Jagua Publication

J. Appl. Health Sci. Med., 5(3):1–7, 2025. DOI: 10.58614/jahsm531

Journal of Applied Health Sciences and Medicine

Journal : https://www.jpub.org/journal-details.php?journal-id=39

Research Article

Analysis Of The Effect of Allelopathic Compounds Extracted From Zea Mays L. On The Growth and Development of Triticum Aestivum L. and Their Impact on Soil Properties

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Article Info

Keywords: *Allelopathic Compounds, Zea mays L, Triticum aestivum L.*

Received: *03.11.2024*
Accepted: *17.02.2025*
Published: *04.03.2025*

Abstract

This study was carried out in the laboratories of the College of Education for Girls at the University of Kufa. Its primary aim was to assess the biological activity of aqueous extracts derived from *Zea mays* residues on the germination and growth of *Triticum aestivum*. In addition, the study investigated whether the allelochemicals present in these extracts contribute to the reduced productivity observed when *Triticum aestivum* is planted following the harvest of *Zea mays* in the same field. The results demonstrated that the residues of *Zea mays* led to a significant decline in the vegetative growth of *Triticum aestivum*. Specifically, the aqueous extracts not only reduced the germination rate of *Triticum aestivum* seeds but also inhibited the subsequent development of its seedlings. Moreover, the toxicity of the residues, once incorporated into the soil, became noticeable after two weeks of decomposition, reached its maximum impact at six weeks, and then gradually diminished. These findings suggest that the allelochemicals released from *Zea mays* residues play a substantial role in limiting the growth and development of *Triticum aestivum*.

1. Introduction

Plants exist in interconnected communities that share similar environmental requirements and often display comparable structural and morphological adaptations. In many natural settings, two or more plant species occupy the same location and complement each other by fulfilling different life requirements. However, the by-products of one plant—its secretions, exudates, or decomposed materials from leaves, stems, roots, fruits, or seeds—can adversely affect seed germination and seedling growth due to the release of toxic compounds [1]. This phenomenon, known as allelopathy, involves the release of chemicals called allelochemicals, which can have either beneficial or harmful effects on agricultural crops [2].

Allelopathy plays a crucial role in environmental and agricultural systems by influencing crop production and mediating the interactions among plants, soil, insects, and various pathogens. Numerous studies have demonstrated that certain crops exhibit allelopathic effects on neighboring or subsequent crops within the same field. These effects occur through mechanisms such as leaching, root exudation, microbial decomposition of plant residues, or volatilization. The allelochemicals involved—often phenolics, terpenes, alkaloids, and their derivatives—can inhibit or stimulate key physiological processes, including seed germination and seedling development, depending on their chemical nature and concentration.

Investigating allelopathic effects is essential for developing sustainable strategies to integrate trees with crops, diversify agricultural production, and maintain ecological balance [3].

How To Cite: S.A.A. Hammood. Analysis Of The Effect of Allelopathic Compounds Extracted From Zea Mays L. On The Growth and Development of Triticum Aestivum L. and Their Impact on Soil Properties. *Journal of Applied Health Sciences and Medicine*, 5(3):1–7, 2025. https://doi.org/10.58614/jahsm531

It has also been observed that allelopathic compounds often act synergistically, with their effects becoming evident in natural environments under various stress conditions that influence plant growth and development. The phenomenon of allelopathy has been extensively studied in several agricultural crops, including maize, rice, cotton, and sunflower [4], among others.

However, available information on the impact of allelopathic compounds on various physiological and biochemical processes in plants remains limited. This is primarily due to the complexity of these compounds, as each may exert multiple physiological effects. Therefore, it is essential to further explore the allelopathic phenomenon, particularly in terms of how different plant species and cultivars vary in their ability to produce allelopathic compounds at different stages of their life cycle.

In this context, understanding the impact of *Zea mays* extracts and the allelochemicals they contain on key growth parameters of *Triticum aestivum* plants cultivated in the same field after maize harvest is crucial [5].

2. Materials and Methods

Collection of Plant Residues

Residues of *Zea mays* were collected from a field cultivated with maize in Najaf Governorate. To determine the amount of dry matter contributed by the plant to the soil, several dry plants were uprooted, and soil samples were collected from a depth of 20 cm below the surface. These samples were then dried and weighed. The dry matter content was calculated by dividing the dry weight of the plant by the dry weight of the surrounding soil. The analysis revealed that *Zea mays* contributed approximately 4 grams of dry matter per kilogram of dry soil [6].

Crushing and Storage of Samples

The collected *Zea mays* residues were initially dried by exposing them to sunlight for a few hours. They were then cut into small fragments and spread on a cloth under laboratory conditions, with continuous stirring to prevent decomposition. Once fully dried, the samples were crushed using a Wiley Mill Standard No. 3 (Arthur) grinder. The resulting powder was sieved using a 60-mesh sieve and subsequently stored in nylon bags under laboratory conditions until the extraction process.

Extraction of Samples

A total of 200 g of crushed plant residue was weighed and placed in a 500 ml glass beaker containing 80% ethyl alcohol. The mixture was left for 24 hours with periodic shaking to ensure thorough extraction. The filtrate was then concentrated using a rotary evaporator, removing both alcohol and water to obtain a thick extract [7]. After drying, the extract was weighed, and the total yield was recorded. The final extract was stored in **50 ml** plastic bottles and kept in a freezer until further use in assessing its biological activity against *Triticum aestivum*.

Evaluation of *Zea mays* Residues on the Growth of *Triticum aestivum*

(The next section would detail the methodology for testing the effects of *Zea mays* residues on *Triticum aestivum* growth.)

Evaluation of the Duration of Toxicity from *Zea mays* Residue Decomposition in Soil and Its Effect on *Triticum aestivum* Growth

Preparation of Soil Samples

A uniform mixture of *Zea mays* whole-plant powder was incorporated into the soil at a concentration of 6.4 g of plant residue per kg of soil. The treated soil was placed in plastic pots with a capacity of 500 g each. For the control treatment, peat moss was added at the same rate (6.4 g/kg soil). *Triticum aestivum* seeds were sown at a density of 10 seeds per pot. After two weeks, the seedlings were thinned to three per pot and allowed to grow for an additional three weeks.

At the end of the experiment, the plants were harvested, and their root systems were carefully extracted using running water. The vegetative and root biomass from each treatment was dried in an electric oven at 65°C, and the results were compared based on dry weight.

To investigate the persistence of toxic compounds released from *Zea mays* residue decomposition in soil and their effect on *Triticum aestivum* growth, additional treatments were prepared. Dried *Zea mays* residues, including roots, stems, and leaves, were left to dry for one week in a greenhouse before being cut into small pieces (2–3 cm in length). These residues were then added to the soil at varying concentrations (20, 40, 60, 80, and 100 g/kg soil), with untreated soil serving as a control. The soil-residue mixtures were placed into plastic pots (5 kg soil capacity), and water was added to bring the soil to field capacity. The pots were covered with perforated nylon sheets for aeration and randomly placed in a dark environment within the greenhouse. Soil samples were collected from each treatment at different decomposition intervals: 1, 2, 4, 6, 8, and 10 weeks [8].

Extraction of Toxins Released from *Zea mays* Residues and Their Effect on *Triticum aestivum* Growth

To extract the plant-derived toxins released into the soil, 200 g of soil from each treatment was separately collected, and 100 ml of 80% ethyl alcohol was added. The mixtures were left for 48 hours with periodic shaking. Filtration was performed using a vacuum-assisted funnel and filter paper. This extraction process was repeated three consecutive times with 80% ethyl alcohol to ensure complete toxin recovery [9].

After the extracts reached a dry state, the residue was dissolved in 50 ml of distilled water, and the volume was adjusted to 100 ml for further biological activity assessment against *Triticum aestivum*. Petri dishes (9 cm in diameter) were prepared, each containing 60 g of white sand and 20 *Triticum aestivum* seeds. A total of 15 ml of the aqueous extract from the treated soil samples was added to each dish. The dishes were sealed with wax paper, leaving small ventilation holes, and were then randomly placed inside a growth incubator.

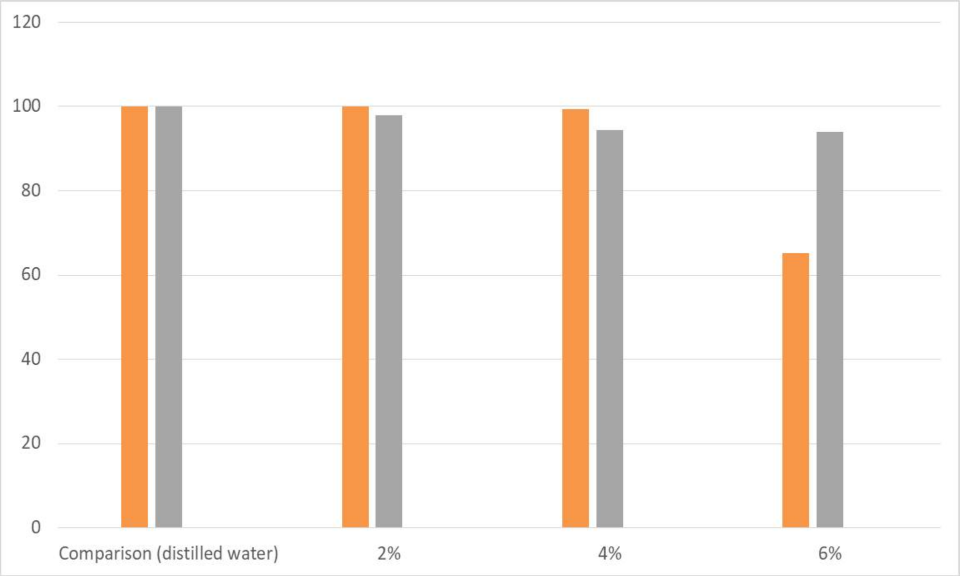

Figure 1: Effect of Alcoholic Extracts from *Zea mays* Root and Shoot Systems on *Triticum aestivum* Seed Germination

After 10 days, the germination percentage was calculated using the following formula [10]:
Germination percentage=(Number of germinated seedsTotal number of seeds)×100

$$\text{Germination percentage} = \left(\frac{\text{Number of germinated seeds}}{\text{Total number of seeds}}\right) \times 100$$

In addition to germination rate, the following growth indicators were measured:

- **Root and shoot length**
- **Seedling length**, evaluated according to the method of [7]
- **Dry weight of roots, shoots, and entire plant**, measured following the method of [11]

3. Results

Effect of Alcoholic Extracts from the Root and Shoot Systems of *Zea mays*

The data presented in Figure 1 indicate that alcoholic extracts derived from the root and shoot systems of *Zea mays* had a significant effect on the germination of *Triticum aestivum* seeds.

The results demonstrate that the presence of these extracts notably influenced the germination percentage of *Triticum aestivum* seeds, suggesting a potential allelopathic impact of *Zea mays* residues.

Figure 2 illustrates the significant impact of *Zea mays* residue addition at concentrations of 4 g and 6 g per kg of soil on the growth of *Triticum aestivum*. The presence of these residues led to a notable reduction in both root and shoot development, which consequently affected overall plant growth.

The reduction was statistically significant across all measured growth parameters, except for the shoot system at a concentration of 4 g waste/kg soil. The highest reduction was observed at a concentration of 6 g waste/kg soil, resulting in a growth reduction rate of 27.10%.

Each value in the table represents the mean of three replicates, with each replicate calculated as the average of three plants. This methodology applies to all tables in the study.

The results indicate that toxins released from decomposed *Zea mays* residues significantly reduced the germination of *Triticum aestivum* seeds compared to the control treatment, as shown in Figure 3. No significant differences were observed among the last three residue concentrations, while the two lower concentrations, including the 20 g residue/kg soil treatment, also showed no significant difference. However, a statistically significant reduction was noted between the 20 g and 60 g residue/kg soil treatments, with the latter exhibiting a more pronounced inhibitory effect.

The highest inhibition rates were recorded at 4, 8, and 10 weeks after decomposition, followed by moderate inhibition at 1 and 6 weeks. The most severe reduction in germination occurred at the 2-week decomposition mark.

An interaction effect was observed between decomposition duration and residue concentration. After one week of decomposition, the 20 g and 60 g residue/kg soil treatments significantly inhibited *Triticum aestivum* seed germination. A similar inhibitory effect was observed at the 2-week mark. However, beyond this period, no further negative effects on seed germination were detected.

Figure 4 illustrates the impact of toxins released from decomposed *Zea mays* residues on *Triticum aestivum* root length in comparison to the control treatment. The results indicate a significant reduction in root growth, with the most pronounced decrease observed at the 20 g residue/kg soil treatment, followed by the 10 g residue/kg soil concentration. The latter did not show a statistically significant difference from the 40 g and 60 g residue/kg soil treatments.

Regarding the decomposition periods, the most substantial reduction in root length was recorded after one and two weeks of decomposition. As decomposition progressed, the inhibitory effect gradually declined, with root lengths measuring 5.73 cm and 5.71 cm after four and six weeks, respectively. The reduction further lessened to 7.61 cm at eight weeks and 7.88 cm at ten weeks of decomposition.

A significant interaction was also observed between decomposition duration and residue concentration. The first four decomposition

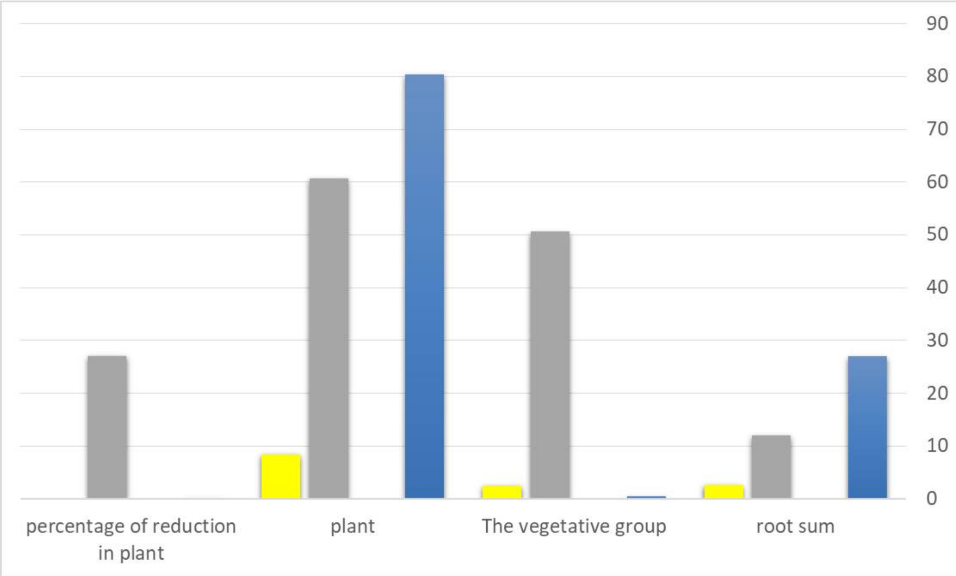

Figure 2: Effect of *Zea mays* Residues on *Triticum aestivum* Growth

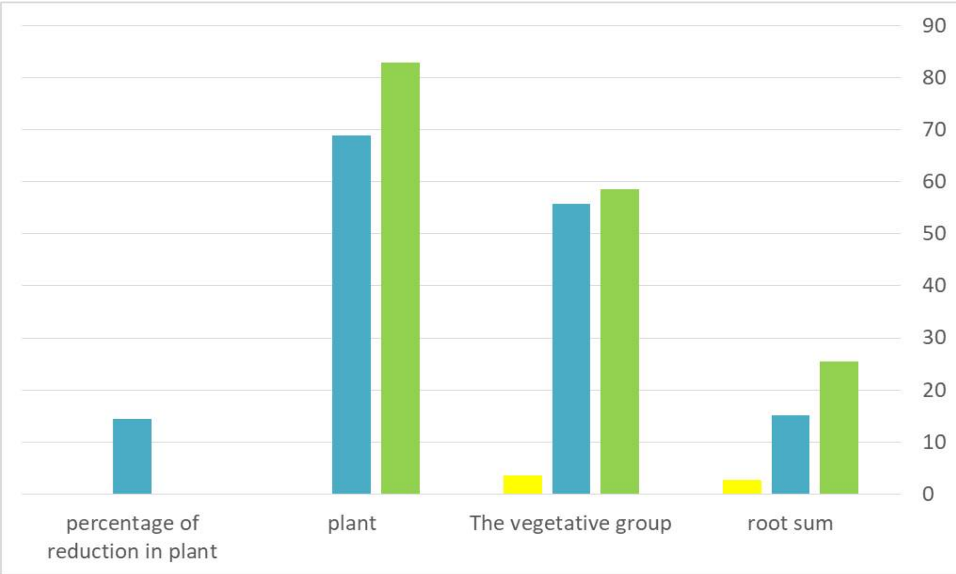

Figure 3: Effect of Toxins Released from Decomposed *Zea mays* Residues in Soil Over Different Periods on *Triticum aestivum* Seed Germination (%)

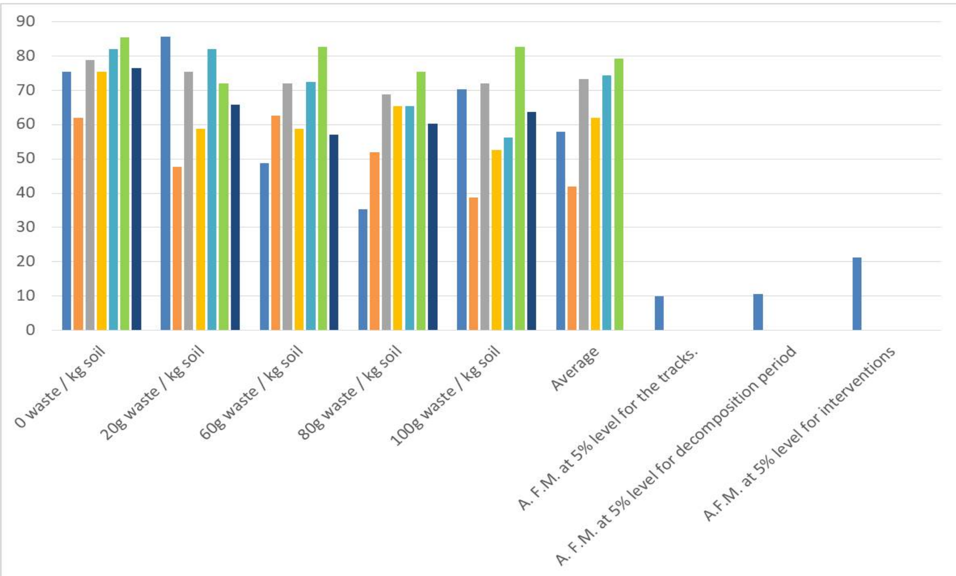

Figure 4: Effect of Toxins Released from Decomposed *Zea mays* Residues on *Triticum aestivum* Root Length

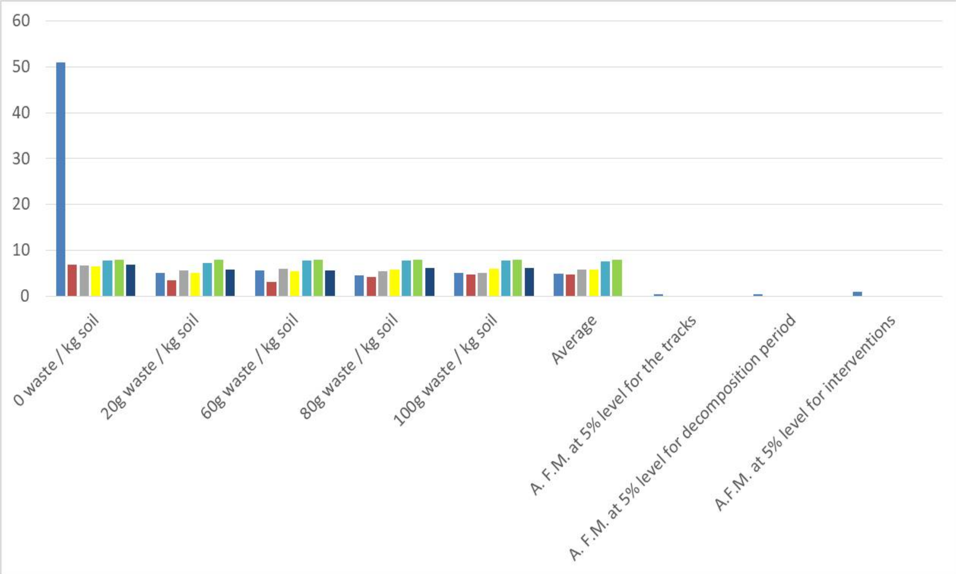

Figure 5: Impact of Toxins Released from Decomposed *Zea mays* Residues on *Triticum aestivum* Root Length (cm) Over Different Decomposition Periods

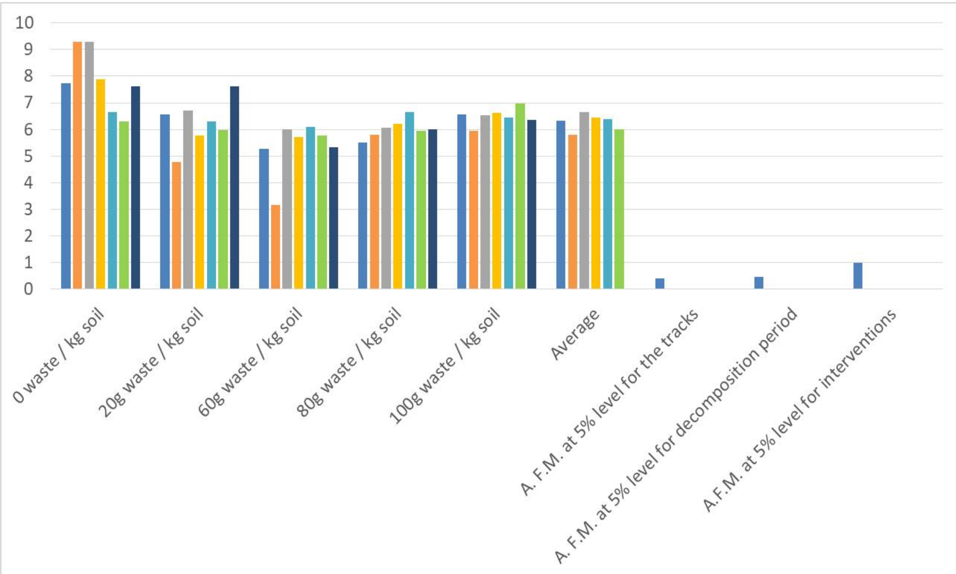

Figure 6: Effect of Toxins Released from Decomposed *Zea mays* Residues on *Triticum aestivum* Shoot Length (cm) Over Different Decomposition Periods

periods demonstrated notable reductions in root length across treatments compared to the control, except for the two lower concentrations after six weeks, where the reduction was not significant. By weeks eight and ten, no significant differences in root length were detected among all residue concentrations, including the control treatment.

Figure 6 demonstrates that the different concentrations of *Zea mays* residues had a significant impact on the shoot length of *Triticum aestivum* compared to the control treatment. The most substantial reduction in shoot length was observed at the highest concentration (20 g waste/kg soil).

Regarding decomposition periods, the longest shoot length was recorded after four weeks, reaching 6.64 cm. Additionally, the interaction between decomposition period and residue concentration had a notable influence on shoot growth. As shown in Figure 6, all tested concentrations significantly reduced shoot length compared to the control. The most pronounced reduction was observed at the 20 g waste/kg soil concentration after two weeks of decomposition.

Effect of *Zea mays* Residue Concentrations on the Length of *Triticum aestivum*

Figure 7 presents the significant impact of different concentrations of *Zea mays* residues on the length of *Triticum aestivum* plants. The greatest reduction in plant length was observed at the 20 g waste/kg soil concentration, which exhibited a statistically significant difference from the other treatments. However, the remaining concentrations did not show notable differences from each other.

Regarding decomposition periods, the most substantial decrease in plant length occurred after one and two weeks of decomposition. As the incubation period progressed, this reduction gradually lessened, with plant length reaching 120.01 cm and 12.03 cm after 8 and 10 weeks of decomposition, respectively.

Moreover, a significant interaction was observed between residue concentration and decomposition duration. The most pronounced reduction in plant length was recorded at the 20 g waste/kg soil concentration after two weeks of decomposition.

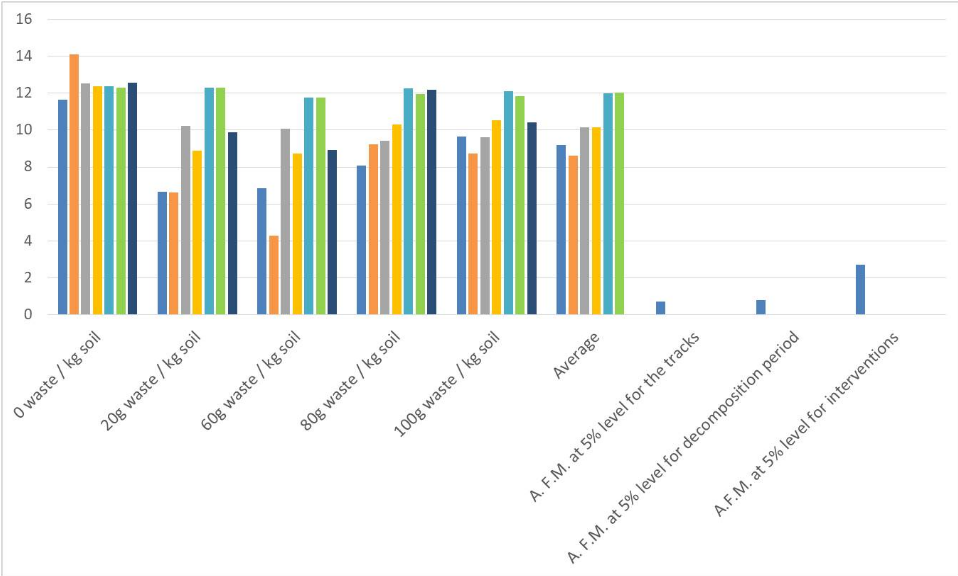

Figure 7: Impact of Toxins Released from Decomposed *Zea mays* Residues in Soil Over Different Periods on *Triticum aestivum* Plant Length (cm)

4. Discussion

Allelopathy is an ancient biological phenomenon discovered approximately 2,000 years ago. Molisch defined it as the biochemical interactions, both beneficial and harmful, that occur between plant species, including microorganisms. Numerous studies investigating this phenomenon and its ecological role have confirmed that these interactions result from the release of toxic compounds, known as allelochemicals, which are classified as secondary metabolites.

Research has shown that leaves and roots are the primary sources of allelopathic compounds, although these substances can also be present in other plant parts, including stems, flowers, fruits, rhizomes, and pollen grains. While roots produce allelopathic compounds in amounts comparable to leaves, their toxicity tends to be lower. The adverse effects of these compounds include inhibition of seed germination and seedling growth, reduced water and nutrient absorption, increased plant susceptibility to pathogens and parasites, and decreased soil fertility, ultimately leading to lower crop yield and productivity [12].

Researchers in various countries, including Iraq, have observed growth suppression when certain crops are grown successively in the same field or in rotation with specific other crops, despite proper field management, irrigation, fertilization, and pest control. Additionally, studies in Iraq have found that burning *Zea mays* and sunflower residues before planting can enhance crop production. This improvement has been attributed to the elimination of pathogenic agents such as insects, fungi, and other soilborne threats [13].

Researchers have highlighted the impact of allelochemicals released by the first crop on subsequent crops. These chemical compounds are introduced into the environment through processes such as leaching, root exudation, or microbial decomposition of plant residues post-harvest. Once mixed with the soil, these compounds influence the growth of the next crop planted in the same field [14].

In this study, a bioassay was conducted to evaluate the impact of aqueous extracts from the roots and vegetative parts of *Zea mays* on the growth of *Triticumeastevium*. The results confirmed that *Zea mays* residues significantly inhibited the growth of *Triticumeastevium*, affecting both root and shoot development. Interestingly, at lower concentrations, the residues appeared to have a stimulatory effect, suggesting that minimal amounts may either have a negligible impact or promote growth at certain developmental stages. These findings align with [4], who reported that allelopathic compounds inhibited plant growth starting from germination, reducing seedling length and both fresh and dry biomass, even at low concentrations.

The observed decrease in growth inhibition at higher concentrations of *Zea mays* residues may be attributed to the suppression of soil microbial activity. This, in turn, slows down residue decomposition, delaying the release of toxic compounds into the soil [1]. The results further demonstrated that the allelopathic effects of *Zea mays* residues persist for over six weeks (Figures 2, 3, 4, and 6), meaning that these compounds continue to influence *Triticumeastevium* germination, shoot length, root length, and overall plant growth.

To determine the underlying cause of reduced crop productivity, it was observed that the presence of *Zea mays* residues in the soil, combined with rainfall or irrigation, led to a decline in *Triticumeastevium* yield [15]. Researchers successfully identified allelopathic compounds released from *Zea mays* residues, supporting findings by [2], who reported that aqueous extracts of decomposing *Zea mays* residues inhibited *Triticumeastevium* growth by approximately 70%, with toxicity gradually decreasing over a 10-week decomposition period.

The following allelopathic compounds were identified in *Zea mays* residues: **p-coumaric acid, hydroxybenzoic acid, syringic acid, vanillic acid, ferulic acid, and hydroxyphenylacetic acid**. These compounds have been shown to significantly inhibit *Triticumeastevium* germination and seedling growth by interfering with cellular structures, plant hormone biosynthesis and balance, cell membrane integrity, stomatal regulation, pigment formation, photosynthesis, respiration, protein synthesis, nitrogen fixation, enzyme activity, vascular transport, water uptake, ion absorption, and genetic material function [16].

The results of this study align with findings by [6], who reported that plant toxins released from decomposing maize residues reduced maize growth to some extent, though they did not completely prevent it. The variation between allelopathic inhibition and stimulation depends on factors such as chemical composition, concentration, location within plant tissues, and environmental conditions [2]. However, [8] suggested that the growth-inhibitory effect is linked to disruptions in the activity of key enzymes, particularly peroxidase and alpha-amylase.

5. Conclusion

Based on these findings, we recommend cultivating *Triticumeastevium* varieties that exhibit greater resistance to the allelopathic toxins released by *Zea mays*, particularly when grown in succession within the agricultural cycle. It is also advisable to remove as much *Zea mays* residue as possible before planting *Triticumeastevium* to minimize its inhibitory effects.

Further research in this field is essential, and we encourage supplementing laboratory and greenhouse studies with field experiments under natural conditions to validate results and develop practical recommendations. Additionally, investigating the allelopathic effects of residues from other plant species on different *Triticumeastevium* varieties, alongside a comprehensive chemical analysis of allelopathic compounds, will provide valuable insights into their impact on cellular structures and overall plant physiology.

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