Research Article

Allelopathic Potential of Poplar (*Populus deltoides* L.) Leaves Aqueous Extract on Cereal Crops

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Abstract | The phytotoxic impact of functional allelopathy from perennial plants (trees) surrounding our crops in the field is our focus in agroforestry. To quantify its severity, the phytotoxic impact of popular (*Populus deltoides* L.) leaves aqueous extract was determined in cultivated oat (*Avena sativa* L.), maize (*Zea mays* L.), rice (*Oryza sativa* L.), pearl millet (*Pennisetum glaucum*L.), bread wheat (*Triticum aestivum* L.) and sorghum [*Sorghum bicolor* (L) Moench. Response of aqueous leaves extract was assessed through various agronomic and physiological parameters including number of plants emerged, leaves per plant, chlorophyll content, root and shoot length, plant fresh and dry biomass were studied. The strong phytotoxic effect of aqueous extract on all the studied parameters was recorded when applied @ 25 g L^{-1}(w/v). The data revealed that aqueous extract produced an inhibitory effect on all the crops' growth parameters studied. It is recommended that unplanned planting of poplar (*P. deltoides* L.) around the cereal crop fields should be avoided in order to obtain optimum crop population and finally the grain yield.

Received | January 21, 2022; **Accepted** | April 01, 2022; **Published** | June 28, 2022
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Citation | Hussain, I., S.A. Jatoi, M.J. Nazir, E. Haq, F. Abbas and M.S.R. Shah. 2022. Allelopathic potential of poplar (*Populus deltoides* L.) leaves aqueous extract on cereal crops. *Pakistan Journal of Agricultural Research,* 35(2): 311-316.
DOI | https://dx.doi.org/10.17582/journal.pjar/2022/35.2.311.316
Keywords | *Populus deltoides* L., Allelopathy, Cereals, Leaves, Extract

Introduction

Agroforestry is a multidisciplinary struggle to increase the productivity per unit area through a combination of perennial vegetation (trees) and our economic agricultural vegetation. The concept of agroforestry has introduced in the late 1970s an advanced management technology for improvement in the economy of underdeveloped countries, where resources are available for agriculture and sustainability (Hayat *et al.*, 2020). Here, growing trees around the crops introduced an agroforestry culture that helped to improve soil fertility, reduce soil erosion, increase water quality, conserve biodiversity, and enhance photosynthetic activity to reduce pollution (Ramachandran *et al.*, 2009). Major cereal crops (bread wheat, rice, maize, cultivated oat, pearl millet, and sorghum) account for 20-83% in value addition of agriculture and approximately 4% in GDP (GOP, 2020). Plants possess many phytochemicals like volatile, non-volatile and essential oils which enter the agroecology of crops, it may directly or indirectly impact germination physiology, seedling growth, and lateral development in the neighboring crops. Poplar (*P. deltoides*), a cool climatic deciduous plant, belongs to the family salicaceae, which is a multipurpose rapidly growing valuable timber species. Origin of popular is found in Europe and Asia. It is found near rivers and in those forests where heavy rains occurred throughout the year in North Africa. It is also found in central and Western Asia, the Himalayas and in west China. Poplar has evolved as one of the most profitable species for sustainable Agri silviculture system and proved to be a promising tree in agro-eco-systems of northern parts of India and is being raised either as block vegetation or along field boundaries/windbreaks (Chandra, 1986). Erect clean bole canopy and leaflessness during the cool season also make poplar suitable for the agroforestry. White poplar (*P. deltoides*) is a normal stature, rapid establishing deciduous plant growing on all types of climates, where water is available in the Mediterranean region. It often grows by watersides, in regions with hot summers and cold to mild winters (Rushforth, 1999). The allelochemicals are biological chemicals released by plants that pass into the soil and adversely influence the physiological development of neighboring crops in the form of interference (Cheng and Cheng, 2015). Many trees release some phytochemicals in the soil which adversely affect the germination and yield of crops. Major allelochemicals released by trees with documented allelopathic activity are phenolic compounds (Chang *et al*., 2015) which at moderate concentrations inhibit seedling emergence and establishment. There are several reports where allelochemicals/plants extracts with a saturated solution with inhibiting and suppressing properties have an adverse impact on germination physiology and seedling growth of other plants. Some phytochemicals also act as a repellent and have insecticidal and fungicidal properties (Khan *et al*., 2009). In this preview, the plants with allelopathic potential may widely be used in agriculture to control herbs/ weeds and insects/pests. A tincture prepared from the bark of this plant is reportedly used for treating scurvy, gout and rheumatism, various infections of the stomach, kidneys and chest (Duke, 1983), curing herpes and filling of dental cavities (Wamidh and Mahasneh, 2010). In the agroforestry system of India, poplar became a cash crop with valuable production. Diverse tree-crop combinations are practiced by the farmers in poplar-based agroforestry culture. Bread wheat during the rabi season is the most popular crop growing underneath in the forest of poplar. Variable performance of bread wheat cultivars in association with various tree species has been observed. The partially decomposed aqueous extract of *P. deltoides* L. leaves suppresses the germination growth of bread wheat seedlings. Incomplete decomposition has more adverse impact than complete decomposition of leaves in the earlier growth stage of plants (Nandal and Dhillon, 2007). High concentration of its leaves litter has a toxic influence after decomposition process on neigbouring plants. Irrespective of the decomposition stage, there is a linear relationship between the concentration of the extracts and the intensification of adverse impact. The plants growing near and under the shade of popular tress established were more affected may be due to the accumulation of allelochemicals which was more pronounced with an increment of tree age. Most of allelochemicals are water soluble like alkaloids, flavonoids, tannins and cinnamic acid derivates. Water extract use to promote growth at low concentration and inhibit the growth and development at high concentration (25% w/v) (Farooq *et al*., 2013).

In Pakistan, there is no significant study about agroforestry of *P. deltoides* with cereal crops. Very little knowledge is available about its allelopathic potential.

The current study aimed to analyze the poplar mixed cereal cropping system with specificity to explore the allelopathic impact of poplar (*P. deltoides*) on cereals i.e., bread wheat, cultivated oat (winter), rice, maize, sorghum and pearl millet (summer).

Materials and Methods

A laboratory study was carried out in Post-graduate Agronomy Lab., Faculty of Agriculture, Gomal University, Dera Ismail Khan, Kp., Pakistan in Completely Randomized Design (CRD) to determine the phytotoxic impacts of three and four-years old poplar (*P. deltoides*) trees present in wet agro-climatic conditions of D.I.Khan on cereals i.e. bread wheat (*Triticum aestivum* L.), cultivated oat (*Avena sativa* L), rice (*Oryza sativa* L.), maize (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench.]and pearl millet (*Pennisetum glaucum* L.), in pots along with an untreated check. The sample poplar leaves were collected in several bags, cleaned, dried and sterilized at a hot air oven at 80°C. The dried Phyto biomass was ground using a mechanical grinder. The fine ground flour sample was sealed under vacuum and stored at room temperature for further experiments. The leaves flour with 25% w/v was soaked in distilled water for 3 days at room temperature then an aqueous mixture was filtered and collected in a jar as an extract. For each leaf litter treatment, four replications were considered. Pots were irrigated (1 L/ pot) with water a day prior to seed sowing and approximately one liter on subsequent days to keep the soil moist. The specimen experimental soil of site was clay in texture having 9 to 10% sand, 38% silt, 55 to 60% clay, 8.5 pH, 8 ppm P_2O_5, 0.21 organic matter, 0.023 % nitrogen, 95 ppm potassium, soil porosity 51 to 60 %, Bulk density 1.23 % and EC 1100.34. Every single pot filled with 5 kg air-dried 0.5 mm mesh sieved (mixed wholly) soil.

The seed germination and seedling growth were recorded after ten days of sowing. In each pot, only 8 seeds were sown and one healthy seedling was retained 2-weeks after sowing. After one month of sowing, fresh and dry biomass of plants and other germination and physiological data were recorded. The procedure was adopted according to by Farooq *et al.* (2013).

Results and Discussion

Plants emergence

Saturation of aqueous water of *P. deltoides* significantly enhanced the number of plants (emerged) as compared to control treatment (Table 1). The tested effect exhibited statistically significant differences for the number of plants emergence. An increasing trend of the number of plants by aqueous extract of *P. deltoides* was found. The maximum number of plants (4.50 and 4.66) were recorded in cultivated oat and maize crops, respectively by the application of an aqueous extract of *P. deltoides*. Phytochemicals are bioactive compounds derived from plant parts containing phenolic acids. They possess different biochemical functions in other plants species like germination, growth development and microbiological control (Kuppusamy *et al.*, 2018). Xaxa *et al.* (2018) described that allelochemicals released from *P. deltoides* may have beneficial (positive allelopathy) in case of germination in some crops but found detrimental (negative allelopathy) influence on target crops they studied.

Table 1: *Allelopathic Effect of Populus deltoideson number of plants emergence and leaves count plant $^{-1}$.*

Treatments	Number of plantsemerged		Leaves count plant $^{-1}$	
	Control	Extract	Control	Extract
T1 (Oat)	3 b	4.5 a	1.10 c	1.00 c
T2 (Maize)	1 d	4.66 a	3.00 a	2.15 ab
T3 (Rice)	2 c	3.50 b	2.00 b	1.04 c
T4 (Pearl millet)	2 c	2.66 c	1.38 b	1.20 c
T5 (Bread wheat)	3 b	4.00 a	1.63 b	1.30 b
T6 (Sorghum)	2 c	3.50 b	1.45 b	0.40 d
LSD $_{0.05}$	1.18		0.87	

Mean values in respective groups having different letter(s) are significant (P<0.05).

Leaves count plant $^{-1}$

The study revealed that leaves count plant $^{-1}$of different crops were significantly influenced with *P. deltoides* aqueous extract application (Table 1). It was noted that the concentration of aqueous extract has differentially influenced the number of leaves (2.15) of various crops studied. Maximum decrease 0.4 was recorded in the number of leaves of sorghum followed by bread wheat crop, (1.45) with the application of aqueous extract compared with the control treatment. The cultivated oat crop was not affected by the application of poplar aqueous extract. This variability could be attributed to the genetic capability in different crops and their characters to cope with allelochemicals. Aqueous extract of poplar has an inhibitory action on maize and rice. Singh and Sharma (2007) proved in their experiment that leaves of poplar affected the neighboring crop growth by declining the availability of soil nutrients, changing the C:N ratio and releasing phytochemicals.

Fresh biomass (g)

The data indicated that fresh biomass of the various crops decreased significantly with the application of an aqueous extract of *P. deltoides* (Table 2). A maximum decrease was noted in maize, while the minimum decline was observed in rice. Sirohi and Bangarwa (2017) also found similar results in bread wheat. They noted suppression of bread wheat growth by observing low fresh biomass in 45 days seedlings as compared to control and suppressing effect of *P. deltoides* leaves on the emergence and other physiological parameters in cereal crops.

Dry biomass(g)

Statistical analysis of the data showed that aqueous extract of *P. deltoides* leaves had a significant (P≤0.05) effect on dry biomass of the different cereal crops under study (Table 2). The highest inhibition in dry biomass among the tested cereals was deciphered in maize. The data showed that sensitivity to the extract was evident in all the test crops to a varying degree. Xaxa *et al.* (2018) has also reported in their studies that photosynthesis, fresh and dry biomass reduction in bread wheat was due to *P. deltoides* leaves litter. Consequently, the productivity of bread wheat was reported to be declined in the field sheltered by *P. deltoides*.

Table 2: *Allelopathic effect of Populus deltoideson fresh and dry biomass (g).*

Treatments	Fresh biomass (g)		Dry biomass (g)	
	Control	Extract	Control	Extract
T1 (Oat)	0.75 bc	0.25 c	0.30 b	0.12 c
T2 (Maize)	3.00 a	0.90bc	0.14 c	0.87 a
T3 (Rice)	0.44 bc	0.33 c	0.18 c	0.08 d
T4 (Pearl millet)	0.42 bc	0.20 c	0.11 d	0.01 c
T5 (Bread wheat)	1.00 b	0.50 bc	0.22 d	0.13 c
T6 (Sorghum)	0.86 bc	0.60bc	0.16 c	0.01 c
$LSD_{0.05}$	1.05		0.35	

Mean values in respective groups having different letter(s) are significant (P<0.05).

Plant tallness (cm)

The data regarding plant tallness were also affected significantly by the aqueous extract of *P. deltoides*. It revealed that maize crop had maximum plant tallness (19.03 cm). while pearl millet crop (5.1 cm) had dwarf plants as compared to all other crops in treated as well as in control. Plants which indicated the highest inhibition in maize, sorghum and rice in this parameter among the tested cereals. It was noted that aqueous extract had an inhibitory effect on cereals as compared to the untreated check. Khan *et al.* (2014) also reported that water leaf leachate of 3 different plants (Eucalyptus, Guava and litchi) was found suppressive to plant length of tested cereals viz. *Zea mays* L., *Triticum aestivum* L. and *Sorghum bicolor* L. They found that suppressing influence was increased as the extract concentration increased. They also found a reduction in plant tallness and fresh biomass at 30 and 60 days after sowing of some winter season crops such as *Triticum aestivum* L., *Lens culinaris*, *Phaseolus vulgaris*, *Avena sativa*, *Trifolium alexandrinum* and *Brassica juncea*, when grown under *P. deltoides* as compared to the treeless field. Singh *et al.* (2001) have concluded from their studies that *P. deltoides* reduced the plant tallness due to allelopathic disturbance from leaves and its litter.

Table 3: *Allelopathic effect of Populus deltoideson plant tallness (cm) and shoot length (cm).*

Treatments	Plant tallness (cm)		Shoot length (cm)	
	Control	Extract	Control	Extract
T1 (Oat)	14.16 bc	10.10d	9.19 c	6.10 d
T2 (Maize)	24.00 a	19.03	17.30 a	13.23 b
T3 (Rice)	16.00 ab	8.47d	8.00 c	5.03 d
T4 (Pearl millet)	7.85 d	5.10e	3.10 e	5.82 d
T5 (Bread wheat)	18.17 b	16.10ab	10.20 c	12.47 b
T6 (Sorghum)	11.50 c	6.61 e	1.30 e	5.63 d
$LSD_{0.05}$	5.78		4.19	

Mean values in respective groups having different letter(s) are significant (P<0.05).

Shoot length (cm)

Shoot length was significantly affected by the aqueous extract of *P. deltoides* on cereals. Data analysis showed that among the test species, the highest shoot length (13.23 cm) was recorded in maize by application of the aqueous extract of poplar, while minimum shoot length (5.0 cm) was recorded in rice as compared to control. The inhibition in shoot growth of different crops might be due to the application of aqueous extract and the presence of phytochemicals present in the extract. Similarly, Nandal and Dhillon (2007), Khan *et al.* (2014) and Xaxa *et al.* (2018) reported the inhibitory impact of *P. deltoides* on the shoot length of different species. Khan *et al.* (2014) claimed the low production of agricultural crops due to phytotoxic impacts of *P. deltoides*. The tree leaves litter accumulating in the soil in fall (autumn) released phytotoxins, which decreased the productivity of different species underneath.

Root length (cm)

The study revealed that the root length of different crops was significantly influenced statistically with *P. deltoides* aqueous extract (Table 4). It was noted that higher aqueous extract greatly reduced root length of sorghum, pearl millet, rice, cultivated oat and bread wheat but remained to be the same in maize. Maximum inhibition (17.48cm to 5.1cm) was observed in sorghum with the application of aqueous extract. The study also expressed that aqueous extract had an inhibitory effect on root elongation of crops as related to control treatment. The perusal of data depicted that maize is tolerant to the extract tested. Nandal and Dhillon (2007) also reported the suppressing effect of *Populus deltoides* on the root length of different species in their test. Similarly, Carvalho *et al.* (2015) and Hussain *et al.* (2019) concluded in their research study that the root length of maize was suppressed by using aqueous extracts of eucalyptus, neem and poplar.

Table 4: *Allelopathic Effect of Populusdeltoideson Root length (cm) and Chlorophyll Content (µg cm^{-2}).*

Treatments	Root length (cm)		Chlorophyll content (µg cm^{-2})	
	Control	Extract	Control	Extract
T1 (Oat)	4.97 b	3.1 c	15.00de	10.00 f
T2 (Maize)	6.7 b	6.7 b	32.5 b	25.00 c
T3 (Rice)	3 c	7 b	18.00 d	13.00 e
T4 (Pearl millet)	2.02 cd	1.1 d	40.00 a	22.00 c
T5 (Bread wheat)	5.8 b	3.01 c	16.00 e	12.00 e
T6 (Sorghum)	17.48a	5.1 b	36.00 a	14.00 e
LSD $_{0.05}$	3.05		6.5	

Mean values in respective groups having different letter(s) are significant (P<0.05).

Chlorophyll content (µg cm^{-2})

The data revealed that aqueous extract had an adverse impact on chlorophyll contents of crops in their comparison (Table 4). Chlorophyll is coloured organic complex molecules found in the photosynthetic plant (green plant) in a biological system that absorbs light energy (Sinha, 2014). The aqueous extract concentration of *P. deltoides* revealed that maize crop had the highest chlorophyll content (25.00 µg cm^{-2}) while cultivated oat crop had the lowest chlorophyll content (10.00 µg cm-2) as compared to control treatment. This may be due to the C_3 and C_4 nature of these two crops genetically. Vaithiyanathan *et al.* (2014) depicted similar results in chlorophyll contents of various plants in their appraisal with the application of neem and tobacco extracts. While Hussain *et al.* (2019) explained that chlorophyll synthesis and photosynthesis are negatively disturbed by these allelochemicals. In this research, there was a strong negative phytotoxic influence on the chlorophyll content of five species of cereal crops, which might have disturbed metabolism due to the application of extract in the tested species.

Conclusions and Recommendation

Agroforestry of compatible crops is today's need to fulfill the increased dietary, industrial and ecological demand of the increasing human population. Allelopathic potential of *P. deltoides* have been observed in the field but little work has been done on photochemical nature of this tree and their adverse effect on neighborhood plants. However, it was left in imperative to study about its allelopathic impact on cereal crops.

But in our studies of *Populus deltoides* extract (25% w/v) mostly had an adverse effect on most of the agronomic and physiological parameters of various cereal crops studied. However, each cereal crop responded differently in different parameters. For further research, it is suggested, to evaluate the allelopathic effect of other parts of *P. deltoides* like the bark of stem and roots to further confirm their impacts on the crops intercropped. Therefore, judicious thinking is essential in using the agroforestry approach of poplar with the cereals.

Novelty Statement

In Pakistan, there is no significant study about agroforestry of P. deltoides with cereal crops. Very little knowledge is available about its allelopathic potential. The current study aimed to analyze the poplar mixed cereal cropping system with specificity to explore the allelopathic impact of poplar (P. deltoides) on cereals i.e., bread wheat, cultivated oat (winter), rice, maize, sorghum and pearl millet (summer). By this study we can explore the alleolopathic potential of popular in cereals.

Author's Contribution

Iqtidar Hussain: Principal author.
Shakeel Ahmad Jatoi: Conceived the idea
Muhammad Jawad Nazir, Ehtesham Ul Haq, Faheem Abbas and Muhammad Saqib Raza Shah: Collected data.

Conflict of interest

The authors have declared no conflict of interest.

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