Research Article

Allelopathic Effects of *Populus nigra* L. Leaf Powder on Germination and Early Growth of Wheat Cultivar Akbar-19

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Abstract | This research was conducted in the Botanical Garden of Government Postgraduate College, Swabi, from 28 January 2025 to 15 March 2025. *Triticum aestivum* L. is one of the most important cereal crops cultivated worldwide as a staple food source. However, wheat productivity and quality are significantly affected by various weeds and associated tree species. The present study was conducted to investigate the allelopathic effects of *Populus nigra* L. leaf powder on the germination and early growth parameters of the wheat cultivar Akbar-19. The wheat cultivar Akbar-19 was subjected to four concentrations of *Populus nigra* leaf powder: 25 g, 50 g, 75 g, and 100 g. A total of 75 healthy wheat seeds were sown in 15 pots, with each pot containing five seeds and three replicates per treatment. The soil used in the experiment was silty clay loam, consisting of 40% silt, 40% clay, and 20% sand. The effects of the leaf powder treatments were evaluated on seed germination, seed vigor index (SVI), mean germination time (MGT), speed of germination (SG), germination index (GI), number of leaves, leaf size, shoot length, root length, and fresh and dry biomass under open-field conditions. Statistical analysis revealed significant ($P \leq 0.05$) effects of *Populus nigra* leaf powder on seed vigor index ($P = 2.16 \times 10^{-7}$), mean germination time ($P = 0.032304$), leaf size ($P = 0.000658$), fresh biomass ($P = 0.001043$), and dry biomass ($P = 0.001164$). In contrast, non-significant ($P \geq 0.05$) effects were observed for germination index ($P = 0.059445$), number of leaves ($P = 0.521359$), root length ($P = 0.447700$), shoot length ($P = 0.349496$), and seed germination percentage, which remained at 100%. Further studies are required to evaluate the allelopathic effects of *Populus nigra* under field conditions on related crop species and to identify the specific phytotoxic compounds responsible for these effects.

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Introduction

Pakistan is an agricultural country, and wheat (*Triticum aestivum* L.) is its major cereal crop. Wheat belongs to the Poaceae family, commonly known as the grass family, and is native to Southwest Asia and the Mediterranean region. It is the most important winter cereal crop in Pakistan (Inayat *et*

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al., 2024). Wheat is one of the oldest and most widely cultivated cereal crops, serving as a staple food for billions of people worldwide. It is a self-pollinated annual crop and represents one of the most economical sources of food, providing a substantial amount of calories and protein in the daily diet of humans (Kumar *et al*., 2011). In Khyber Pakhtunkhwa, wheat is grown under different agro-climatic conditions, resulting in variations in sowing and harvesting periods. In plain areas, the recommended sowing period extends from 25 October to 15 December, whereas in hilly areas it ranges from 1st November to 15 December. Wheat harvesting in Pakistan begins in late March in the southern regions and continues until the end of July in the northern regions (PARC, 2023-24).

Populus nigra L., commonly known as Black Poplar, is a deciduous tree native to Europe, Southwest and Central Asia, and Northwest Africa. It commonly grows in riparian zones, floodplains, and moist lowland areas. The tree typically attains a height of 20–30 m and may occasionally reach up to 40 m. It possesses thick, dull-grey bark and alternate, deltoid leaves measuring 5–10 cm in length, with a bright green coloration on both surfaces. Black Poplar is a dioecious species, with male and female flowers borne on separate trees. The flowers are arranged in pendulous catkins that emerge before leaf development in early spring. Its fruits are capsules containing numerous seeds equipped with cotton-like hairs that facilitate wind dispersal. The species has a deep root system capable of extracting moisture from deeper soil layers, enabling it to tolerate drought stress (Broeck, 2003). In Pakistan, wheat is commonly cultivated in association with boundary plantations of *Populus nigra* L. Such agroforestry systems can improve the physical and chemical properties of soil through the addition of organic matter derived from leaf litter and other plant residues. However, the decomposition of plant materials may also release allelochemicals that influence the growth and development of neighboring crops (Coleman *et al*., 2004).

Allelopathy refers to the biochemical interactions among plants and other organisms through the release of secondary metabolites known as allelochemicals. The term "allelopathy" is derived from two Greek words: *allelon*, meaning "opposite" or "one another," and *pathos*, meaning "suffering" or "feeling." The concept was first introduced by the Austrian scientist Molisch (1937), who defined allelopathy as the direct or indirect influence of one plant on another through the release of chemical compounds into the environment (Molisch, 1937). In 1996, the International Allelopathy Society expanded the definition to include the effects of secondary metabolites produced by plants, microorganisms, fungi, and viruses on agricultural and biological systems (Kong *et al*., 2004). These allelochemicals can either stimulate or inhibit seed germination, growth, and development of neighboring plants (Iqbal *et al*., 2020).

The present study was conducted to evaluate the allelopathic effects of *Populus nigra* L. leaf powder on the germination and early growth parameters of wheat cultivar Akbar-19 under pot experimental conditions in District Swabi.

Materials and Methods

Experimental site

The research was conducted in the Botanical Garden of Government Postgraduate College, Swabi, Khyber Pakhtunkhwa, Pakistan.

Soil collection and analysis

Soil was collected from Ghulama (Syeed Abad), Tehsil Razar, District Swabi. The collected soil was analyzed for its textural composition and was classified as a silty-clay loam, consisting of 40% silt, 40% clay, and 20% sand.

Collection and preparation of leaf powder

Fresh leaves of *Populus nigra* L. were collected from Charbagh, District Swabi. The collected leaves were air-dried at room temperature and subsequently ground into a fine powder using an electric grinder. The leaf powder was weighed into four different quantities (25 g, 50 g, 75 g, and 100 g) and stored in labeled packets until use.

Experimental design

A total of fifteen plastic pots (15 × 14 cm) were used in the experiment. The pots were arranged into five treatment groups, each consisting of three replicates. The treatments were designated as Control (T_0), Treatment 1 (25 g leaf powder), Treatment 2 (50 g leaf powder), Treatment 3 (75 g leaf powder), and Treatment 4 (100 g leaf powder). Healthy wheat seeds were surface-sterilized with a 3% sodium hypochlorite solution and subsequently rinsed several times with sterile distilled water. The powdered leaves of *Populus nigra* L. were uniformly mixed with 1000 g of soil at the respective treatment levels (25 g, 50 g, 75 g, and 100 g). Thereafter, 200 mL of water was added to each pot.

Watering/ Irrigation

An adequate amount of water is essential for proper seed germination. In the present study, approximately 200–400 mL of water was applied to each pot immediately after sowing to maintain soil moisture. Thereafter, the same amount of water was applied to all pots at three-day intervals throughout the experimental period.

Sowing

A total of seventy-five healthy wheat seeds (sown on 28/01/2025) were used in the experiment under different treatments (Control, T1–25 g, T2–50 g, T3–75 g, and T4–100 g), with 15 seeds assigned to each treatment group. After sowing, the pots were covered with polythene sheets for the first three days to raise the temperature in cold conditions. After germination, the seedlings were protected for the first two weeks with a fiber net to prevent damage from birds.

Parameters studied

Data for germination indices were recorded 14 days after sowing. The germination indices included Germination Percentage (G%), Seed Vigor Index (SVI), Mean Germination Time (MGT), Speed of Germination (SG), and Germination Index (GI).

Growth parameters were recorded 28 days after sowing and included the number of leaves per plant, leaf size, shoot length, root length, fresh biomass, and dry biomass of wheat cultivar Akbar-19.

Statistical analysis

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates. The collected data were subjected to Fisher's Analysis of Variance (one-way ANOVA) at a 5% level of significance using Microsoft Excel 2016. The statistical procedures were performed according to the method described by Inayat *et al.* (2024).

Results and Discussion

Germination indices

Statistical analysis of the data showed that *Populus nigra* L. leaf powder (PNL) had a non-significant effect on the germination percentage of wheat cultivar Akbar-19 (Table 1, Figure 1). The present findings are in agreement with Inayat *et al.* (2024), who also reported non-significant effects of PNL powder on germination percentage among different wheat varieties, including Ghazanvi, Siran, Atta Habib, and Janbaz. In contrast, Hussain *et al.* (2022) reported that aqueous extracts of *Populus deltoides* significantly enhanced the emergence of *Avena sativa* L. (oat), *Zea mays* L. (maize), and *Triticum aestivum* L. (wheat).

Table 1: *Germination Indices of wheat cultivar Akbar-19 under different concentration treatments of Populus nigra L. leaf powder.*

	Germination indices				
Treatments	**G%**	**SVI**	**MGT**	**SG**	**GI**
Control (T0)	100.00%	84.33	5.05 days	1.07	27.66
T1-(25 g)	100.00%	36	5.53 days	1.07	27
T2-(50 g)	100.00%	22.67	5 days	1.07	26.33
T3-(75 g)	100.00%	19	5 days	1.07	25.66
T4-(100 g)	100.00%	16	5 days	1.07	22.66

Keys: G = Germination, SVI = Seed Vigor Index, MGT = Mean Germination Time, SG = Speed of Germination, GI = Germination Index.

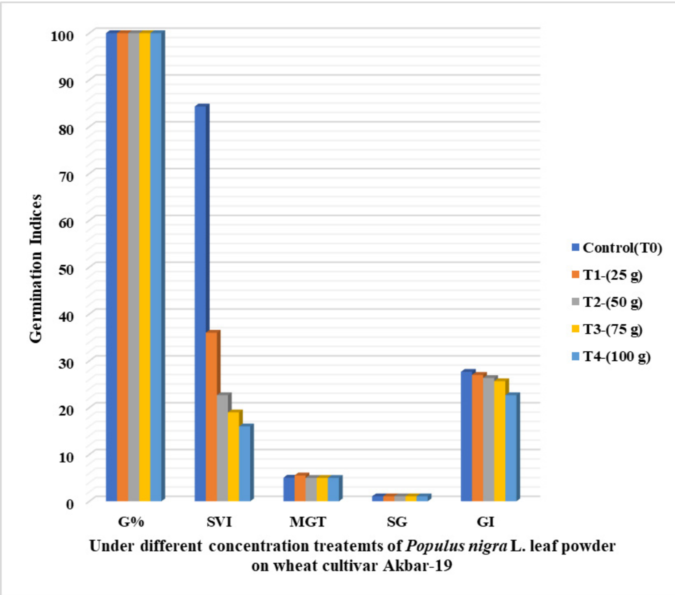

Figure 1: *Germination Indices of wheat cultivar Akbar-19 under different concentration treatments of Populus nigra L. leaf powder.*

The seed vigor index showed a highly significant effect (P ≤ 0.05; 2.16 × 10^{-7}) on wheat cultivar Akbar-19 (Table 2). The highest seed vigor index (84.33) was recorded in the control pots, while the lowest value (16) was observed in Treatment 4 (100 g)

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(Table 1, Figure 1). These results are consistent with Pushpa *et al.* (2020), who reported that soil residues of allelopathic weeds such as *Chenopodium album* and *Convolvulus arvensis* exert inhibitory effects on germination percentage, seed vigor index, mean germination time, and germination index in wheat.

Table 2: *Results of ANOVA analysis of different concentration treatments of Populus nigra L. leaf powder on Germination Indices of wheat cultivar Akbar-19.*

Germination indices	Source of variation	df	F	P-value
Seed Vigor Index	Between groups	4	74.13514	2.16E-07*
	Within groups	10		
	Total	14		
Mean Germination Time	Between groups	4	4.087137	0.032304*
	Within groups	10		
	Total	14		
Germination Index	Between groups	4	3.25	0.059445^NS
	Within groups	10		
	Total	14		

Key: ''- Significant at P ≤ 0.05, 'NS'- Non-Significant at P ≥ 0.05.*

Table 3: *Growth Parameters of wheat cultivar Akbar-19 under different concentration treatments of Populus nigra L. leaf powder.*

Treatments	Growth parameters					
	Number of leaves	Leaf size (cm)	Shoot length (cm)	Root length (cm)	Fresh biomass (g)	Dry biomass (g)
Control (T0)	17.66	8.46	22.16	6.83	1.92	0.97
T1-(25 g)	20	5.23	25.16	6.26	3.03	1.51
T2-(50 g)	18.33	4.35	23.6	6.80	2.84	1.42
T3-(75 g)	18	4.52	22.03	7.36	1.37	0.68
T4-(100 g)	17.33	4.05	21	7.10	1.32	0.66

For mean germination time (MGT), the statistical analysis indicated a significant effect (P ≤ 0.05; 0.032304) (Table 2). In the control, MGT was 5.05 days. Treatment 1 recorded an average MGT of 5.53 days, whereas treatments T3 and T4 showed values of approximately 5 and 5 days, respectively (Table 1). These findings partially support Abdul Majeed *et al.* (2017), who reported that *Populus deltoides* L. did not significantly affect MGT, with values ranging from 4.13 to 4.75 days across treatments.

Regarding the speed of germination, all treatments of Poplar leaf powder, including the control, showed non-significant effects on wheat cultivar Akbar-19, with a uniform value of 1.07 (Table 1, Figure 1). These results differ from Fuller *et al.* (2012), who reported that increasing salinity stress reduced the speed of germination in *Triticum aestivum* L. These differences may be attributed to variations in experimental conditions.

For the germination index, the results showed a non-significant effect (P ≥ 0.05; 0.059445) (Table 2). These findings contrast with Abbas *et al.* (2018), who reported that wheat germination was significantly affected by priming techniques and duration, although their interaction was non-significant. Similarly, Hmissi *et al.* (2023) observed that increasing salinity stress reduced the germination index in wheat cultivars. The differences observed in the present study may be due to the tolerance of wheat cultivar Akbar-19 to *Populus nigra* L. leaf powder or differences in experimental conditions.

Growth parameters

Statistical analysis of the data showed that *Populus nigra* L. leaf powder had a non-significant effect on the number of leaves of wheat cultivar Akbar-19 (P ≥ 0.05; 0.521359) (Table 4). These findings are in contrast to Inayat *et al.* (2020) and Kohli *et al.* (1997), who reported significant effects of Poplar leaf powder on the number of leaves of *Triticum aestivum* L.

For leaf size, the statistical analysis revealed a significant effect of *Populus nigra* L. leaf powder on wheat cultivar Akbar-19 (P ≤ 0.05; 0.000658) (Table 4). The present findings are consistent with Inayat *et al.* (2024), who reported that different concentrations of poplar leaf powder significantly reduced leaf length in various wheat varieties.

Shoot length showed a non-significant response to Poplar leaf powder treatment (P ≥ 0.05; 0.349496) (Table 4). However, shoot length initially increased at lower concentrations (25 g to 50 g) and subsequently decreased at higher concentrations (75 g to 100 g), indicating a possible inhibitory effect at higher doses (Table 3, Figure 2). These results are partially supported by Inayat *et al.* (2024), who observed maximum shoot length at 20 g Poplar leaf powder concentration (79.77 cm). The non-significant overall effect in the present study may be attributed to the tolerance of wheat cultivar Akbar-19 to allelochemicals present in Poplar leaf powder compared to other wheat varieties.

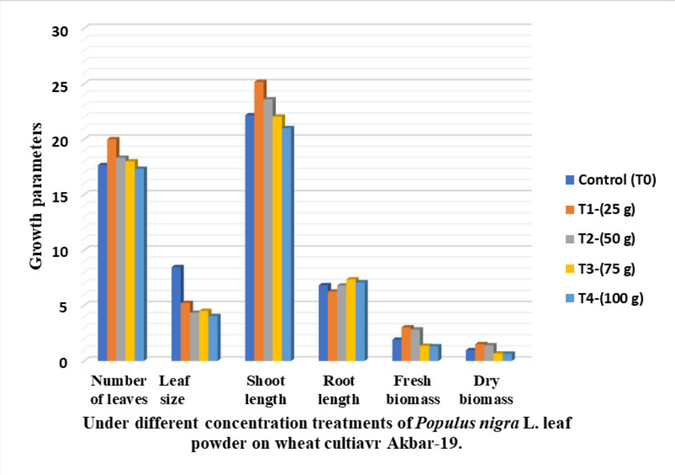

Figure 2: *Growth parameters of wheat cultivar Akbar-19 under different concentration treatments of Populus nigra L. leaf powder.*

Table 4: *Results of ANOVA analysis of different concentration treatments of Populus nigra L. leaf powder on Growth Parameters of wheat cultivar Akbar-19.*

Growth parameters	Source of variation	df	F	P-value
Number of leaves	Between groups	4	0.857143	0.521359[NS]
	Within groups	10		
	Total	14		
Leaf size	Between groups	4	12.53071	0.000658*
	Within groups	10		
	Total	14		
Root length	Between groups	4	1.243399	0.353492 [NS]
	Within groups	10		
	Total	14		
Shoot length	Between groups	4	1.254767	0.349496[NS]
	Within groups	10		
	Total	14		
Fresh biomass	Between groups	4	11.1618	0.001043*
	Within groups	10		
	Total	14		
Dry biomass	Between groups	4	10.85616	0.001164*
	Within groups	10		
	Total	14		

Key: ''- Significant at P ≤ 0.05, 'NS'- Non-Significant at P ≥ 0.05.*

For root length, statistical analysis indicated a non-significant effect of poplar leaf powder treatment (P ≥ 0.05; 0.4477) (Table 4). The lowest mean root length was recorded in the control (7.73 cm), whereas the highest root length was observed in Treatment 1 (25 g; 9.23 cm), followed by Treatment 3 (75 g; 9.10 cm) (Table 3, Figure 2). The comparatively lower root length in the control may be associated with the silty-clay loam soil texture, which can become compact due to higher clay content, potentially restricting root elongation. These findings differ from Khalid *et al.* (2020), who reported that extracts of *Populus nigra* L., *Morus alba*, and *Euphorbia helioscopia* significantly reduced radicle length in *Brassica campestris*. Similarly, Pushpa *et al.* (2020) observed significant inhibitory effects of *Chenopodium album*, *Convolvulus arvensis*, and *Avena fatua* on wheat root length. These differences may be attributed to variations in test species and experimental methodologies.

For fresh biomass, statistical analysis showed a significant effect of *Populus nigra* L. leaf powder on wheat cultivar Akbar-19 (P ≤ 0.05; 0.001043) (Table 4). The highest fresh biomass (3.03 g) was recorded in Treatment 1 (25 g), while the lowest value (1.32 g) was observed in Treatment 4 (100 g). The control pots recorded an average fresh biomass of 1.92 g (Table 3, Figure 2). These results are in agreement with Inayat *et al.* (2024), Pushpa *et al.* (2020), and Gul *et al.* (2022), who reported that different allelopathic weeds and tree species significantly affect fresh biomass accumulation in wheat.

For dry biomass, statistical analysis also showed a significant effect of *Populus nigra* L. leaf powder on wheat cultivar Akbar-19 (P ≤ 0.05; 0.001164) (Table 4). The highest dry biomass (1.51 g) was recorded in Treatment 1, while the lowest value (0.66 g) was observed in Treatment 4. The control pots exhibited an average dry biomass of 0.96 g (Table 3, Figure 2). These findings are consistent with previous studies by Inayat *et al.* (2024), Gul *et al.* (2022), Pushpa *et al.* (2020), and Jabeen *et al.* (2013), who reported that allelopathic effects of *Populus nigra* L., *Melia azedarach* L., *Morus alba* L. and various weed species, such as *Chenopodium album*, *Convolvulus arvensis*, *Euphorbia hirta*, and *Avena fatua*, significantly reduce dry biomass in wheat varieties.

Conclusion and Recommendations

The present study revealed that *Populus nigra* L. leaves contain allelochemicals that exert inhibitory effects on the germination and growth parameters of wheat (*Triticum aestivum* L.). Overall, *Populus nigra* L. leaf powder significantly affected seed vigor index, mean germination time, leaf size, fresh biomass, and dry biomass, while it showed non-significant effects on germination index, number of leaves, root length, and shoot length of wheat cultivar Akbar-19.

Based on these findings, it can be concluded that the presence of *Populus nigra* L. leaf residues in soil may negatively influence wheat performance, particularly at higher concentrations.

It is recommended that the accumulation of *Populus nigra* L. leaf litter in wheat fields should be minimized before sowing to reduce potential allelopathic effects. Where *Populus nigra* L. trees are present near agricultural fields, proper removal or management of fallen leaves is advised before wheat cultivation.

Farmers and local communities should be made aware of the possible allelopathic effects of *Populus nigra* L. in order to improve crop management practices.

Furthermore, wheat cultivar Akbar-19 showed relatively better tolerance compared to expected responses reported in previous studies; therefore, it may be considered for cultivation in areas where *Populus nigra* L. is commonly present. However, further field studies are recommended to confirm varietal tolerance under different environmental conditions.

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Novelty Statement

In District Swabi, particularly in Tehsil Razzar, limited information is available regarding the agroforestry interactions of Black Poplar (*Populus nigra* L.) with cereal wheat cultivars. The present study was designed to evaluate the allelopathic effects of *Populus nigra* L. leaf powder on wheat cultivar Akbar-19 under the agro-climatic conditions of Tehsil Razzar, District Swabi, Pakistan. This research provides novel insights into the agroforestry interaction between Black Poplar and wheat in the study area.

Author's Contribution

Shahid Ali: Supervision and proofreading.
Aafaq Ahmad: Data collection, manuscript writing, and formatting.
Sohail Bacha: Collection of *Populus nigra* L. leaves from Charbagh village.
Muhammad Muneeb: Soil collection and soil texture analysis.
Ayaz Akhtar, Safi Ullah, and Munsif Ali: Data analysis and interpretation.
Ubaid Ullah: Manuscript review and editing.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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