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PEARL MILLET (*PENNISETUM GLAUCUM* L.) YIELDS AS AFFECTED BY ALLELOPATHIC AND SELF-TOXIC EFFECTS UNDER MONOCROPPING CONDITIONS

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Abstract

Pennisetum glaucum L., a member of the Poaceae family usually grown under monocropping conditions due to which its subsequent yield in the same field sternly affected as a consequence of selftoxicity. Therefore, the present study investigates the self-toxic effect of *P. glaucum* on its growth rate using seeds and whole plant extracts. The outcomes of the study revealed that the growth of pearl millet was improved by 5% of its aqueous extract but affected significantly at higher concentrations. Pearson's correlation analysis showed a positive linear association at 5%, while a negative linear correlation was perceived at 10% and 15% of both seeds and whole plant extracts ($p<0.01$). It was seen that the root length of the Bajra possessed the highest inhibitory effect by the action of the seeds and whole plant extracts in comparison to shoot length. On comparison of both extracts, seed extract was found to be more potent than that of the entire plant extract. From the current studies, it was revealed that Bajra is an allelopathic plant and can induce an inhibitory effect on the other growing plants as well as, it can induce autotoxic effects.

Key words: Monocropping, Selftoxicity, Phenolic compounds, Growth inhibition, Aqueous extract.

Introduction

In the natural environment, different plants are growing, and these plants are continuously exposed to many biotic and abiotic stresses like salinity, temperature, light, allelopathy, etc. Among stresses subjected to crops, the allelopathy is of great importance as it causes 35% of field crop production losses in the agriculture field (Shah *et al*., 2006). Allelopathy is a biological phenomenon in which biochemicals are produced by plants with either a negative or a positive effect on the survival, growth, and reproduction of neighboring plants (Callaway & Aschchoug, 2000). This term was first coined by Molisch (1937) to describe the biochemical interactions of the plants which impede the growth and development of neighboring plants. The main factor of allelopathy is allelochemicals may be present in any part of allelopathic plants and serves as secondary metabolites. It was initially assumed that plant allelopathy could be a not only harmful and beneficial effect on surrounding plants. However, Sarheed *et al*., (2020) reported that allelopathic plants have only detrimental effect on other plants by emitting specific chemical compounds. Weed species as competing plants with field crops used to be prone to allelopathic properties. Though, certain crops like pearl millet are capable of bearing allelopathic properties. *Pennisetum glaucum*, generally recognized as pearl millet (Bajra) belonging to the Poaceae family and Panicoideae subfamily. There are numerous millet species about (6,000) in the world (Anon., 2006). It is one of the oldest tropical cereal crops used for human consumption as a staple food product (Raily, 2006). It contributes to, 1/3 human diet and 40% of world cereal production. It is the sixth important cereal grains, of the world. It is one of the oldest cultivated and staple foods for humans. Seeds of millet are very nutritious and used for making porridge and cakes (Raemaekers, 2001). Millets are grown for their grain production, although some varieties are used as forage, building materials and for fuel (Gibbon & Pain, 1985). Despite its high nutritional value pearl millet was known as an allelopathic crop (Radhoune, 2014). By creating inter-specific interaction (teletotoxicity) with other plants through the emission of allelochemicals. The functional principle of allelochemicals in the lysis of the cell which introduces inhibitory effects in different parts of plants (Wu *et al*., 2003). These allelochemicals directly attack the cell and rise the cell permeability which leads to exosmosis and raised lipid peroxidation and produces cytotoxic effects which ultimately caused the demise of plant tissues while (Qureshi *et al*., 2014) found that seeds extracts of *P. glaucum* at different concentrations inhibited the growth parameters of mung bean, red beans, and black gram. A number of cereal crops like *Avena sativa, Triticum durum, Hordeum vulgare* which are affected by millet seeds extracts (Radhoune *et al*., 2014). Pearl millet is also to stimulate selftoxicity which affects its growth and physiology under monoculture incorporating crop residues into the soil is harmful to the succeeding pearl millet crop (Sexena *et al*., 1995, 1996). Furthermore, Radhoune *et al*., (2013) gave the idea that pearl millet seeds attributed many water-soluble phenolic compounds that may perform as allelochemicals and can cause seedling inhibition. It was seen that these phenols have two biosynthetic pathways from which allelochemicals arise from Shikimic acid (Li *et al*., 2010). It is a fact that bajra has an allelopathic effect on different crops as well as it also induces selftoxicity, for this purpose the current study was conducted to evaluate the self-toxic effects of pearl millet on its seedling growth.

Materials and Methods

A Laboratory-based study was conducted at the Botany department of Federal Urdu University of Arts, Science and Technology during the summer season *i.e.* May 2018 to August 2018 to evaluate allelopathic and self-toxic effects of pearl millet.

Collection of material: A well-managed pearl millet field was grown inside the Botany department of Federal Urdu University of Arts, Science, and Technology for the collection of desired plant material. When these plants reached maturity, they were uprooted and kept under the sunlight for the drying process while seeds of pearl millet were bought from the local seeds market.

Preparation of seeds and whole plant extracts: Firstly, millet seeds were surface sterilized with 2% $HgCl_2$ and thoroughly washed with tap water. Seeds were air-dried at room temperature and ground to make a fine seed powder while in case of whole plant powder, whole plant material was collected from the millet field. After drying it was ground to make a whole plant powder. Aqueous extracts were prepared by soaking different concentrations of both seeds and whole plant powder (5%, 10% and 15% g/l) into distilled water at room temperature for 24 hours. Both extracts were centrifuged for 5 minutes and filtration was done to get pure extracts (Handa *et al*., 2008).

Treatments and experimental design: Sterilized pearl millet seeds were sown in Petri dishes containing double-layered Whatman No. 1 filter paper. Different concentrations of both extracts were applied to their respective Petri dishes while control was treated with distilled water. All the bioassays having five replicates with each ten pearl millet seeds of bajra. Germination records were taken every day whereas, shoot and root elongation measurements were made in alternative days. The trials were terminated after fourteen days before terminating. The experimental design used for the current study was Randomized control block design.

Statistical analysis

Data subjected to analysis of variance (ANOVA) using SPSS (20). Means and % inhibition of root and shoot length were carried out for significance by using the Tukey's test at $p<0.05$. Whereas, the correlation was determined based on Pearson's approach.

Percent Inhibition (I) was calculated by the following formula (Surendra & Pota, 1978).

$$I = 100 - (E_2 \div E_1) \times 100$$

where I = % inhibition, E_1 = Response of control plant, E_2 = Response of treated plant.

Results

Seedling development as influenced by seeds extract: Pearl millet seeds extract induce significant inhibition in root and shoot growth at higher concentrations, namely10 and 15 % extracts while a significantly lower growth development was observed in 5% in comparison to control at $p<0.05$ (Tables 1 & 3).

Growth rate as influenced by whole plant extract: A significant decline in pearl millet growth rate was observed in 10 and 15% extracts whereas, it was enhanced at a lower concentration of 5% extract with respect to control (Tables 2 & 3).

Table 1. Autotoxic effect of pearl millet seeds extract on seedling growth of *P. glaucum*.

Treatments		Mean (cm)	Std. Deviation	Std. Error
Root	Control	8.0667	2.38976	0.61703
	5%	11.4667	0.23094	0.13333
	10%	6.9667	0.20817	0.12019
	15%	5.1000	0.20000	0.11547
Shoot	Control	11.2733	2.65343	0.68511
	5%	14.4667	0.32146	0.18559
	10%	10.3667	0.25166	0.14530
	15%	7.0000	0.17321	0.10000

Table 2. Selftoxic effect of pearl millet seeds extract on the growth rate of *P. glaucum*.

Treatments		Mean (cm)	Std. Deviation	Std. Error
Root	Control	8.7000	0.78102	0.45092
	5%	11.5000	0.26458	0.15275
	10%	6.7000	0.20000	0.11547
	15%	4.7000	0.52915	0.30551
Shoot	Control	12.1000	0.52915	0.30551
	5%	14.4667	0.32146	0.18559
	10%	10.3667	0.30551	0.17638
	15%	6.9000	0.20000	0.11547

Association between seeds and whole plant extract and their impact on % inhibition of root and shoot length of pearl millet: Seeds and whole plant extract had a distinct causatum on % inhibition of root and shoot length (Fig. 1) showing that 5% of both extracts possessed lowest % inhibition as compared to all treatments whereas, the least % inhibition was noticed in 5% whole plant extract (-27.4%) while highest % inhibition was noted in 15% of seeds extract (65.9 %).

Correlation between the concentration of extracts and seedling growth of pearl millet: There was a highly significant relationship found among the treatments (control, 5%, 10%, and 15%) and seedling growth of pearl millet at $p>0.05$. A positive linear correlation was observed in 5% of extracts while a negative correlation was seen at 10% and 15% of extracts (Fig. 2).

Discussion

The outcomes of the present study showed that seeds and whole-plant extracts of pearl millet possessed self-inhibitory effects and substantially inhibited the growth and length of pearl millet roots and shoots ($p<0.05$) at higher concentrations respectively (Tables 3 & 4). Our results were in line with those reported by Vandana *et al*., (2021); Kumar *et al*., (2013); Narwal, (2012); Sexena *et al*., (1995); who suggested that for the initiation of autotoxicity, there must be an accumulation of a sufficient amount of pearl millet tissues in soil and caused reduction in the production of monocrop yield of pearl millet. Phenolic compounds are the basic component of allelopathy that may be present in various parts of plants and brought harmful effects on the field by the leaching process (Haghighi & Saharkhiz, 2021); (Inderjit & Duke 2003).

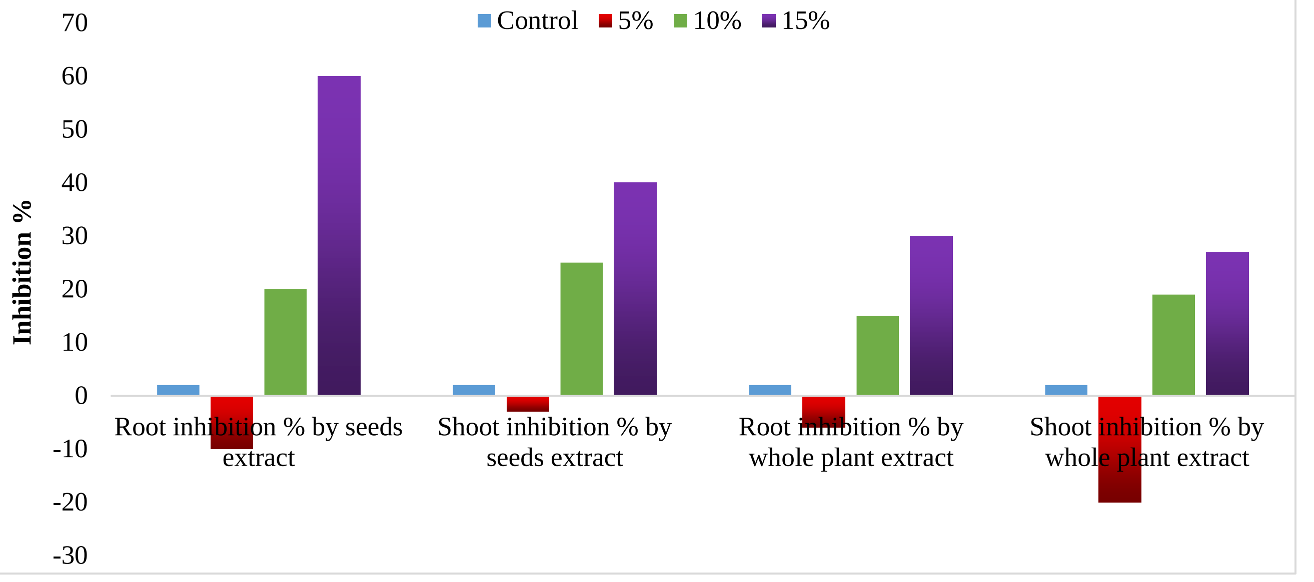
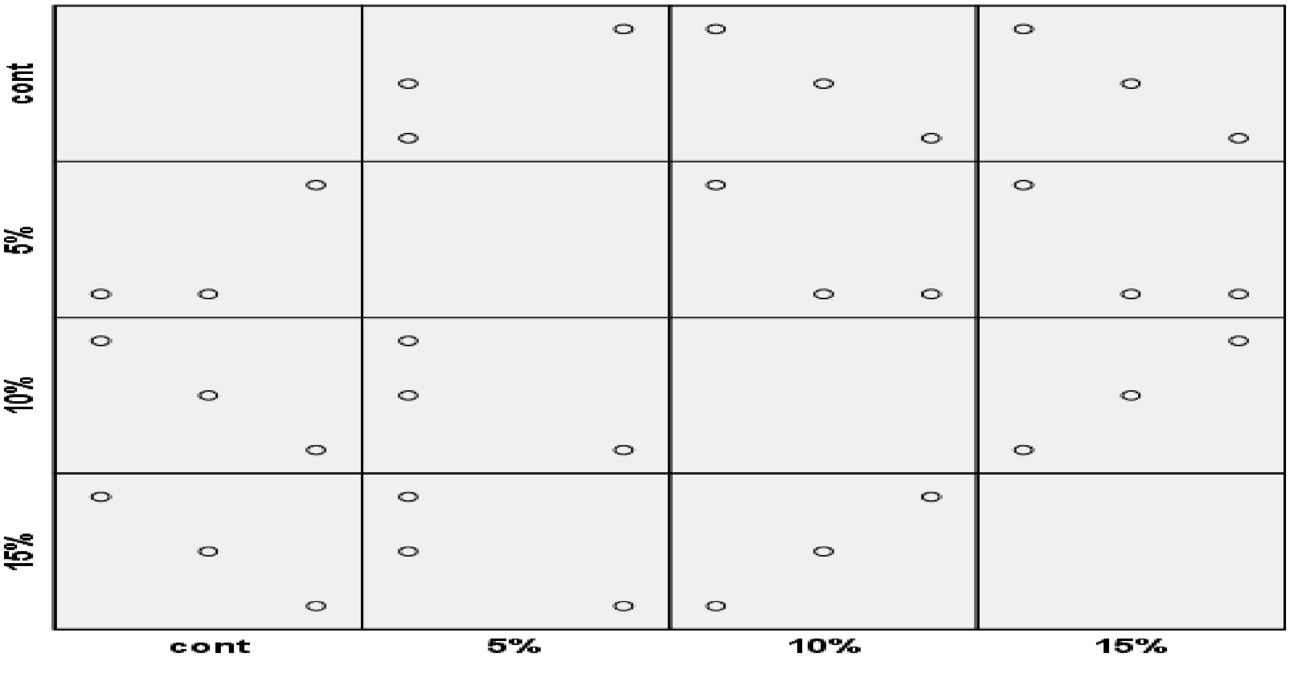


Fig. 1. Comparative analysis of seeds and whole plant extract on % inhibition of root and shoot growth of pearl millet.



Correlation considered significant when $p<0.01$

Fig. 2. Correlation between the concentration of extracts and seedling growth of *P. glaucum.*

Findings of the current study revealed that lower concentration *i.e.* 5% of seeds and whole plant enhanced the growth rate of root and shoot. This might be due to the fact that most of the phenols have stimulatory effect at lesser concentrations and have inhibitory effect at high concentration (Mousavi *et al*, 2021); (Stanek *et al*, 2021); (Rice, 1984) Where ever as the concentration of entire plant and seed extracts were increased to 10 and 15 % seedling growth of pearl millet moved towards decline (Table 1 & 2). The difference in the effects was might be due to concentrations of extracts as suggested by (Ben-Hamouda *et al*., 2001) that the effect of different parts of the same plant cause various type of inhibition on each other. However, for the initiation of selftoxicity, there should be an accumulation of allelochemicals in an adequate quantity else insufficient amount can enhance the productivity of soil (Radhoune & Fattouch, 2009). The results of the present study are consistent with the findings of Qureshi *et al.*, (2014) who stated that pearl millet seeds extract (5%, 10%, and 15%) significantly reduced % germination along with all the growth parameters of chickpeas, red beans, and mung beans.

In light of the above results, it was revealed that the inhibition in seedling growth is caused by selftoxicity which was concentration-dependent. This was proved by many researchers i.*e.* (Hussain & Illahi, 2009) that differences in allelopathic effect depend upon the concentrations of extracts used and the nature of recipient plants.

The correlation was found to be highly significant between treatments (5%, 10%, and 15% extracts) and the seedling growth ($p < 0.01$) whereas, at 5% extract positive linear correlation is found while at 10% and 15% of the extract showed negative linear correlation (Fig. 2). Our results are consistent with the findings of Radhouane (2014), who reported that pearl millet was an allelopathic plant in which seeds extract reduced seedling growth of cereal crops *i.e*. wheat, barley, and oat. In comparison, it was found that seeds powder extract of pearl millet had a much higher inhibitory effect than that of whole plant extract. Our findings corroborate observations made by different authors (Radhouane *et al*., 2013; Radhouane & Fattouch, 2009). Millet seeds contain several phenolics compounds that may diminish the seed germination speed and seedling growth of other growing plants. Similar findings regarding the phytotoxic effects of pearl millet extract on cereal crops in Pakistan were reported by (Qureshi *et al*., 2015).

Conclusion

The preceding investigations suggested that pearl millet had a potential to alter its own growth, as it bears phytotoxic influence although, it could provide useful response when used it at low amount, further investigations are required to identify its toxic level.

Table 3. Autotoxic effect of pearl millet whole plant extract on seedling growth of itself.

		ANOVA				
		Sum of squares	**df**	**Mean square**	**F**	**Sig.**
Shoot	Between groups	86.362	3	28.787	5.818	0.005
	Within groups	98.963	20	4.948		
	Total	185.325	23			
Root	Between groups	64.547	3	21.516	5.364	0.007
	Within groups	80.227	20	4.011		
	Total	144.773	23			

The mean difference is significant at the 0.05 level

Table 4. Selftoxic Effect of pearl millet seeds extract on seedling growth.

		ANOVA				
		Sum of squares	**df**	**Mean square**	**F**	**Sig.**
Shoot	Between groups	75.840	3	25.280	101.120	0.000
	Within groups	2.000	8	0.250		
	Total	77.840	11			
Root	Between groups	91.296	3	30.432	235.602	0.000
	Within groups	1.033	8	0.129		
	Total	92.329	11			

The mean difference is significant at the 0.05 level

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