was found when *P. minor* Retz. was treated with the highest concentration (5%) of *B. napus* L.

Data regarding the effect of leaf aqueous extract of *A. nilotica* L., *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. in different concentrations on seedling fresh weight of *A. fatua* L. and *P. minor* Retz., is presented in (Fig. 7). Data indicates that except 1% of *A. nilotica* L., all the tested concentrations of all the tested species decreased the seedling fresh weight of *A. fatua* L. and *P. minor* Retz., significantly, when equated with control. Leaf aqueous extract of 1% concentration of *A. nilotica* L. had non-significant effect upon seedling fresh weight of both the weeds. Furthermore, seedling fresh weight was found to be decreased gradually with increasing concentrations in leaf aqueous extracts. Highest average seedling fresh weight of *A. nilotica* L. (1.667 mg) and *P. minor* Retz. (1.0417 mg) was observed in case of control and it was significantly similar to the treatment, where leaf aqueous extract of 1% concentration of *A. nilotica* L was used. Least average seedling fresh weight (0.0469 mg) was found when *A. fatua* L. was treated with the highest concentration (5%) of *S. bicolor* L., whereas the lowest average seedling fresh weight (0.0740 mg) was found when *P. minor* Retz. was treated with the highest concentration (5%) of *B. napus* L.

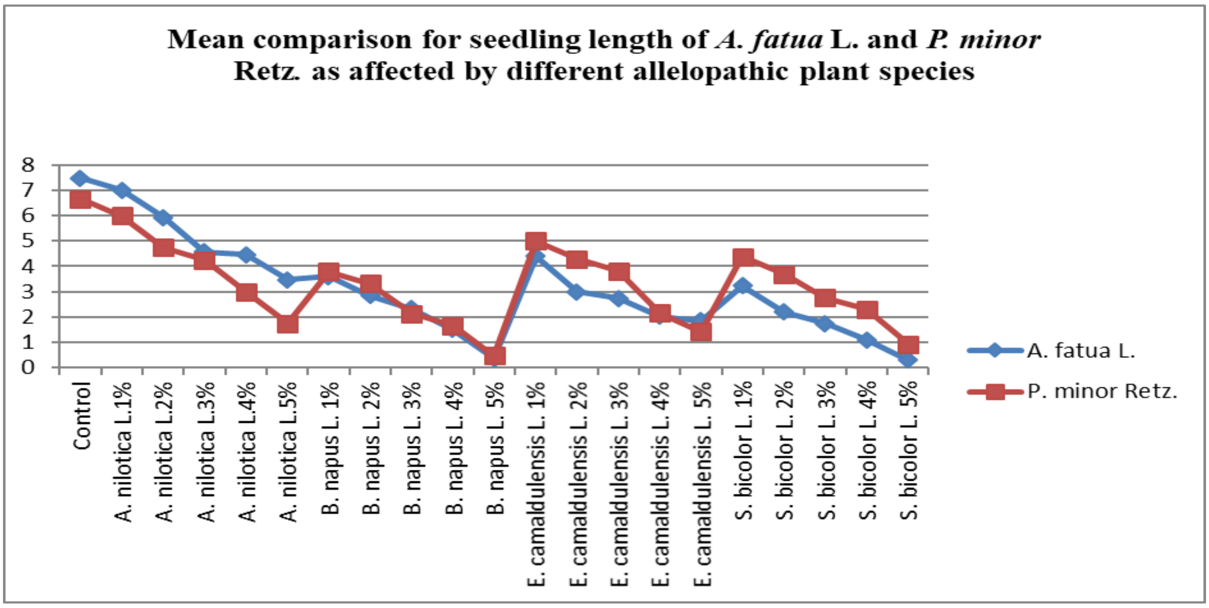

Figure 5: Effect of seedling length of *A. fatua L.* and *P. minor* Retz affected by different allelopathic plant species

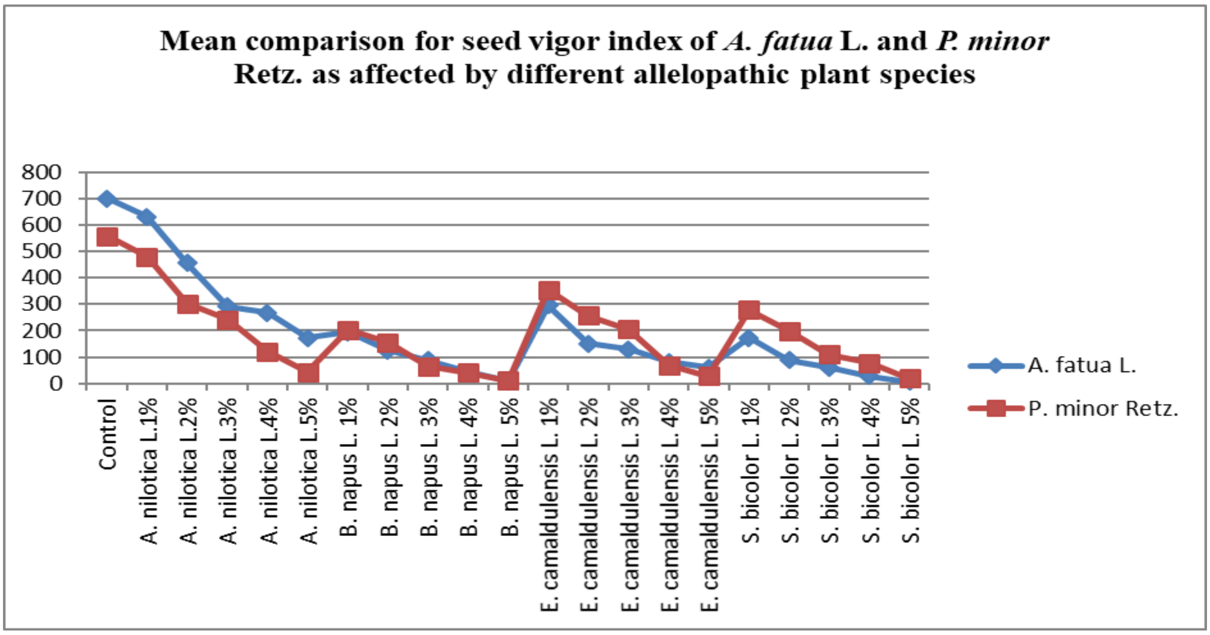

Figure 6: Effect of seed vigor index of *A. fatua L.* and *P. minor* Retz affected by different allelopathic plant species

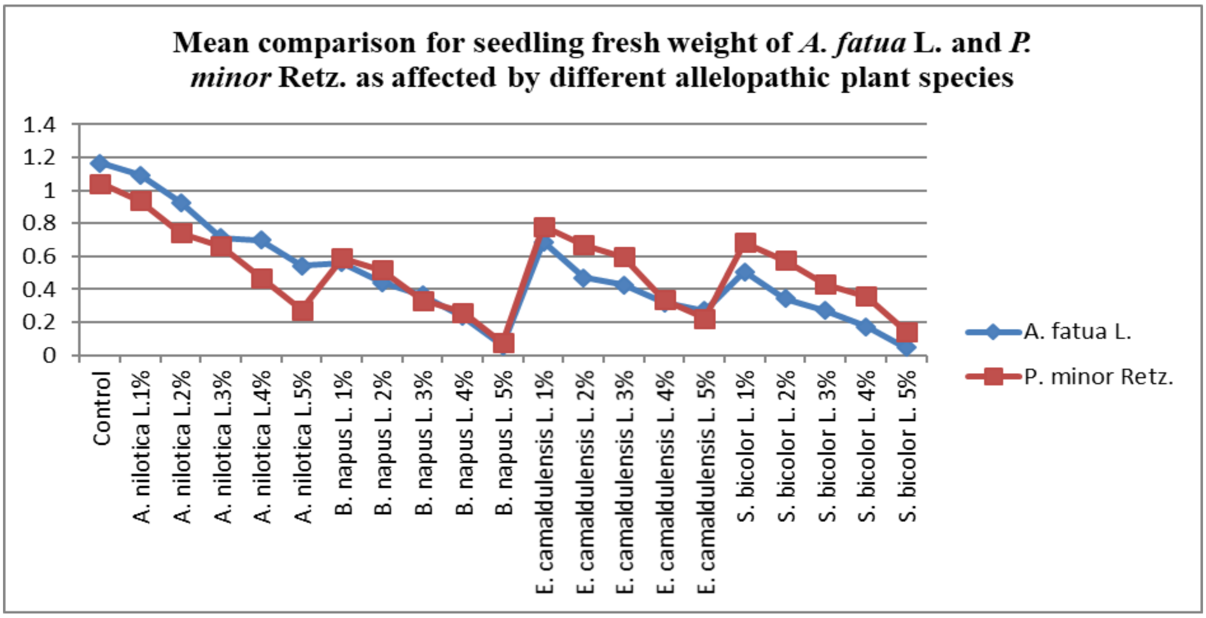

Figure 7: Effect of seedling fresh weight of *A. fatua L.* and *P. minor* Retz affected by different allelopathic plant species

Data regarding the effect of leaf aqueous extract of *A. nilotica* L., *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. in different concentrations on seedling dry weight of *A. fatua* L. and *P. minor* L. is presented in (Fig. 8). Data indicates that except 1% of *A. nilotica* L., all the tested concentrations of all the tested species decreased the seedling dry weight of *A. fatua* L. and *P. minor* Retz., significantly, when equated with control. Leaf aqueous extract of 1% concentration of *A. nilotica* L. had non-significant effect upon seedling dry weight of both the weeds. Furthermore, seedling dry weight was found to be decreased gradually with increasing concentrations in leaf aqueous extracts. Highest average seedling dry weight (0.3555 mg) of *A. fatua* L. and (0.2793 mg) of *P. minor* Retz., was observed in case of control and it was significantly similar to the treatment, where leaf aqueous extract of 1% concentration of *A. nilotica* L was used. Least average seedling dry weight (0.0079 mg) was found when *A. fatua* L. was treated with the highest concentration (5%) of *S. bicolor* L., whereas least average seedling dry weight (0.0113 mg) was found when *P. minor* Retz. was treated with the highest concentration (5%) of *B. napus* L.

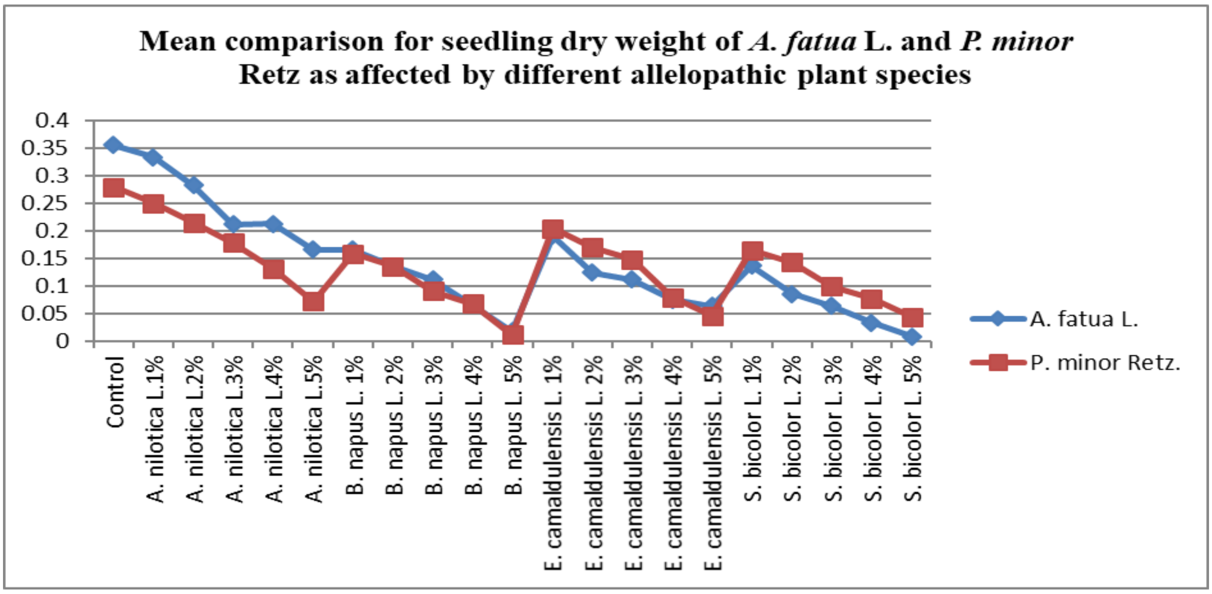

Figure 8: Effect of seedling dry weight of *A. fatua L.* and *P. minor* Retz affected by different allelopathic plant species

Discussion

The plant species, i.e. *Acacia nilotica* L., *Brassica napus* L., *Eucalyptus camaldulensis* L. and *Sorghum bicolor* L. are renowned for their allelopathic potential. This specialty had become the base of this study. The aim was to determine the minimum level of their concentrations against which the germination and growth of *Avena fatua* L. and *Phalaris minor* Retz., may be hindered. Final germination percentage is the overall exhibition of its related parameters like mean germination time, promptness index and emergence index. Similarly, the seedling development which is mainly characterized by seedling length (root and shoot), seed vigor index, seedling fresh weight and seedling dry weight, is an indicator of the capacity of a newly emerged herb to develop into a mature and economically valuable plant. The said parameters were used as the base to assess the tolerance capacity of *A. fatua* L. and *P. minor* Retz., against mentioned allelopathic plant species. Germination % age and all related parameters were found affected significantly against the tested concentrations i.e. 1% to 5% of *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L., when equated with control. The lower concentration i.e. 1% of *A. nilotica* L, did not affect the germination and its related attributes, for the weeds, while other concentrations i.e. 2%, 3%, 4% and 5% of *A. nilotica* L. reduced the germination and related attributes significantly. The reduction in overall germination % age, including the decrease in promptness index, emergence index and mean germination time (days) of *A. fatua* L. and *P. monor* Retz. seeds, when treated with higher concentrations of *Acacia nilotica* L. may because of the tannis, flavonoids and phenolic acids present in it **[24, 25]**. These allelochemicals are involved in the formation and activation of stress proteins which are responsible for the folding, assembling, translocation and degradation of normal cellular processes such as germination and improvement of plant growth along with physiological and molecular characteristics [26, 27]. The inhibition of *A. fatua* L. seeds which is revealed from the present study resemble to the results of [28], who found that the leachates from acacia specie hindered the germination, respiration and photosynthetic activity of *H. hibernica* L. and *D. glomerata* L. Results are also found similar to [29], who reported that the aqueous leaf leachate of acacia species significantly reduced the frequency of seed germination of gram seeds. Brassica species are well known for their allelopathic properties. The leaf aqueous extracts of *B. napus* L. curtailed the germination and related attributes of *A. fatua* L. and *P. minor* Retz., significantly, irrespective of its concentration. The reason behind this hindrance may be the glucosinolates and its breakdown products like isothiocyanates (i.e., allyl-isothiocyanate, Benzyl-isothiocyanate, ionic-thiocyanate) present in Brassica, which are reported to reduce the seed germination and plant growth [15]. The mechanism of breakdown products of glucosinolates is to suppress the protease enzyme activity which results in reduced water uptake and lead to poor seed germination. The results evolved by the study resemble to those of [30]. who found significant reduction in emergence and growth of *Phalaris paradoxa* L. and *Sisymbrium irio* L. weeds due to phytotoxic chemicals present in *Brassica*, [31]. who found reduced germination and growth of horse purslane (*Trianthema portulacastrum* L.) when treated with aqueous extracts of Brassica, [32], who found brassica allelochemicals reducing the germination and growth of weed species, i.e., *Phalaris minor* Retz., *Convolvulus arvensis* L. and *Sorghum halepense* L. *Eucalyptus Camaldulensis* L. is a famous tree species grown in Pakistan is also reported to have allelopathic properties [33]. Some volatile compounds like benzoic, cinnamic and phenolic acids are released by Eucalyptus species which are reported to curtail the growth of weeds and crops present near it [34, 35]. It has been reported by [36] that benzoic acid and cinnamic acid damage cell membrane integrity by a decrease in sulfhydryl groups. The germination inhibition resulted from this very experiment resembled to those of [37], who revealed that the essential oil extracted from leaves of Eucalyptus were inhibitory to *Amaranthus blitoides* L. and *Cynodon dactylon* L. curtailing the germination percentage, germination rate, radicle and plumule length and seedling length. Results also look similar to the results of [38]. who reported that leaf litter extracts *E. camaldulensis* L. significantly inhibit the germination speed of radish and Chinese cabbage and the inhibition increased with increasing concentration. Results also were similar to those of [39]. who studied the allelopathic effect of *Eucalyptus camaldulensis* L. on tomato crop and found that leaf, root, bark and fruit extracts of *E. camaldulensis* L. were inhibitory to germination along with root and shoot elongation of tomato plants. In the past few decades, sorghum has gained attention as major allelopathic crop in agricultural ecosystem. Sorghum is reported to contain Benzoic acid, p-hydroxy benzoic acid, vanillic acid, m-coumaric acid, p-coumaric acid, gallic acid, caffeic acid, ferulic acid and chlorogenic acid which are phytotoxic to weeds [40]. Sorgoleone, a unique hydrophobic p-benzoquinone, isolated from sorghum roots by [41] is reported to suppress the growth of weeds [42]. The inhibitory actions of mentioned allelochemicals is the base of strong allelopathic properties of sorghum. For example, benzoic acid is reported to damage the cell membrane integrity and induce the structural changes in membranes that include alterations in a variety of membrane proteins [43, 44]. Vanillic acid is counted to weaken the oxygen absorption capacity of the plants inhibiting enzymatic activities and reducing the permeability of the seeds [45]. coumaric acids are testified as decreasing agents of cell division at mitosis level, caffeic acid and chlorogenic acid along with other allelochemicals disturb the hydraulic activity and alter the normal water potential [46] and ferulic acid is well known to limit the water utilization [47]. The significant hang-up effects on germination and other related parameters of *A. fatua* L. and *P. minor* Retz. by sorghum leaf aqueous extracts resemble to those of who reported that plant aqueous extracts of sorghum (*Sorghum bicolor* L.) was inhibitory to horse purslane (*Trianthema portulacastrum* L.), jungle rice (*Echinochloa colona* L.), barnyard grass (*E. crus-galli* L.) and purple nutsedge (*Cyperus rotundus* L.). Results also seem alike [48]. to who found that the water extracts of sorghum inhibited the seed germination and its attributes of *Trianthema portulacastrum* L., *Dactyloctenium aegyptium* L. and *Eleusine indica* L. against control (distilled water treatment). The results were also found similar to those of [49] who evaluated the herbicidal effects of aqueous extracts of sorghum (Sorghum bicolor L.) against the germination and found that germination was significantly reduced by the extract.

Conclusion

It is concluded that leaf aqueous extracts of *A. nilotica* L. (except 1%) *B. napus* L., *E. camaldulensis* L. and *S. bicolor* L. can be used as natural herbicides against *Avena fatua* L. and *Phalaris minor* Retz. of winter season in Pakistan. While among the tested crop species, *B. napus* L. and *S. bicolor* L. were crops with most deterring behavior towards weeds. So, different concentrations of mentioned species can be tested against arable crop plants in laboratory, wire-house and field experiments to finally curtail the synthetically prepared herbicides to save the environment.

Authors' contributions

Conceived and designed the experiments: MA Shahzad & AR Shah, Performed the experiments: MA Shahzad & RM Ikram, Analyzed the data: MA Shahzad & M Aslam, Contributed materials/ analysis/ tools: J Iqbal & M Roman, Wrote the paper: MA Shahzad & RM Ikram.

References

1. Kachroo D, Dixit AK & Bali AS (2003). Weed management in oilseed crop-a review. *SKUAST J Res* 2(1): 1-12.
2. Zimdal RL (2018). Fundamentals of weed science (3rd ed). Academic Press, USA.
3. Guglielmini A, Verdu A & Satorre E (2017). Competitive ability of five common weed species in competition with soybean. *Int J Pest Manag* 63(1): 30-36.
4. Jabran K, Cheema ZA, Farooq M, & Hussain M (2010). Lower doses of Pendimethalin mixed with allelopathic crop water extracts for weed management in canola (*Brassica napus*). *Int J Agric Biol* 12(1): 335-340.
5. Jack O, Menegat A & Gerhards R (2017). Winter wheat yield loss in response to *Avena fatua* competition and effect of reduced herbicide dose rates on seed production of this species. *J Plant Dis Prot* 124(4): 371-382
6. Norsworthy JK, Ward SM, Shaw DR, Llewellyn RS, Nichols RL, Webster TM, Bradley KW, Frisvold G, Powles SB, Burgos NR & Witt WW (2012). Reducing the risks of herbicide resistance: best management practices and recommendations. *Weed Sci* 60(2): 31-62.
7. Kaushik S (2009). Management of Phalaris minor, an exotic weed of cropland. In Management of Invasive Weeds. pp. 279-286.
8. Iqbal J & Cheema ZA (2009). Response of purple nutsedge (*Cyperus rotundus* L.) to crop extracts prepared in various solvents. *Allelopathy J* 23(2): 450-452.
9. Tesio F & Ferrero A (2010). Allelopathy, a chance for sustainable weed management. *Int J Sustain Dev* 17(5): 377-389.
10. Farooq, M. (2008). Allelopathic effects of rice on seedling development in wheat, oat, barley and berseem. *Allelopathy J* 22: 385-390.
11. Kohli RH, Batish DR & Singh HP (2006). Allelopathic interactions in

agroecosystems. Springer, Dordrecht. In Allelopathy. pp. 465-493.
12. Callaway RM & Ridenour WM (2004). Novel weapons: invasive success and the evolution of increased competitive ability. *Front Ecol Environ* 2(8): 436-443.
13. Haddadchi GR & Gerivani Z (2012). Effects of phenolic extracts of canola (*Brassica napuse L.*) on germination and physiological responses of soybean (*Glycin max L.*) seedlings. *Int J Plant Prod* 3(1): 63-74.
14. Yasumoto S, Matsuzaki M, Hirokane H & Okada K (2010). Glucosinolate content in rapeseed in relation to suppression of subsequent crop. *Plant Prod Sci* 13(2): 150-155.
15. Halkier BA & Gershenzon J (2006). Biology and biochemistry of glucosinolates. *Annu Rev Plant Biol* 57: 303-333.
16. Zhang C & Fu S (2010). Allelopathic effects of leaf litter and live roots exudates of Eucalyptus species on crops. *Allelopathy J* 26(1): 91-100.
17. Florentine SK & Fox JED (2003). Allelopathic effects of *Eucalyptus victrix* L. on Eucalyptus species and grasses. *Allelopathy J* 11(1): 77-84.
18. Ataollahi R, Dejam M & Khaleghi SS (2014). Phytotoxic effects of Eucalyptus globulus leaf extract on Solanum nigrum. *South-West J Hortic Biol Environ* 5(1): 43-53.
19. Allolli, TB & Narayanareddy P (2000). Allelopathic effect of Eucalyptus plant extracts on germination and seedling growth of cucumber. *Karnat J Agric Sci* 13(4)*:* 947-951.
20. El-Khawas SA & Shehata MM (2005). The allelopathic potentialities of Acacia nilotica and Eucalyptus rostrata on monocot (*Zea mays L.*) and dicot (*Phaseolus vulgaris L.*) *Plants Biotech* 4(1): 23-34.
21. Fikreyesus S, Kebebew Z, Nebiyu A, Zeleke N & Bogale S (2011). Allelopathic effects of Eucalyptus camaldulensis dehnh. on germination and growth of tomato. *Am-Eurasian J Agric Environ Sci* 11(5): 600-608.
22. Shafique S, Bajwa R, Javaid A & Shafique S (2005). Biological control of Parthenium IV: suppressive ability of aqueous leaf extracts of some allelopathic trees against germination and early seedling growth of *Parthenium hysterophorus* L. *Pak J Weed Sci Res* 11(1-2):75-79.
23. Steel RGD & Torrie JH (1997). Principles and procedures of statistics. A biometrical approach. pp: 204-227.
24. Fagg CW & Stewart JL (1994). The value of Acacia and Prosopis in arid and semi-arid environments. *J Arid Environ* 27(1): 3-25.
25. Gonzalez L, Souto XC & Reigosa MJ (1995). Allelopathic effects of Acacia melanoxylon R. Br. phyllodes during their decomposition. *For Ecol Manag* 77(1-3): 53-63.
26. El-Khawas SA (2004). Physiological and biochemical adaptation of *Triticum vulgaris L*. to pH stress by hormonal application. *Pak J Biol Sci* 7: 852-860.
27. Wang W, Vinocur B, Shoseyov O & Altman A (2004). Role of plant heat-shock proteins and molecular chaperones in the abiotic stress response. *Trends Plant Sci* 9(5): 244-252.
28. Lorenzo P, Palomera-Pérez A, Reigosa MJ & Gonzalez L (2011). Allelopathic interference of invasive Acacia dealbata Link on the physiological parameters of native understory species. *Plant Ecol* 212(3): 403-412.
29. Das CR, Mondal NK, Aditya P, Datta JK, Banerjee A & Das K (2012). Allelopathic potentialities of leachates of leaf litter of some selected tree species on gram seeds under laboratory conditions. *Asian J Exp Biol Sci* 3(1): 59-65.
30. Al-Sherif, E, Hegazy AK, Gomaa NH & and Hassan MO (2013). Allelopathic effect of black mustard tissues and root exudates on some crops and weeds. *Planta Daninha* 31(1): 11-19.
31. Mushtaq MN, Cheema ZA & Khaliq A (2010). Effects of mixture of allelopathic plant aqueous extracts on *Trianthema portulacastrum* L. weed. *Allelopathy J* 25(1): 205-212.

32. Aliki HM, Reade JP & and Back MA (2014). Effects of concentrations of *Brassica napus (L.)* water extracts on the germination and growth of weed species. *Allelopathy J.* 34(2).
33. Khan MA, Marwat KB, Gul H & Zahid H (2005). Bioherbicidal effects of tree extracts on seed germination and growth of crops and weeds. *Pak J Weed Sci Res* 11(3/4): 179-184.
34. Batish DR, Kaur S, Singh HP & Kohli RK (2005). Herbicidal activity of volatile oils from Eucalyptus citriodora. In Second European Allelopathy Symposium" Allelopathy-from understanding to application. pp- 29.
35. Sasikumar K, Vijayalakshmi C & Parthiban KT (2006). Allelopathic effects of four Eucalyptus species on red gram (*Cajanus cajan L.*). *J Trop Agric* 39(2): 134-138.
36. Baziramakenga R, Leroux GD & Simard RR (1995). Effects of benzoic and cinnamic acids on membrane permeability of soybean roots. *J Chem Ecol* 21: 1271-1285.
37. Rassaeifar M, Hosseini N, Asl NHH, Zandi P & Aghdam AM (2013). Allelopathic effect of Eucalyptus globulus' essential oil on seed germination and seedling establishment of Amaranthus blitoides and Cyndon dactylon. *Trakia J Sci* 11(1): 73-81.
38. Zhang C & Fu S (2010). Allelopathic effects of leaf litter and live roots exudates of Eucalyptus species on crops. *Allelopathy J* 26(1): 91-100.
39. Fikreyesus S, Kebebew Z, Nebiyu A, Zeleke N & Bogale S (2011). Allelopathic effects of Eucalyptus camaldulensis dehnh. on germination and growth of tomato. Am-Eurasian *J Agric Environ Sci* 11(5): 600-608.
40. Cheema ZA (1988). Weed Control in Wheat Through Sorghum Allelochemicals. Ph. D. Thesis. Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.
41. Netzly DH & Butler IG (1986). Root of sorghum exudes hydrophobic droplets containing biologically active compounds. *Crop Sci* 26(4): 775-778.
42. Forney DR &. Foy CI (1985). Phytotoxicity of products from rhizosphere of sorghum-sudangrass hybrid. *Weed Sci* 33(5): 597-604.
43. Politycka B (1997). Free and glucosylated phenolics, phenol β-glucosyltransferase activity and membrane permeability in cucumber roots affected by derivatives of cinnamic and benzoic acids. *Acta Physiol Plant* 19(3): 311-317.
44. Muscolo A, Panuccio MR & Sidari M (2001). The effect of phenols on respiratory enzymes in seed germination. *Plant Growth Regul* 35(1): 31-35.
45. Barkosky RR, Einhellig FA & Butler JL (2000). Caffeic acid-induced changes in plant-water relationships and photosynthesis in leafy spurge (*Euphorbia esula*). *J Chem Ecol* 26(9): 2095-2109.
46. Holappa LD & Blum U (1991). Effects of exogenously applied ferulic acid, a potential allelopathic compound, on leaf growth, water utilization, and endogenous abscisic acid levels of tomato, cucumber, and bean. *J chem ecol* 17(5): 865-886.
47. Khaliq A, Matloob A, Khan MB & Tanveer A (2013). Differential suppression of rice weeds by allelopathic plant aqueous extracts. *Planta Daninha* 31(1): 21-28.
48. Mubeen K, Nadeem MA, Tanveer A & Zahir ZA (2012). Allelopathic effects of sorghum and sunflower water extracts on germination and seedling growth of rice (*Oryza sativa L.*) and three weed species. *J Anim Plant Sci* 22(3): 738-746.
49. AL-Tawaha, ARM & Nidal ODAT (2010). Use of sorghum and maize allelopathic properties to inhibit germination and growth of wild barley (Hordeum spontaneum). *Not Bot Horti Agrobot* 38(3): 124-127.

.