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A Study on the Allelopathic Effects of Wild Barley (*Hordeum spontaneum*) Residue Incorporated with Soil on Growth of Some Plant species

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ABSTRACT

This study examines the allelopathic effects of wild barley (***Hordeum spontaneum***) on the growth and yield of bread wheat (***Triticum aestivum***), barley (***Hordeum vulgare***), and wild barley (***Hordeum spontaneum***). The experiment was conducted in a greenhouse at Shamamar-Hawler/ Kurdistan Region of Iraq using a complete randomized factorial design (CRD) within 3 replications. The roots, shoots, and seeds of wild barley were dried, powdered, and added to the soil at different concentrations (0%, 10%, 20%, 30%, and 40%) in 500 g pots. Each pot was planted with 5 seeds, which were later reduced to 3 seedlings. Growth parameters such as shoot and root lengths, dry weights, number of tillers, weight of spikes, seeds number per plant, and biological yield was measured. The results indicated significant effects of wild barley residues on the studied crops. Wheat showed the highest roots, shoots and total lengths were (29.56 cm, 17.05 cm and 46.58 cm, respectively) and the highest shoots and roots dry weights were (0.24 g and 0.30 g). Barley showed the highest number of stems (1.96) but the lowest shoots and dry weights of roots were (0.11 g and 0.23 g). Wild barley had the highest biological weight and harvest index (HI). Among the plant parts, seed extracts significantly enhanced growth parameters, while roots and shoots extract had the greatest inhibitory effects as wild barley residue concentrations increased. Nevertheless, the HI showed a decline as the concentrations increased, suggesting a detrimental effect on growth efficiency. The study shows the potential of wild barley as a bio-herbicide, emphasizing its allelopathic effects. This suggests that agricultural practices should be carefully considered to maximize the efficiency of crops. Incorporating these results into precision agriculture can greatly improve crop management and increase yield.

1.Introduction

Allelopathy is a complicated substance phenomenon that is continually observed in both natural and generated by humans ecosystems. Allelopathy is the process by which plants and micro-organisms interact through the release of specific compounds known as allelopathic allelochemicals or allelopathic compounds. (Gniazdowska and Bogatek, 2005), Allelopathy is the term used to describe interactions that take place in the natural environment. The study conducted by (Soltys-Kalina et al., 2012) indicated that allelopathies arise from the synthesis of secondary metabolites and non-nutritional primary metabolites. These secondary metabolites are categorized into three major chemical groups (Weir et al., 2004, Iqbal and Fry, 2012). All plant parts release allelochemicals into the surroundings. Most allelopathic interactions are predominantly negative, while positive relationships are uncommon. Allelopathic compounds impact the germination and growth of nearby plants by interfering with multiple physiological processes, including photosynthesis, respiration, water regulation, and hormonal balance (Soltys-Kalina et al., 2013). The allelopathic effects on Hordeum genus have been observed since 300 BC (Chancellor, 1985). Barley plants have been discovered to possess inhibitory compounds, including coumarin, hydroxyl cinnamic acid and its derivatives, besides vanillic acid. (Overland, 1966) has stated that these compounds are believed to be the possible inhibiting factors. (An et al., 2005) reported that live cultivated barley roots leachates greatly affected white mustard plants decreasing their overall dry weight. In addition, 3 distinct allelochemicals obtained from barley plants were also identified as: gramine (N,N-dimethyl-3-aminomethylindole), hordenine (N,N-dimethyltyramine), and DIBOA (2,4-dihydroxy, 4-benzoxazin-3-one). The dry weight of the plants was effectively lowered by these compounds. Modern agriculture can use allelopathy instead of synthetic herbicides which have detrimental effects towards the environment and human beings in general and thus it is considered an environmentally friendly method for weed control in modern agriculture with the increase of crop productivity. Weed management strategies including intercropping; crop rotation; mulching; applying either allelopathic crop water extracts alone or together with reduced doses of herbicide and cover cropping into cropping systems have been found to be effective against various weed ecotypes (Nawaz et al., 2014). Crop residues inhibit weed development and growth through diverse mechanisms, encompassing both physical and chemical impacts. These effects relate to affecting the physical, chemical, and biological characteristics of the soil. This transformation comes from 2 potential sources of allelochemicals: secondary metabolites may be released directly from crop litter or they could be produced by microorganisms utilizing plant residues as a substrate (Ferreira and Reinhardt, 2010). The study conducted by (Rasul and Ali, 2020) showed that incorporating radish root into the soil significantly affected growth and yield of 2 wheat species, wild barley, and wild oat. This finding supports earlier research conducted by (Hamidi et al., 2006) reported that the components of the wild barley produce compounds that can inhibit the growth of other plants. Furthermore, the aboveground body of the wild barley when extracted in water displays varying degrees of toxicity to other plants and itself. Most allelochemicals are secondary metabolites that are generated as by-products during various physiological processes in plants under different conditions (Bhadoria, 2010, Farooq et al., 2011). The main factor determining the effectiveness of allelochemicals is their concentration. This research was aimed at investigating the allelopathic effect of wild barley ***(Hordeum spontaneum***) incorporated in soil on 2 crop species (wheat and barley) and one endemic weed particular to this region. The aim of the research was to examine the impact of incorporating wild barley root, shoot, and seed of (***Hordeum spontaneum***) into the soil at various rates on the growth and yield of bread wheat (***Triticum aesitivum***), barley (***Hordeum vulgre***), and wild barley (***Hordeum spontaneum***).

2.MATERIALS AND METHODS

The experiment was conducted in the greenhouse at Shamamar – Hawler/ Kurdistan

Region of Iraq, which serves as the research field for ard Agriculture company, to investigate the effect of wild barley (***Hordeum spontaneum***) residues which were consist 3 parts (roots, shoots and seeds) in mixing with soil in different rate to ensure the influences of allelopathic potential on the growth and yield of 3 crop species wheat (***Triticum aesitivum***), Barley (***Hordeum vulgare***) and Wild barley (***Hordeum spontaneum***). The study used a complete randomly factorial design (CRD) with 3 replications. After collecting the wild barley plant, it dried in shadow and the plant was collected as green with completed spikes and roots. After drying divided in to 3 parts (roots, shoots and seeds). Plastic of pots (500 g) with diameter of 12 cm and a depth of 10 cm capacities were used. Wild barley roots, shoots and seeds were cut into small piece and powder. The pots were filled with a mixture of soil, incorporated with roots, shoots, and seeds of wild barley at 5 different concentrations: 0%, 5%, 10%, 20%, 30%, and 40% (w/w). Subsequently, the pots were filled with mixing soil and panted with the plant species wheat, barley and wild barley. Five seeds were planted in each pot at a depth of 2 cm. Every pot was reduced to only 3 germinated seedlings. Eventually, the examined plants were collected by cutting the above-ground shoots and cleansing the root portions by rinsing them with tap water using a sieve. Subsequently, the shoots and roots samples were placed in an electrical oven (FAITHFUL GX-45BE) at a temperature of 70 °C for 72 h (Alsaadawi and Rice, 1982, Mallik, 1992). The subsequent parameters were then recorded:

1. The shoot length (cm): The length of the shoot that was nearest and the longest was measured in cm. (Abdul-baki and Anderson, 1972).
2. The root length (cm): The longest and nearest shoot was measured in cm. (Abdul-baki and Anderson, 1972).
3. The total length (cm): The total sum refers to the sum lengths of both shoots and roots. (Oliveira et al., 2013).
4. The shoots and the roots dry weights (g): The samples were dried in a digital oven at a temperature of 70 °C for 72 h, after which their weights were measured using a highly accurate electronic balance manufactured by DENVER INSTRUMENT (Wen and Renee, 2007).
5. The total dry weights (g): The combined weights of the aboveground shoots and belowground roots of the plant, without accounting for any moisture content. (Wen and Renee, 2007).
6. Number of tiller (No/pot), weights of spikes, No. of seeds per plant, weight of seeds (g), biological yield (g/pot), and the (HI) and the determination was made by calculating the ratio of grain yield to biological yield (Hamblin, 1983).

3.Analysis of statistics

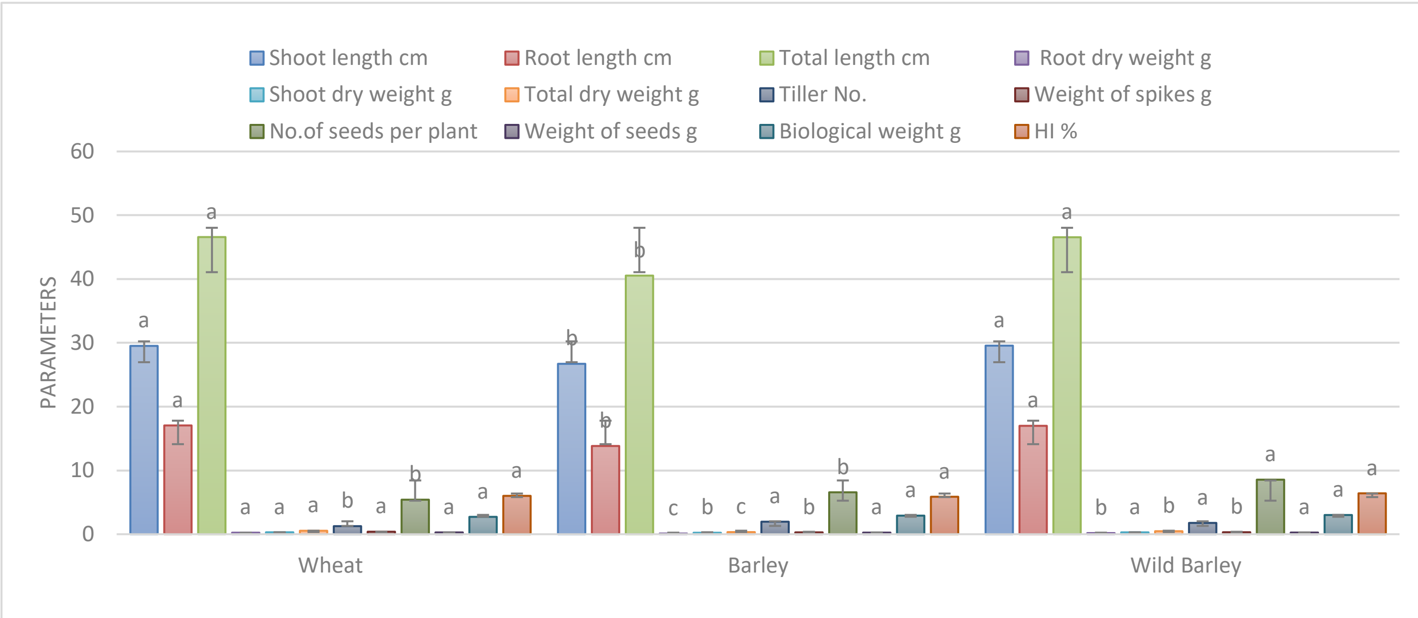
The study was conducted using a factorial completely randomized design (Factorial CRD) with 3 replicates. The data were evaluated using standard analysis of variance (ANOVA), and the Tukey's test were applied for multiple comparisons in statistical analysis, which was utilized to compare the means at a 1% significance level to obtain interpretable results. The analysis was carried out on a computer using Microsoft Excel Worksheet 2016 and SPSS version 25 (Weinberg and Abramowitz, 2008).

4.RESULTS AND DISCUSSION

4.1Effect of mixing wild barley residues with soil on wheat, barley and wild barley crops

The incorporation of wild barley residues to soil has a significant effect on the examined parameters (Figure 1). The highest number in the shoots, roots and total lengths (29.56, 17.05 and 46.58 cm) was recorded for wild barley and wheat respectively, whereas the lowest number (26.71, 13.83 and 40.54 cm) was noted for barley crop, while the maximum number of shoots, roots and total dry weights (0.24, 0.3 and 0.54 g) were registered for wheat crop, at the same time the minimum value was also recorded (0.11, 0.23 and 0.33 g) for barley crop, in contrast to that barley registered the highest value in number of tillers which was (1.96) and the lowest values were noted for wheat crop an is about (1.26). Whereas the greatest weight of spikes and seeds (0.39 and 0.38 g) were recorded for wheat crop and the lowest weight of spikes and seeds were (0.29 and 0.25). However, for wild barley the maximum number of seeds per plant, biological weights and HI (8.55, 3.01 and 6.41), respectively, while the minimum value were noted for wheat and barley which were (5.41, 2.72, and 5.87) separately. The results were in agreement with (Y. Ashrafi et al., 2007, Hamidi et al., 2008, Rasul and Ali, 2020) who studied various allelopathic crops, and showed that they possess phytotoxic effect against a variety of crops or weeds that are found in similar environments.

Figure (1): Effects of plant species on some parameters of crop species and weeds

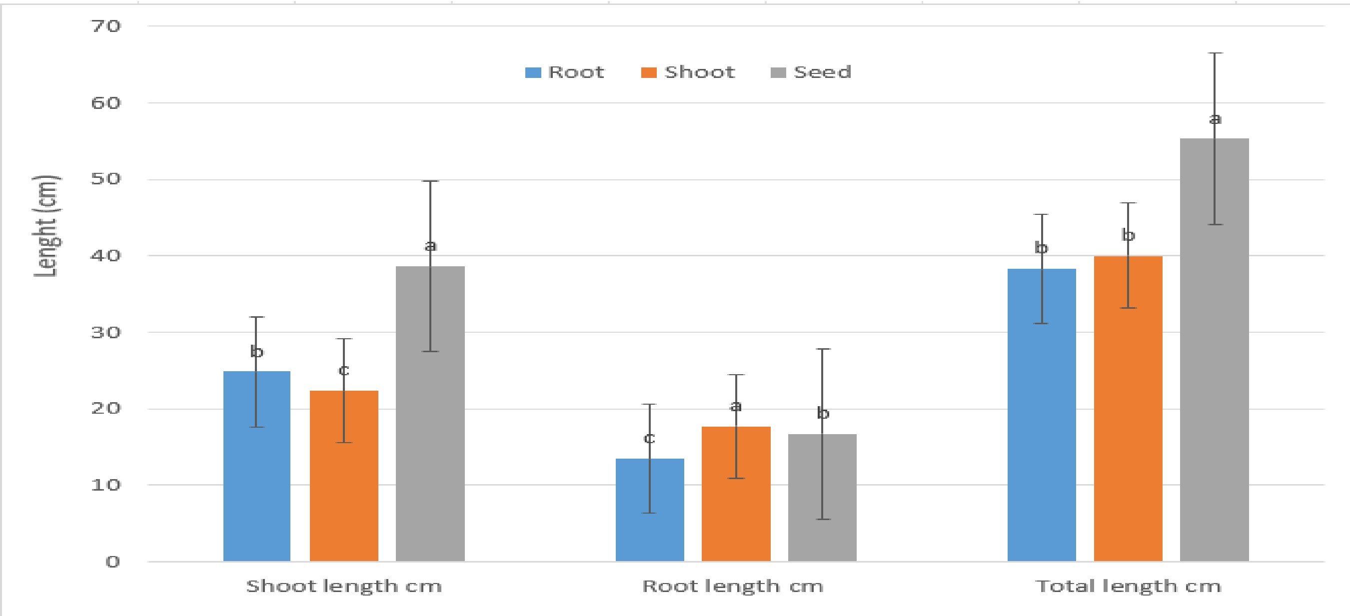


* Different letters means that there was significant difference at 1 % probability level by Tukey test.

4.2Effect of wild barley plant parts on studied parameters of plant species

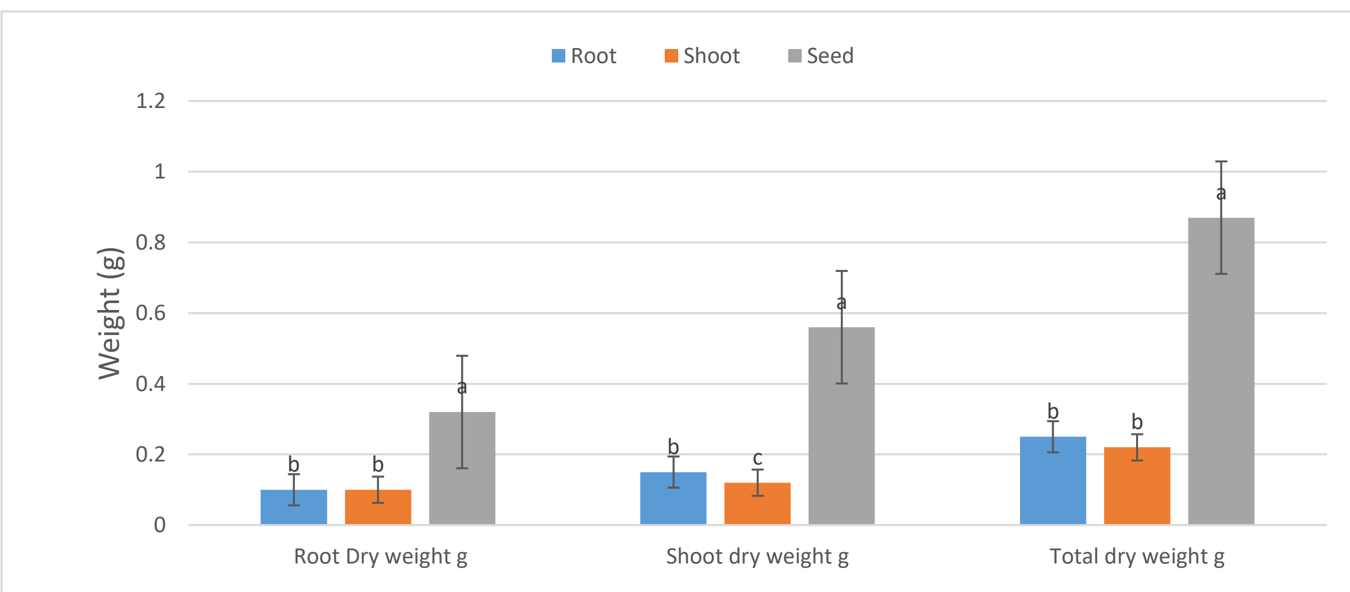
The study revealed significant allelopathic effects of wild barley plant parts on wheat, barley, and wild barley (Figure 2). The maximum shoot lengths was observed with the seeds extract (38.62 cm) and the minimum with the shoots extract (22.35 cm). Root lengths was the highest with the shoots extract (17.69 cm) and lowest with the roots extract (13.47 cm). Total lengths was maximized by the seeds extract (55.32 cm) and minimized by the roots extract (38.29 cm). These results indicated that wild barley's roots extract is the most potent inhibitor, while the seeds extract has the least inhibitory effect (Rigon et al., 2012, Fioreze et al., 2019). While, the seed part had the most significant positive impact, with the highest dry weights of roots (0.32 g), dry of shoots (0.56 g), and total dry weights (0.87g). In contrast, the shoots and roots parts showed the lower values, both with a root dry weight of 0.10 g. The shoots parts had the lowest dry weights (0.12 g), while the roots parts had a moderate dry weight (0.15 g). The seeds part was the most effective in enhancing plant biomass, likely due to its higher nutrient content and growth-promoting compounds (Al Tawaha and Turk, 2003) who examined wild barley seeds germinated on *Brassica nigra* extracts and found that they produced comparable results. The values for abnormal seedlings were found to be higher in white oat seeds when the extract was double-concentrated. When compared to the control values for germination parameters, neither the aboveground nor the roots extracts showed any significant differences. This suggests that incorporating wild barley seeds could improve crop productivity (Figure 3). Whereas, in the seeds part resulted in the highest tiller number (2.99), weight of spikes (0.83), number of seeds per plant (17.12), weight of seeds (0.69), biological weight (5.56), and HI (11.89) (Figure 4). In contrast, the roots and shoots parts had much lower values across all parameters, with the lowest being associated with the shoots part for weights of spikes (0.07), number of seeds per plant (1.56), weights of seeds (0.05), biological weight (1.5), and HI (2.91). These differences can be attributed to the higher nutrient and growth-promoting compound concentrations in the seeds compared to the other plant parts. Additionally, seeds contain essential growth hormones that enhance germination and initial growth stages leading to the better overall plant development. Lastly, seeds often have a higher metabolic activity that supports more vigorous growth and reproductive success, which is reflected in the improved parameters (Y. Ashrafi et al., 2007).

Figure (2): Effect of wild barley plant parts on root, shoot and total length of plant species



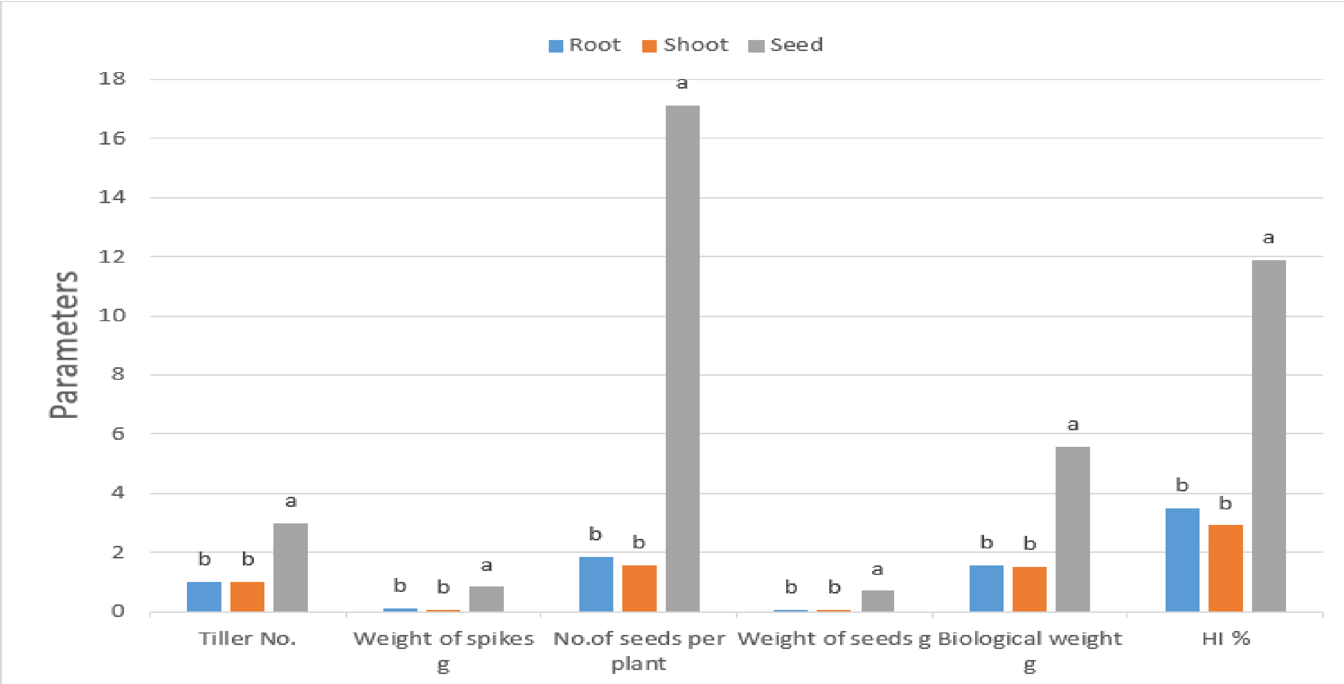
* Different letters means that there was significant difference at 1 % probability level by Tukey test.

Figure (3): Effect of wild barley plant parts on root, shoot and total dry weight of plant



* Different letters means that there was significant difference at 1 % probability level by Tukey test.

Figure (4): Effect of wild barley plant parts on growth parameters of plant species

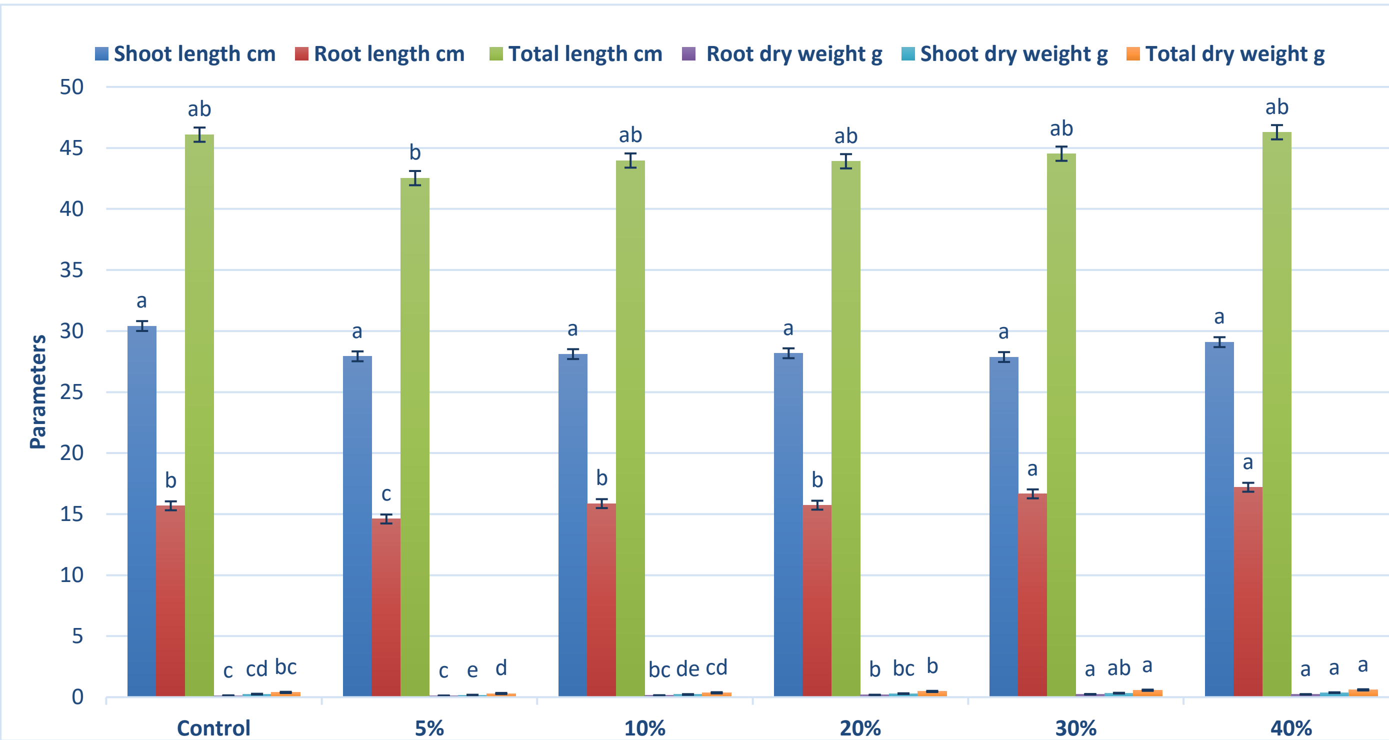


* Different letters means that there was significant difference at 1 % probability level by Tukey test.

4.3Effect of wild barley concentrations on studied parameters of plant species

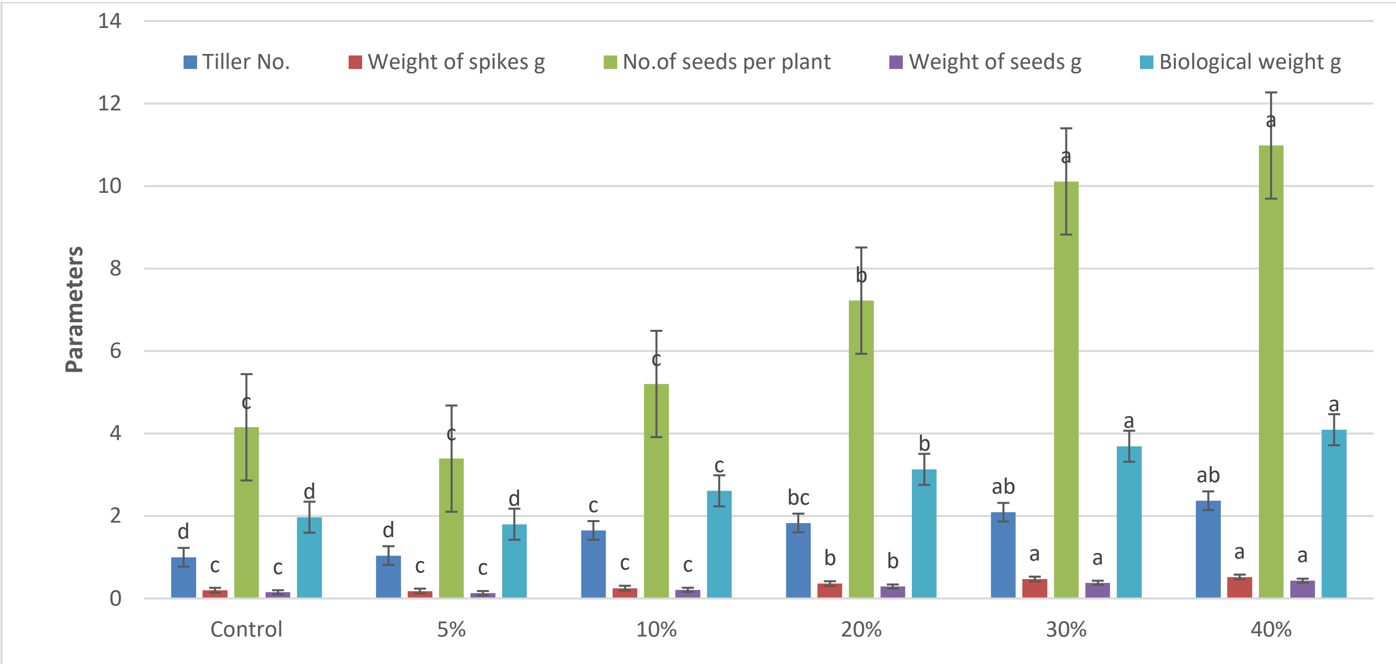
Increasing residue concentrations of wild barley (***Hordeum spontaneum***) resulted in significant affects for all parameters except shoots length, the highest value residue concentration effects for each of roots length, total length, roots dry weight, shoots dry weight and total dry weight were observed in 40 % treatments (17.2cm, 46.29cm, 0.23g, 0.37g and 0.6g) respectively. Whereas the lowest values were recorded in 5 % treatments for roots length, total length, roots dry weight, shoots dry weight and total dry weights (14.6 cm, 42.53 cm, 0.12 g, 0.17 g and 0.3 g), respectively (Figure 5). These results were in agreement with (Alrawiq et al., 2021) in which they detected that the highest concentration of plant residues as a result of the shorter length of the plant and the retardation of barley growth, may be due to the presence of allelopathic chemicals as a result of the inhibition of cell division. It is apparent from this study that increased amounts of wild barley residues had a significant effect on the studied parameters (Figure 6). At highest dose level of 40%, tiller numbers (2.37); spike weights (0.52g); number of seeds per plant (10.98); seeds weight (0.43g); biological weights (4.09g) were recorded. The control had the least values for several parameters like tillers number (1.0), spike weights (0.2g), number of seeds per plant (4.15), seeds weight (0.15g) and biological weights (1.97g). Recent studies showed that adding materials such as leaves or stalks from wild barley to soils enhances soil fertility status through nutrient enrichment and improved soil structure resulting in better roots development and vitality (Hamidi et al., 2008). In addition, allelochemicals present in dead parts suppress weed growth which reduces competition between plants (Norsworthy, 2003). Similarly, they increase microbial activity which improve nutrient cycling enhancing nutrient availability in the soil; thereby, increasing crop yield and productivity. When these features are combined they lead to higher biomass production; thus, leading to greater yields as they enhance competitive growth advantages, decrease weeds competition and increase overall crop vigor. As a result, HI for wheat, barley and unimproved barely decline significantly with increasing concentration levels of its own wastes. The control group without any wild barley has the highest (HI) value at 7.58, while the 10% concentration had the lowest HI (5.41). The decline in a consistent fashion suggests that allelopathic compounds present in wild barley resulted to significant reductions in plant growth efficiency as well as biomass allocation. Previously, allelopathic influences were known to be involved in the reduction of roots and shoots development; thereby, lowering resource partitioning needed for grain production. Previous research had shown that a relationship between allelopathy and reduced distribution of resources essential for grain yield through impairment of both roots and shoots development can occur. The results align with the research conducted by (Rasul and Ali, 2020), who similarly observed that increased levels of allelopathic compounds from wild barley had a negative impact on the HI of different crops. As a result, when there are higher concentrations of wild barley, the HI decreases indicating a negative impact on plant productivity (Figure 7).

Figure (5): Effect of wild barley concentrations on some growth parameters of plant species and weeds



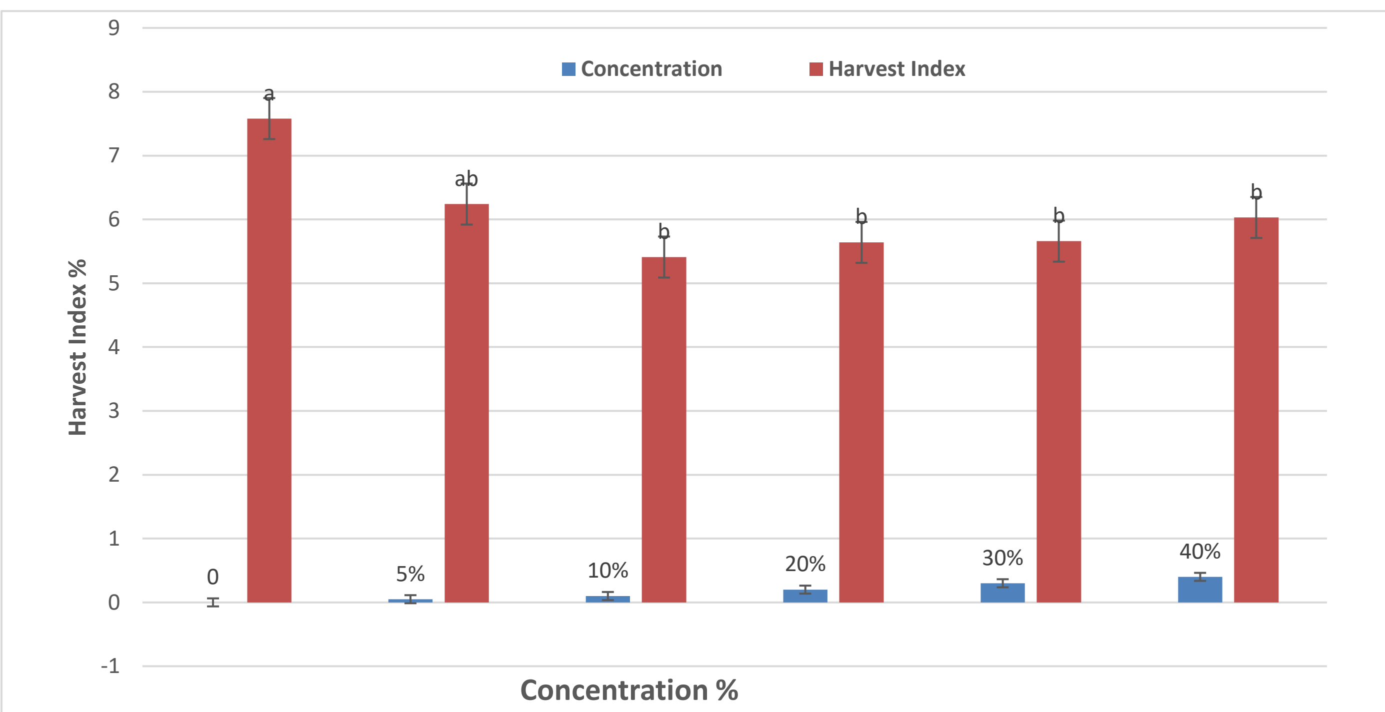
* Different letters means that there was significant difference at 1 % probability level by Tukey test.

Figure (6): Effect of wild barley concentrations on some growth parameters of plant species and weeds



* Different letters means that there was significant difference at 1 % probability level by Tukey test.

Figure (7): Effect of wild barley concentrations on HI %



* Different letters means that there was significant difference at 1 % probability level by Tukey test.

4.4Effects of the interaction between plant parts of wild barley and plant species on examined parameters.

The interaction of wild barley (***Hordeum spontaneum***) plant parts and plant species significant differences on studied characteristics (Table 1). The maximum rate of shoots, roots and total lengths were recorded in seeds and shoots part and wild parley plants (42.52cm, 20.49cm and 59.36 cm), respectively, while the minimum values (20.51cm, 12.1cm, 35.17cm) were in roots and shoots part and barley plants. The highest values records of roots, shoots and total dry weights (0.44 g, 0.65 g and 0.97 g), respectively, were observed in seeds part and both wheat and wild barley plants. Whereas, the maximum tillering number (3.89) was noted in seeds parts and barley plant, while the minimum number (1) were recorded in both roots and shoots parts for each of wheat, barley and wild barley plants. The major record 1.02 g, 20.07 and 0.77 g for weight of spikes, number of seeds per plant and weights of seeds were in wheat and wild barley treated with seed parts, but the minor values were 0.06 g, 0.42 and 0.02 g, respectively, noted for shoots parts in wheat and barley plants. Biological weights and (HI) recorded the highest values 5.98 g and 15.05% for seeds parts for all plant species wheat, barley and wild barley, but the lowest values (1.36 g and 1.23%) were observed with shoots parts in wheat and barley plants. The results outlined with (An et al., 2005, Hamidi et al., 2006, Ali and Sakri, 2010) who reported that wild barley has the allelopathic potential to release compounds into the soil either through its decomposed residue or through reside root extracts due to the particular that different plant species have varying degrees of sensitivity to allelopathic compounds.

Table (1): The influence of interactions between plant parts and plant species on the studied parameters.

Plant parts X Plant species		Shoot length cm	Root length cm	Total length cm	Root dry weight g	Shoot dry weight g	Total dry weight g	Tiller No.	Weight of spikes g	No.of seeds per plant	Weight of seeds g	Biological weight g	HI %
Root	Wheat	26.72c	14.69d	41.41cd	0.14cd	0.23c	0.37c	1d	0.09c	0.58c	0.04c	1.83c	1.76de
	Barley	24.25cd	12.1f	36.35e	0.06f	0.1de	0.15e	1d	0.08c	2.04c	0.06c	1.38c	4.14c
	Wild Barley	23.49cd	13.62e	37.11de	0.11def	0.12de	0.22de	1d	0.1c	2.93c	0.08c	1.54c	4.55c
Shoot	Wheat	23.87cd	17.92b	41.79cd	0.13de	0.16d	0.28cd	1d	0.06c	0.42c	0.02c	1.62c	1.23e
	Barley	20.51d	14.66d	35.17e	0.07ef	0.09e	0.15e	1d	0.06c	1.62c	0.05c	1.36c	3.28cd
	Wild Barley	22.67cd	20.49a	43.17c	0.11def	0.11de	0.22de	1d	0.09c	2.65c	0.07c	1.52c	4.2c
Seed	Wheat	37.98ab	18.54b	56.53a	0.44a	0.52b	0.97a	1.78c	1.02a	15.22b	0.77a	4.72b	15.05a
	Barley	35.37b	14.71d	50.09b	0.2c	0.49b	0.69b	3.89a	0.72b	16.06b	0.65b	5.98a	10.17b
	Wild Barley	42.52a	16.84c	59.36a	0.31b	0.65a	0.96a	3.31b	0.76b	20.07a	0.63b	5.98a	10.46b

* Different letters means that there was significant difference at 1 % probability level by Tukey test.

4.5Effects of the interaction between plant parts and concentrations of wild barley on examined parameters.

Table 2 shows the significant differences of plant parts and level concentrations of wild barley on studied characteristics. Data of the highest shoots, roots and total lengths were reported in seeds and shoots parts at 40% concentrations (44.08 cm, 20.72 cm and 61.93 cm), respectively. Whereas, the lowest values recorded in shoots and roots parts at 30% and 20% concentrations (19.53 cm, 12.24v cm and 34.28 cm). The largest values of roots, shoots and dry weights (0.54 g, 0.92 g and 1.46g), respectively were registered for seed parts at 40% concentrations, although the minimum values were recorded (0.08 g and 0.19 g) for roots and shoots parts at 30% and 40% concentrations. The maximum tillering numbers was recorded (5.11) for seeds parts at 40% concentrations, while the minimum number (1) was noted for roots, shoots and seeds parts at different concentrations. However, the weights of spikes, number of seeds per plant and weights of seeds registered the highest values (1.45 g, 30.83 and 1.23 g), respectively for seeds parts at 40% concentrations. Whereas, the lowest values were recorded (0.04 g, 0.83 and 0.02 g), respectively in shoots parts at 10%, 20%, 30% and 40% concentrations. The largest values for biological weights and HI were observed (9.47 g and 13.63%) in seeds parts at 40% concentration, while the minimum values (1.35 g and 1.6%) were noted in shoots parts at both 30% and 40% concentrations. The results are in agreement with (Belz, 2004, Hassannejad et al., 2013) who elucidated that the allelopathic effects can be stimulatory and the may have been beneficial for crops growth.

Table (2): The influence of interactions between plant parts and concentrations on the studied parameters.

Plant parts X	Concentrations	Shoot length cm	Root length cm	Total length cm	Root dry weight g	Shoot dry weight g	Total dry weight g	Tiller No.	Weight of spikes g	No.of seeds per plant	Weight of seeds g	Biological weight g	HI %
Root	Control	30.41cd	15.68efg	46.09cd	0.13cd	0.25ef	0.39de	1d	0.2e	4.15de	0.15de	1.97ef	7.58b
	5%	27.33cde	13.42hi	40.76de	0.11cd	0.13g	0.24ef	1d	0.09e	2.17e	0.06e	1.56ef	4.09c
	10%	23.33def	13.66hi	36.99e	0.11cd	0.16fg	0.27def	1d	0.06e	1.33e	0.04e	1.59ef	2.32c
	20%	23.53def	12.24i	35.77e	0.09d	0.13g	0.23ef	1d	0.06e	1.22e	0.03e	1.5ef	2.3c
	30%	21.47ef	12.81i	34.28e	0.09d	0.1g	0.19f	1d	0.05e	0.94e	0.03e	1.42ef	1.87c
	40%	22.83ef	13.02i	35.86e	0.08d	0.12g	0.19f	1d	0.06e	1.28e	0.04e	1.45ef	2.75c
Shoot	Control	30.41cd	15.68efg	46.09cd	0.13cd	0.25ef	0.39de	1d	0.2e	4.15de	0.15de	1.97ef	7.58b
	5%	22.53ef	14.9gh	37.43e	0.1cd	0.11g	0.21ef	1d	0.07e	1.56e	0.04e	1.49ef	2.99c
	10%	21.39ef	17cde	38.39e	0.1d	0.09g	0.19f	1d	0.04e	1.11e	0.03e	1.41ef	1.85c
	20%	19.89f	18.5bc	38.39e	0.09d	0.09g	0.18f	1d	0.04e	0.89e	0.03e	1.39ef	1.69c
	30%	19.53f	19.36ab	38.88de	0.11cd	0.08g	0.18f	1d	0.04e	0.83e	0.02e	1.4ef	1.6c
	40%	20.36ef	20.72a	41.08de	0.08d	0.08g	0.16f	1d	0.04e	0.83e	0.02e	1.35f	1.71c
Seed	Control	30.41cd	15.68efg	46.09cd	0.13cd	0.25ef	0.39de	1d	0.2e	4.15de	0.15de	1.97ef	7.58b
	5%	33.92bc	15.48fg	49.39bc	0.16cd	0.28e	0.44cd	1.11d	0.37d	6.44d	0.28d	2.36e	11.65a
	10%	39.61ab	16.93def	56.54ab	0.2c	0.42d	0.62c	2.94c	0.65c	13.17c	0.56c	4.83d	12.06a
	20%	41.11ab	16.46def	57.57a	0.36b	0.65c	1.01b	3.5bc	0.99b	19.56b	0.82b	6.5c	12.92a
	30%	42.61a	17.8cd	60.41a	0.52a	0.82b	1.33a	4.28b	1.33a	28.56a	1.08a	8.26b	13.52a
	40%	44.08a	17.84cd	61.93a	0.54a	0.92a	1.46a	5.11a	1.45a	30.83a	1.23a	9.47a	13.63a

* Different letters means that there was significant difference at 1 % probability level by Tukey test.

4.6Effects of the interaction between plant species and concentrations of wild barley on examined parameters.

The interaction results of plant species and different concentrations combining with soil indicated significant different of studied parameters (Table 3). Maximum values of roots, shoots and total dry weights were (0.34 g, 0.4 g and 0.71 g), respectively. In wheat and wild barely plant species at different concentrations which are 30% and 40%, although the minimum values were observed (0.09 g, 0.12 g and 0.21 g), separately in barley crop at 5% and 10%. The highest rates (3.11 and 13.44) were reported for number of tillering and number of seeds per plant

in barely and wild barley at 40% concentration, while the lowest rates were noted (1 and 1.67) in control and 5% concentrations for each of wheat, barley and wild barley. Among examined plant species each of wild barely, wheat and barley recorded maximum values for shoots, roots and total lengths which were (33.44, 19.88 and 51.24 cm), respectively that observed in control treatments and 40% concentrations even though the minimum values were (25.69, 12.54 and 39.18 cm) reported in barley at 5% and 20% concentrations. Weights of spikes, weight of seeds and biological weights were recorded the maximum rates (0.63, 0.43 and 4.5 g), respectively, for wheat and barley plants. At the same time, as the minimum values (0.13, 0.1 and 1.61 g) were noted in barley crop at 5% concentration; However, the highest HI % (9.28 %) was observed in control treatment and wild barley plant, while the lowest % (4.21%) was recorded in barley and 10% concentrations. Stimulating the growth of other species belonging to the same or different plant parts may be induced by some allelochemicals to the same or different plant parts at varying concentrations. Also, these substances inhibit their growth but it occurred at varies concentrations. Therefore, it had become essential to determine the exact concentration at which each specific response occurred in order to effectively utilize allelopathic interactions in weed management programs. Furthermore, various parts of plants may exhibit differences in their ability to produce allelopathic effects (Chon and Kim, 2002, Economou et al., 2002, Tawaha and Turk, 2003, Ferreira and Reinhardt, 2010, Narwal, 2012).

Table (3): The influence of interactions between plant species and concentrations on the studied parameters.

Plant species X Concentrations		Shoot length cm	Root length cm	Total length cm	Root dry weight g	Shoot dry weight g	Total dry weight g	Tiller No.	Weight of spikes g	No.of seeds per plant	Weight of seeds g	Biological weight g	HI %
Wheat	Control	29.39ab	15.33efg	44.72abcd	0.15cd	0.31a-e	0.46bcde	1f	0.17gh	1.67h	0.11hi	2.09fgh	5.01c
	5%	28.17ab	15.39efg	43.56bcd	0.14cd	0.21efgh	0.35efg	1f	0.22efgh	2.89gh	0.16e-i	1.93gh	6.88abc
	10%	30ab	15.9def	45.9abcd	0.18bcd	0.25c-g	0.43cdef	1.17f	0.27efgh	3.33fgh	0.19e-i	2.29efgh	5.74bc
	20%	31.14ab	16.71cde	47.85abc	0.28ab	0.34abc	0.61abc	1.44ef	0.43cd	6.06defg	0.29b-f	3.09cde	5.23c
	30%	28.72ab	19.11ab	47.83abc	0.34a	0.33abcd	0.67a	1.44ef	0.61ab	9.39abcd	0.44ab	3.39bcd	6.37abc
	40%	29.72ab	19.88a	49.6ab	0.34a	0.37ab	0.71a	1.5def	0.63a	9.11bcde	0.48a	3.55abcd	6.85abc
Barley	Control	28.39ab	13.92ghi	42.31bcd	0.09d	0.19fgh	0.28efg	1f	0.18fgh	4.22fgh	0.15fghi	1.74h	8.46ab
	5%	26.86ab	12.54i	39.41d	0.1d	0.12h	0.21g	1.06f	0.13h	3.22fgh	0.1i	1.61h	5.97bc
	10%	26.36ab	14.48fgh	40.84cd	0.09d	0.18gh	0.26fg	2.06bcde	0.19fgh	4.94efgh	0.17e-i	2.76defg	4.21c
	20%	25.69b	13.49hi	39.18d	0.11d	0.23defg	0.34efg	2bcde	0.33cdef	7.11c-g	0.3b-f	3cdef	5.86bc
	30%	25.86b	13.91ghi	39.77d	0.14cd	0.29b-f	0.43cdef	2.56ab	0.43cd	9.56abcd	0.37abcd	3.85abc	5.09c
	40%	27.08ab	14.62fgh	41.71cd	0.13cd	0.34abc	0.47bcde	3.11a	0.46bcd	10.39abc	0.43abc	4.5a	5.59bc
Wild Barley	Control	33.44a	17.8bc	51.24a	0.16cd	0.26c-g	0.42def	1f	0.24efgh	6.56c-g	0.19e-i	2.07fgh	9.28a
	5%	28.75ab	15.87def	44.62abcd	0.13cd	0.19gh	0.32efg	1.06f	0.18fgh	4.06fgh	0.13ghi	1.87gh	5.88bc
	10%	27.97ab	17.21cd	45.18abcd	0.14cd	0.24c-g	0.38efg	1.72cdef	0.3defg	7.33b-f	0.26d-h	2.77defg	6.29abc
	20%	27.69ab	17cd	44.69abcd	0.17cd	0.3bcde	0.46bcde	2.06bcde	0.33cdef	8.5bcde	0.28c-g	3.31bcd	5.82bc
	30%	29.03ab	16.94cd	45.97abcd	0.23bc	0.38ab	0.6abcd	2.28bcd	0.37cde	11.39ab	0.32a-e	3.85abc	5.52bc
	40%	30.47ab	17.09cd	47.56abc	0.23bc	0.4a	0.63ab	2.5abc	0.46bc	13.44a	0.39abcd	4.22ab	5.65bc

* Different letters means that there was significant difference at 1 % probability level by Tukey test

4.7Effects of the interaction between plant parts, plant species, and various concentrations of wild barley on examined parameters.

The interface between plant parts (shoots, roots, and seeds), plant species (wheat, barley, and wild barley), and varying concentrations (control, 5%, 10%, 20%, 30%, and 40%) of wild barley significantly influences key growth parameters (Table 4), elucidating the allelopathic effects of

wild barley. Wild barley under control conditions exhibited the highest shoots length 33.44 cm and total lengths 51.24 cm, indicating superior growth potential in non-stress environments. Conversely, the lowest values were observed at higher concentrations (30% and 40%), indicating a pronounced allelopathic effect on wheat and barley. For shoots characteristics, wheat under control conditions recorded the maximum shoots length (29.39 cm) and total lengths (44.72 cm), whereas barley and wild barley showed significant growth reductions at higher concentrations, with barley displaying the lowest shoots length (17.33 cm) at 20% concentration. Seed characteristics further accentuated the allelopathic impact, with wheat under control conditions demonstrating the highest total lengths (64.42 cm) and biological weights (7.37 g), while wild barley at 40% concentration had the lowest biological weights (1.29 g). These outcomes confirm the findings of (Lovett and Hoult, 1994) which documented allelopathy in barley had been noted through producing several bioactive compounds which avoid other plants nearby from growing. Such chemicals cause physiological changes in plants through inhibition of nutrient uptake as well as photosynthesis; hence, resulting into shorter leafy stems or roots accordingly. Less weight in both parts combined with full unit production rate under normal circumstance is consequential (Naby and Ali, 2021). Several studies had shown that wild barley residues possess strong effects of allelopathy, which showed that they can be a bio-herbicide for weed management on the cereals (Tawfeeq and Ali, 2017, Mirkhan and Ali, 2024). The current study identifies the importance of integrating allelopathic interactions in agriculture particularly through crop rotations as well as intercropping pattern that would reduce negative effects on crop performance while maintaining farming practices sustainable. Moreover, integrating such information into precision agriculture might sharpen crop management practices; hence, reduces the negative effects of allelopathy and at the same time raising productivity and quality of crops. The study therefore provides an inclusive understanding on the complex interactions among plant species, as well as the allelopathic effects of wild barley. Agronomists and farmers aiming to improve crop productivity in various farming areas will find this information useful (Zimdahl, 2018, Iqbal et al., 2019).

Table (4): The influence of interactions between plant parts, plant species, and wild barley concentrations on the studied parameters.

Plant parts X Plant species X Concentrations			Shoot length cm	Root length cm	Total length cm	Root dry weight g	Shoot dry weight g	Total dry weight g	Tiller No.	Weight of spikes g	No.of seeds per plant	Weight of seeds g	Biological weight g	HI %
Root	Wheat	Control	29.39d-o	15.33g-m	44.72d-k	0.15f-j	0.31ijk	0.46fghi	1g	0.17ij	1.67ij	0.11hi	2.09ij	5.01g-n
		5%	26.83g-o	14.93h-m	41.77e-k	0.15f-j	0.18i-o	0.33ghij	1g	0.09ij	1j	0.05i	1.75ij	2.68klmn
		10%	27g-o	14.63i-n	41.63e-k	0.16f-j	0.25i-n	0.4f-j	1g	0.08ij	0.17j	0.02i	1.88ij	0.91n
		20%	28.08f-o	13.23l-p	41.32e-k	0.13f-j	0.25i-n	0.38f-j	1g	0.06j	0.17j	0.01i	1.81ij	0.51n
		30%	22.33lmno	15.67g-m	38hijk	0.13f-j	0.17j-o	0.29ghij	1g	0.03j	0j	0i	1.62ij	0n
		40%	26.67h-o	14.37j-o	41.03f-k	0.15f-j	0.22i-o	0.37f-j	1g	0.08ij	0.5j	0.03i	1.81ij	1.45n
	Barley	Control	28.39e-o	13.92j-p	42.31e-k	0.09ij	0.19i-o	0.28ghij	1g	0.18hij	4.22hij	0.15ghi	1.74ij	8.46e-l
		5%	29.42d-o	11.2p	40.62f-k	0.06j	0.09mno	0.14hij	1g	0.07j	2.33ij	0.06i	1.36j	4.38h-n
		10%	23.42k-o	13mnop	36.42ijk	0.05j	0.11lmno	0.15hij	1g	0.05j	1.67ij	0.04i	1.35j	2.46lmn
		20%	22.92k-o	11.73nop	34.65jk	0.06j	0.07mno	0.14hij	1g	0.05j	1.5ij	0.04i	1.32j	3.03klmn
		30%	20.33lmno	11.27p	31.6k	0.04j	0.07mno	0.11ij	1g	0.06j	0.83j	0.03i	1.28j	2.44lmn
		40%	21lmno	11.5op	32.5k	0.04j	0.06mno	0.09j	1g	0.06j	1.67ij	0.05i	1.24j	4.06h-n
	Wild Barley	Control	33.44b-m	17.8d-h	51.24a-h	0.16f-j	0.26i-m	0.42f-j	1g	0.24ghij	6.56hij	0.19ghi	2.07ij	9.28d-j
		5%	25.75i-o	14.13j-p	39.88g-k	0.12ghij	0.12k-o	0.23hij	1g	0.11ij	3.17ij	0.08i	1.56ij	5.2f-n
		10%	19.58mno	13.33l-p	32.92k	0.13f-j	0.12k-o	0.24hij	1g	0.06j	2.17ij	0.06i	1.55ij	3.6i-n
		20%	19.58mno	11.77nop	31.35k	0.09ij	0.07mno	0.16hij	1g	0.06j	2ij	0.05i	1.38j	3.35j-n
		30%	21.75lmno	11.5op	33.25k	0.09ij	0.07mno	0.16hij	1g	0.05j	2ij	0.05i	1.36j	3.18klmn
		40%	20.83lmno	13.2l-p	34.03k	0.06j	0.07mno	0.12ij	1g	0.05j	1.67ij	0.04i	1.29j	2.72klmn
Shoot	Wheat	Control	29.39d-o	15.33g-m	44.72d-k	0.15f-j	0.31ijk	0.46fghi	1g	0.17ij	1.67ij	0.11hi	2.09ij	5.01g-n
		5%	24.83j-o	15.27g-m	40.1g-k	0.11hij	0.16j-o	0.28hij	1g	0.08j	0.5j	0.02i	1.62ij	1.4n
		10%	23.75k-o	16.3f-k	40.05g-k	0.12ghij	0.13k-o	0.25hij	1g	0.03j	0.17j	0.01i	1.52j	0.53n
		20%	22.58k-o	17.33d-i	39.92g-k	0.09ij	0.11lmno	0.2hij	1g	0.04j	0.17j	0.01i	1.43j	0.46n
		30%	21.25lmno	19.83bcd	41.08f-k	0.17f-j	0.11lmno	0.28ghij	1g	0.03j	0j	0i	1.59ij	0n
		40%	21.42lmno	23.47a	44.88d-k	0.12ghij	0.1lmno	0.22hij	1g	0.03j	0j	0i	1.47j	0n
	Barley	Control	28.39e-o	13.92j-p	42.31e-k	0.09ij	0.19i-o	0.28ghij	1g	0.18hij	4.22hij	0.15ghi	1.74ij	8.46e-l
		5%	21lmno	11.27p	32.27k	0.07ij	0.07mno	0.14hij	1g	0.08j	2.17ij	0.07i	1.35j	4.9g-n
		10%	21.33lmno	15.03h-m	36.37ijk	0.07ij	0.09mno	0.15hij	1g	0.05j	1.5ij	0.04i	1.35j	2.6klmn
		20%	17.33o	15.23g-m	32.57k	0.07ij	0.07mno	0.14hij	1g	0.02j	0.67j	0.02i	1.29j	1.16n
		30%	16.33o	16.5f-j	32.83k	0.07ij	0.04o	0.11ij	1g	0.02j	0.5j	0.01i	1.24j	0.95n
		40%	18.67no	16.03f-l	34.7jk	0.04j	0.06no	0.09j	1g	0.03j	0.67j	0.02i	1.21j	1.62mn
	Wild Barley	Control	33.44b-m	17.8d-h	51.24a-h	0.16f-j	0.26i-m	0.42f-j	1g	0.24ghij	6.56hij	0.19ghi	2.07ij	9.28d-j
		5%	21.75lmno	18.17defg	39.92g-k	0.12ghij	0.1lmno	0.22hij	1g	0.05j	2ij	0.04i	1.49j	2.68klmn
		10%	19.08no	19.67cde	38.75hijk	0.1ij	0.07mno	0.16hij	1g	0.05j	1.67ij	0.04i	1.36j	2.43lmn
		20%	19.75mno	22.93a	42.68e-k	0.12ghij	0.08mno	0.2hij	1g	0.06j	1.83ij	0.05i	1.45j	3.46j-n
		30%	21lmno	21.73abc	42.73e-k	0.09ij	0.08mno	0.16hij	1g	0.07j	2ij	0.05i	1.38j	3.84h-n
		40%	21lmno	22.67ab	43.67d-k	0.09ij	0.07mno	0.16hij	1g	0.06j	1.83ij	0.05i	1.37j	3.52i-n
Seed	Wheat	Control	29.39d-o	15.33g-m	44.72d-k	0.15f-j	0.31ijk	0.46fghi	1g	0.17ij	1.67ij	0.11hi	2.09ij	5.01g-n
		5%	32.83b-n	15.97f-l	48.8c-j	0.16f-j	0.29ijkl	0.46fghi	1g	0.5efg	7.17hij	0.4efgh	2.42ij	16.55ab
		10%	39.25a-i	16.77e-j	56.02a-e	0.27fghi	0.38ghi	0.65fg	1.5g	0.69def	9.67ghi	0.55def	3.48hi	15.77abc
		20%	42.75abcd	19.57cde	62.32abc	0.61abc	0.65def	1.25abcd	2.33fg	1.2bc	17.83efg	0.86cd	6.04ef	14.72abcd
		30%	42.58a-e	21.83abc	64.42ab	0.72ab	0.7cdef	1.42abc	2.33fg	1.77a	28.17bc	1.33ab	6.95def	19.12a
		40%	41.08a-g	21.8abc	62.88abc	0.75a	0.8bcd	1.55ab	2.5efg	1.78a	26.83bcd	1.4a	7.37cde	19.1a
	Barley	Control	28.39e-o	13.92j-p	42.31e-k	0.09ij	0.19i-o	0.28ghij	1g	0.18hij	4.22hij	0.15ghi	1.74ij	8.46e-l
		5%	30.17c-o	15.17h-m	45.33d-k	0.16f-j	0.2i-o	0.36ghij	1.17g	0.23ghij	5.17hij	0.18ghi	2.1ij	8.64e-k
		10%	34.33b-l	15.4g-m	49.73b-i	0.14f-j	0.34hij	0.47fghi	4.17bcd	0.48efgh	11.67fgh	0.42efg	5.59ef	7.58e-m
		20%	36.83a-k	13.5k-p	50.33a-i	0.18f-j	0.56efg	0.73ef	4cde	0.92cd	19.17def	0.85cd	6.39ef	13.39a-e
		30%	40.92a-h	13.97j-p	54.88a-f	0.32efg	0.76cd	1.07cde	5.67b	1.22bc	27.33bcd	1.07bc	9.03bc	11.89bcde
		40%	41.58a-f	16.33f-k	57.92abcd	0.33def	0.89abc	1.22bcd	7.33a	1.28b	28.83abc	1.21ab	11.04a	11.08b-f
	Wild Barley	Control	33.44b-m	17.8d-h	51.24a-h	0.16f-j	0.26i-m	0.42f-j	1g	0.24ghij	6.56hij	0.19ghi	2.07ij	9.28d-j
		5%	38.75a-j	15.3g-m	54.05a-g	0.16f-j	0.34hij	0.5fgh	1.17g	0.39fghi	7hij	0.26fghi	2.55ij	9.77c-h
		10%	45.25ab	18.63def	63.88ab	0.2f-j	0.53fgh	0.73ef	3.17def	0.79de	18.17ef	0.69de	5.41gh	12.83bcde
		20%	43.75abc	16.3f-k	60.05abc	0.3fgh	0.73cde	1.03de	4.17bcd	0.86d	21.67cde	0.74d	7.08cdef	10.66b-g
		30%	44.33abc	17.6d-h	61.93abc	0.51cde	0.98ab	1.49ab	4.83bc	0.99bcd	30.17ab	0.85cd	8.8bcd	9.53d-i
		40%	49.58a	15.4g-m	64.98a	0.53bcd	1.08a	1.61a	5.5bc	1.28b	36.83a	1.07bc	9.99ab	10.71b-g

*Different letters means that there was significant difference at 1 % probability level by Tukey test

5.CONCLUSION

The presence of wild barley (*Hordeum spontaneum*) residues had a significant impact on the growth and yield parameters of the plant species in this study. Seed residue typically promotes growth, whereas roots and shoots components hinder the growth of plant species. The presence of residue at a concentration of 5% significantly enhanced the growth parameters. Nevertheless, elevated concentrations resulted in decreased HI, indicating a decline in growth efficiency. Wild barley exhibits significant potential as a bio-herbicide and is recommended for utilization in precision agriculture to improve crop management and productivity.

AUTHOR'S CONTRIBUTION

This paper is a component of first author's Ph.D. dissertation. The experiment was conducted by the 1st author, who also conducted the data collection and analysis. The 2nd author oversaw the experiment, including all fieldwork, data analysis, and the review of the research paper.

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