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Total Phenolic Exudation and Allelopathic Potential of Sunflower Residues as Sustainable Weed Management

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Abstract

Total releasing phenolic compounds and allelopathic potential of the three sunflower genotypes *Helianthus annuus* L. residues were evaluated under open field conditions on weed flora associated with the proposed crops; wheat, broad bean and flax which are cultivated usually after the sunflower crop as successive crops. After getting seed from the sunflower crop. After getting seeds, sunflower plant parts were chopped and incorporated with field soil using a rotavator. Regarding the phenolics, total phenolic compounds released from sunflower residues were increased in-field soil and reached the highest concentration in the fourth week after mixing with soil. Significant suppression of weed flora was observed when the weed density and weed dry matter were reduced. Sakha sunflower genotype had the most effect, while Ishaqi genotype had the least amount of phenolic compounds. The residue of the Sakha genotype effectively suppressed over 80% of targeted weeds. The results indicate that the allelopathic potential of sunflower residues can cause suppression of weed flora which can be useful as an attractive alternative natural way to reduce synthetic herbicides as sustainable weed management.

Keywords: Allelopathic Potential, Sunflower Residues, Sustainable Weed Management, Total Phenolic Compounds.

محتوى الإفرازات الفينولية والتأثير الأليلوباثي لمتبقيات زهرة الشمس ودورها كعوامل إدارة مستدامة لمكافحة الأدغال

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الخلاصة

تم تقيم محتوى الإفرازات الفينولية والتاثير الأليلوباثي لمتبقيات ثلاثة تراكيب وراثية من زهرة الشمس *Helianthus annuus* L. في نمو وانتشار نباتات الادغال النامية مع محاصيل الحنطة والباقلاء والكتان والتي تزرع عادة بعد محصول زهرة الشمس . بعد الحصول على البذور من محصول زهرة الشمس تم تقطيع النباتات وخلطت مع تربة الحقل بواسطة ألة Rotavator.

اظهرت النتائج زيادة في إجمالي المركبات الفينولية المنبعثة من بقايا نباتات زهرة الشمس في تربة الحقل ووصلت إلى أعلى تركيز لها في الأسبوع الرابع من بعد عملية الخلط بالتربة. بينت النتائج ايضا انخفاض

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معنوي في اعداد الادغال واختزال الوزن الجاف لها. كان التركيب الوراثي سخا هو الأكثر تأثيراً في اختزال اعداد الادغال وازانها الجافة نتيجة لارتفاع المواد الفينولية في متبقياته بينما سجل التركيب الوراثي إسحاقي أقل كمية من المركبات الفينولية. ساهمت متبقيات التركيب الوراثي سخا باختزال ما يقرب من 80٪ من الادغال النامية بالمقارنة مع المعاملة المدغلة على طول موسم النمو. اشارت النتائج إلى أن التاثير الاليلوباثي لبقايا زهرة الشمس يمكن أن تكون مفيدة لمكافحة الادغال ضمن برامج الادارة المتكاملة للادغال كطريقة بديلة لتقليل مبيدات الأدغال التقليدية بغية التقليل من تاثيراتها السلبية على البيئة.

1. Introduction

The term Weed plants or Weeds refer to the most worldwide agronomic problem facing agricultural systems by the competition of unwanted plants with the economical crops on the available growth requirements which is water, nutrients, air and sunlight. Chemical weed control is a very important method used to reduce losses comes from weed plans which played an important role in increasing the yield qualitatively and quantitatively. Otherwise, using chemical weed control presented by synthetic herbicides began to cause a huge concern due to its negative impact on the environment, which led to an urgent need to minimize their use and to_find suitable alternatives to control weeds. In addition to this, the negative impact of synthetic herbicide residues on an environment that is used in about three million tons of agriculture worldwide per year [1]. Furthermore, using these materials caused another problem when the inherited ability of some targeted plant species helps to survive while other plant species in the same area were eradicated by the used herbicide which is called weed resistance [2].

To this, the world goes towards attractive alternative ways from chemical control to efficient and less harmful to the environment and humans. One of the most promising ways presented to decrease the use of synthetic herbicides is by using secondary metabolites produced by some plants which can suppress or catalyst the germination and growth of neighboring plants this is known as Allelopathy [3].

Allelopathy is defined as the chemical interactions between plants or plants with microorganisms that lead to either positive or negative effects on the performance of neighboring organisms. Allelopathy plays a major role in natural ecosystems by determining vegetation patterning, plant dominance, plant succession, and plant biodiversity, preventing seed decay, and causing seed dormancy [4]. Allelopathy plays an important role in the study of suitable agricultural systems as well as in weed control [5]

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Also, allelopathy has a significant role in agricultural ecosystems. It plays a significant role in weed-crop, crop-weed, crop-crop, forestry and nutrient cycling [6]. Sunflower is an annual dicotyledonous plant that can be grown throughout the year in subtropical and tropical regions for its seeds. Adding the residues of plants known for their allelopathic potential help to reduce reliance upon high concentrations of herbicide and improves agroecosystem sustainability [7].

The allelopathic potential of sunflower is presented to inhibit the growth and development of other plants. The allelopathic effects of sunflower plants on weeds, successive crops, and soil properties vary from stimulation to inhibition depending on the quantity and quality of the bioactive compounds in this plant and their residues. Phenolic compounds are a class of the most important and common plant allelochemicals in the ecosystem. Phenolics are involved in several ecological and economic problems, including suppression of germination and growth of a wide range of plant species as well as declines in crop yield [8].

Over 200 natural bioactive compounds include allelopathic compounds characterized in sunflower plants. Most of these compounds are involved in inhibiting or stimulating the germination and growth of organisms. Heliannuols, terpenoids, flavonoids, chlorogenic acid, chlorogenic acid, and scopoletin were the most bioactive compounds found in sunflower plants [9]. Phenolic compounds are considered to be the most important allelochemical compounds in sunflower plants and are widely distributed among various plant parts. According to the above, the current study aims to screen the total phenolic compounds of three sunflower genotypes and their allelopathic potential on successive crops and companion weeds in trying to minimize the use of chemical conventional herbicides.

2. Materials and Methods

2.1. Field Assay

Field-grown mature plants of three sunflower *Helianthus annuus* L. genotypes which were Sakha, Akmar and Ishaqi planted with a density of 60,000 plants. ha^{-1}. Sunflower plants after getting seeds chopped and mixed well with the field soil using a rotavator machine. After one month, the proposed successive crops; wheat *Triticum aestivum* L., broad bean *Vicia faba* L. and flax *Linum ustatissmim* L. were cultivated in the same plots of sunflower residues.

2.2. Estimation of crop Injury Symptoms

The injury symptoms of successive crops were estimated once a week beginning from cultivation until the fifth week from germination by eye observation using a numerical scale from (0–5) as 0: no harm, 1: slight yellowing, 2: yellowing or burning, or visible dwarfing, 3: yellowing, burning or severe spotting, 4: semi-dead plants and 5: complete plant death.

2.3. Weed properties

Weed density of weed flora was taken after 30 and 60 days from successive crop cultivation by using a $1m^2$ square using woody frame dropped in each plot. Regarding Weed dry matter, it was measured when getting weed density after 60 days then weed flora was harvested near the soil surface and dried by oven set at 48 °C until the weight was stable.

2.4. Determination of Total Phenolic Compounds

Soil field samples were taken from each plot once a week for eight weeks beginning by mixing sunflower parts with soil to determine the total phenolics at 0-30cm depth as three samples for each plot and mixed well. Total phenolic compounds exudates from sunflower residues were determined by the method of [10] using the Folin-Ciocalteu reagent with slight modifications. 5gm of soil sterilized for 10 minutes in the oven at 50ºc and then mixed with organic solvent (50% ethanol 99% and 50% alcoholic ether) at a rate of 1 soil / 5 solvent and left overnight in the darkroom. The extract is filtered with P8 filter paper size 9mm. 0.5 ml of the filtrate was added to 2.5 ml of Ciocalteu reagent and was diluted 10 times with distilled water for three minutes. 2.5 mL of Na_2Co_3 solution was added at a concentration of 7.5%, and the final solution was left for an hour in the dark at room temperature. The absorbance of phenolic compounds was measured with a UV spectrophotometer with a wavelength of 765 nm. The concentration of total phenolic compounds was estimated basis on a standard curve of Gallic acid at concentrations of 100, 200, 300, 400 and 500 ppm as linear regression equation ($y = 0.0022x + 0.0586$ $R^2 = 0.873$).

2.5. Statistical Analysis

The obtained data were subjected to one analysis of variance (ANOVA) using the SASS system, version (9). The experiment was conducted in (RCBD) design with three replications.

The differences between mean values were determined using Dunkin's range test ($P \leq 0.05$) [11].

3. Results and Discussion

3.1 Total phenolic content in the soil field

The results were derived from a calibration curve ($y = 0.0022x + 0.0586$ $R^2 = 0.873$) of gallic acid (100–500 ppm) shown in (Figure 1) and total phenolic compounds isolated from soil mixing with sunflower residues are shown in (Table 1). As seen, most treatments of sunflower residues have differed significantly from each other in the case of their content from phenolic compounds. The highest content observed in the soil field mixed with Sakha genotype at the 4th week after mixing recorded 1.48mg/g while the phenolic content at the control treatments (soil without residues) recorded the lowest content in most of the week measuring.

Many research indicated that the sunflower plant contains various phenolic compounds in different plant parts such as the study of [12,13,14] which mentioned that sunflower disc florets contain a considerable amount of phenolic compounds, such as caffeic acid, p-coumaric acid, chlorogenic acid and isoquercitrin.

In a study [15] which was conducted about the identification of the total phenols in sunflower plants it has been found that total phenols in the leaves were more as compared to the stem which was (0.0316 and0.016 mM/g) respectively. As can be observed from the data presented in (Table 1), the phenolic content isolated from sunflower genotypes to the field soil began to increase gradually from the first week of mixing until reached the highest content in the 4th week then decrease progressively. Many environmental factors can affect the decomposition of phenolic compounds such as the pH of the soil, temperature, oxygen, and soil substance [16,17].

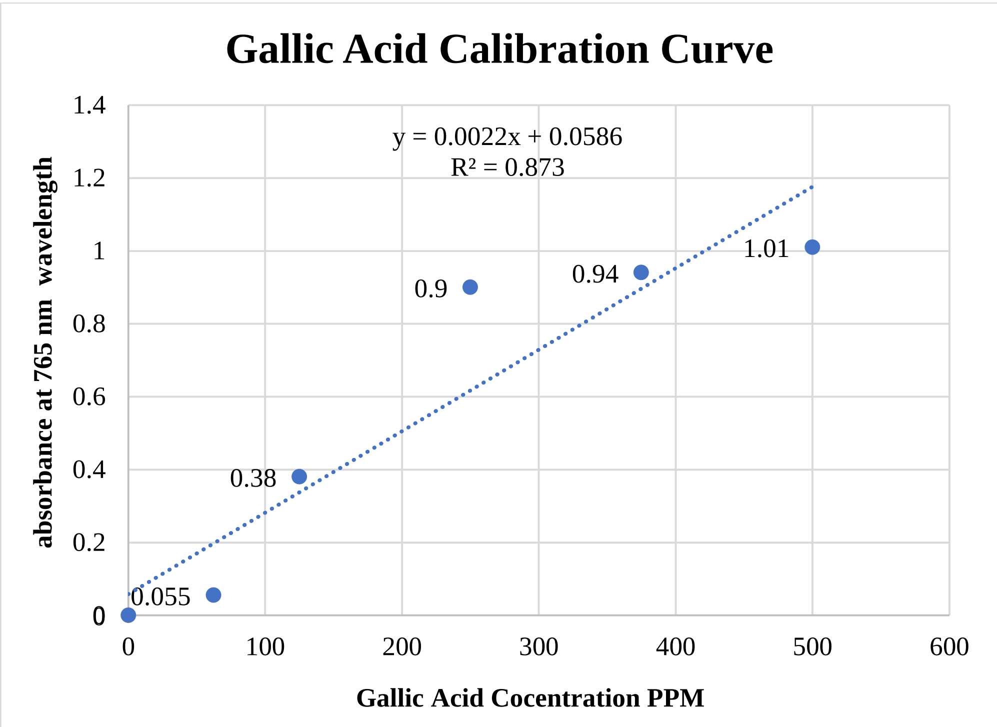

Figure 1: Gallic acid calibration

Table 1: Total Phenolics of sunflower exudation for eight weeks after mixing sunflower plant parts with the field soil

Sunflower Genotypes	Weeks							
	w1	w2	w3	w4	w5	w6	w7	w8
Sakha	0.057klm	0.54de	1.28b	1.48a	0.63cd	0.71c	0.56cde	0.21ijk
Akmar	0.22ijk	0.25hij	0.29ghi	0.60cd	0.49de	0.54de	0.29ghi	0.15jkl
Ishaqi	0.13klm	0.33fgh	0.27hij	0.56cde	0.44ef	0.33fgh	0.41efg	0.27hij
Control	0.06klm	0.05lm	0.06klm	0.12klm	0.04lm	0.030m	0.05lm	0.09kl

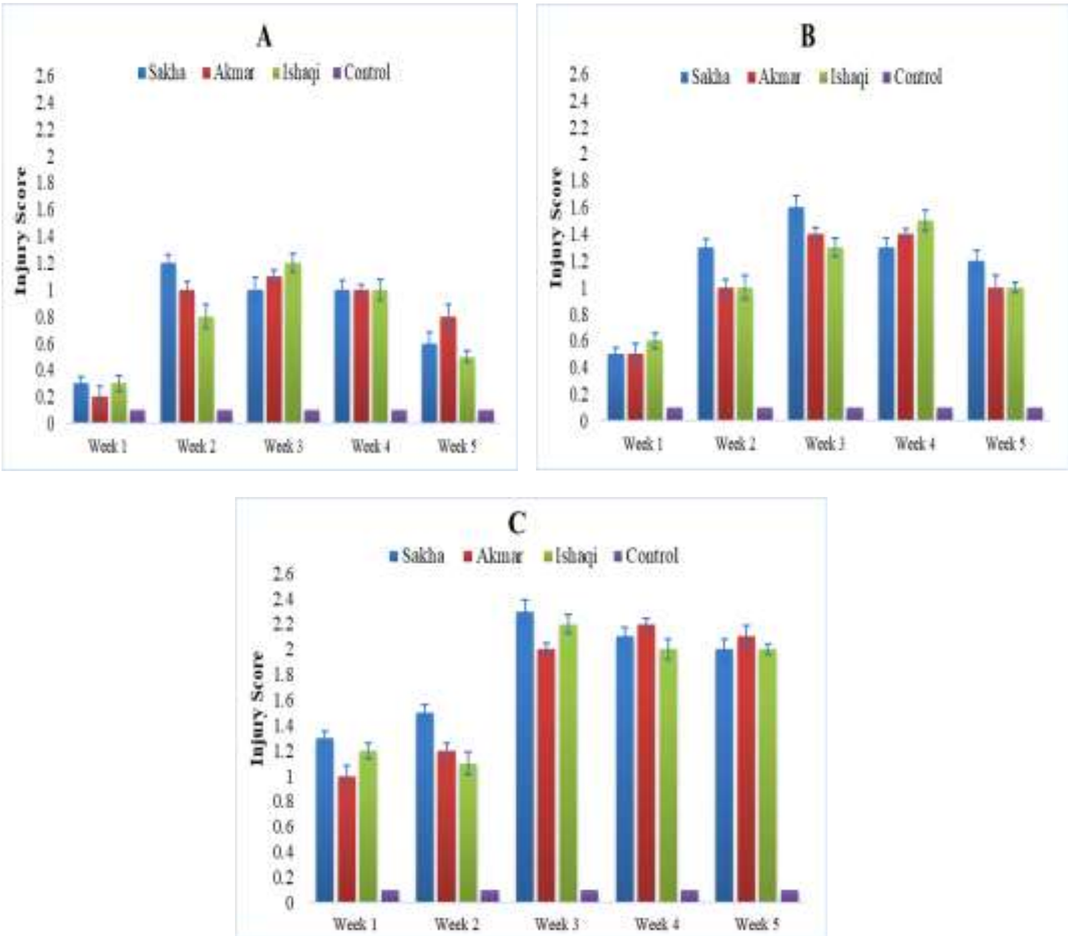

Figure 2: Injury symptoms of proposed successive crops affected by residues of the three sunflower genotypes mixed with field soil A: Wheat B: Broad bean C: Flax

3.2 Crop Injury Symptoms

The injury symptoms of the proposed successive field crops were presented in Figure2. Wheat plants were represented by changing the green color to a pale green color as a result of the damage that occurred to the plant as a result of sunflower residues. Regarding the Broad bean crop, the injury score in this plant affected by sunflower residues behaved the same as wheat plants except for slight dwarfing, but the general condition of the plant is rather good. Regarding flax crops, plants showed more sensitivity to the sunflower residues in all three genotypes.

Various crop sensitivity to the sunflower residues is due to genetic factors related to genetic variation. Many researchers concluded that the field crops grown after sunflower were affected diversely and the degree of effect was dependent upon the concentration of the extract and the sunflower biomass in the field soil [18].

3.3 Weed density

Weed density per m2 at 30 and 60 DAC of weed population affected by the residues of the three sunflower genotypes are shown in Table 2. Using sunflower residues was the most efficient to control weeds associated with the successive crops where the weed density of the two durations 30 and 60 DAC have reduced the weed population significantly with the comparison with control.

The improvement in the efficacy of sunflower residues has also been reported earlier by studies such as [19] who mentioned that the Rhizosphere soil of sunflowers drastically smothered the weed germination, population, and biomass. The residual suppression effect of sunflowers plants also persisted in the next crop for up to 75 days. Another field experiment indicated that sunflower residues incorporated into the field soil significantly inhibited the total number and biomass of weeds growing in the wheat field [20]. The best allelopathic effects of the three sunflower genotypes based on the current study were observed when the wheat crop was cultivated in the same area as a successive crop as compared with the other crops; broad bean and flax. The findings are coherent with [21] that wheat plants have been attributed to hydroxamic acids, the related compounds and phenolic acids released from roots to the soil. Therefore, it could effectively reduce the associated weeds.

Table 2: Allelopathic potential of sunflower residues on density and dry matter of weed accompanying with the successive crops

Sunflower Genotypes	Successive crops	Weed density 30 DAC	Weed density 60 DAC	Weed dry matter g.m^2
Sakha	**Wheat**	82.00c	57.22d	72.67c
	Broad Bean	117.27c	128.30cd	160.66c
	Flax	134.00c	94.60d	136.74c
Akmar	**Wheat**	64.00c	62.18d	60.651c
	Broad Bean	81.00c	186.92bcd	115.32c
	Flax	136.00c	128.30cd	68.68c
Ishaqi	**Wheat**	44.00c	53.31d	76.00c
	Broad Bean	82.00c	186.11bcd	154.21c
	Flax	144.00c	129.11cd	105.56c
Control	**Wheat**	372.00ab	233.39bc	302.00b
	Broad Bean	432.00ab	434.61a	477.33a
	Flax	520.38a	298.27b	365.33b

3.4 Weed Dry matter

The allelopathic effects of the sunflower residues of three genotypes on the weed population under open field conditions are summarized in Table 2. All the traits of the sunflower residues showed desired reduction against weed dry matter when differed significantly from the control trait. The result came in line with the results of [22] when found that sunflower residue incorporation caused 44-57% reduction in weed density and 58-70% reduction in weed dry weight compared with the control. However, similar to the results of the weed population density, the lowest dry matter rate was observed with the weed associated with the wheat crop. There was also a discrepancy between the weed dry matter growing in control treatments, which indicates that the crop species significantly impact the growth of the bush growing with it and ranged according to its severity. The wheat tolerance against weeds has also been confirmed by [23, 24] when mentioned that the wheat crop is considered one of the successful crops that have a high tolerance to weed comparative and then maintain high yields in the presence of weeds.

4. Conclusions

In the current study, there was a desired amount of total phenolic compounds released from sunflower residues into field soil. Also, sunflower residues showed a strong allelopathic potential against a wide range of weed species associated with the successive crops. These results indicate that sunflower residues can be useful for sustainable weed management to control weeds naturally. More studies are required to determine the tolerance range of successive crops in order its grow and produce which allows the cultivation of these crops after sunflower plants.

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