STUDY ON BIOTIC STRESS IN CEREALS AND NON-CEREALS THROUGH PHYTO-TOXICITY CAUSED BY *Chenopodium album*

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ABSTRACT

In agro-ecosystem of crops, weeds and microbes constitute biotic component of environment. These interactions are undoubtedly important factors in determining species distribution and abundance in an ecosystem. Weeds, a major threat to agriculture system causing productivity decline. *Chenopodium album* L. belonging to family Chenopodiaceae is one of the five most widely distributed plants worldwide. It is a common weed in about 40 crops containing 8% saponins, 10% phenolic compounds and many secondary metabolites shared significant phytotoxicity on neighbouring plants. So, under *in vitro* conditions in Department of Agronomy, Gomal University, D.I.Khan, an experiment was launched to explore phytotoxic (allelopathic) potential of *C. album* on cereals (barley, sorghum, maize, millet) and non-cereal (gram, canola, mung, sunflower). Aqueous extract of *C. album* (all parts mixed) and pure water (control) were used to decipher its effectiveness on aforementioned crops. Data obtained by applying water extract of *C. album* on above crops revealed its phytotoxicity on all crops. Parameters days to germination, germination count, germination (%), root/shoot sizes, plant size, fresh/dry weight, moisture present in plant, plant growth rate, chlorophyll, photosynthetic efficiency and crude protein in leaves are suppressed by *C. album* extract (25% w/v). It is concluded that *C. album* has biologically a unique entity as an allelopathic plant. Its presence in field crop may cause loss of economic yield up to 15 to 45%. So, more extensive studies are required to explore allelopathic potential responsible for inhibitory effects on seed germination, plant growth and economic yield with its management.

Keywords: Allelopathy, Cereals, *Chenopodium album*, Growth and development, Non-cereals, Water extract.

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INTRODUCTION

Chenopodium album L. is member of Chenopodiaceae or Amaranthaceae family of plants. Lamb's quarters and goosefoot are some of the more common names for this plant, while locallay it is called as Bathua. It is a fast-growing annual plant that reaches a height of around one meter (Lipniak and Kliszcz, 2020). Each plant has a capacity to produce 72,000 seeds (DeGreeff *et al.*, 2018). It is broad leaved weed. Since ancient times, this weed has been farmed in Europe. Goosefoot is branching and has a pile root. Its stem likewise contains a lot of branches and might be reddish in color. The leaves are diamond-shaped or lanceolate in form, with a sharp edge and wedge-shaped base. Its seeds can sprout from mid-April to mid-June. In July, *Chenopodium album* blooms, and it can remain until November with little pale green flowers. It bears fruit (small nut with black seeds) after blooming. Goosefoot seeds adapt well to different climatic conditions and can sprout over several years. Allelopathy is the capacity of plants to exude substances that prevent or encourage the development of nearby plants in the environment. Although the definition of "allelopathy" has changed over time, it is

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now described as "any direct or indirect detrimental or helpful effects by one plant on another through the synthesis of chemical compounds that it emits into the environment (Birkett *et al.*, 2001). The allelopathic activity not only suppresses germination but also delays germination, potentially affecting plant competitiveness. Allelochemicals are a subgroup of secondary metabolites that aren't required for the metabolism of allelopathic organisms (Kalwar *et al.*, 2022). Turpenoids, polyphenolic compounds, alkaloids, fatty acids, and polyacetylenes are examples of secondary metabolites that can act as allele-chemicals (Blokker *et al.*, 2006). Weeds emit allelochemicals into the soil, and when large levels of allelochemicals build in the soil, they hinder germination and growth processes, reducing crop output.

Chenopodium album is a noxious plant found in wheat, barley, sugarcane, soybean, and vegetable crops in many regions of the world (Alam *et al.*, 2002). In a nutrient solution, aqueous extracts of its leaves or residues hindered the development of other plants, while its roots exudate slow growth of corn shoots and roots. Its aqueous extract inhibited cucumber plant growth, soybean hypocotyl growth, and wheat root and shoot length and weight. The common lambs quarters may be found in many agricultural areas, is one of the most bothersome weeds on the planet, and it was also regarded one of the top five most extensively dispersed weeds worldwide.

It has been reported by DeGreeff *et al.* (2018) that currently, common lambsquarters became one of the most important weeds in the globe. Weeds are one of the primary challenges in agricultural operations, according to the field of modern management systems and attempts to eliminate these undesirable plants (Buhler, 2002). Weeds produce 10–30% agricultural losses, however crop losses without weed management might be 45–95%, depending on agroclimatic circumstances (Mennan *et al.*, 2012). Weeds are undesirable plants with little economic importance that thrive in close proximity to cultivated crops. They have an impact on crops at various stages of development and compete for different resources. For lengthy periods of time, their seeds are dormant. *Chenopodium album* grows in a broad range of soil conditions and pH levels and may be found in gardens, ruderal locations, road sides, irrigated areas, and sub-humid regions. The crop output suffers 41.6% reduction in tillering capacity as a result of this problematic weed (Salam *et al.*, 2014). Because of its enormous seed production and long germination time, control of this plant is challenging (Tharp and Kells, 2001). The adoption of competitive cultivars with high yields and early herbicide administration has the potential to reduce grain yield losses caused by common lambs quarters in spring wheat. Sugar beet and corn seed germination were reduced by 60.8 and 53.4 %, respectively, by an ethanolic extract of *C. album* (Saringer, 2000). *C. album* extract also slowed the development of soybeans, corn and wheat (Alam *et al.*, 2001). *C. album* residuals have been shown to reduce soybean and corn yield in several studies. *C. album* L. had the greatest influence on root and shoot dry weight, root length, and biomass reduction (Rezaie and Yarnia, 2009). *Rumex dentatus* L. and *C. album*, according to Tehmina and Rukhsana (2010), are the primary reason of reduced wheat production in Pakistan. Weed lambs quarters competition reduced grain production, yield components, and harvest index by a substantial amount (Pooryousef and Myandoab *et al.*, 2011). Aqueous extracts of *C. album* (root, leaf, and root + leaf) demonstrated impacts on germination, however leaf extract was more inhibitory than root and root + leaf extracts, according to Namvar *et al.*, (2009). Majeed *et al.*, (2012) found that aqueous leaf extracts of *C. album* have a substantial negative impact on wheat plant development and production. Therefore, this study was aimed to find out the allelopathic effect of *C. album* on different cereals as well as other crops.

MATERIALS AND METHODS

Study Area

The research was carried out at Postgraduate Agronomy Lab, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan.

Collection of *Chenopodium album* L. leaves for extract

C. album leaves were collected from the Faculty of Agriculture's Research Area at Gomal University, Dera Ismail Khan, Pakistan. Sickle was used to harvest the plants. Dust and other contaminants were removed from the plants. Leaves separated from plants were sun dried for 10 days before being oven-dried for 72 hours at 75°C. Their leaves were then powdered in a grinder. The finished ground sample was placed in paper bags and used in the experiment.

Preparation of *C. album* Water Extracts

After collection, the dried powder of *C. album* leaves was weighed and mixed in distilled water at a concentration of 25 g L^{-1} at room temperature for 48 hours before being filtered with muslin cloth and Whatman No. 1 filter paper to obtain the water extract. The water extract was bottled to be used in the experiment.

Experimental design and material used

A lab experiment was done to investigate the allelopathic effect of *C. album* on germination and growth of cereal and non-cereal crops in the Agronomic Post Graduate Lab, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan, during Rabi 2021-22. Ten (10) seeds of each crop specie were planted in 24 plastic pots with a height of 12 cm and a diameter of 15 cm for experiment. With eight crop species and three repeats, the experiment was assessed using completely randomized design (CRD). As needed, aqueous extracts of *C. album* leaves extract were applied to selected plastic pots. These pots were compared to the control pots. To compare the effects of aqueous extracts on growth and germination, four cereal crops (barley, sorghum, maize, millet) and four non-cereal crops (gram, canola, mung bean, sunflower) were selected. The experiment lasted 25 days during which, different parameters were recorded.

RESULTS AND DISCUSSION

Days to germination

Data in Fig. 1 and 2 showed that aqueous extract of *Chenopodium album* L. adversely affected days to germination of different cereal and non-cereal crops. In cereal crops, the maximum days to germination was observed in millet (13) followed by maize having 11 days to germination, whereas minimum days to germination were noted in barley and sorghum having 9.4 & 9 days to germination, respectively. In case of non-cereal crops, highest days to germination were noted in sunflower, followed by gram having 11 and 10.2 days, respectively. However, lowest germination was noted in canola (7.6) and mung (4.6 days). Hussain *et al.* (2022) checked the allelopathic effect of poplar (*Populus deltoides* L.) on cereal crops. They described that water soluble phytochemicals released from plants parts having phenolic compounds, alkaloids, flavonoids and other compounds might cause delay in germination and suppress the growth of embryo. They further explained that these phytochemicals may have beneficial in some crops but found suppressor in other crops as in our case.

Germination count

Fig. 3 showed that aqueous extract of *C. album* extremely affected all cereal crops, except barley. The application of aqueous extract of *C. album* didn't affect the germination count of barley as compared to control. However, sorghum, maize and millet were adversely affected by aqueous extract. Positive effect of *C. album* on germination count of all non-cereal crops, except sunflower was noticed (Fig. 4). The application of 25% aqueous extract of *C. album* adversely affected germination count in sunflower as compared to control. However, germination count of gram, canola and mung enhanced with the application of *C. album*. Allelopathy is a stimulatory or inhibitory effect of one plant species on other to suppress germination, growth and development. The allelopathic weeds may influence germination of important crops (Mengal *et al.*, 2015). Ayub *et al.* (2013) found similar results. Leachate of legume weeds produced determined and suppressing impact on germination of maize.

Germination (%)

Results shown in Fig. 5 represent that *Chenopodium album* L. adversely affected all cereal crops, except barley. The aqueous extract of *C. album* didn't affect the germination percentage of barley, however, inhibitory (60%) effect was noted in sorghum, maize and millet. Similarly, the data shown in Fig. 6 represented that *C. album* negatively affected the germination (%) of all non-cereal crops. Maximum inhibitory effect was observed in mung (60%), whereas minimum inhibitory effect (50%) was observed in gram, canola and sunflower. Mengal *et al.* (2015) stated that donor plant releases phytochemicals into environment after decomposition in water or on soil, these phytochemicals cause reduction in germination by killing the embryo. The allelopathic weeds like *C. album* may influence the germination process of neighbor and subsequent crops (Abbas *et al.*, 2017). Similar findings were also determined by Salam *et al.* (2014).

Shoot size (cm)

Application of aqueous extract of *Chenopodium album* L. on shoot size of cereal crops (Fig. 7) showed adverse effects on barley and sorghum shoot having 8.7 and 8.1 cm size, respectively. However, this extract gave positive effect on shoot size of maize and millet showing 13.5 and 5.1 cm shoot size, respectively over control. In Fig. 8, it is shown that aqueous extract of *C. album* caused inhibitory effect on shoot size of all non-cereal crops. Maximum shoot size (4.7 cm) was noted in sunflower, followed by canola (4.1 cm). However, minimum shoot was noted in gram followed by mung with 3.2 and 3.4 cm size, respectively. The inhibitory effect on shoot size of different cereal and non-cereal crops might be due to the application of aqueous extract of *C. album*. Khan *et al.* (2014) and Xaxa *et al.* (2018) concluded that allelopathic weeds may suppress the growth and size of shoot in neighbor planted crops. The phytotoxic impact of this weed on cereal (wheat and maize) is also reported by Salam *et al.* (2014).

Root size (cm)

Data in Fig. 9 depicted that extract of *Chenopodium album* L. inhibited the root size of barley and sorghum having 12.1 and 12.8 cm roots, whereas maize and millet were not affected by the aqueous extract when compared with control. Likewise, effect of *C. album* on root size of non-cereal crops showed inhibitory effects on all non-cereal crops (Fig. 10). Maximum root size was recorded in canola (8.3 cm), whereas minimum was recorded in sunflower (4.5 cm). The root size recorded for gram and mung (5.6 and 6.5 cm) showed inhibitory effect of aqueous extract of *C. album*. Salam *et al.* (2014) reported that root growth of cereals (wheat and maize) was significantly inhibited by *C. album* extract. Our results clearly shown that growth parameters of all tested species (cereal and non-cereal) were suppressed, specially root size when water extract of *C. album* was tested as determined by Rezaie and Yarnia (2009).

Plant size (cm)

The data presented in Fig. 11 showed that application of aqueous extract of *Chenopodium album* L. negatively affected the barley and sorghum having plant size 20.8 cm and 20.9 cm, respectively. However, aqueous extract showed positive effect on maize and millet with plant size 29.9 cm and 14.1 cm, respectively. Similarly, inhibitory effect of aqueous extract of *C. album* on plant size of non-cereal crops was observed (Fig. 12). Maximum plant size (12.4 cm) was recorded in canola, while minimum plant size was recorded in gram having 8.8 cm. Plant size of mung and sunflower were 9.9 and 9.2 cm, respectively. Weeds are most problematic factor in crop production. They influence the growth of neighboring crops by competition and allelopathy. Salam *et al.* (2014) concluded inhibitory impact of *C. album* on cereals (wheat and maize) regarding plant size. Similar findings were reported by Majeed *et al.* (2012). They explained that *C. album* inhibitory activity could be related to allelochemicals like phenolic acids, flavonoids and alkaloids present in the water solution of this plant. Khan *et al.* (2014) depicted the inhibitory impact on winter cereal and non-cereal crops by applying these different plants water extract and concluded that allelopathic compound released from plant's parts accumulate in water, which reduced the plant's size.

Fresh weight of seedlings (g)

Fig. 13 showed that the application of aqueous extract of *Chenopodium album* L. on fresh weight of seedlings of cereal crops had no effect on sorghum (0.4 g) and millet (0.1 g) over control. Aqueous extract showed positive affect on maize having 2.4 g, while negatively affect barley having 0.5 g as compared to control. Fig. 14 showed the inhibitory effect of aqueous extract of *C. album* on fresh weight of seedlings of non-cereal crops. The results showed that maximum fresh weight was noted in sunflower having 6.7 g while, minimum fresh weight was noted in gram followed by canola and mung having 0.5 g, 0.8 g and 2.5 g, respectively. Sorghum and millet both are allelopathic grasses. They also inhibit the growth of neighboring plants. Non-cereal crops are adversely affected by application of *C. album* water solution. Towa and Xiangping (2014) concluded that weight of rice plants was adversely affected by applying irrigation of water under mulching condition of *C. album.* Ayub *et al.* (2013) recorded maximum fresh weight of maize in control and minimum was recorded in treatment where sesbania leaf-leachate was applied. Similar results were also declared by Hussain and Abbas (2022) on cereal crops. They did osmopriming of cereal seeds (wheat, oat, rice, maize and sorghum) with *Conocarpus lancifolium* aqueous extract.

Dry weight of seedlings (g)

The effect of aqueous extract of *Chenopodium album* L. on dry weight of seedlings of cereal crops (Fig. 15) showed no effect on sorghum and positive effect on maize having dry weight 0.09 and 1.3 g as compared to control. The results also showed inhibitory effect on barley and millet having 0.11 and 0.02 g. The inhibitory effect of aqueous extract of *C. album* on dry weight of seedlings of non-cereal crops are shown in Fig. 16. The results showed that maximum dry weight was noted in sunflower (1.3 g). However, minimum dry weight was noted in gram followed by canola and mung having dry weight 0.12, 0.23 and 0.91 g, respectively. The data regarding inhibitory effect of *C. album* except maize and sorghum was due to presence of some phytochemicals in its watery solutions. Similar nature of results was produced by Hussain and Rashid (2022). Decrease in dry weight of seedling of cereal and non-cereal crops might be due to allelo-chemicals has also been reported by Ayub *et al*. (2013).

Moisture in plants (g)

Fig. 17 depicted non-significant effects of aqueous extract of *Chenopodium album* L. on moisture present in plants of cereal crops. The results showed that aqueous extract had no effect on sorghum, while it was positive on maize and millet having 0.31, 1.1 and 0.08 g moisture, respectively as compared to control. Inhibitory effect was noted in barley having 0.39 g moisture present in the plants. It was shown in Fig. 18 that aqueous extract of *C. album* had inhibitory effect on moisture present in plants of non-cereal crops. Results showed that maximum moisture was recorded in sunflower (5.4 g) whereas, minimum moisture was recorded in gram followed by canola and mung having 0.38, 0.57 and 1.59 g, respectively. Similar trend of fresh weight, dry weight and moisture present in plants was found. Jefferson and Pennacchio (2003) determined the allelopathic potential of *Chenopodium* species. They stated that allelochemicals in aqueous solution of *C. album* inhibited water movement and ions in associated plants near about them.

Chlorophyll content (SPAD readings)

Inhibitory effect of aqueous extract of *Chenopodium album* L. on chlorophyll (SPAD value) of cereal crops are shown in Fig. 19. The results showed that highest SPAD value (28.9) was recorded in maize, whereas minimum (12.5) was recorded in barley. The chlorophyll of sorghum was 17.8, followed by millet with 16.8 readings. The same inhibitory effects were also observed on non-cereal crops (Fig. 20). Maximum SPAD value (22.7) was recorded in sunflower, whereas minimum (9.8) was recorded in barley followed by canola and mung having chlorophyll values 11.5 and 13.3, respectively. Salam *et al.* (2014) observed seven types of phenolic acids present in *C. album* water extract, which influenced biologically and interrupted the process of water uptake, chlorophyll formation and photosynthesis. Hussain and Rashid (2022) reported similar findings in their research on cereals germination physiology and explained that chlorophyll content is adversely affected by allelochemicals present in water solutions.

Photosynthetic Efficiency (%)

Results pertaining to photosynthetic efficiency (Fig. 21) shown inhibitory effects of aqueous extract of *Chenopodium album* L. on cereal as well as non-cereal crops over control. The data showed that highest photosynthetic efficiency (0.19) was recorded in maize, followed by millet having 0.16 reading, whereas minimum photosynthetic efficiency (0.05) was recorded in barley followed by sorghum (0.08). Similarly, highest photosynthetic efficiency was recorded in sunflower followed by mung and canola (0.23, 0.21 and 0.19, respectively). However, lowest photosynthetic efficiency (0.03) was recorded in gram. The suppressing of photosynthesis in cereal and non-cereal by aqueous extract of *C. album* can be expected to allelo-chemical released in water solution as reported by Salam *et al.* (2014).

Crude protein in leaves (mg g^{-1})

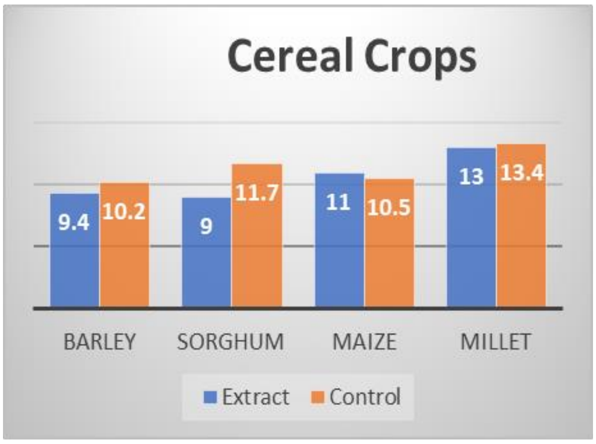
Data presented in Fig. 23 showed allelopathic effect of aqueous extract of *Chenopodium album* L. on crude protein in leaves of all cereal crops. Maximum crude protein was recorded in maize having crude protein 10.6 mg g^{-1}, followed by sorghum and barley having crude protein in leaves 8.9 and 7.5 mg g^{-1}, respectively. Minimum crude protein was recorded in the leaves of millet having crude protein 6.9 mg g^{-1}. Data shown in Fig. 24 depicted adverse effects on crude protein in leaves of all non-cereal crops. Maximum crude protein was recorded in sunflower having crude protein 13.72 mg g^{-1}, followed by mung and gram having crude protein in leaves 12.6 and 11.7 mg g^{-1}, respectively. Minimum crude protein was recorded in the leaves of canola having crude protein 10.6 mg g^{-1}. Amino acid and protein formation take place after photosynthesis. Photosynthesis retardation delayed and inhibited the process of protein in leaves of cereals and non-cereals.

Plant growth rate (g m^{-2} day^{-1})

Data on growth rate (Fig. 25) depicted inhibitory effect caused by aqueous extract of *Chenopodium album* L. over control. Results showed that highest plant growth rate (0.52 g m^{-2} day^{-1}) was recorded in maize followed by sorghum having plant growth rate 0.46 g m^{-2} day^{-1}, whereas minimum plant growth rate (0.24 g m^{-2} day^{-1}) was recorded in barley followed by millet having plant growth rate 0.33 g m^{-2} day^{-1}. Inhibitory effect of aqueous extract of *C. album* on plant growth rate of non-cereal crops (Fig. 26) shown that highest plant growth rate was recorded in sunflower followed by canola and gram having growth rate of 0.45, 0.39 and 0.34 g m^{-2} day^{-1}, respectively. However, lowest plant growth rate (0.23 g m^{-2} day^{-1}) was recorded in gram. Chlorophyll, photosynthesis and protein inhibition over all affected the plant growth rate. *C. album* water extract inhibited all growth developmental parameters as compared to control in cereals and non-cereals. *C. album* released the phytochemicals and affect the growth as described by Salam *et al.* (2014). Similar results were also reported by Majeed *et al.* (2012).

CONCLUSION

It is concluded from our research trial that phytochemicals present in water extract of *Chenopodium album* L. cause suppressive impact on cereal and non-cereal crops through allelopathy and competition. It is estimated that 40 to 60% yield losses occurred by infestation of this weed. So, this weed must be eradicated from field at initial stages of crop growth to elude their harmful effect.



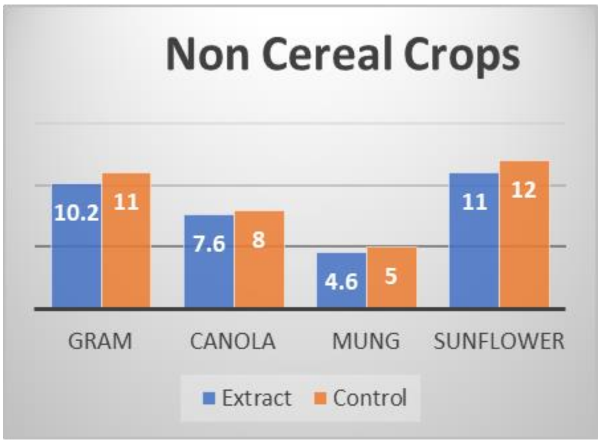
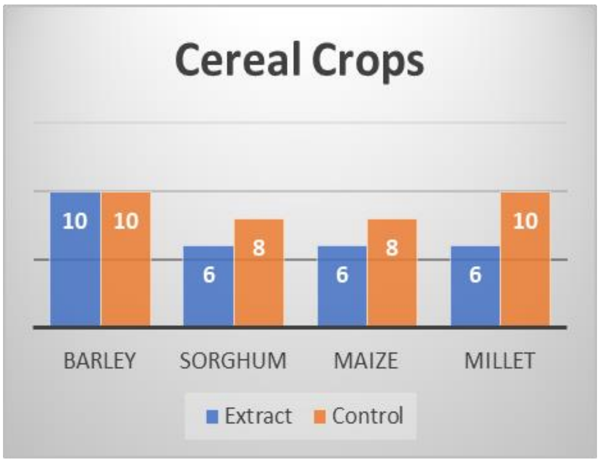


Figure 1 & 2. Days to Germination in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*



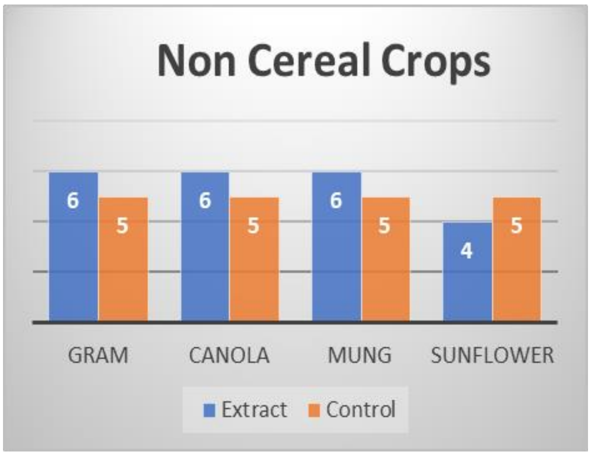
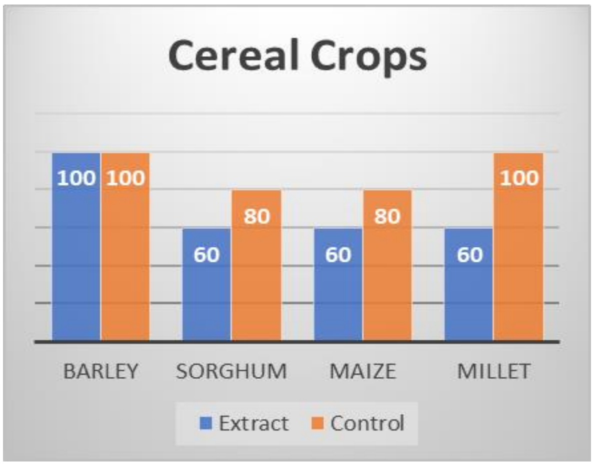


Figure 3 & 4. Germination count in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*



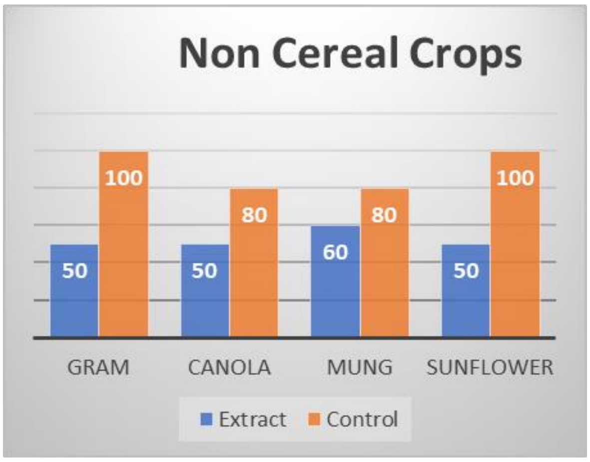
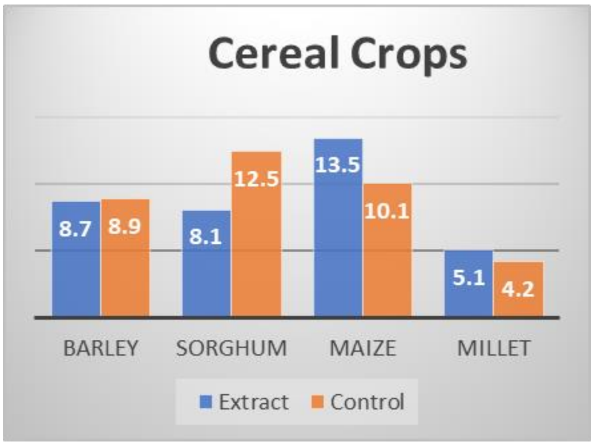


Figure 5 & 6. Germination (%) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*



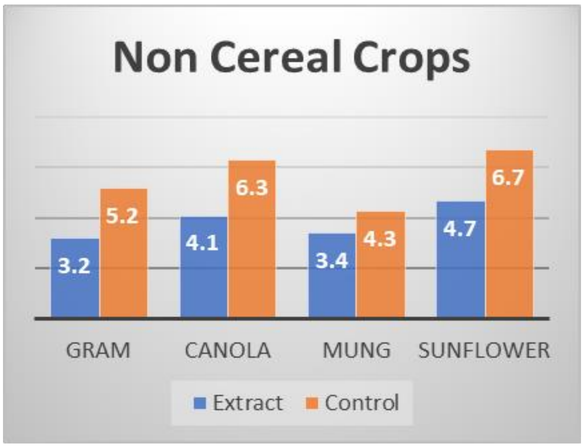
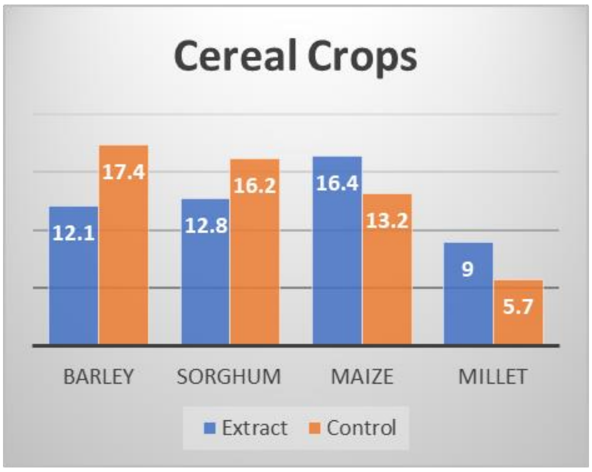


Figure 7 & 8. Shoot size (cm) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*



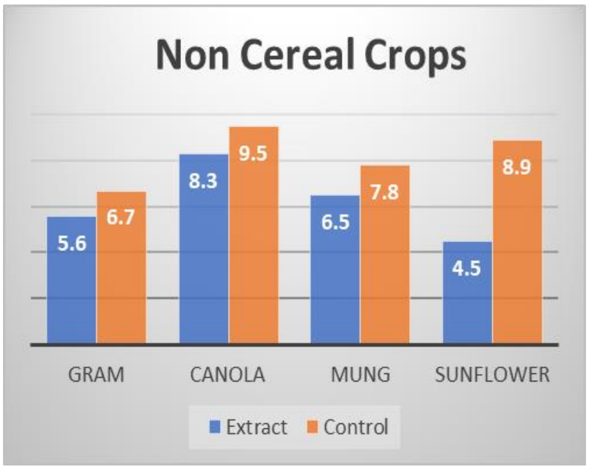
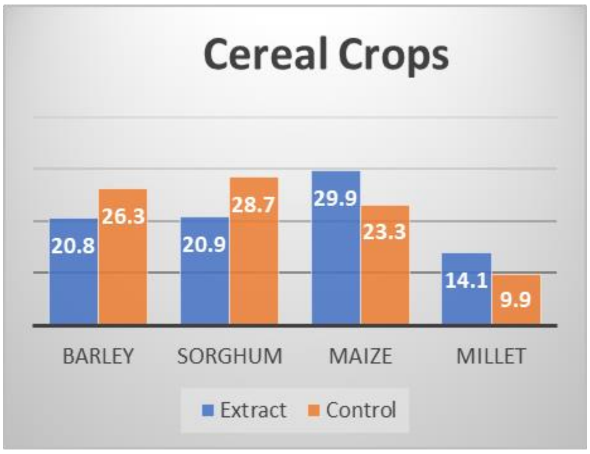


Figure 9 & 10. Root size (cm) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*



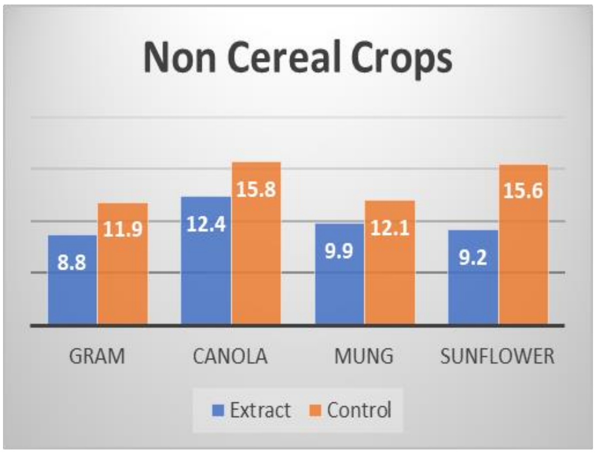


Figure 11 & 12. Plant size (cm) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*

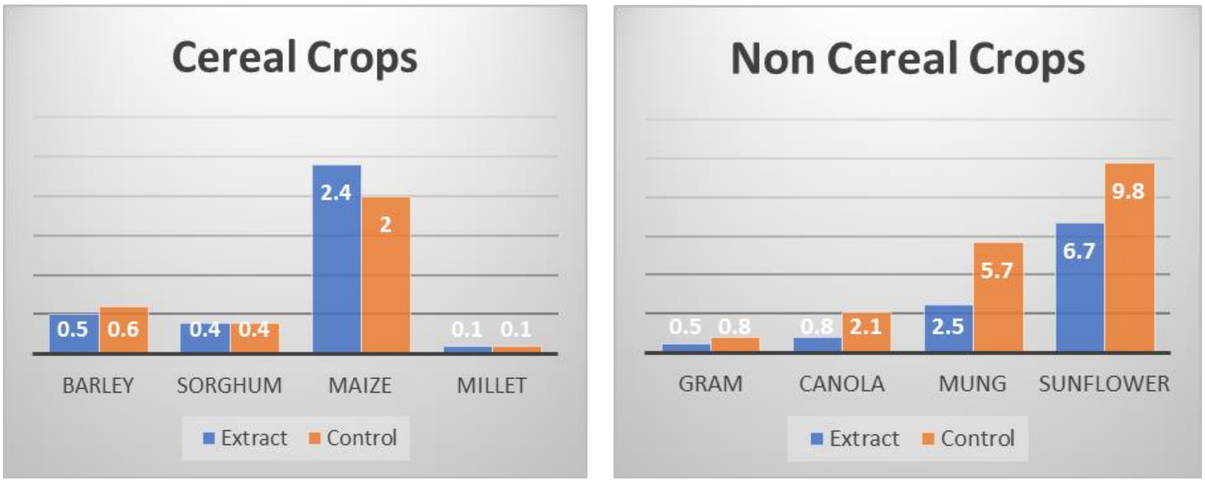


Figure 13 & 14. Fresh weight of seedlings (g) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*

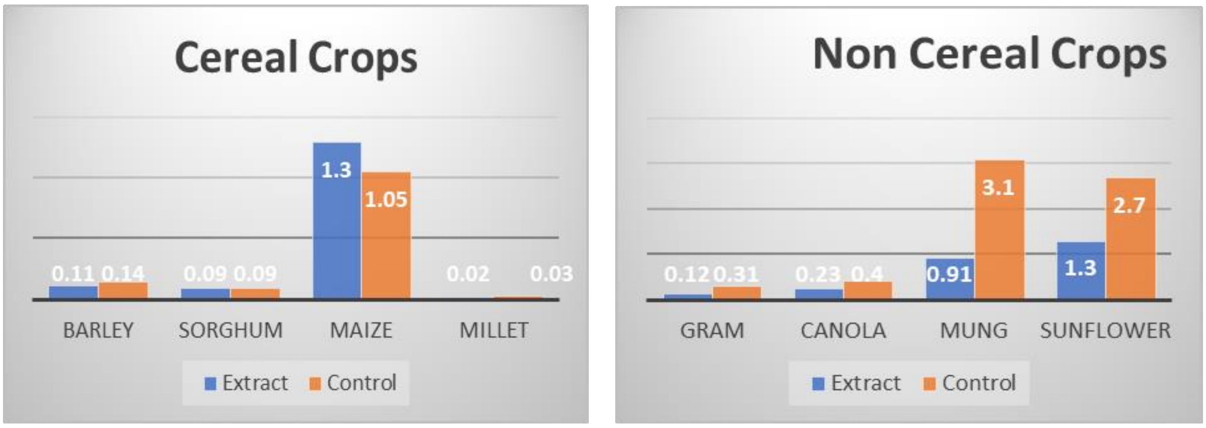


Figure 15 & 16. Dry weight of seedlings (g) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*

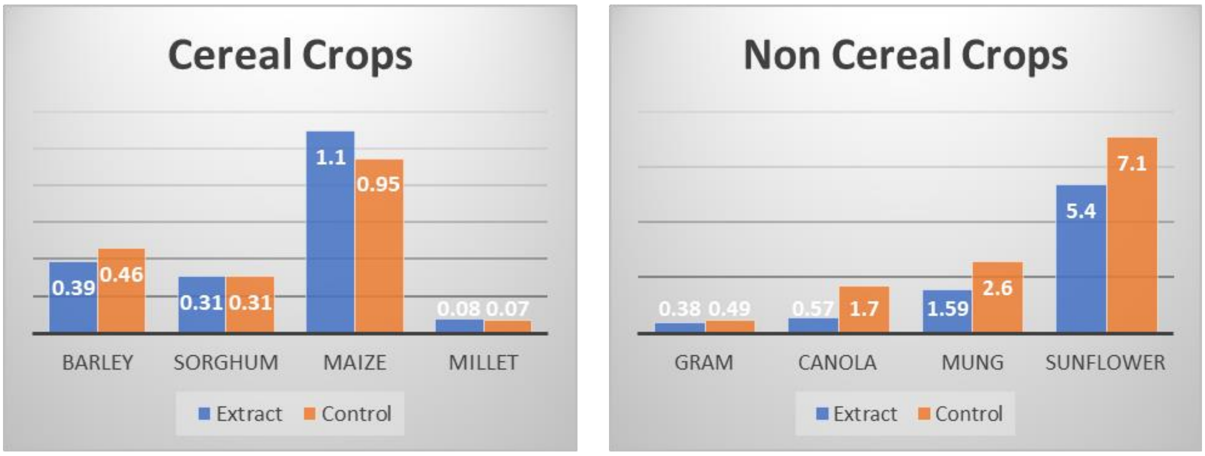


Figure 17 & 18. Plant moisture (g) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*

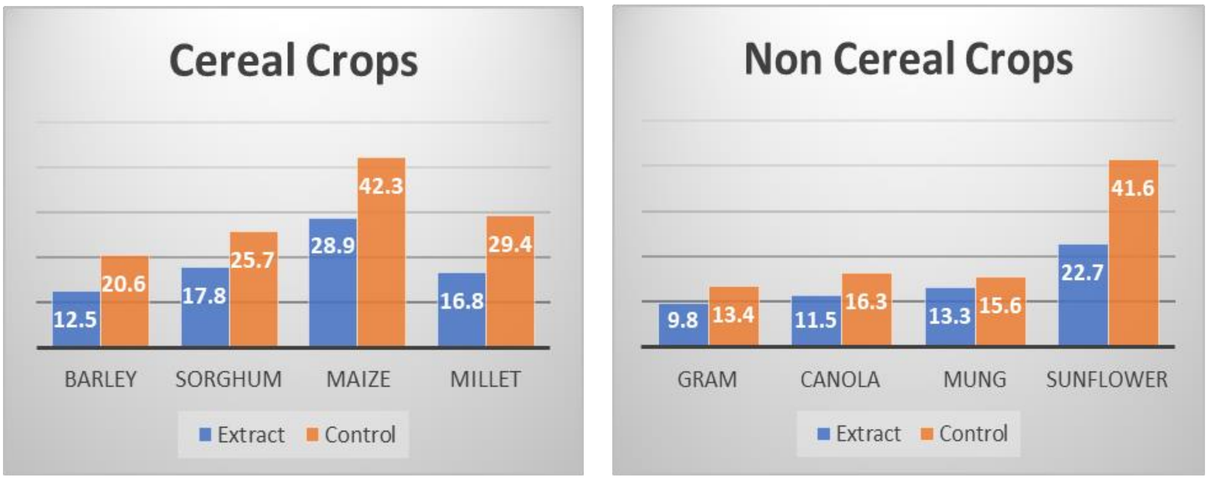


Figure 19 & 20. Chlorophyll contents (SPAD values) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*

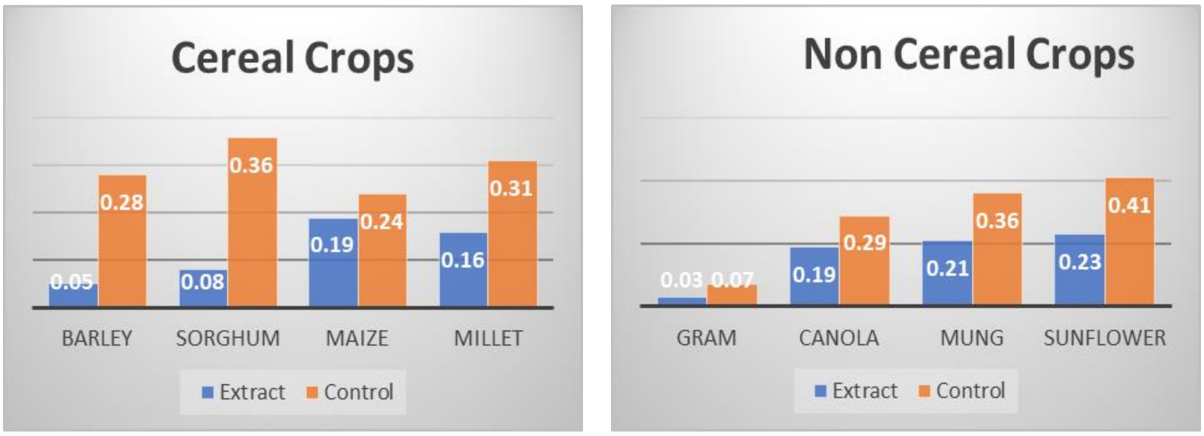


Figure 21 & 22. Photosynthetic efficiency (%) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*

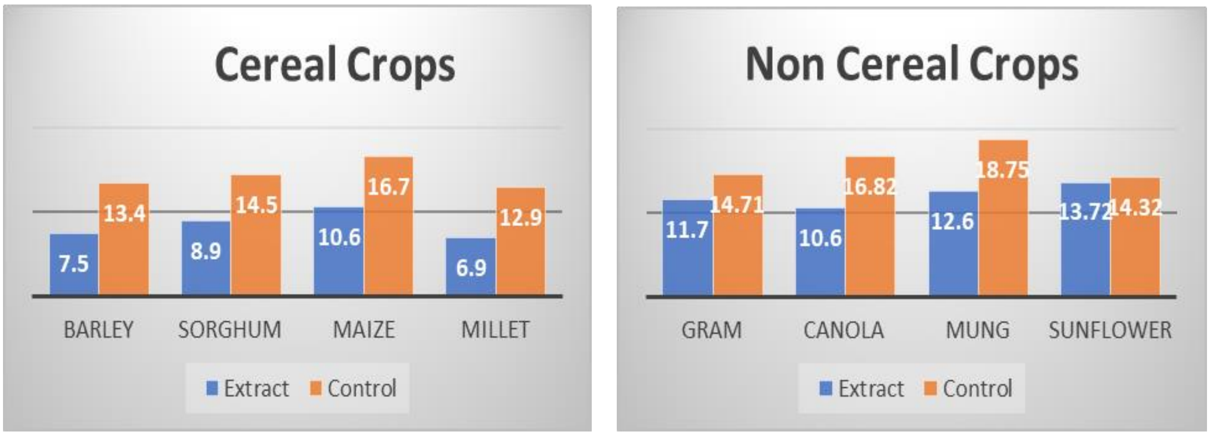


Figure 23 & 24. Crude protein in leacves (mg g^{-1}) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*

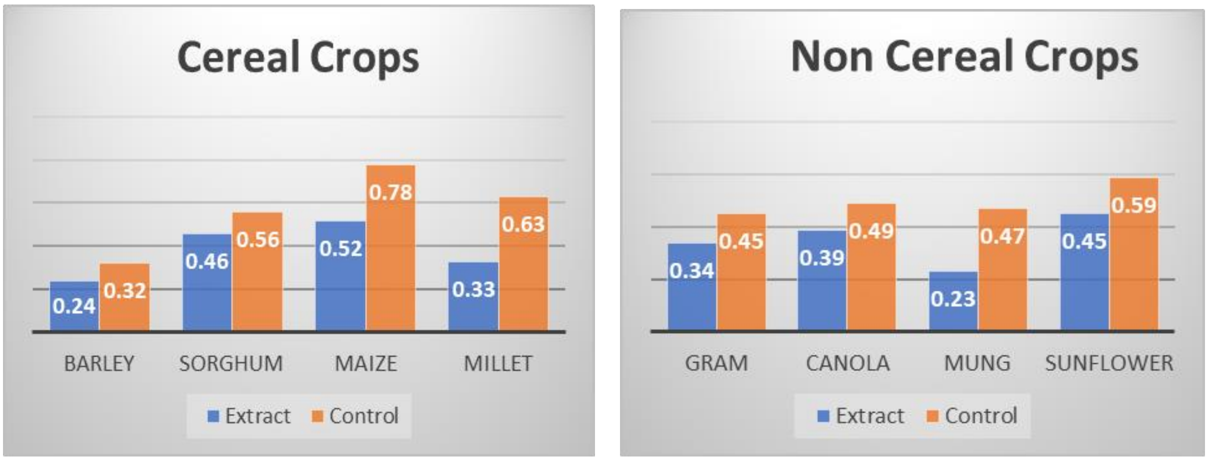


Figure 25 & 26. Plant growth rate (g m^{-2} day^{-1}) in cereals and non-cereals as influenced by phyto-toxicity of *Chenopodium album*

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