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GERMINATION METRICS AND EARLY SEEDLING GROWTH OF MAIZE AS INFLUENCED BY PHYTOTOXICITY OF SOME COMMON WEEDS

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ABSTRACT

Various weeds, through their stubbles and residues, may suppress germination and growth of economic crops by releasing many phyto-chemicals directly or after decomposition into the environment. This trial was carried out to investigate phytotoxicity of ten weeds on maize. A Laboratory experiment, was carried out at post graduate laboratory, Department of Agronomy, Faculty of Agriculture., Gomal University, D. I. Khan KPK., Pakistan. The trial was conducted in pots under controlled laboratory conditions using a completely randomized design with factorial arrangement. Fresh and dry biomass (100 g) of ten different weed species was mixed with sterilized soil to evaluate their allelopathic effects on maize germination and seedling growth. Our results revealed that all phyto-amendments (Fresh or dry biomasses) of weeds suppressed the germination metrics, coleoptile length, shoot & root sizes. Our study revealed the beneficial effect of Senji (*Melilotus indica*) on shoot size, dry weight, root fresh weight, and root dry weight compared to other weeds. In addition, weeds like Pohli (*Carthamus oxyacantha*), Aak (*Calotropis procera*), Jangli palak (*Rumex dentatus*), Bhathu (*Chenopodium album*), Lehli (*Convolvulus arvensis*), Gajarbooti (*Parthenium hysterophorus*), Deela grass (*Cyperus rotundus*), Jangli jai (*Avena fatua*), Billi booti (*Anagallis arvensis*) have lethal effect on germination and seedling growth of maize. Based our results, it was concluded that all weeds had a toxic effect on germination but after decomposing, Senji have stimulatory impact on maize seedling growth.

Keywords: Allelopathy, Phyto-amendments, Phytotoxicity, weed biomass, *Zea maize*.

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INTRODUCTION

Maize (*Zea mays*), commonly known as corn, is one of the most widely cultivated cereal crops globally, ranking third after wheat and rice. According to the Pakistan Economic Survey (2023–24), maize was grown on 1.6 million hectares, showing a 4.5% decrease from the previous year (1.7 million hectares), with production falling from 11 million tons to 9.8 million tons a 10.4% decline. The crop contributes 0.7% to Pakistan's GDP and 2.9% to agricultural value addition, with reduced cultivation being a major factor in the production decline (GOP, 2024).

Weeds are undesirable plants that emerge voluntarily, competing with crops and disrupting land management

objectives. Their phytotoxic potential significantly reduces crop productivity by suppressing plant populations. Globally, weeds pose a greater threat to crops than insects, diseases, or viruses due to their allelopathic effects. Common weeds such as *Avena fatua*, *Convolvulus arvensis*, *Chenopodium album*, and *Parthenium hysterophorus* have been observed to inhibit maize germination, particularly during spring planting. *Parthenium hysterophorus* locally known as Gajar Booti is especially aggressive due to its rapid growth and allelopathic properties.

Other problematic weeds include foxtail and nut sedge, which negatively affect crops like soybean and maize (Aldrich, 1984). Similarly, *Avena fatua* residues hinder

wheat growth, while *Cyperus rotundus* impacts barley, maize, and cotton. *Euphorbia* species also suppress wheat development. Raju (2001) found that extracts from *Convolvulus arvensis* and *Cirsium arvense* inhibit germination in wheat and barley. Weeds such as *Portulaca*, *Polygonum*, *Digitaria*, *Chenopodium*, *Echinochloa*, and *Amaranthus* release allelochemicals that damage crops like cabbage, radish, and pepper. Perennial weeds tend to have stronger inhibitory effects than annual species, posing a greater challenge to agricultural productivity.

Allelopathy refers to the chemical interaction between plants, where certain species release compounds into the environment that can either inhibit or promote the growth of nearby plants (Sangeetha & Baskar, 2015). These interactions play a key role in weed-crop competition and can significantly influence crop establishment and yield. Mechanical weed control often incorporates fresh weed biomass and stubble into the soil. Upon decomposition, these residues release phytochemicals into the soil environment, which can be harmful to current or subsequent crops. This study investigates maize tolerance to such phytotoxic effects. This experiment aimed to determine the phytotoxicity of selected weed species, using both fresh and dry biomass, on maize germination. Evaluating soil amendments with weed residues will help clarify weed crop interaction dynamics. Some weed residues may inhibit maize growth, while others may stimulate early seedling development. Understanding these interactions will support strategies to improve maize productivity by managing weed interference more effectively.

MATERIALS AND METHODS

Site of Experiment

The experiment was conducted in the postgraduate laboratory of the Department of Agronomy, Gomal University, Dera Ismail Khan. The study was carried out in pots under room temperature conditions (25–30 °C). It was designed to evaluate the stimulatory or inhibitory effects of various weed residues (fresh and dry) on maize germination indices and seedling growth. A completely randomized design (CRD) with factorial arrangement was used, comprising four replications per treatment. Each treatment included mixing 100 grams of fresh or dry weed residue with 900 grams of sterilized soil in individual pots. To prevent cross-contamination, each pot was labeled clearly, separated spatially, and handled using sterilized tools for each treatment during mixing and sowing. To ensure consistency and confirm the reliability of results, the experiment was repeated once under identical conditions,

and data from both trials were pooled for analysis. After germination, when seedlings reached a suitable height (approximately 20 days), 4 plants per pot were retained, and the rest were used for initial data recording.

Plant Material

Ten common weed species were selected for this study: Pohli (*Carthamus oxyacantha*), Aak (*Calotropis procera*), Senji (*Melilotus indica*), Jangli Palak (*Rumex dentatus*), Bhathu (*Chenopodium album*), Lehli (*Convolvulus arvensis*), Gajarbooti (*Parthenium hysterophorus*), Deela grass (*Cyperus rotundus*), Jangli Jai (*Avena fatua*), and Billi Booti (*Anagallis arvensis*).

Approximately 3 kg of healthy fresh and dry leaves of each species were collected from the research area of Gomal University. The collected material was washed thoroughly with tap water and shade-dried. For treatments, 100 grams of chopped fresh weed residue were mixed into 900 grams of sterilized soil per pot. Separately, 100 grams of plant material were oven-dried at 75 °C for 72 hours to obtain constant weight. The dried samples were powdered and similarly mixed into sterilized soil at the same rate (100 g dry residue + 900 g soil).

Maize Seed Collection and Sterilization

Certified seeds of maize (*Zea mays*) were procured from a registered seed store in Dera Ismail Khan. Uniform, healthy seeds were surface sterilized using 1% sodium hypochlorite solution for 45 minutes and then rinsed thoroughly with distilled water several times to remove any chemical residues (Khan et al., 2008). Twelve seeds were sown per pot, and data on germination and seedling growth were recorded accordingly.

Parameters Studied

Germination count was recorded daily for each pot from the time of sowing until the final day of seed emergence. Germination percentage was calculated by dividing the number of germinated seeds by the total number of seeds sown and multiplying the result by 100. Germination energy, representing the vigor of seed emergence, was measured on the 7th day after sowing as the percentage of seeds germinated relative to the total number of seeds sown, following the method described by Farooq et al. (2005), and observations continued up to the 15th day. Coleoptile length was measured using a standard scale 20 days after crop emergence. Similarly, shoot size was measured at 20 days after emergence by averaging the lengths of three randomly selected plants using a scale. Shoot fresh and dry weights were determined at the same time point by weighing three sample plants using a digital balance, and the results were averaged. Root size was also measured at 20 days after

emergence using a scale, while root fresh and dry weights were recorded using a digital balance, based on three sample plants, and averaged accordingly.

Statistical Analysis

The research data will be checked with the analysis of variance protocol for analysis (Statistics 8.1). Average of treatments will be done by using LSD-test at the probability level 0.05 (Steel *et al.*, 1997).

RESULTS

The phytochemicals released from weeds play a major role in allelopathic mode of action. Previous literature evidenced that weeds release a diversity of phytochemicals into neighboring edaphic environment consisting of phenols, alkaloids, long chain hydro carbons, flavonoids, glucosides and various secondary metabolites Rice (1984). Weeds may have ability to inhibit the germination and growth of other plants due to their allelopathic potential. So, ten weeds are selected due their allelopathic nature. Allelochemicals are entered into neighboring environment from all plant parts by

means of leaching, root exudation, vitalization, vaporization, reduce decomposition and other mechanisms in both natural and agricultural ecosystem (Chou, 1990). Maize was considered relatively tolerant to allelopathic effect from Gramineae family (Daffaallah and Twom, 2017).

Germination Counts

Seed germination marks the beginning of new plant growth, starting with water uptake by dry seeds and ending with the emergence of the radicle through the seed coat (Bewley, 1997). Successful germination depends on adequate water and mineral availability in the soil. As shown in Table 1, germination counts varied significantly across treatments. The highest germination was recorded in the control treatment (T1), with an average of 7.75 seeds, followed by T5 (Jangli Palak fresh biomass, 6.00) and T12 (Pohli dry biomass, 5.75). The lowest germination was observed in T3 (Aak fresh biomass), with only 1.75 seeds, indicating strong phytotoxic effects likely caused by allelopathic compounds released by *Calotropis procera*.

Table 1: Germination counts and germination (%) of maize in response to phytotoxic effects of common weeds.

Treatments	Germination count	Germination %
T1 = Control	7.75 a	64.58 a
T2 = Fresh biomass of pohli (<i>Carthamus oxycantha</i>)	4.00 bc	33.33 bc
T3 = Fresh biomass of aak (<i>Calotropis procera</i>)	1.75 c	14.58 c
T4 = Fresh biomass of senji (<i>Melilotus indica</i>)	3.00 bc	25.00 bc
T5 = Fresh biomass of jangli palak (<i>Rumex dentatus</i>)	6.00 ab	50.00 ab
T6 = Fresh biomass of bhathu (<i>Chinnopodium album</i>)	5.00 ac	41.66 ac
T7 = Fresh biomass of lehli (<i>Convolvulus arvensis</i>)	4.75 abc	39.58 ac
T8 = Fresh biomass of gajarbooti (<i>Parthenium hysterophorus</i>)	3.75 bc	31.25 bc
T9 = Fresh biomass of deela grass (<i>Cyperus rotundus</i>)	4.25 bc	35.41 bc
T10 = Fresh biomass of jangli jai (<i>Avena fatua</i>)	4.25 bc	35.41 bc
T11 = Fresh biomass of billi booti (<i>Anagallis arvensis</i>)	2.75 bc	22.91 bc
T12 = Dry biomass of pohli (<i>Carthamus oxycantha</i>)	5.75 ab	47.91 ab
T13 = Dry biomass of aak (<i>Calotropis procera</i>)	4.75 ac	39.58 ac
T14 = Dry biomass of senji (<i>Melilotus indica</i>)	4.25 bc	35.41 bc
T15 = Dry biomass of jangli palak (<i>Rumex dentatus</i>)	3.75 bc	31.25 bc
T16 = Dry biomass of bhathu (<i>Chinnopodium album</i>)	2.25 c	18.75 c
T17 = Dry biomass of lehli (<i>Convolvulus arvensis</i>)	4.75 ac	39.58 ac
T18 = Dry biomass of gajarbooti (<i>Parthenium hysterophorus</i>)	3.50 bc	29.16 bc
T19 = Dry biomass of deela grass (<i>Cyperus rotundus</i>)	4.00 bc	33.33 bc
T20 = Dry biomass of jangli jai (<i>Avena fatua</i>)	3.75 bc	31.25 bc
T21 = Dry biomass of billi booti (<i>Anagallis arvensis</i>)	3.75 bc	31.25 bc

Means having common letters are not significant at $P>0.05$; LSD_{0.05} for germination count=3.38; LSD_{0.05} for germination % = 28.21

Germination Percentage (%)

Seed germination marks the beginning of a plant's life cycle and depends on both internal seed viability and external

environmental conditions. It begins with water uptake through the seed coat and ends with the emergence of the radicle (future root) and plumule (future shoot). Germination

percentage is an important indicator of seed quality and directly impacts crop establishment and yield. As shown in Table 1, maize germination (%) was significantly affected by the phytotoxic effects of different weed residues. The control treatment showed the highest germination rate at 64.58%, indicating ideal conditions without allelopathic interference. In contrast, the fresh biomass of Aak (*Calotropis procera*) exhibited the lowest germination percentage (14.58%), suggesting a strong phytotoxic influence. Other treatments showed moderate effects: Pohli (*Carthamus oxyacantha*): 47.91%, Jangli Palak (*Rumex dentatus*): 50.00%, Senji (*Melilotus indica*): 41.66%. These results suggest that while some weeds like Aak strongly inhibit maize germination, others such as Pohli, Jangli Palak, and Senji have relatively minor or neutral effects.

Germination Energy

Germination energy reflects the vigor and speed of seed

sprouting during the early stages of germination. It is a key parameter for assessing seed performance beyond just germination percentage. As presented in Table 2, significant differences were observed among treatments, indicating that weed residues (both fresh and dry) had varied effects on maize germination energy. The highest germination energy was recorded in the control treatment (T1) with a value of 10.47, followed by T12 (Pohli dry biomass) 9.72, T2 (Pohli fresh biomass) 9.50. These values suggest that *Carthamus oxyacantha* (Pohli) had relatively low phytotoxic effects and may have even supported early seed vigor. In contrast, the lowest germination energy was observed in T8 (Gajarbooti fresh biomass) 6.62, T18 (Gajarbooti dry biomass) 7.10. This indicates that *Parthenium hysterophorus* (Gajarbooti), especially in fresh form, had a significant inhibitory effect on maize seed vigor.

Table 2: Germination energy and Coleoptile length (cm) of maize in response to phytotoxic effects of common weeds.

Treatments	Germination energy	Coleoptile length (cm)
T1 = Control	10.47 a	2.92 a
T2 = Fresh biomass of pohli (<i>Carthamus oxyacantha</i>)	9.50 bc	2.61 ac
T3 = Fresh biomass of aak (<i>Calotropis procera</i>)	9.45 bc	2.25 ae
T4 = Fresh biomass of senji (<i>Melilotus indica</i>)	9.40 bc	2.97 a
T5 = Fresh biomass of jangli palak (<i>Rumex dentatus</i>)	9.17 bd	2.50 ac
T6 = Fresh biomass of bhathu (<i>Chinnopodium album</i>)	8.17 eg	1.22 gj
T7 = Fresh biomass of lehli (<i>Convolvulus arvensis</i>)	8.25 ef	2.08 bf
T8 = Fresh biomass of gajarbooti (<i>Parthenium hysterophorus</i>)	6.62 i	0.90 hj
T9 = Fresh biomass of deela grass (<i>Cyperus rotundus</i>)	8.27 ef	1.42 fi
T10 = Fresh biomass of jangli jai (<i>Avena fatua</i>)	7.07 hi	1.80 cg
T11 = Fresh biomass of billi booti (<i>Anagallis arvensis</i>)	8.32 df	2.52 ac
T12 = Dry biomass of pohli (<i>Carthamus oxyacantha</i>)	9.72 ab	2.68 ab
T13 = Dry biomass of aak (<i>Calotropis procera</i>)	9.42 bc	1.47 ei
T14 = Dry biomass of senji (<i>Melilotus indica</i>)	8.80 ce	2.40 ad
T15 = Dry biomass of jangli palak (<i>Rumex dentatus</i>)	9.17 bd	1.55 ei
T16 = Dry biomass of bhathu (<i>Chinnopodium album</i>)	8.35 def	0.76 ij
T17 = Dry biomass of lehli (<i>Convolvulus arvensis</i>)	8.45 df	2.38 ad
T18 = Dry biomass of gajarbooti (<i>Parthenium hysterophorus</i>)	7.10 hi	0.57 j
T19 = Dry biomass of deela grass (<i>Cyperus rotundus</i>)	7.32 gi	1.65 dh
T20 = Dry biomass of jangli jai (<i>Avena fatua</i>)	7.70 fh	1.65 dh
T21 = Dry biomass of billi booti (<i>Anagallis arvensis</i>)	8.42 df	2.07 bf

Means having common letters are not significant at $P > 0.05$; LSD_{0.05} germination energy = 0.88; LSD_{0.05} coleoptile length = 0.82

Coleoptile Length (cm)

The coleoptile is the developmental structure that leads the plumule towards light and sun. It shelters the embryo, plumule, and other components of the seedling against cut, physical harm, and chemical toxicity. It examines the support for maize seedlings during emergence. The length of the

coleoptile improves seed growth in plants and help in drought resilience. Coleoptile length of maize in response to phytotoxic effects of common weeds are presented table 2. The shortest coleoptile lengths were observed in T8 Gajarbooti (*Parthenium hysterophorus*) at 0.90 cm and T6 Bhathu (*Chenopodium album*) at 1.22 cm, both due to fresh biomass

burial. Similarly, observation was taken in the dry biomass burial treatment, T18 *Gajarbooti* (*Parthenium hysterophorus*) recorded the shortest coleoptile length at 0.57 cm, followed by T16 *Bhathu* (*Chenopodium album*) at 0.76 cm.

Shoot Size (cm)

The response of phytotoxic effects of common weeds on shoot size of maize as shown in table 3. Numerically analyzed data distinct differences among various treatments with a Smallest significant difference (LSD) of 2.22 cm at $P \leq 0.05$. In case of fresh biomass buried conditions, largest shoot was noted in the control treatment (T1) at 7.00 cm,

trailed closely by Senji (*Melilotus indica*, T4) at 6.60 cm, whereas, shortest shoot was measured in Bhathu (*Chenopodium album*, T6) with a shoot length of 3.25 cm, demonstrating a noteworthy inhibitory effect. The dry biomass buried treatments, jangli palak (*Rumex dentatus*, T15) presented the supreme shoot length at 6.42 cm, which was statistically similar to senji T14 (6.35), gajarbooti (T18) and aak (*Calotropis procera*, T13). While shortest shoot size was noted in Billi booti (*Anagallis arvensis*, T21) with 4.02 cm, tailed by jangli jai (*Avena fatua*, T20) and deela grass (*Cyperus rotundus*, T19).

Table 3: Shoot size (cm), shoot fresh and dry weight (g) of maize in response to phytotoxic effects of common weeds after 20 days of emergence.

Treatments	Shoot size (cm)	Shoot fresh weight (g)	Shoot dry weight (g)
T1 = Control	7.00 a	1.12 cg	0.33 b
T2 = Fresh biomass of pohli (<i>Carthamus oxycantha</i>)	4.60 bd	1.3250 bg	0.26 bd
T3 = Fresh biomass of aak (<i>Calotropis procera</i>)	5.55 abc	0.90 fg	0.09 h
T4 = Fresh biomass of senji (<i>Melilotus indica</i>)	6.60 ab	1.15 cg	0.50 a
T5 = Fresh biomass of jangli palak (<i>Rumex dentatus</i>)	6.15 ac	1.20 cg	0.12 fh
T6 = Fresh biomass of bhathu (<i>Chinnopodium album</i>)	3.25 d	0.82 g	0.16 eh
T7 = Fresh biomass of lehli (<i>Convolvulus arvensis</i>)	6.10 ac	1.05 dg	0.21 cf
T8 = Fresh biomass of gajarbooti (<i>Parthenium hysterophorus</i>)	6.45 ab	1.17 cg	0.35 b
T9 = Fresh biomass of deela grass (<i>Cyperus rotundus</i>)	5.50 ac	1.12 cg	0.11gh
T10 = Fresh biomass of jangli jai (<i>Avena fatua</i>)	5.25 ad	1.07 dg	0.10 gh
T11 = Fresh biomass of billi booti (<i>Anagallis arvensis</i>)	4.00 cd	1.35 bg	0.27 bd
T12 = Dry biomass of pohli (<i>Carthamus oxycantha</i>)	5.35 ad	1.45 ae	0.29 bc
T13 = Dry biomass of aak (<i>Calotropis procera</i>)	6.35 ab	1.02 eg	0.10 gh
T14 = Dry biomass of senji (<i>Melilotus indica</i>)	6.35 ab	1.95 a	0.52 a
T15 = Dry biomass of jangli palak (<i>Rumex dentatus</i>)	6.42 ab	1.62 ac	0.16 eh
T16 = Dry biomass of bhathu (<i>Chinnopodium album</i>)	6.17 ac	1.07 dg	0.21 ce
T17 = Dry biomass of lehli (<i>Convolvulus arvensis</i>)	5.15 ad	1.42 af	0.28 bd
T18 = Dry biomass of gajarbooti (<i>Parthenium hysterophorus</i>)	6.37 ab	1.57 ad	0.48 a
T19 = Dry biomass of deela grass (<i>Cyperus rotundus</i>)	4.95 ad	1.42 af	0.14 eh
T20 = Dry biomass of jangli jai (<i>Avena fatua</i>)	4.57 bd	1.55 ae	0.15 eh
T21 = Dry biomass of billi booti (<i>Anagallis arvensis</i>)	4.02 cd	1.47 af	0.35 b

Means having common letters are not significant at $P > 0.05$; LSD $_{0.05}$ shoot size = 2.22; LSD $_{0.05}$ shoot fresh weight = 0.52; LSD $_{0.05}$ shoot dry weight = 0.09

Shoot Fresh Weight (g)

Shoot fresh weight as affected by phytotoxic effects of weeds in maize crop with a Least significant difference (LSD) of 0.52 g at $P \leq 0.05$ (Table 3). In fresh biomass buried treatments, Pohli (*Carthamus oxycantha*, T2) and Billi booti (*Anagallis arvensis*, T11) showed the heaviest shoot fresh weights at 1.32 g and 1.35 g, respectively, which were statistically similar to each other and among the top most performing treatments whereas, least shoot fresh weight at 0.82 g T6= Bhathu (*Chinnopodium album*), indicating a suppressive influence on accumulation of shoot biomass. Regarding dry biomass buried treatments, Senji

(*Melilotus indica*, T14) presented the maximum shoot weight at 1.95 g, significantly maximum than all other treatments. This was trailed by Gajarbooti (*Parthenium hysterophorus*, T18) at 1.57 g. The lowest most reading was verified for aak (T13) with 1.02 g.

Shoot Dry Weight (g)

Dry mass production in crops depends on the net assimilation rate (NAR), which is the balance between photosynthesis and respiration. While abiotic factors like sunlight, temperature, and moisture influence dry matter accumulation, biotic stress such as the presence of weeds and their decomposed residues can also alter plant tissue permeability, ion exchange, and

water retention (Dhanai et al., 2013). The shoot dry weight results are presented in Table 3, showing significant variation among treatments. In fresh biomass treatments, the highest shoot dry weight was observed in T4 (Senji) 0.36 g, T8 (Gajarbooti) 0.35 g, T1 (Control) 0.33 g. These values suggest minimal phytotoxic effects from *Melilotus indica* and *Parthenium hysterophorus* in fresh form. In contrast, the lowest shoot dry weights were recorded in T3 (Aak) 0.09 g, T10 (Jangli Jai) and T9 (Deela grass) ≤ 0.11 g. For dry biomass treatments, the trend was different T18 (Gajarbooti dry biomass) showed the highest shoot dry weight 0.47 g, Followed by T17 (Lehli) 0.28 g. Again, Aak (T13) recorded one of the lowest values 0.10 g, confirming its strong phytotoxic impact. *Calotropis procera* (Aak) consistently reduced shoot biomass, while *Parthenium hysterophorus* and *Melilotus indica* showed more favorable or less harmful effects, particularly in dry form.

Root Length (cm)

Root length is a critical indicator of early seedling development, reflecting both nutrient uptake potential and resistance to soil stress. The results presented in Table 4 showed statistically significant differences among

treatments. In fresh biomass treatments, the control (T1) produced the longest root size at 12.95 cm, significantly greater than all other treatments. Among weed treatments, the top performers were T4 (Senji) 9.70 cm, T5 (Jangli Palak) 9.00 cm, T6 (Bhathu) 8.77 cm. The shortest root length was observed in T7 (Lehli) – 5.42 cm. In the dry biomass group, T14 (Senji) again showed strong performance with a root length of 10.57 cm, followed by T16 (Bhathu) 9.65 cm. The lowest root size was noted in T12 (Pohli) 5.20 cm, T20 (Jangli Jai) 6.27 cm. These results indicate that Senji, Bhathu, and Jangli Palak had relatively less phytotoxic effects, maintaining root growth closer to the control. In contrast, Pohli, Lehli, and Jangli Jai significantly inhibited root elongation particularly Pohli in its dry form.

Root Fresh Weight (g)

Weeds release a range of phytotoxic compounds, including allelochemicals that affect plant growth by interfering with root function and development (Zohaib et al., 2016; Matlob et al., 2010). Roots, being crucial for water and nutrient uptake, are highly sensitive to such interference. Table 4 presents the data on root fresh weight, with a least significant difference (LSD) of 0.26 g at $P \leq 0.05$.

Table 4: Root fresh weight (g) of maize in response to phytotoxic effects of common weeds after 20 days of emergence.

Treatments	Root size (cm)	Root fresh weight (g)	Root dry weight (g)
T1 = Control	12.95 a	0.47 ac	0.14 ab
T2 = Fresh biomass of pohli (<i>Carthamus oxycantha</i>)	5.70 bc	0.25 cf	0.05 df
T3 = Fresh biomass of aak (<i>Calotropis procera</i>)	7.07 bc	0.20 df	0.02 f
T4 = Fresh biomass of senji (<i>Melilotus indica</i>)	9.70 ac	0.60 a	0.12 b
T5 = Fresh biomass of jangli palak (<i>Rumex dentatus</i>)	9.00 ac	0.32 af	0.03 df
T6 = Fresh biomass of bhathu (<i>Chinnopodium album</i>)	8.77 ac	0.12 f	0.02 f
T7 = Fresh biomass of lehli (<i>Convolvulus arvensis</i>)	5.42 bc	0.27 cf	0.05 df
T8 = Fresh biomass of gajarbooti (<i>Parthenium hysterophorus</i>)	7.30 bc	0.27 cf	0.08 ce
T9 = Fresh biomass of deela grass (<i>Cyperus rotundus</i>)	7.07 bc	0.30 bf	0.03 ef
T10 = Fresh biomass of jangli jai (<i>Avena fatua</i>)	5.52 bc	0.37 af	0.03 df
T11 = Fresh biomass of billi booti (<i>Anagallis arvensis</i>)	7.77 ac	0.17 ef	0.03 df
T12 = Dry biomass of pohli (<i>Carthamus oxycantha</i>)	5.20 c	0.27 cf	0.05 df
T13 = Dry biomass of aak (<i>Calotropis procera</i>)	7.35 bc	0.40 ae	0.04 df
T14 = Dry biomass of senji (<i>Melilotus indica</i>)	10.57 ab	0.62 a	0.13 ab
T15 = Dry biomass of jangli palak (<i>Rumex dentatus</i>)	9.60 ac	0.45 ad	0.04 def
T16 = Dry biomass of bhathu (<i>Chinnopodium album</i>)	9.65 ac	0.42 ae	0.08 cd
T17 = Dry biomass of lehli (<i>Convolvulus arvensis</i>)	7.15 bc	0.55 ab	0.11 bc
T18 = Dry biomass of gajarbooti (<i>Parthenium hysterophorus</i>)	8.05 ac	0.55 ab	0.16 a
T19 = Dry biomass of deela grass (<i>Cyperus rotundus</i>)	7.77 ac	0.57 a	0.05 cf
T20 = Dry biomass of jangli jai (<i>Avena fatua</i>)	6.27 bc	0.55 ab	0.05 df
T21 = Dry biomass of billi booti (<i>Anagallis arvensis</i>)	8.92 ac	0.42 ae	0.08 cd

Means having common letters are not significant at $P > 0.05$; LSD_{0.05} for root size = 5.26; LSD_{0.05} for root fresh weight = 0.26; LSD_{0.05} for root dry weight = 0.0

In fresh biomass treatments, the control (T1) recorded a root fresh weight of 0.47 g, which was statistically comparable to

T4 (Senji) 0.44 g. The lowest value was observed in T6 (Bhathu) 0.12 g. In dry biomass treatments, root fresh

weight values were generally higher. The maximum root weight was noted in T14 (Senji) 0.62 g followed closely by T19 (Deela grass) 0.55 g, T18 (Gajarbooti) 0.55 g, T20 (Jangli Jai) 0.55 g. Interestingly, these values exceeded the control, indicating possible stimulating effects of some dry residues. The lowest dry biomass value was recorded in T12 (Pohli) 0.27 g, though still statistically above the LSD threshold compared to the control.

Root Dry Weight (g)

The root dry weight data are presented in Table 4, with a least significant difference (LSD) of 0.05 g at $P \leq 0.05$. Under fresh weed biomass treatments, the control (T1) showed the highest root dry weight at 0.14 g, followed by T4 (Senji) with a slightly lower but statistically significant value. Most other treatments, including T2 (Pohli), T3 (Aak), T5 (Jangli Palak), T6 (Bhathu), T10 (Jangli Jai) had substantially lower values, ranging between 0.02 g and 0.05 g, indicating strong phytotoxic effects. The lowest root dry weight was observed in T3 (Aak) and T6 (Bhathu), each at 0.02 g, highlighting severe inhibition of root development by their fresh residues. In the dry biomass treatments, results improved slightly. The highest root dry weights were recorded in T18 (Gajarbooti) 0.16 g, T14 (Senji) 0.14 g followed by T17 (Lehli) 0.11 g, T21 (Billi Booti) 0.08 g, T16 (Bhathu) 0.08 g. Most remaining treatments showed low values (0.03–0.05 g), consistent with the inhibitory trends seen in fresh biomass. The generally higher root dry weight in dry biomass treatments may be due to reduced phytotoxicity as allelochemicals degrade over time. Fresh residues of *Aak* and *Bhathu* had the most severe inhibitory effects on root dry weight. Dry residues, particularly of *Gajarbooti* and *Senji*, allowed better root development possibly due to reduced allelopathic activity after decomposition.

DISCUSSION

The results demonstrated that *Calotropis procera* (Aak) significantly reduced maize seed germination percentage and germination energy. This inhibitory effect is likely due to the release of allelopathic compounds, a finding consistent with previous research indicating that certain weed species emit phytochemicals that suppress seed metabolic activity (Rehman et al., 2014; Khan et al., 2017). Similarly, *Parthenium hysterophorus* (Gajarbooti) exhibited strong negative effects on germination energy, particularly in its fresh form. This may be attributed to the gradual decomposition of its biomass, during which phytotoxic compounds are released into the soil environment (Jabran et al., 2024). In contrast, species such as *Melilotus indica*

(Senji) and *Rumex dentatus* (Jangli Palak) caused only minimal reductions in germination parameters, indicating either a weak allelopathic potential or neutral interaction with maize seeds. These findings reinforce the species-specific nature of allelopathic responses in agroecosystems. The coleoptile length of maize was particularly affected by *Parthenium hysterophorus* and *Chenopodium album* (Bhathu), which significantly reduced shoot elongation. This supports previous findings that allelochemicals can interfere with cell division and elongation processes during early seedling growth (Jabeen et al., 2011; Lie et al., 2010). The mode of action may involve disruption of membrane integrity, osmotic balance, and hormonal signaling in developing tissues. Interestingly, *Melilotus indica* showed a consistently positive effect on shoot growth in both fresh and dry biomass forms. As a leguminous plant, its residue might contribute beneficial compounds such as cytokinins (e.g., zeatin), or enhance nitrogen availability during decomposition (Chattha et al., 2015). This suggests that *Senji* could potentially be used as a green manure or mulch in maize-based systems.

On the other hand, *Anagallis arvensis* (Billi Booti) and *Chenopodium album* negatively influenced shoot length in fresh biomass treatments. These effects are likely due to allelopathic interference with nutrient uptake or hormonal regulation during early growth stages (Nouman et al., 2012). Shoot dry weight results confirmed that *Melilotus indica* produced the highest biomass, particularly under dry biomass treatments. In contrast, *Calotropis procera* consistently resulted in the lowest shoot biomass across both biomass types, reinforcing its strongly allelopathic character possibly due to the presence of toxic compounds like cardiac glycosides and latex.

Root growth was similarly inhibited by *Calotropis procera* and *Chenopodium album*, especially in fresh form. The fresh biomass of these species likely contains active allelochemicals that interfere with root elongation and cellular expansion (Zohaib et al., 2016). Conversely, dry biomass of species like *Parthenium hysterophorus*, *Deela Grass* (*Cyperus rotundus*), and *Jangli Jai* (*Avena fatua*) led to improved root growth compared to the control. This may be due to partial degradation of phytotoxic compounds during drying or decomposition, which reduces allelopathic intensity and may release beneficial nutrients (Shahzad et al., 2016). The differential effects observed between fresh and dry biomass forms suggest that allelopathic activity is not only species-dependent but also influenced by the decomposition state of plant residues. While some phenolic compounds are highly phytotoxic in fresh tissue, they may

become less active or degrade into inert forms during drying (Jadhav et al., 2021).

The present study highlights the importance of selective weed residue management in maize-based cropping systems. Species like *Aak* and *Bhathu* pose a strong phytotoxic risk and should not be incorporated as fresh biomass. In contrast, *Senji* and *Deela Grass* showed either neutral or positive effects on seedling development, especially in their dry form, and may be considered for soil amendment purposes. These findings provide a basis for distinguishing between harmful and potentially beneficial weed residues and support the need for targeted use of allelopathic knowledge in crop management. Future studies should include biochemical profiling of weed residues to identify key compounds responsible for the observed effects and explore their application in sustainable agriculture systems.

CONCLUSION

This study demonstrated that the incorporation of both fresh and dry weed biomasses into the soil significantly influences maize germination and early seedling growth, primarily through the release of phytotoxic compounds during decomposition. The extent of inhibition varied depending on the weed species and the form of biomass used. Among the tested weeds, *Avena fatua* (Jangli Jai), *Parthenium hysterophorus* (Gajarbooti), and *Calotropis procera* (Aak) exhibited the most pronounced inhibitory effects on germination and seedling vigor. In contrast, *Melilotus indica* (Senji), in both fresh and dry forms, consistently improved germination parameters and seedling development, likely due to its leguminous nature and beneficial interactions with soil. These findings suggest that *Senji* may be effectively utilized as a green manure to enhance soil fertility and support early maize growth. Conversely, the incorporation of highly phytotoxic weeds especially in their fresh forms should be carefully managed to avoid adverse impacts on subsequent crops. Therefore, the allelopathic potential of weed residues must be considered during mechanical weed control and residue incorporation practices to sustain maize productivity and promote healthier cropping systems.

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AUTHOR CONTRIBUTIONS

IH conceived the idea and designed the experiment. IH, MJN and WHZ writing, and editing. WHZ and EUH performed the experiments. MSA and MJN analyzed the data, MSA helped in the interpretation of the results. AB set references. All of the authors approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY

Data presented in this study will be available on a fair request to the corresponding author.

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