Research Article

# Allelopathic Potential of Crop Water Extracts of *Gossypium hirsutum* on Germination and Growth of Wheat (*Triticum aestivm* L.)

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**Abstract** | *Gossypium hirsutum* L. is among the leading cash crop, grown at 4.7 million acreage area in Punjab province annually. The rotational cultivation of cotton and wheat crops constitutes the major cropping pattern in Pakistan. Current study was undertaken to investigate the allelopathic effect of the post-harvest remnants of cotton crop on the germination and growth parameters of successor wheat crop. Experiment was laid down in complete randomized design. The seeds (n=10) of *Triticum aestivum* L. were placed in each replicate and treated with aqueous extracts from various parts of *G. hirsutum* (root, stem and leaves) at concentration (0-100% v/v). Among the various test extracts of *G. hirsutum*, leaf extract were found to impart maximum inhibitory effect on the germination indices of the wheat (*T. aestivum*) followed by the stem extracts, as the highest concentration of ACWE (i.e. 100%) caused the reduction of 45.65, 54.55, 50.9, 61.6, 5.3 and 9.4 % in germination percentage, germination energy, germination index, vigour index, germination coefficient velocity and relative percentage of wheat, respectively, compared to the control. Delay of 2.98 % mean germination time of wheat. Therefore, it may be inferred that the allelochemicals exuded by *G. hirsutum* crop residues (leave and stem) may have inhibitory effect on the various germination and growth indices of wheat and consequently results in poor crop development and yield statistics.

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## Introduction

Excessive use of chemical pesticides and fertilizers in agricultural field has resulted in magnification of unhealthy chemical residues in agricultural products, posing serious environmental threats to human beings. Scientists are working to adopt new eco-friendly farming concept, termed as green pesticides that may minimize the excessive usage of synthetic chemicals and are more effective and safer to the environment. To cope with increasing demand for organic food production, more than 70 million hectares are protected with green pesticides globally (Willer and Learnoud., 2019).

Allelopathy is an influential phenomenon where various plants maintain their dominace or co-existance in natural as well as cultivated fields, through the production of various chemical substnces, which act on the germination and growth of neighbouring species (Molisch, 1937; Rice, 2012; Weston, 1996). Allelochemicals are non-nutritional secondary metabolites synthesized in plants, animals or microorganisms to resist the biotic and abiotic stresses (Muhammad *et al*., 2011). These chemicals are introduced or secreted directly into environment or rhizosphere as volatiles, leachates or decomposed products that affects the other organisms in the surroundings by interfering their physiological and vegetative growth. Some of the allelochemicals are retained within the foliage of the producers and affect herbivores and pathogens upon feeding (Barto *et al*., 2010; Einhellig, 1987; Rice, 2012).

Cotton (*Gossypium hirsutum*) is a perenial and metabolite enriched crop. Mainly, this crop has been mechanically harvested and post-harvest residues consists of green as well as senesced leaves, a small piece of stems along with primary and secondary roots. The plant debris comprising of mature as well as green foliage that are plughed in field with the cosiderage of a natural source of nutrients. Nevertheless, the presence of extensive allelopathic compounds in cotton, the allelopathic potential of this crop has not been evaluated extensively. Cotton glands contains various phytotoxic compounds (like gossypol and its derivatives) are predominantly secondary metabolites which are toxic against insects and microorganisms (Percy *et al*., 1996).

Gossypol is a principle polyphenolic compound found in cotton plant (root, bark, leaf, petals, and bolls). Wild diploid species of cotton have gossypol-free seed kernels, whereas *G. davidsonii* has 9% and upland cotton has 0.6 to 2% gossypol 0.6 to 2% gossypol 0.6 to 2% gossypol (Lusas *et al*., 1987). Cotton-released allelochemicals accumulate during continuous mono-cropping practice and their inhibitory effects became stronger with every cultivation on the same field (Liu, 2008).

Various studies have illustrated that phenolic compounds synthesized in cotton may also be phytotoxic in nature. Four phenolic acids have been identified in leachate collected from the soils under long term cotton mono-cropping system (Jiang *et al*., 2015). Application of less concentrated crop water extracts is found to promotes growth and germination of various crops (Farooq *et al*., 2013). Low concentrations (6%) of aqueous extracts of green foliage of various weeds inhibited the germination, seedling growth and development of rice showed the presence of various allelochemicals (Hayyat *et al*., 2021).

A number of cotton growers are sowing wheat after partial harvesting of the cotton to increase the profitability and a way to conserve soil and water. On the other hand, introduction of wheat, maize, sunflower and soybean in cotton grown areas has necessitated the development of new cotton-based crop rotations to gain higher returns. Bread wheat (*Triticum aestivum* L.) is principal staple crop with annual production of 771 million tonnes around the globe and is ranked third after maize and rice to meet global food security challenges (FAO, 2017). In Pakistan, wheat crop cultivation alternates with many crops like cotton, maize and rice. In the growing regions, wheat is planted in winter, while cotton is grown in summer season (Ahmad *et al*., 1998). Allelochemicals secreted by the predecessor crop leach down to the soil and after intermediate metabolic transformation reaction, get bounds to soil organic mass (Inderjit and Nilsen, 2003). Many researchers have revealed that allelopathic substances are secondary metabolic products synthesized through shikimic acid or isoprene pathways (Hussain and Reigosa, 2011; Soltys *et al*., 2013).

Aqueous extract bioassays are widely practiced as a first step to investigate probable involvement of allelopathy (Wink *et al*., 1999). Extract bioassays are simple, rapid and inexpensive (Joshi and Joshi, 2016). Moreover, the conflicting allelopathic results among various studies revealed that severity and longevity of effects vary with environmental and geographic locations (Jennings and Nelson, 2002). Previously, allelopathic potential of variety of weeds and crop plants has been extensively studied (Farooq *et al*., 2013; Zahir and Abdul, 2014). Inhibitory effects of various allelopathic crops have been investigated to explore better weed management practices (Farooq *et al*., 2013; Ramadan *et al*., 2018). Limited information is available regarding possible allelopathic effects of the *G. hirsutum* residues on seed emergence of wheat. The aims of this research were to investigate the allelopathic potential of the extracts prepared from the post-harvest residues of cotton on germination and growth of the wheat under laboratory conditions.

## Materials and Methods

*Preparation of ACWEs*

Laboratory experimentation was carried out at Department of Botany, Government Postgraduate College, Faisalabad located at latitude 31° 23' 47" north and longitude 73°4'12" east. The experiment was arranged in a complete randomized design comprising of eight treatments with five replicates per treatment. Allelopathic crop water extracts (ACWEs) were prepared by cold-water extraction procedures using distilled water (Harper and Lynch, 1982). Cotton crop herbage was collected during the growth season from cotton fields of Ayub Agriculture Research Institute, Faisalabad. The cotton plants were uprooted from the field, comprising of complete root system (primary and secondary), stem, and leaves and then chopped into pieces (2 cm) and oven dried at 70 °C for 48 hours and later stored in polypropylene bags separately (roots, stem and leaves) at room temperature. Next, the 100 grams of each dried material was soaked in distilled water (100 ml) at 25 °C with mild agitation for 24 hours. The extracts were then filtered with cheese-cloth and serially diluted up to 100% (v/v) concentration for all the three plant parts (i.e., roots, stem and leaves) as 0.1, 01, 5, 10, 25, 50, and 100 % of the original extract solution. For the experimental setup, 5 mL aliquots of the serially diluted extracts were applied to wheat seeds to investigate the allelopathic effects in each treatment.

*Seed germination studies*

To identify a possible allelopathic potential of the various concentrations of the different extracts, seed germination and radical growth bioassays were carried out with wheat (*Triticum aestivum* L.). The seeds of *T. aestivum* were surface sterilized with 10% bleach solution (commercially available) for 10 minutes, followed by 2 - 3 washing with sterile water. Meanwhile, the glass petri plates (9 cm) were also washed, dried, autoclaved and later, lined with two layers of Whatman paper (Grade 1). About 10 seeds of wheat were placed at equal distance on each perti plate and these plates were kept at room temperature for 10 days. Each treatment comprised of five petri dishes, while 5 ml of distilled water (as a control, i.e., 0% concentration of extracts) or extracts from each of roots, stem and leaves was applied daily to keep the Whatman paper moistened for seedlings emergence.

*Germination assessment parameters*

**Table 1:** *Germination assessment was calculated by observation of parameters.*

| Sr. No. | Parameter | Formula alongwith description | Reference |
|---|---|---|---|
| 1 | Germination Percentage (GP) | GP = (NT/N) ×100<br>$N_T$: Number of germinated seeds; N: Total number of seeds | (Palani *et al*., 1995) |
| 2 | Energy of Germination (EG) | EG = (Number of germinated seeds at 4th day/ Number of germination days) × 100 | (Farooq *et al*., 2005) |
| 3 | Mean Germination Time (MGT) | MGT = Σ(G×T)/F<br>G: Number of germinated seeds on the day of count;<br>T: Day at which germination count was made;<br>F: Final number of seeds which germinated in each replicate | (Baskin *et al*., 1998; Bewley *et al*., 2006) |
| 4 | Germination Coefficient of Velocity (GCV) | GCV= 1/MGT<br>MGT: Mean germination time | (Kotowski, 1926) |
| 5 | Average Accumulative Radicle Growth (AARG) | AARG = Σ(R)/*n*<br>R: Total root length (cm) of seeds in each petri dish;<br>N: Number of germinated seeds/ plate | (Alsadon *et al*., 2014) |
| 6 | Germination Rate Index (GRI) | GRI = $G_1/1+ G_2/2+ \ldots G_i/i$<br>Where, G1 is the germination percentage on day 1, G2 is the germination percentage at day 2 and so on. | (Al-Mudaris, 1998) |
| 7 | Seedling Vigor Index (VI) | VI= (Average shoot length + Average root length) × % germination | (Abdul- Baki *et al*., 1973) |

*Statistical analysis*

Values of wheat germination and growth variables were analyzed and comparison was made with the same obtained from the control group. Means, standard error and 95% confidence intervals of each parameter were calculated separately to evaluate the differences using MS-Excel v. 2016. Moreover, appropriate comparison was also made between different treatment groups separately as well as collectively. Data from each test groups was compared with its corresponding control group to assess the significant difference (P< 0.05) using Dunnett's test. While, the two-way ANOVA (*t*-test (P< 0.05) was applied to address the significance between wheat germination and growth estimates, when treated with various extracts prepared from root, stem and leaves of the cotton biomass. All the post-hoc tests were carried out by using SAS JMP v13.0.

## Results and Discussion

Current study was conducted to explore the effects of the allelochemicals, exuded by the post-harvest residues of *G. hirsutum* on the germination and growth of next successor crops. The aqueous extracts from root, stem and leave were prepared from post-harvest residue of cotton crop and various concentrations were subjected to *in vitro* bioassays to estimate the germination and growth parameters of common bread wheat (*T. aestivum.*), under laboratory conditions. The aqueous extracts (water-soluble compounds) are more convenient to use, as they portrait the same allelopathic scenario, as it may be observed in agricultural field under normal irrigation application.

Seven germination indices i.e., seed germination percentage, germination energy, germination rate index, mean germination time, seed vigor index, germination coefficient of velocity and average accumulative root growth were calculated from data shown in Table 1. Aqueous extract of cotton leaves significantly reduced the seed germination of *T. aestivum* when applied in different concentrations. Pronounced effects were observed at concentrations higher than 5%. All the seven indices showed different results with low variability.

In general, it was observed that the germination percentage was significantly inhibited by application of allelochemical crop water extracts (ACWE) of all the tested plant parts of *G. hirsutum* (i.e., roots, stem and leaves) at higher concentrations (Figure 1A). Moreover, the highest significant decrease ($p < 0.05$) in germination percentage was recorded with extract (100% v/v concentration) i.e. 60 % followed by 56 % and 50 % inhibition of stem and root extracts, respectively. The similar pattern of inhibition was observed for germination energy (Figure 1B).

Generally, higher values of germination rate index (GRI) represent the higher germination percentages. Statistical analysis suggests the significant differences between mean values of GRI to higher concentrations of aqueous extracts. Most of the tested extracts inhibited germination rate index, indicating the possible phytotoxicity of residues of cotton crop. It was observed that highest concentration of leaf aqueous extracts resulted in 100 % decrease in the germination rate index followed by 93.33 % and 83.33 % inhibition when treated with stem and root extracts compared to untreated treatment (Figure 1C).

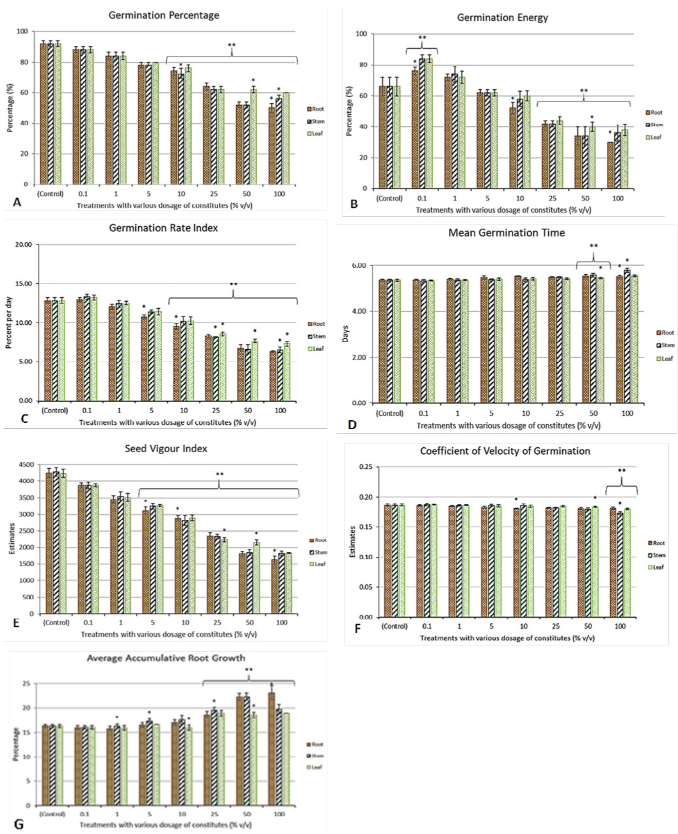


**Figure 1:** *Comparison of various concentrations of aqueous extracts prepared from roots, stems and leaves of G. hirsutum on the seedlings of T. aestivum. (a) germination percentage, (b) germination energy, (c) germination rate index, (d) mean germination time, (e) seed vigor index, (f) coefficient of velocity of germination, (g) average accumulative root growth. *P < 0.05, t-test suggesting that the given variable (root/stem/leaf) in the test treatment is significantly different compared to the rest of the variables, **P < 0.05, Dunnett's test relative to control treatment (i.e. Control).*

The mean germination time (Figure 1D) is represented by the average time (in days) required for the complete germination of seed. Lower value of mean germination time (MGT) indicates fast germination rate. Statistical significant differences were observed for the mean values of MGT with respect to higher concentrations of extracts. Seeds treated with crude extract of stem showed 5.79% increase in MGT values followed by 5.52 and 5.56 % increase by roots and leaves extracts when compared with control and low concentration of extracts has negligible effect over MGT. MGT is an important indicator of germination potential of seeds under stress environments (Palani *et al*., 1995). Generally phenolic metabolites have been found to extend the germination time due to their interference with seed dormancy and enzyme essential for fast germination ability. We found that MGT of wheat seed was prolonged by application of cotton leaf extracts at >10 % concentration which suggest there is presence of some potent allelochemical with inhibitory effect on germination. Presence of similar phenolic metabolites have also been reported in ugarcane residues resulting into suppression of germination and growth of various weeds and crops (Sampietro *et al*., 2006). Our results showed that post-harvest residues of cotton can also minimize the speed of wheat seed germination.

Seed vigor index represents the level of germination potential of the seed during the germination process. It was observed that, the control treatment has significantly higher seed vigor index as compared with those treated with ACWE extracts (Figure 1E). The lowest SVI was recorded in treatments with extracts obtained from leaves of cotton. Whereas least inhibition was observed in treatments that were grown with root extract. All the aqueous extracts with concentration of > 5% showed significant suppression of SVI. The results are comparable to studies conducted with leaf extract of *Trianthema portulacastrum*, which strongly suppressed the length of rice seedling (Mubeen *et al*., 2012). Similarly, Parthenium extracts caused significant reduction of the seedling biomass in *T. aestivum* and other cereals (Maharjan *et al*., 2007; Tefera, 2002).

Coefficient of velocity of germination (GCV) was lowest in treatments with highest concentration of aqueous extract of leaves and roots (i.e., 0.18), while for stem (0.17) (Figure 1F). Concentrated extracts of *Ammi majus* and *Desmostachya bipinnata* inhibited seed germination in *Triticum aestivum* and *Vicia faba*. In another study, differential inhibition of seed germination percentage, seed vigor index and coefficient of velocity of germination of *T. aestivum* and *V. faba* was observed by application of aqueous extracts of weeds (Ramadan *et al*., 2018). Hence, it can be inferred that the GCV could vary through plant to plant specification in the allelopathic relationship. Finally, the average accumulative root growth (AARG) was calculated on the last day of experimentation. It was observed that AARG was 23.14% higher in treatment receiving highest concentration of root extracts. Effect of extracts prepared from stem and leaves were ranked second and third. In general, allelopathic stress increased the AARG values (Figure 1G).

Further, all the estimates of each parameter profiling for leaves, stem and roots are given in Tables 2, 3, 4, respectively. Conclusively, it can be inferred that the suppression in the germination of *T. aestivum* by the application of higher concentrations of ACWE of post-harvest residues of *G. hirsutum* follows the pattern as: seed germination percentage > relative percentage > EG (germination energy) > GRI > MGT > AARG > VI.

**Table 2:** *Comparison for the effects of various dosage of the aqueous extracts prepared from leaves of G. hirsutum on various germination and growth parameters of T. aestivum.*

| Treat-men/ Param-eter | GP (%) | GE | GRI (% / days) | MGT (days) | VI | GCV | AARG |
|---|---|---|---|---|---|---|---|
| Control | 92 ±2.00 | 66 ±6.00 | 12.86 ±0.38 | 5.36 ±0.05 | 4248.20 ±133.05 | 0.19 | 16.32 ±0.33 |
| 0.1 % | 88 ±2.00 | 76 ±2.45 | 12.99 ±0.25 | 5.38 ±0.03 | 3870.60 ±74.00 | 0.19 | 16.00 ±0.39 |
| 1% | 84 ±2.45 | 72 ±2.00 | 12.05 ±0.30 | 5.42 ±0.03 | 3451.60* ±111.32 | 0.18 | 15.79 ±0.45 |
| 5% | 78* ±2.00 | 62 ±2.00 | 10.76* ±0.24 | 5.48 ±0.06 | 3115.60* ±109.15 | 0.18 | 16.51 ±0.46 |
| 10% | 74* ±2.45 | 52 ±3.74 | 9.49* ±0.36 | 5.53 ±0.02 | 2884.80* ±91.83 | 0.18 | 17.02 ±0.55 |
| 25% | 64* ±2.45 | 42* ±2.00 | 8.32* ±0.18 | 5.49 ±0.02 | 2349.00* ±96.70 | 0.18 | 18.62 ±0.69 |
| 50% | 52* ±2.00 | 34* ±6.00 | 6.72* ±0.46 | 5.54* ±0.06 | 1817.40* ±66.96 | 0.18 | 22.31* ±0.77 |
| 100% | 50* ±3.16 | 30* ±0.0 | 6.32* ±0.12 | 5.52 ±0.06 | 1624.40* ±117.64 | 0.18* | 23.14* ±1.52 |

**P < 0.05, Dunnett's test relative to control treatment.*

**Table 3:** *Comparison for the effects of various dosage of the aqueous extracts prepared from stem of G. hirsutum on various germination and growth parameters of T. aestivum.*

| Treatmen/ Parameter | GP (%) | GE | GRI (%/ days) | MGT (days) | VI | GCV | AARG |
|---|---|---|---|---|---|---|---|
| Control | 92 ±2.00 | 66 ±6.00 | 12.86 ±0.38 | 5.36 ±0.05 | 4286.20 ±128.38 | 0.19 | 16.32 ±0.33 |
| 0.1 % | 88 ±2.00 | 84* ±2.45 | 13.33 ±0.32 | 5.35 ±0.05 | 3873.00 ±97.66 | 0.19 | 16.06 ±0.39 |
| 1% | 84 ±2.45 | 74 ±5.10 | 12.42 ±0.48 | 5.38 ±0.04 | 3544.60* ±131.18 | 0.19 | 16.27 ±0.46 |
| 5% | 78* ±2.00 | 62 ±2.00 | 11.39 ±0.23 | 5.38 ±0.05 | 3246.00* ±86.14 | 0.19 | 17.29 ±0.48 |
| 10% | 72* ±3.74 | 58 ±4.90 | 10.22* ±0.58 | 5.39 ±0.07 | 2818.40* ±155.08 | 0.19 | 17.59 ±0.96 |
| 25% | 62* ±2.00 | 42* ±2.00 | 8.17* ±0.08 | 5.49 ±0.02 | 2333.60* ±68.46 | 0.18 | 19.5*4 ±0.57 |
| 50% | 52* ±2.00 | 34* ±6.00 | 6.59* ±0.57 | 5.59* ±0.08 | 1851.20* ±87.51 | 0.18 | 22.35* ±0.77 |
| 100% | 56* ±2.45 | 36* ±5.10 | 6.51* ±0.37 | 5.79* ±0.09 | 1827* ±69.33 | 0.17* | 19.78* ±0.9 |

**P < 0.05, Dunnett's test relative to control treatment.*

**Table 4:** *Comparison for the effects of various dosage of the aqueous extracts prepared from roots of G. hirsutum on various germination and growth parameters of T. aestivum.*

| Treatmen/ Parameter | GP (%) | GE | GRI (%/ days) | MGT (days) | VI | GCV | AARG |
|---|---|---|---|---|---|---|---|
| Control | 92 ±2.00 | 66 ±6.00 | 12.86 ±0.38 | 5.36 ±0.05 | 4243.20 ±119.36 | 0.19 | 16.32 0.33 |
| 0.1 % | 88 ±2.00 | 84* ±2.45 | 13.26 ±0.31 | 5.35 ±0.02 | 3873.20* ±50.04 | 0.19 | 16.06 0.39 |
| 1% | 84* ±2.45 | 72 ±3.74 | 12.55 ±0.26 | 5.37 ±0.02 | 3506.60* ±123.70 | 0.19 | 15.93 0.45 |
| 5% | 80* ±0.00 | 62 ±2.00 | 11.44* ±0.42 | 5.41 ±0.06 | 3268.80* ±29.57 | 0.18 | 16.64 0.00 |
| 10% | 76* ±2.45 | 60 ±3.16 | 10.25* ±0.52 | 5.43 ±0.05 | 2897.20* ±90.09 | 0.18 | 15.99 0.53 |
| 25% | 62* ±2.00 | 44* ±2.45 | 8.57* ±0.25 | 5.43 ±0.04 | 2233.40* ±65.08 | 0.18 | 18.98* 0.56 |
| 50% | 62* ±2.00 | 40* ±3.16 | 7.68* ±0.28 | 5.46* ±0.02 | 2148.20* ±75.97 | 0.18 | 18.59* 0.55 |
| 100% | 60* ±0.00 | 38* ±3.74 | 7.30* ±0.33 | 5.56 ±0.04 | 1834.80* ±13.06 | 0.18* | 18.98* 0.00 |

**P < 0.05, Dunnett's test relative to control treatment.*

Various reports suggested that accumulation of allelochemicals into the soil strongly affects the growth of current and successor crops (Singh and Thaper, 2003). Strong inhibitory effects were caused by the application of aqueous extract rather than soil incorporated residues. Seed grown in petri dishes are directly influenced by allelochemicals due to absence of any transformation, detoxification and breakdown as compared to soil (Inderjit Nilsen, 2003). The above mentioned results from this study have revealed that crude extracts of *G. hirsutum* have significantly inhibited a number of germination indices of common bread wheat. We found that effects caused by allelopathic stress were concentration dependent. The reduction in the germination/growth indices may possibly due to the presence of phenolic metabolites. Presence of growth inhibitory compounds in the plant residues may lead to induction of oxidative damage. Changes in membrane permeability, imbalanced mineral and ion absorption may also results from the activation of anti-oxidative and stress enzymes (Khaliq *et al*., 2012).

Our results are in agreement with the previous findings, illustrating the 20% decrease in seed germination of rice when treated with various extracts of weeds (Chopra *et al*., 2017). Allelopathy is a multi-dimensional science and utilizes naturally occurring, environmental friendly allelochemicals as herbicides (Khaliq *et al*., 2012; Muhammad *et al*., 2011; Nikneshan *et al*., 2011). Higher concentrations of the aqueous leaf extracts of eight varieties of sunflower were found to inhibit the germination indices of wheat (Nasira *et al*., 2013). Allelopathic potential of *A. tenuifolius*, *E. hirta*, and *F. indica* yielded inconsistent results over seed germination, plant height, shoot and root fresh and dry weight of wheat (Ullah *et al*., 2020). Similarly, Ullah *et al*. (2013) treated aqueous leaf extracts of *E. camaldulensis, A. nilotica*, *H. annuus* and *P. hysterophorus* and reported inhibitory effects on seed germination of 20 varieties of wheat (Ullah *et al*., 2013). Rezaee *et al*. (2014) reported auto-allelopathy in cotton which suggests the inhibition of its own seedlings. The aqueous extracts of cotton at 150 ppm concentration caused reduction in number of leaves by 93.91 %, dry weight was reduced by 84% and accessary branches by 75.7 % when compared with control (Rezaee *et al*., 2014).

Extensive research is needed to investigate the allelopathic stress caused by preceding crops which might be helpful for the modification of existing wheat cultivation patterns with other plants (Abbas *et al*., 2014). Fields with continuous cultivation with cotton gains manifold increase in the concentration (0.5 to 2 g/L) of the total phenolic compounds (Gallic acid) causing a significant inhibition of growth, enzymatic (SOD and MDA), and root activities of cotton seedlings (Jiang *et al*., 2015). Studies to explore allelopathic potential of water extracts of onion (*A. cepa*) and cumin (*C. cyminum*) on cotton (*G. hirsutum*) seed germination and seedling growth showed decreased the cotton seed germination, seedling root fresh weight, shoot height and root activity at concentrations of 40 and 60 g/L (Sun *et al*., 2019). *In situ* decomposition of harvested plant residues may have adverse effects on the emergence and growth of successor crops (Khaliq *et al*., 2011). Inderjit and Nilsen (2003) reported the harmful effects of allelochemicals leached in the soil from decomposed plant parts and depends upon concentration of secondary metabolites (Inderjit and Nilsen, 2003). These allelochemicals are introduced in the soil directly from plant residues or as a result of microbial decomposition process (Kumar *et al*., 2006). Allelochemicals of phenolic nature can also affect the germination and seedling growth of successor plants (Duke, 2015).

Currently, a number of secondary metabolites such as phenolic componds, quinones, flavonoids, terpenes, glycosides, alkaloids and non-protein amino acids are considered as allelopathic substances (Zhang *et al*., 2011). Published research showed that phenolic acids have strong herbicidal properties (Alsadon *et al*., 2014).

Li *et al*. (2021) reported inhibitory allelopathic potential of aqueous extracts *of A. argyi* on different plants were investigated through laboratory experiments and field trials on growth of some monocot and dicots (Li *et al*., 2021). Exogenous application of aqueous extracts of plant allelochemical affects some of the physiological processes like alterations membrane permeability at the target site leading to alterations in pH and absorptions potential of water and minerals, which culminates into either positive or negative effects (Barkosky *et al*., 2000; Majeed *et al*., 2012). Aqueous extract cotton at concentrations above 5% inhibited the germination traits of wheat and maximum inhibition was observed in germination percentage, germination energy (EG), mean germination time (MGT), germination index (GI) and relative germination percentage (RP) (Figure-1, A-H) when compared to control treatment. Results presented here are supported by the findings of Zuo *et al*. (2012), who observed strong allelopathic potential of antioxidant compounds of *Alternanthera philoxeroides* at higher concentrations and higher activity of protective enzymes (SOD, POD and CAT) (Zuo *et al*., 2012). The inhibitory effects of the aqueous extracts of *A. philoxeroides*, *A. sessilis* and *E. crusgalli* on seed germination and seedling growth of various economic crops have been documented by extensive research (Dhole *et al*., 2011; Gu *et al*., 2008; Yuan *et al*., 2009).

Extracts of various concentrations and plant organs may have few toxic substances (allelochemicals) which suppressed the root and shoot growth (Barto *et al*., 2010). Literature showed that water-soluble allelochemicals exuded from *A. sessilis* and *A. philoxeroides* significantly reduces the germination and growth indices of wheat (Dhole *et al*., 2011; Yuan *et al*., 2009). Inhibitory effects of extracts were more sever at >5% concentration.

Above mentioned literature clearly indicates that allelopathic weeds have caused deleterious effect on early growth of wheat (Singh and Thaper, 2003) by emission of aqueous phenolic compounds in soil environment. Results from the current study are in accordance with the findings of (Nikneshan *et al*., 2011; Nasira *et al*., 2013). They showed that extracts of various allelopathic weeds strongly inhibits the germination percentage, mean germination time and germination index of wheat.

## Conclusions and Recommendations

Present study reveals that various allelochemicals might be released and their concentration keep on increasing in a field with cotton cropping and may stand accountable for significant arrest of germination and growth activities of the preceding crop, so post-harvest residues of cotton must be uprooted and eliminated from the field. So, the allelopathic effects of different plant parts cotton against wheat have inhibitory effects at higher concentrations.

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## Novelty Statement

Limited information is available regarding possible allelopathic effects of the *G. hirsutum* residues on growth and germination of wheat, so yield losses due to growth inhibition may be considered.

## Author's Contribution

Muhammad Afzal Naeem, conceived the idea and executed the experimental work and wrote the first draft of manuscript, Muhammad Hassaan Khan helped to prepare extracts and consolidated the manuscript, Tahmina Nazish conducted the statistical analysis of the, whereas reviewing and proofreading of manuscript was done by Uzma Bashir and Midrarullah.

*Conflict of interest*

The authors have declared no conflict of interest.

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