EFFECT OF ALLELOCHEMICALS PRESENT IN LEAF LITTER OF *BOMBAX CEIBA* L. AND *POPULUS DELTOIDES* L. TREE SPECIES ON WHEAT IN AGROFORESTRY SYSTEM

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Abstract. The study was organized to analyze the allelopathic influence of leaf litter of *Populus deltoides* (poplar) and *Bombax ceiba* (simal) tree species under the agroforestry system during December 2018-2019 in the research area of the Department of Forestry and Range Management, University of Agriculture, Faisalabad. The allelopathic interference of both tree species was determined on the germination, radicle and plumule length plant height, number of productive tillers, spike length, spikelets per spike, grains per spike 00-grains weight, leaf area index, leaf area duration, grain yield, biological yield and harvest index were recorded. Biochemical analysis of leaf proline, chlorophyll contents, and leaf malondialdehyde contents was also carried out. Water-related attributes were also examined as osmotic potential, water potential and pressure potential of wheat. In the present study, the wheat was grown in pots and screened to analyze the allelopathic potential of *Bombax ceiba* L. and *Populus deltoides* L. by using four different leaf powder concentrations of 0 g/pot 30 g/pot, 60 g/pot and 90 g/pot of both tree species separately. There were observed significant inhibitory effects of *Populus deltoides* L. on wheat as compared to *Bombax ceiba* L. as the concentration of leaf litter of both tree species was increased.
Keywords: *allelopathy, wheat, germination, radicle, plumule, allelochemicals, agroforestry*

Introduction

Agroforestry is a very sustainable practice for sustainable production and livelihood improvement globally. It also plays very vital role in degradation of environmental hazards and socio-economic advantages but some trees emit phytotoxic elements to the soil that have a detrimental effect on the germination and yield of understory crops (Zubay et al., 2021), In agroforestry, allelopathic experiences in tree crop associations have a direct effect on crop production. The release of allelochemicals by a number of trees has adverse effect on the production of understory crops. Allelopathic influence of *Bombax ceiba* L., *Populus deltoides*, *Eucalyptus camaldulesis*, *Acacia nilotica* and *Cassia siamea* species have been reported by Hassan (2018), Xaxa et al. (2018), Singh et al. (2021) and Siregar et al. (2021).

Agroforestry system is also very common in Pakistan like other agricultural countries but it is being declined due to the allelopathic influence of trees on agricultural crops. *Populus deltoides* (poplar) and *Bombax ceiba* (simal) are multipurpose, fast-growing, valuable timber species and are considered very significant and major agrisilviculture tree species in Pakistan. Many other crop rotations used in Pakistan are not as commercially feasible or sustainable as poplar and simal-based agroforestry system is preferred. In the agroforestry system, farmers use a variety of tree-crop combinations including poplar and simal. Poplar and simal creates a lot of biomass in a shorter period

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of time and recycles soil nutrients by introducing leaf litter from its leaf shed during the winter season. Farmers prefer to grow these tree species alongwith wheat due to their smaller rotation and suitable climatic and ecological conditions in the country (Baig et al., 2021; Abbas et al., 2021). Wheat is a staple crop and it is cultivated on a large area (8.8 million hectares) and has more importance than any other kind of crop in Pakistan. It is abundant in vitamins, nutrients, carbohydrates, fats, oils, and protein in their natural state. Wheat is the most commonly planted crop in the interspaces of poplar during the winter season in Pakistan.

Even though agroforestry system has the ability to improve production but it also competes with food crops. Allelochemicals are found in leaf powder, and their toxic effects differ by species (Lebedev et al., 2019; Bakhshayeshan et al., 2020). Before proposing any tree species for an agroforestry program, comprehensive studies on the impact of allelochemicals present in tree species and their negative influence on seed emergence, growth and metabolism of crop plants must be known. Over the last two decades, allelopathy is imparting in serious reduction of growth and yield of major crops and this is an emerging problem which needs to be overcome. There was not any major work is being done in Faisalabad especially regarding poplar and simal agroforestry system. It needs to be studied further. As a result, the current research focuses on determining the allelopathic effect of *Populus deltoides* L. and *Bombax ceiba* L. on the germination and growth characteristics of the wheat crop.

Materials and methods

The research was directed to investigate the allelopathic potential of Poplar tree species on wheat in the research experimental area of the department of Forestry and Range Management, University of Agriculture, Faisalabad. This study was carried out in semi-arid climatic conditions with extremely hot and humid summers followed by cool and dry winters. The average temperature range was a maximum of 40.5 °C (104.9 °F) and a minimum of 26.9 °C (80.4 °F) in June while in January the average temperature range was a maximum of 19.4 °C (66.9 °F) and a minimum 4.1 °C (39.4 °F).

In the present experimental study, leaves of poplar and simal tree species were collected from Punjab Forest Research Institute, Gatwala, Faisalabad. Then leaves of both tree species were sundried for 72 h and grinded in an electric grinder separately. There were given four different treatments including control with four replications for each tree species. The powder of leaves of both tree species was collected and mixed with the sandy clay loam soil separately at different concentration levels of 0 g/pot (control), 30 g/pot, 60 g/pot and 90 g/pot. After mixing the leaf litter the pots were filled with 7 kg soil with the similar mixed soil. Wheat variety was grown in the pots filled with sandy clay loam soil. The cultivar used for sowing was Ujala 2014. Twenty seeds were planted in each pot on Nov 15, 2017, and harvested on April 25, 2018.

On the seventh day after sowing, germination was inscribed and data recorded for 15 days. The number of germinated seeds was used to determine germination rate (%) while a ruler was used to measure the length (cm) of the radicle and plumule of the germinated crop. Plant height (cm) was measured at maturity stage with a meter rod. The number of productive tillers was counted by counting the tillers bearing spikes. Spike length (cm) was measured from the base to the uppermost tip of the spikelet with a measuring scale. Spikelets per spike were counted the spikelets from each experimental unit and the average was calculated. Grains per spike were calculated by

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counting the grains of each experimental unit and the average was calculated. 100-grains weight (g) was calculated for each experimental unit was obtained by using an electric weighing balance. Leaf area was measured with a leaf area meter (CT-202, CID Inc. USA) and leaf area index was computed as the ratio of leaf area to land area followed by Ploschuk et al. (2021). Leaf area duration (LAD) was determined using following Hunt's formula as exhibited by Mubeen et al. (2021).

$$LAD = \frac{(LAI1 + LAI2) \times (t2 - t1)}{2}$$

LAI_1 and LAI_2 are respectively indices at time's t_1 and t_2.

Wheat was thrashed manually grain yield (g) biological yield (gm $^{-2}$) and total dry matter (gm $^{-2}$) was calculated with a measuring scale and harvest index (%) was computed. Water-related attributes were examined, in which relative water contents were calculated by following Barr and Weatherley's method described by Sapes et al. (2021). Osmotic potential was followed by Wenkert (1980), while water potential was calculated by following Scholander et al. (1964). The leaf chlorophyll contents were determined using Arnon methodology as expressed by Ahmad et al. (2022). Further leaf proline contents were examined by following the approach of Bates et al. (1973). Leaf malondialdehyde contents were examined by following the methodology of Hnilickova et al. (2021) and Leng et al. (2021).

Soil was collected from 3-6 ft depth and soil samples were taken before adding the leaf powder of *P. deltoides* and *B. ceiba* and also at harvest (from pots) for soil analysis. Soil texture was analyzed using bouyoucos hydro-meter mechanism presented by Acevedo et al. (2021). Soil organic matter was examined by following the Walkley and Black method as expressed by Xing et al. (2021). Soil available nitrogen (N) (Akaline-$KMno_4$ method), phosphorus (P) (P-Olsen method) and potassium K (Flame photometric method) were measured as exhibited by Mukherjee et al. (2021), Eberhardt et al. (2021) and Chen et al. (2021) respectively. PH of the soil was assessed by using PH-meter (HORIBA D-54) as revealed by Zeng et al. (2021). Electrical conductivity (EC) of the soil was explored by using Hanna EC-meter, Romania (Stanek et al., 2021). Soil saturation was estimated with gravimetric method exposed by Duarte et al. (2021). Total soluble phenolic (TSP) contents were investigated by following the methodology of Akomeng et al. (2021).

This study was statically analyzed using a two-way ANOVA to test the species (S) effects, treatments (T) effects and their interaction effect (S × T). Significant differences between all the treatments were respectively compared to controlled treatments using Dunnett's test. All tests were taken significantly at $p < 0.05$. The software (Statistica 12.5, Maisons-Alfort, France) was used to run all the tests.

Results

Wheat germination, growth and yield parameters

The order of reduction in all parameters under treatments for both species (leaf powder) was T4 (90 g leaf powder) > T3 (60 g leaf powder) > T2 (30 g leaf powder) > T1 (control). However, poplar leaf powder showed greater inhibitory effects and reduction as compared to simal leaf powder for all parameters. The allelopathic interaction of poplar and Simal tree species on wheat germination and growth parameters is demonstrated in

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the following *Table 1*. Poplar leaf powder showed a higher inhibitory effect on wheat as compared to simal. The leaf powder of *Populus deltoides* distinctly inhibited wheat seed germination. The highest reduction in germination rate was found in the T_4 group of *Populus deltoides* L. tree species obtained 90 g leaf powder. The ratio of seed germination decreased as the concentration of leaf powder increased for both tree species, with the lowest germination (73.45%) recorded in leaf powder of *Populus deltoides* L. with treatment T_4 (40 percent powder concentration).

Wheat crop radicle and plumule lengths were measured and compared to control plants. Application of leaf powder delayed the development of both radicle and plumule (*Table 1*). The effect of leaf powder of *Bombax ceiba* L. and *Populus deltoides* on growth parameters decreased as the concentration of leaf powder increased but higher inhibitory effect of leaf powder of *Populus deltoides* L. was observed as compared to the leaf powder of the *Bombax ceiba* L. on wheat. The maximum radicle length (4.20 cm) and plumule length (3.18) were documented in T_1 (control) treatment of *Bombax ceiba* L. as compare to *Populus deltoides* L. while the maximum reduction was determined in radicle length (2.49 cm) and plumule length (1.68 cm) in T_4 (40% conc) treatment of leaf powder of *Populus deltoides* L. as compared to *Bombax ceiba* L.

The highest mean values of plant height were measured (76.08 cm for simal and 74.34 cm for poplar) in control (T1), followed by T2 (30 g leaf powder): 70.82 cm and 68.62 cm for simal and poplar respectively. The lowest plant height was observed for T4 (90 g leaf powder) for simal and poplar tree species 14.95% and 20.74% respectively as compared to control. The maximum productive tillers (9.87 and 9.69) were recorded for T1 (control) for both species. It reduced gradually with the increase of leaf powder concentration of both species. The smallest number of productive tillers (6.97) was calculated for T4 i.e. 90 g leaf powder of poplar. The maximum spike length was measured (11.74 cm for simal and 11.53 cm for poplar) in control (T1), followed by T2 (30 g leaf powder): 10.85 cm and 10.20 cm for simal and poplar respectively. For T3 (60 g leaf powder), spike length reduced by 15.84% for simal and 16.39% for poplar as compared to control. The minimum spike length was measured for T4 (90 g leaf powder) for both simal and poplar tree species18.64% and 19.16% respectively as compared to control. The maximum mean value of spikelets (15.88 and 15.74) was recorded for T1 (control). It reduced gradually with the increased concentration of leaf powder for both species. The minimum mean value of spikelets per spike (13.54) was calculated for T4 (90 g leaf powder) for poplar and was 2.54% lower than the mean value of spikelets at 90 g leaf powder of simal.

The maximum number of grains was noted (36.52 for simal and 36.46 for poplar) in control (T1), followed by T2 (30 g leaf powder): 33.72 and 32.50 for simal and poplar respectively. For T3 (60 g leaf powder), the number of grains per spike reduced by 13.6% for simal and 22.35% for poplar as compared to control. The minimum grains per spike was measured for T4 (90 g leaf powder) simal and poplar tree species was 23.63% and 32.66% respectively as compared to control. The maximum grain yield was recorded (8.72 g/pot for simal and 8.68 g/pot for poplar) in control (T1), followed by T2 (30 g leaf powder): 8.28 g/pot and 7.88 g/pot for simal and poplar respectively. For T3 (60 g leaf powder), the grain yield reduced by 13.3% for simal and 20.9% for poplar as compared to control. The minimum grain yield was measured for T4 (90 g leaf powder) for simal and poplar tree species was 16.51% and 29.03% respectively as compared to control. Harves index was also declined in both tree species but higher reduction was noticed under poplar as compared to simal as described in *Table 1*.

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Table 1. *Effect of allelochemicals present in leaf litter powder of P. deltoides L. and B. ceiba L. on germination and growth parameters of wheat crop. A two-way ANOVA was used to test for species effect (S-effects), treatment effect (T-effects), and interaction effect (S × T). Significant differences between treatments within each species tested using the Dunnett's test are denoted by small letters. At p < 0.05, all tests were considered significant*

Treatments	Growth parameters																											
	Germination (%)		**Radicle length (cm)**		**Plumule length (cm)**		**Plant height (cm)**		**No. of productive tillers**		**Spike length (cm)**		**Spikelets per spike**		**Grains per spike**		**100 grains weight (g)**		**Leaf area index**		**Leaf area duration (Days)**		**Grain yield (g/pot)**		**Biological yield (gm $^{-2}$)**		**Harvest index (%)**	
	B. ceiba	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*	*B. ceiba*	*P. deltoides*
0 g/pot leaf powder (Control) (T_1)	91.4d	90.8b	4.2e	4.15c	3.18b	3.17c	76.08f	74.34a	9.87b	9.696c	11.74a	11.53a	15.886c	15.744d	36.522b	36.46a	5.12d	4.89e	5.772a	5.73c	240a	236f	8.70 a	8.59f	24.78b	24.46b	26.1a	25.9e
30 g/pot leaf powder (T_2)	86.4c	78.6d	3.91e	3.72c	2.92a	2.78b	70.82e	68.62b	8.86e	7.906d	10.85d	10.206a	15.32a	15.07b	33.724b	35.502c	4.75b	4.35f	5.446a	5.334b	233c	228e	8.08 e	7.56f	22.98c	21.8a	24.5c	23.6f
60 g/pot leaf powder (T_3)	80.8b	73.6a	3.48f	3.22d	2.34c	2.12d	67.28a	60.98c	7.514g	7.154e	9.882c	9.648b	14.456e	14.156g	31.558a	28.314e	4.06a	3.46a	5.23b	5.062a	221d	217a	7.21 d	6.72a	19.57a	18.1b	21.4d	20.2a
90 g/pot leaf powder (T_4)	70a	61.8e	2.95d	2.49b	1.89f	1.68a	64.6b	58.92c	7.036f	6.97a	9.558b	9.32c	13.894e	13.548a	27.862d	24.664f	3.15f	2.67d	4.756d	4.614d	212a	205c	6.72 c	5.95c	16.23 d	15.3c	19.2b	17.7c
S-effect	0.53**		0.28**		0.31**		0.47**		0.34**		0.32**		0.41**		0.48**		0.51**		0.08**		1.58**		0.52**		0.70**		1.44**	
T-effect	1.02**		0.52**		0.66**		1.05**		0.56**		0.61**		0.63**		0.68**		0.73**		0.080**		2.30**		0.79**		1.05**		2.11**	
(S×T) ($p \leq 0.05$)	1.25**		0.63*		1.16**		1.33**		0.89*		0.81**		0.92**		1.17**		1.09*		0.19**		2.67*		1.14*		1.22**		3.01**	

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The maximum leaf area was computed for control and it gradually decreased with increasing the concentration of leaf powder. The highest leaf area was calculated (5.72 for simal and 5.73 for poplar) in control while the lowest leaf area was estimated for T4 (90 g leaf powder) for simal and poplar tree species was 17.13% and 19.54% respectively as compared to control. The maximum leaf area duration (240 and 236 days) was recorded for T1 (control) for both species. It was reduced gradually for different concentrations of leaf powder for both species. The lowest leaf area duration (205 days) was calculated for T4 (90 g leaf powder) for poplar and was 3.30% lower than the leaf area duration at 90 g leaf powder of simal as compared to control.

Water-related attributes

Osmotic potential

The osmotic potential showed significant variation under different concentrations of leaf powder of both tree species. The higher osmotic potential was computed for control and it gradually decreased with increasing the concentration of leaf powder. The maximum measured osmotic potential was (0.169 for simal and 0.096 for poplar) in control (T1), followed by T2 (30 g leaf powder): 0.155 and 0.087 for simal and poplar respectively. The minimum osmotic potential was measured for T4 (90 g leaf powder) for both tree species as described in *Figure 1*.

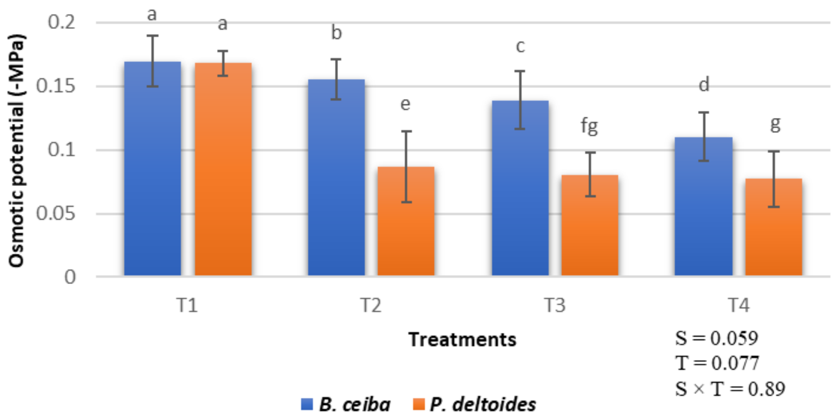

Figure 1. *Effect of P. deltoides and B. ceiba leaf powder on osmotic potential of wheat*

Water potential

It was noted that different concentrations of leaf powder of both tree species have shown significant variation regarding water potential (*Fig. 2*). The maximum water potential was computed for T4 (90 g leaf powder) and it gradually decreased for the lower level of leaf powder concentration. The highest mean value of water potential was measured 1.44 for simal in (T4), followed by T3 (60 g leaf powder): 1.36 and 1.31 for simal and poplar respectively. The reduction in water potential under control treatment was 28.47% for simal and 30.21% for poplar respectively as compared to T4.

Pressure potential

It was recorded that different concentrations of leaf powder of both tree species have shown significant variation for pressure potential. The maximum pressure potential was

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computed for T4 (90 g leaf powder) and it gradually decreased for the lower level of leaf powder. The highest mean value of pressure potential was measured (1.33 for simal in T4 (90 g leaf powder) followed by T3 (30 g leaf powder 60 g leaf powder): 1.22 and 1.16 for simal and poplar respectively as demonstrated in *Figure 3*. The lowest pressure potential was observed for control (0 g leaf powder) for both tree species.

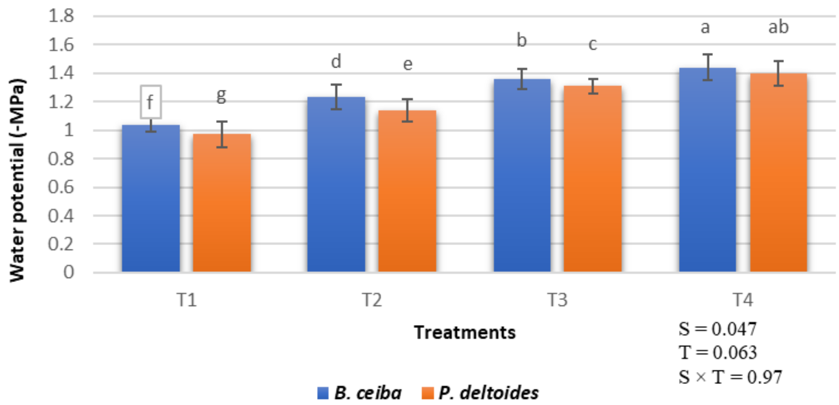

Figure 2. *Effect of P. deltoides and B. ceiba leaf powder on water potential of wheat*

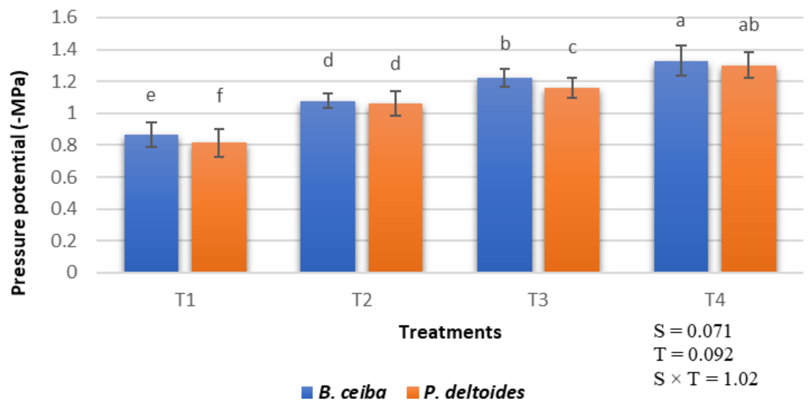

Figure 3. *Effect of P. deltoides and B. ceiba leaf powder on pressure potential of wheat. A two-way ANOVA was used to test for species effect (S-effects), treatment effect (T-effects), and interaction effect (S × T) regarding Figures 1, 2 and 3. Significant differences between treatments within each species tested using the Dunnett's test are denoted by small letters. At p < 0.05, all tests were considered significant*

Biochemical attributes

Chlorophyll a

It was found that the chlorophyll a content decreased gradually with the increase of concentration of tree leaf powder, however, this reduction was greater for poplar leaf powder as compared to simal (*Fig. 4*). The maximum chlorophyll a (0.292 µg g^{-1} and 0.288 µg g^{-1}) was recorded for T1 (control) for both species. The minimum chlorophyll a content (0.236 µg g^{-1}) was calculated for T4 (90 g leaf powder) for poplar and was 3.67% lower than the chlorophyll content a, at 90 g leaf powder of simal.

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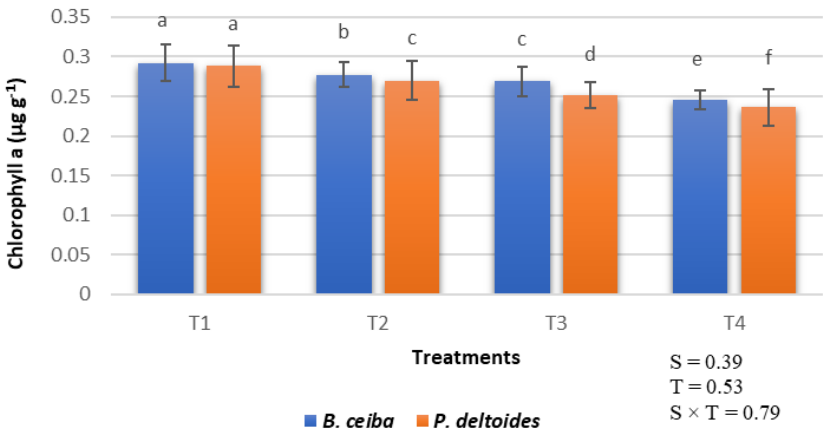

***Figure 4.** Effect of P. deltoides and B. ceiba leaf powder on chlorophyll a of wheat*

Chlorophyll b

It was observed that the chlorophyll b decreased gradually with the increase of concentration of tree leaf powder concentration, however, this reduction was greater for poplar leaf powder as compared to simal as shown in *Figure 5*. The maximum chlorophyll b (0.223 µg g^{-1} and 0.202 µg g^{-1}) was recorded for T1 (control) for both species. The minimum chlorophyll b content (0.151 µg g^{-1}) was calculated for T4 (90 g leaf powder) for poplar and was 4.43% lower than the chlorophyll b, at 90 g leaf powder of simal.

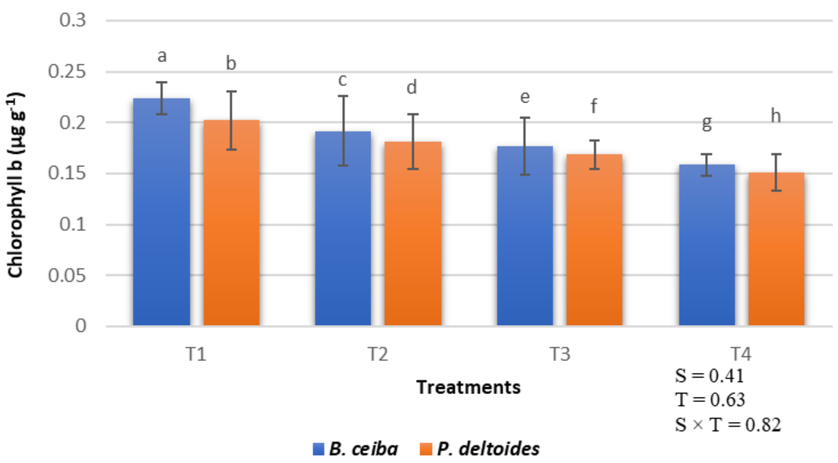

***Figure 5.** Effect of P. deltoides and B. ceiba leaf powder on chlorophyll b of wheat*

Leaf proline

It was observed that different concentrations of leaf powder of both tree species have shown significant variation in proline content. The maximum proline content was computed for T4 (90 g leaf powder) and it gradually decreased for the lower level of leaf powder as revealed in *Figure 6*. The highest mean value of proline content was measured (0.41 µmol g^{-1} for simal in T4 (90 g leaf powder), followed by T3 (60 g leaf powder): 0.36 µmol g^{-1} and 0.35 µmol g^{-1} for simal and poplar respectively. The lowest proline content was observed for control (0 g leaf powder) for simal and poplar was 29.26% and 31.57% respectively as compared to T4 for both species.

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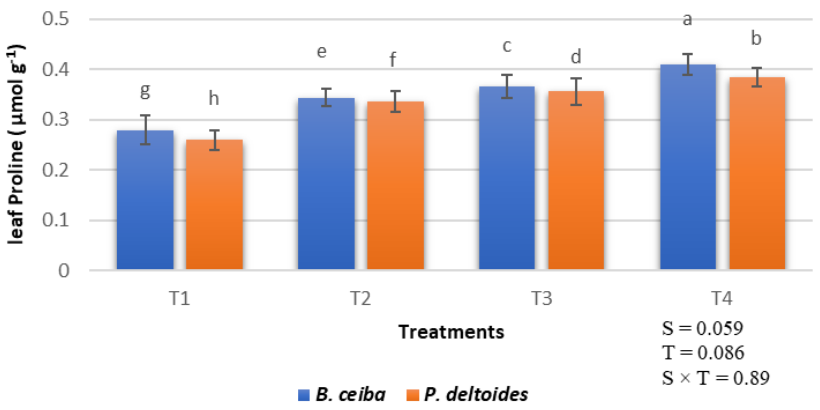

Figure 6. *Effect of P. deltoides and B. ceiba leaf powder on leaf proline of wheat*

Malondialdehyde (MDA)

It was recorded that different levels of leaf powder of both tree species have shown significant variation in MDA content. The maximum MDA was computed for control and it gradually decreased with increasing the concentration of leaf powder as expressed in *Figure 7*. The highest leaf MDA was calculated (5.41 µmol g^{-1} for simal and 5.33 µmol g^{-1} for poplar) in control (T1), followed by T2 (30 g leaf powder): 4.82 µmol g^{-1} and 4.27 µmol g^{-1} for simal and poplar respectively. The lowest mean MDA value was estimated for T4 (90 g leaf powder) of simal and poplar was 37.15% and 45.40% respectively as compared to control.

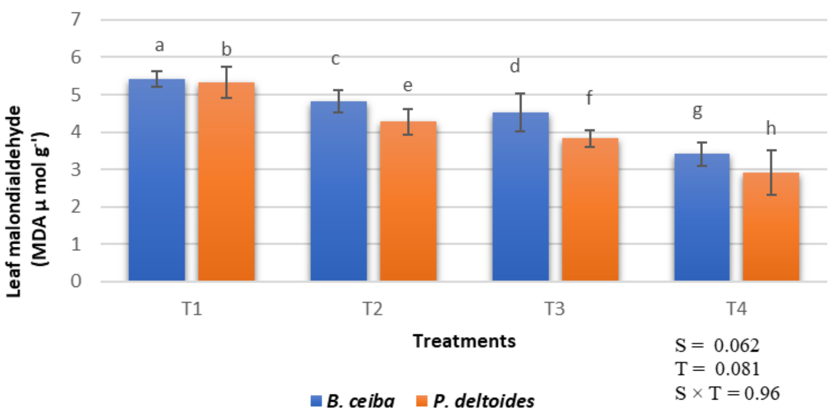

Figure 7. *Effect of P. deltoides and B. ceiba leaf powder on leaf malondialdehyde (MDA) of wheat. A two-way ANOVA was used to test for species effect (S-effects), treatment effect (T-effects), and interaction effect (S × T) regarding Figures 4, 5, 6 and 7. Significant differences between treatments within each species tested using the Dunnett's test are denoted by small letters. At $p < 0.05$, all tests were considered significant*

Effect on soil properties

The results regarding soil showed the phytotoxic impact on the soil properties in both tree species but highest reduction was recorded in *P. deltoides* as compared to *B. ceiba* tree species as expressed in *Table 2*. The resulted indicated that soil orgaic matter, N,P,K was significantly declined in *P. deltoides* while PH and EC of the soil was noted higher in *P. deltoides* as compared to *B. ceiba as* demonstrated in *Table 2.* The saturation of the soil was remained same in both tree species. Total soluble phenolics also showed the significant elevation under *P. deltoides* (8.55 mg g^{-1}) as compared to *B. ceiba* (7.03 mg g^{-1}).

Table 2. *Phytotoxic effect on soil properties under agroforestry system based on Populus deltoides L. (poplar) and B. ceiba L. (simal) tree species along with wheat crop*

Serial No.	Parameters	Values (at sowing without leaf powder of *P. deltoides* and *B. ceiba*)	Values (at harvest)	
			Wheat along with *P. deltoides* L.	Wheat along with *B. ceiba* L.
1	Soil texture	Sand 36%, Silt 43%, Clay 19% (Loam)	Sand 36%, Silt 43%, Clay 19% (Loam)	Sand 36%, Silt 43%, Clay 19% (Loam)
2	Organic matter (%)	1.06	1.02	1.09
3	Available nitrogen (N) (%)	0.055	0.051	0.058
4	Available phosphorus (P)(ppm)	12.7	13.1	13.6
5	Available potassium (K) (ppm)	125	129	136
6	PH	7.4	7.4	7.2
7	EC (dSm-1)	0.89	0.88	0.82
8	Soil saturation (%)	36	35	35
9	Total soluble phenolic (TSP) (mg g^{-1})	6.12	8.55	7.03

Discussion

The current findings back up a previous study by Tahir et al. (2019), which found that leachate from the leaves, roots and tubers of *Pistacia atlantica* tree species inhibited the germination and growth of food crops. In addition, Khalid et al. (2020), Adhikari et al. (2020) and Kumar et al. (2021) revealed that the inhibitory effects of different tree species included *Dalbergia sissoo*, *Populus deltoides* L. and *Bombax ceiba* L. leaf powder on germination on the wheat crop was proportional to the powder concentration. Moreover, Elbouzidi et al. (2021) found that as the concentration of leaf leachates of *Matricaria chamomilla* L. was increased, the reduction in germination, radicle and plumule length of wheat was observed. Alazzam et al. (2021) also found that leaf powder of *Rumex vesicarius* L. and *Zygophyllum coccineum* L. is similarly noxious to *T. aestivum* germination, plumule, and radicle formation. Correspondingly, Hachani et al. (2019) found that the *Populus nigra* and *Casuarina glauca* inhibited the plumule duration and radicle length of *T. aestivum*. Ahmad et al. (2020) have observed that the agroforestry trees *J. regia*, *M. azedarach*, and *A. altissima* had an allelopathic impact on wheat seed germination and development. Leachates had concentration-dependent effects on wheat crops.

The application of leaf powder of both selected tree species in the present study also showed inhibitory effects on the leaf area index, duration and crop growth rate of the wheat crop. This reduction was higher at greater concentration levels of leaf powder of poplar has greater inhibitory effects on leaf area index, duration, crop growth rate and dry matter accumulation as compared to simal leaf powder. It was also found that the

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leaf area index, duration and crop growth rate decreased substantially at 90 g poplar leaf powder application as compared to simal. Similar results were reported by Ibáñez et al. (2019) in crops and invasive species while Hussain et al. (2020) revealed the phytotoxic influence of *Acacia melanoxylon* on *Lactuca sativa*; Kato-Naguchi and Hisashi (2021) for agricultural crops.

The findings of this study are also concur with the results reported by Ayalew et al. (2020), Lalremsang et al. (2020) and Hussain et al. (2021) who reported the allelopathic effect of tree species: *E. camaldulensis, G. Robusta, C. equisetifolia, P. deltoides, A. indica* and *M. azedarach* on various crops including Maize, Wheat cowpeas and rice. Seed germination and survival of germinated seedlings were also inhibited by Eucalyptus tree species. Allelopathic plants greatly affected the growth parameters such as plant height, spike length, grain and biological yield. The allelopathic influence of leaf powder of *Juglans nigra* showed the maximum effect on all the growth and yield parameters of *T. aestivum* and *O. sativa* (Ochekwu et al., 2020). Our results are in agreement with Vasishth et al. (2020) who described the effect of allelochemicals compounds secreted by different tree species *Boehmeria rugulosa*, *Ougeinia oojeinensis* and *Zanthoxylum armatumand* which reduce the growth and yield of wheat and other agricultural crop.

Biochemical-related attributes findings are in agreement with the findings of de Sousa et al. (2020) described the reduction in biochemical attributes under the higher concentrations of leaf powder as compared to control. Similar inhibitory results for Eucalyptus and some other allelopathic trees including *P. deltoides* and *B. ceiba* were observed in wheat crop (Tahir et al., 2018; Guo et al., 2020; Gao et al., 2021; Tian et al., 2022). The allelochemicals actuated oxidative stress in the objective plant tissues and hinder the cell reinforcement component (Alqarawi et al., 2018; Ladhari et al., 2020; Šoln et al., 2022). It appears to be that phytotoxic extracts of *Descurainia sophia, Galium tricorne*, wild oat, and *sativa* caused oxidative stress by invigorating lipid peroxidation in *T. aestivum* and higher MDA contents were recorded higher in each treatment except for control (Shao et al., 2018). Comparable inhibitory consequences of poplar and some other allelopathic trees were seen in wheat yield (Ghafarizadeh et al., 2018; Šućur et al., 2021). Decline in the water-related attributes is in agreement with the results of Shah et al. (2020). Similar allelopathic inhibitory findings were reported for *E. camaldulensis* and some other tree species in *T. aestivum* and some other major crops (Bali et al., 2019; Rizvi et al., 2020; Heile et al., 2021; Hassanisaadi et al., 2022).

Trees have the abilities to affect the soil properties (Bargali et al., 2019; Tajik et al., 2019; Ahirwal et al., 2020). The results of this research are comprising with the findings of Mantino et al. (2019), Dibala et al. (2021) and Seyfried et al. (2021). They documented that agroforestry trees including poplar-based agroforestry system influenced the different soil properties including organic matter, PH, soil nutrients and as well as texture of the soil. N, P, K of the soil were reduced significantly under *P. deltoides* and *B. ceiba* trees in the current study. However, the reduction was higher under *P. deltoides* as compared to *B. ceiba*. Similar outcomes relating with soil nutrients decline due to trees interference were portrayed by Sauvadet et al. (2019), Wang et al. (2021) and Woś et al. (2021). Further studies have been depicted that *A. pseudoplatanus, A. platanoides, A. alba, B. pendula, C. betulus, F. sylvatica, P. sylvestris, Q. robur, T. cordata* and many other tree species are involved in affecting the soil chemical properties and soil nutrient including PH and electrical conductivity due to their phytotoxic litter which is in agreement with the present study (Álvarez et al.,

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2021; Stefanowicz et al., 2021; Amorim et al., 2022; Cesarz et al., 2022). The effect on soil properties and decreasing nutrient ultimately cause the negative influence on the crop growth, yield and soil fertility (Castro-Díez et al., 2019; Puttaso et al., 2020; Gillespie et al., 2021; Yates et al., 2021). The findings related to total soluble phenolic contents are inclined with the results of Yaseen et al. (2020) and Irshad et al. (2021) there is clearly indicated that moringa and *J. Curcus* trees increased the TSP contents.

Conclusion

Allelopathy is the release of chemicals from a plant that inhibits the growth of neighboring plant. *Populus deltoides* L. and *Bombax ceiba* L. both tree species have allelopathic ability to decline the wheat crop production according to this study report. Allelochemicals present in both tree species suppressed the wheat crop germination, radicle, and plumule length according to recorded data but it was also noticed that the concentration of leaf powder of *Populus deltoides* L. has higher adverse effects to inhibit the germination and growth parameters of the wheat crop as compared to *Bombax ceiba* L. The findings of this study also revealed that phytotoxicity of *P. deltoides* and *B. ceiba* caused negative impacts on the soil properties and it also varies from species-species dependent on releasing phytotoxic compounds at different leaves. Regarding these findings, it is being confirmed that allelopathy is a concentration-dependent process, in which the adverse effects of leaf litter of both tree species on receptor plants escalate as the concentration of leaf litter rises.

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