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Allelopathic Potential of Three Sunflower Cultivars on Some Successive Crops and Companion Weeds

A Thesis

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I acknowledge that this thesis which entitled “**Allelopathic Potential of Three Sunflower Cultivars on Some Successive Crops and Companion Weeds** " submitted by master student (**Taisir Mezher Flayyih**) was carried out under my supervision as a partial fulfillment requirement for the master degree in University of Anbar- College of Agriculture- Field Crops Department.

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Committee certification

We, the Examining Committee, certify that we have read this thesis in titled″**Allelopathic Potential of Three Sunflower Cultivars on Some Successive Crops and Companion Weeds**″ and have examined the student ″**Taisir Mezher Flayyih**″ in its contents and that in our opinion; it's a accepted as a thesis for awarding the master degree in Agricultural Sciences.

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Dedication

I dedicate the fruit of my efforts to…

To the first names that I uttered, to the source of giving and tenderness in this world, Who taught me, and guided me to the right path **… My mother and my father.**

My fairy tale , the moon that illuminated my path and the first to believe in my success and taught me how to achieve it. **… My wife.**

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To those whom I love , who were always standing beside me**… my sisters.**

To the person closest to my soul, to the person with noble stances, who has always stood by me, helped me and supported me, my dear brother**… Humam**

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Summary

Field Trail was carried out in Alhamdhia Research Station of College of Agriculture / University of Anbar during the agricultural season (2021 - 2022). Allelopathic potential of residue parts for three sunflower cultivars *Helianthus annuus L.* These were Sakha, Akmar and Ishaqi were evaluated under open field conditions against weed flora associated with the proposed crops; wheat, broad bean and flax, the crops were cultivated usually after sunflower crop as successive crops. After getting seed from sunflower , plant parts were chopped and incorporated with field soil using a rotavator.

The results showed the following:

Highest content of total phenolic compounds observed in the field mixed by Sakha cultivar at 4th week after mixing recorded $(1.48 \mathrm{mg\,g})^{-1}$ while the phenolic content in control (soil without residues) recorded lowest content in most of the weeks measuring.

Studied soil properties indicated that the sunflower residues enhanced soil properties by increasing the essential nutrients; NPK. Moreover, organic matter and C/ N ratio also increased from 44 to 143% regarding the variations between the time after mixing the residues and sunflower cultivar .

Weed density per m^2 at 30 and 60 days after cultivation significantly reduced by residues of the three sunflower cultivars . Furthermore, all traits of the sunflower residues showed desired reduction against weed dry matter. However, lowest dry matter average was observed with weed associated with wheat crop. There was also a discrepancy between weed

dry matter growing in control treatments, which indicates that crop species significantly impact the growth of weed growing with it and ranged according to its severity.

Data of crop injury symptoms in successive crops effected by sunflower residues showed changing green color of wheat plants to a pale green color as a result of the damage that occurred to the plants from allelopathic stress. Regarding broad bean crop, the injury score in this crop affected by sunflower residues behaved same as wheat plants except for slight dwarfing, but the general condition of the plant is rather good. On the contrary, flax plants showed more sensitivity to sunflower residues in addition to yellowing, damage exceeded dwarfing and burning of the edges of some leaves were seen.

Sunflower resides improved growth properties of wheat crop, thus increasing the grain yield average 22.75, 22.6 and 19% for Sakha, Akmar and Ishaqi cultivars.

Allelopathic potential of sunflower residues appeared inversely on developing the growth of bean and flax crops, which did not achieve an increase in the final yield despite the supply of soil with essential growth requirements.

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Introduction

CHAPTER ONE

1. INTRODUCTION

Introduction

The term Weed plants refers to the most worldwide agronomic problem facing agricultural systems by the competition of weed plants with the economical crops on the available growth requirements which are water, nutrients, oxygen and sunlight. Chemical weed control is a very important method used to reduce losses from weed plans which played an important role in decreasing the yield qualitatively and quantitatively. Otherwise, using chemical weed control presented by synthetic herbicides began to cause concern about its negative impact environment, which the need to reduce using the synthetic herbicides to minimum doses and find suitable alternatives to control weeds. The negative impact of synthetic herbicides residues on an environment that is used in about three million tons of agriculture systems worldwide per year, using these chemical caused the problem of Weed Resistance (Almarie *et al*., 2016). Allelopathy is one of the most promising methods presented to minimize the use of synthetic herbicides by utilizing the secondary metabolites produced by some plants which have the ability to inhibit or minimize the germination and growth of neighboring plants .

Allelopathy phenomenon is defined as the chemical interactions among plants or plants with microorganisms leading to either positive or negative effects on the performance of surrounding 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 (Rice, 1984). Nowadays, allelopathy became an important player in suitable agricultural systems as well as in weed control (Singh *et al*., 2012 and Cheng and Cheng, 2015). Sunflower is an annual dicotyledonous plant that can be grown throughout the year in subtropical and tropical regions for its seeds. Allelopathic potential of sunflower 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.

Over 200 natural bioactive compounds include , allelochemicals are identified in sunflower. 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 (Jabran, 2017). Moreover, sunflower residues contribute to increase the organic matter of the soil, and thus become a natural organic fertilizer that provides the soil with the essential nutrients without the need for chemical fertilizers.

1.1 The aim of study

1-To investigate the allelopathic effect of sunflower plants on the growth and yield of successive crops and companion weeds.

2-To reduce using synthetic herbicides by taking advantage of the inhibitory effect of the sunflower residues.

3-To indicate the variability of the sunflower cultivars of its allelopathic effect towards successive crops and companion weeds.

Literature Review

CHAPTER TWO

2. Literature Review

2.1 Weed plant

Weed plant with crop plants term refers to unvalued plants that spontaneously grow without human effort and grow in unwelcome places (Zimdahl, 2013). These plants are characterized by their ability to compete with the economical plants on available growth requirements which were water, oxygen, light, nutrients, and even the place. Weed competition comes through the high germination rate of their seeds and the speed of plant growth in the early stages, and the formation of large root groups in a short time, in addition to their high ability to adapt themselves to various growing conditions. (Beckie and Tardif, 2012) . Weeds are considered the main reason for economic and environmental crop loss by causing enormous environmental damage and reducing agricultural production.

Weed competition ,therefore, can lead to more significant losses in the agricultural sector more than the losses due to the other pest; mainly insects and diseases combined. The losses in yield due to weed competition have been estimated to be about $95 billion per season, compared to $35 billion losses due to pathogens, $46 billion due to insects, and $2.4 billion due to vertebrates, including humans (FAO, 2009; Memon *et al.*, 2007). So, reducing the weed competition will provide good opportunities for the crop to exploit water, light, mineral nutrients, and even the place which reflected to improve the plant yield quantitatively and qualitatively (Almarie, 2017).

2.2 Weed Management

Weed control has become an indispensable thing when yield reductions caused by uncontrolled weed growth throughout the growing season have been estimated to be 45 to 95%, depending on crop species, weed species, weed densities, and environmental factors (Ampong-Nyarkoand De Datta, 1991). Therefore, weed management is a key element of most agricultural systems. Various methods of weed control have been practiced including, mechanical, chemical, and biological methods. However, the application of chemical by weed control herbicides is still a major method that enabled the intensification of agriculture in the past decades till now.

Today, herbicides played a dominant role in weed management and increased crop production qualitatively and quantitatively compared with other applications including traditional methods such as cultivation practice and hand weeding (Ginessi and Wiliams, 2012; LeBaron *et al*., 2011). Herbicides have become an integral part of the complex global agricultural production as inputs required in the modern production system and accepted as a standard practice by farmers on around the world (Gianessi, 2012).

The continuous use of herbicides gives rise to important phenomenon - weed resistance (Vencill et al., 2012).Many weeds which are resistant to various herbicides have been identified in different parts of the world (Owen and Zelaya, 2005). According to the 'International Survey of Herbicide Resistant Weeds', 486 herbicide-resistant weed biotypes have been reported globally, 147 are in dicot and 106 are in monocot groups. A total of 92 crops have been reported to be infested by herbicide-resistant weeds. Glyphosate, AHAS inhibitor, HPPD inhibitor and PPO inhibitor herbicides are widely used to kill or suppress weeds in crop fields. Among these herbicides, the highest 159 identified unique cases of weed resistance were of AHAS-inhibiting herbicides; In addition, there have been 39 cases of resistance identified against glyphosate, 2 against HPPD-inhibitors and 13 against PPO-inhibiting herbicides, and the number is increasing daily (Heap, 2018).

To encounter the problem of the evolution of resistant weeds and to minimize the overuse of herbicides, alternative agricultural strategies including the use of multiple herbicides in conjunction with traditional methods are suggested which constitutes an effective integrated weed management practice.

Moreover, it is extremely important to maintain the diversity in herbicide use for efficacy by exploiting the properties of important presently available herbicides to manage the weeds proficiently for the long term. The development of transgenic crops that are resistant to two or more herbicides remains a major challenge and a priority area of agricultural programs (Bonny, 2016). As the factors for the success of any program to control weed plants depend on many factors, including the type, intensity, and severity of the damage caused by the weed, in addition to the prevailing climatic conditions in that region.

2.3 Effect of synthetic herbicides on human health and ecosystems

The uses of synthetic pesticides such as insecticides, fungicides, and bactericides including herbicides have directly and indirectly brought about several adverse effects on the soil surface, groundwater and organisms as well as in the atmosphere. The above changes have negative ramifications for the community and disrupt the ecological balance, hence risking human life.

2.3.1 Effect of synthetic herbicides on human health

A report from WHO (1990) mentioned that no segment of the population is completely protected from the risks of pesticide exposure and the high-risk groups were not only the people of the developing countries but all the countries over the world (Akhtar and Arshad 2013). The hazards of synthetic pesticides are summarized by their impact on food commodities, surface water, groundwater and soil contamination and the effects on soil fertility (beneficial soil microorganisms) and non-target vegetation (Potts *et al.,* 2010).

In another report, Williams *et al*. (2000) also highlighted the complain of contacts diseases, acute ulcers, heart pain, skin irritation respiratory condition, and eye problem of the people in the survied area. Another study by Niemann *et al.* (2015) on glyphosate, a common non-selective systemic herbicide promoted by the manufacturers as a safer herbicide reported tracing of its residues in both human and animal urine. It was then suggested that the use of glyphosate may have to be re-evaluated to reduce human exposure to the dangers of synthetic herbicides.

2.3.2 Effect of synthetic herbicides on ecosystems

Using synthetic herbicides even at recommended rates can lead to a negative impact on the ecosystems, especially the harmful effects that come from their residues. On the other hand, the efficiency of these compounds will be slowly decreased due to the increase in the resistance of the weed plants as a result of the continuous use of these compounds to control the same weed species. Hence, using these synthetic herbicides continuously becomes a double-edged sword.

As it is well known, insecticides are the most toxic to the environment, followed by fungicides and herbicides. But some herbicides can be highly toxic and much more serious than insecticides. Such problems that emanated from the utilization of synthetic herbicides cannot be overlooked regardless of the benefits accruing from its application (Rashid *et al.,* 2010). According to Williams *et al.* (2000), the herbicide applied in agricultural lands can be leached and washed by rain or precipitation. The herbicide effects on the soil and the environment were detected and found to contaminate the groundwater and the source of fresh drinking water even at recommended levels, causing an acute decrease in the biomass such as microorganisms, plant tissues and soil organic matter in a study of two year campaign (Guzzella *et al.,* 2006). Furthermore, a wide range of non-targeted plant species is more sensitive to herbicides, especially during the reproductive stages of their life cycle. This is further compounded by the effect of external factors such as wind and rainfall, which can adversely affect this most important stage of the plant's life cycle. In this regard, Boutin *et al. (2014)* mentioned the delays in flowering and the reduction in seed production observed in a large number of non-target plant species, including climbing and hedgerow plants, through the spraying of herbicides within the vicinity of their growing locations.

2.4 Allelopathy

The earliest written record of allelopathy can be traced back to c. 300 BC, when the Greek philosopher Theophrastus noticed that, chick pea plants ‘exhaust’ the soil and destroy weeds (Hort, 1916). Allelopathy is a complex environmental phenomenon that includes biochemical interactions between plants, It occurs as a result of the releasing of some chemical compounds in different ways into the surrounding environment and can negatively or positively affecting the growth and functions of the organisms that receive them. Terpenes, flavonoids, etc., are either produced naturally inside the plant as secondary products that are stored inside the cell vacuole or are released to the external environment to affect plants and other organisms, or they are produced accidentally as a result of mechanical or physiological damage such as diseases, insects and other environmental stresses .The types of these compounds differ according to the plant type, groth stages plant part, and their concentrations increase or decrease due to the influence of various environmental and biological factors. (Rice,1984) Allelopathy is a biological and natural phenomenon that constitutes an important sub-discipline of chemical ecology. The eco-physiological interactions between higher plants are mediated via the secretion of certain chemical compounds known as “allelochemicals”. Those chemical compounds could be found naturally in many parts of plants, e.g., roots, seeds, leaves, and stems, with different portions (Respatie *et al.*, 2019).

The most acceptable definition of allelopathy describes it as an ecological phenomenon, in which plants provide themselves with a competitive advantage through biochemical pathways, where secondary metabolites produced by plants, microorganisms, viruses and fungi influence the growth and development of other plants and organisms in a stimulatory or inhibitory way (Almarie, 2020). The allelopathic traits of a species can be used by exploiting the germplasm to select the weed-suppressive cultivars, or including the species as a rotational crop, intercrop, or cover crop for effective weed control (Wallstedt *et al.,* 2001). Most of these compounds are phenolic acids in the first place, produced by plants that possess allelopathic potentials, such as sunflower *Helianthus annuus* L. and rice *Oryza sativa* and others (Alsaadawi *et al.,* 2007). This inhibitory role of these compounds has been used directly or indirectly for weed management, and one of the reasons that enhance their use as a practical alternative to industrial weed pesticides is that they are environmentally safe and have no residual or toxic effects (Bhadoria, 2011).

Plants may interfere with the establishment and growth of neighboring plants through competition, allelopathy, or both. Differing from competition for resources, allelopathy involves the release of allelochemicals from living or dead plants into the environment (Meiners *et al.,* 2012).

The donor allelopathic plant inhibits the seed germination and growth of target species by releasing allelochemicals through leaching volatilization, root exudation and the microbial decomposition of the dead plant parts(Singh *et al.,* 2016 and Xiao 2017). These compounds are emitted from different plant parts through residual decomposition, root exudation, stem flow, and leaching into the environment (Birkett *et al.,* 2001). The most important part of allelopathy depends on the presence of chemical compounds that are released from living or disintegrating plant parts (Dayan *et al.,* 2000). The allelopathic phenomenon differs from the concept of competition because competition means taking materials from the environment, while allelopathic occurs when a chemical substance is added to the environment to affect plants or other organisms (Rice, 1984). By reviewing a comprehensive review of the number of research completed in the field of allelopathy, It has multiplied several times until it is used by physiologists, plants, soils, weeds, and natural product chemists. (Macias, 2002).

2.4.1 Allelochemicals

The allelopathic effect of plants in the agricultural cycle resulted from the secretion of allelopathic compounds from roots or the leaching of their vegetative part, or the volatilization and decomposition of their residues in the soil (Rice, 1984). It has been estimated that over 10.000 allelochemicals are produced by higher plants, with significant variability in their activity and mode of action in target plants (Weston *et al.,* 2012). Living roots of many weed and economic plants including crops continuously produce and secrete both low- and high-molecular-weight compounds into the rhizosphere in response to biotic and abiotic stresses (Bertin *et al.,* 2003). Allelochemicals that are exuded through the plant roots are added to the soil surface. These are either decomposed to by-products or received by micro-organisms or other surrounding plants (Macías *et al.,* 2014). The plants exudate allelochemicals into the soil environment are called ‘donor’ plants, while the ones receiving these allelochemicals are called ‘receiver or targeted plants (Kato-Noguchi *et al.,* 2012). Both original allelochemicals and their by-products may be absorbed by the receiver plants. The allelochemicals in the receiver plants are usually translocated to aerial parts where they express an allelopathic activity (Macías *et al.,* 2014). Allelopathic compounds are released to the environment by volatilization, leaching, root exudates, or residues decomposition of the roots, vegetative and fruits of plants with an allelopathic effect by the action of microorganisms present in the soil. (Jamil *et al.,* 2009).

The severity of the allelochemical compounds depends on the concentration of the inhibitory substances they contain and their solubility in water (Turk *et al.,* 2002). Plants produce and release a wide variety of primary and secondary metabolites, including carbohydrates, proteins, vitamins, and other organic chemicals with low molecular weight. Nearly 5–30% of all photosynthetically fixed carbon is transferred to the environment through the release of metabolites (Farrar, 2003).

In living organisms such as plants, insects and livestock are controlled by secondary metabolism. These compounds are found in plant tissues of leaves, stems, roots, flowers, pollen grains, and seeds (Bhowmik *and doll.,* 1984 and Cheng, 1992). Over 80% of secondary metabolites or identified natural products have been derived from plants so far. Therefore, plants represent an important source of active ingredients with multiple functions for the environment, as well as human affairs (Böttger *et al.,* 2018).

Sometimes allelochemical compounds are found in two plant parts of the plant at the same time. Accordingly, the identification of allelochemicals from plants and their environments is key to understanding the plant-plant allelopathic interactions. So far, numerous allelochemicals have been investigated and identified from a variety of plant species. These allelochemicals are chemically diverse, being represented by phenolic compounds (simple phenolics, flavonoids, coumarins, and quinones), terpenoids (monoterpenes, sesquiterpenes, diterpenes, triterpenes, and steroids), alkaloids and nitrogen-containing chemicals (non-protein amino acids, benzoxazinoids, cyanogenic glycosides), and many other chemical families (Macías *et al.,* 2019).

It is difficult to determine the exact role of each allelochemical compound due to the similarity of its mechanism and action as well as the interactions between its effects (Belz, 2007). Most of these compounds are more effective when present in the soil, such as phenolic acids, cyanamide, momilactones and other substances, due to modifications that take pleace by some microorganisms and different environmental conditions that increase their impacts such as pH, humidity, temperature, light, oxygen, and others (Wetson, A, Lesile ., Ulrike . Mathesius (2013).

Allelochemicals are usually produced in plant cells and accumulated in certain organs and sometimes in special organelles. Leaves may be the most stable source, while stems and roots contain less of these compounds (Li *et al.,* 2010 and Weston and Mathesius, 2012).

Most of these materials are completely or partially soluble in water, which makes them more effective and suitable than those industrial chemicals because they are rich in oxygen and hydrogen and relatively few metals (halogen substitutes), which are characterized by the absence of unnatural rings and these properties enable the environment to reduce the half-life of these materials chemical compounds and then prevent the accumulation of the compound in the soil and the eventual effect on non-target organisms.

On the other hand, these substances despite their strong effect and characterized by the demise of this effect and the short duration of their activity. They are compounds of a complex composition and possess many effective groups, which makes them more effective and unstable .

Rapid degradation of one of these chemical groups can reduce the antagonistic biological activity of the whole compound or group of compounds accumulated together (Rachmilevitch *et al.,* 2006).

Generally, allelochemicals disturb the cell structure, cell division, cell membrane activities, cultivar respiration, photosynthesis, and nutrient uptake in plants. Hydroxamic acids may disturb the enzyme activities and cellular functions in plants (Venturelli *et al.* 2015).

2.5 Roles of Allelopathy in agricultural systems

Recently , agriculture had to deal with the increasing environmental pollution which is mainly arising from two aspects linked by a common goal: the maximization of yields and the improper utilization of synthetic chemicals for weed and pest control in agroecosystems otherwise, the mismanagement of fertilization, principally for nitrogen is also needed. Usual methods of weed control such as mechanical and chemical are known to be: expensive, energy and labor intensive, require repeated applications, and are unsuitable for managing wide spread plant invasions in ecologically fragile conservation areas or low-value habitats, such as range lands and many aquatic systems. Also, mechanical methods cause soil disturbance that may eventually lead to erosion. On the other hand, chemical weed control causes pollution that poses dangers to human health and wildlife, and certain weed species have developed resistance to some chemical herbicides (Harding and Raizada 2015).

Menaria (2007) discussed the technique of an eco-friendly approach to weed management using bio herbicides and explained that the use of synthetic herbicides leaves some chemical residues in food commodities that directly or indirectly affect human health. So, this situation led to the search for alternative methods that are environmentally friendly and to be effective against weed plants. Allelopathy has offered a new attractive alternative way for the development of ecofriendly agricultural practices, with the dual purpose of enhancing crop productivity and maintaining ecosystem stability (Scavo *et al.* 2018).

Allelopathy plays an important role in the agroecosystems, leading to various interactions between the crop-crop, crop-weed and tree-crops. Generally, these interactions are harmful to the receiver plants but provide a selective benefit to the donor plant. Soil microbes determine such interactions as they change the allelochemicals and nature of allelopathic interactions. The allelochemicals released from the plant residues are left in fields after crop harvests. The allelopathic potential of crop species is a well-established phenomenon and can be exploited to control weeds in field crops (Jabran *et al.* 2015).

2.6 Sunflower Residues and its allelopathic potential

Sunflower plant *Helianthus annuus* L. is one of 67 species of the *Helianthus* genus which is a Greek word (Helianthus means sun and Anthus flower). Sunflower plants moved to Europe at the beginning of the sixteenth century. It was initially planted in Spain, then England and France (Heiser, 1978).

Sunflower *Helianthus annuus* L. crop is grown worldwide in temperate, subtropical and tropical climates under a wide range of agro-environments. Among oilseeds, it ranked 3rd in 2018 behind soybean and rapeseed (4th after palm, soybean and rapeseed for edible oil) with an average annual world production of about 52milion tons (Oil World Annual, 2019). Sunflower benefits from broad and established markets and it is primarily grown for its edible oil but also its achenes (confectionary types) both commonly used in human food. High-oleic cultivars are widely appreciated by the food industry because of their oxidative and thermal oil stabilities (Dunford, 2015 and Pilorgé, 2020).

Sunflower is a plants that have a great allelopathic effort resulting from the release of chemicals to the environment, causing harmful effects on the growth and development of the plant (Irons *et al.*, 1982). The effectiveness of the allelopathic substances of the sunflower plant has been of interest to many researchers, as the effectiveness of these substances and the way they affect plants have been identified, and many of them have been isolated. These substances are released from sunflower plants in the field by washing, root secretions and decomposition of plant biomass. Several studies confirmed that the allelopathic compounds of sunflower residues and root secretions in the soil are responsible for inhibiting the germination of seeds found in soil and have the ability to affect crop growth (Leather, 1983). Narwal et al. (1999) mentioned that Sunflower (Helianthus annuus L.) is the source of high-quality vegetable oil and exhibits allelopathic effects on subsequent crops and weeds.

More than 50 compounds from ten chemical classes were found in Sunflower and some of these compounds contain allelopathic potential, especially water-soluble compounds which are mainly Phenolics, Flavonoids and Terpenes (El Marsni *et al.*, 2015).

Studies have shown that decomposition of sunflower plant residues is an important source of releasing bio-antagonistic compounds into the environment. The effectiveness of the released sunflower compounds depends on the quality of the residues, the conditions of decomposition and the age of the plant. When water is available and oxygen is absent, a large amount of bio-antibiotic chemicals can be produced (Mandava, 1985).

These compounds are released in several ways as decomposition of fallen leaves, washing and root secretions. These phenolic acids spread in a radius between 0-10 cm, and this percentage decreases further away from the plant.

The substances released from the sunflower plant reduce the growth of crops grown after the sunflower plant, the reason for the effect of the sunflower plant on the plants that follow it is what this plant leaves from toxic compounds in the soil, although it adds to the soil a group of nutrients such as nitrogen, phosphorous and potassium ions zinc, iron and manganese (Pariana, 1992).

2.7 Allelochemicals in Sunflower parts

Numerous articles (about 40 in Web of Science) reported that the allelopathic potential of sunflower plants and tissues in controlling weeds in sunflower and successive crops with possible unwanted effects on subsequent crop species. This high allelopathic activity could be exploited more than currently done to reduce chemical weed control in sustainable agriculture. Several articles reviewed these effects such as (Gawronska *et al.*, 2007; Albuquerque *et al.*, 2011 and Jabran, 2017).

As compared with other crops, sunflower is known to have a well-developed and deeply penetrating root system that is capable of fully depleting the water (and nutrients) present in subsoil layers. This was extensively reported by comparative field studies (Bremner et al., 1986; Hattendorf *et al.*, 1988., Dardanelli *et al.*, 1997 and Merrill *et al.*, 2002).

Sunflower's root system is "explorative" of large soil volumes with a combination of thick and thin roots, small average specific root length, and small root length density. This explains why sunflower can extract more water than most other crops, especially from deep soil layers Connor and Hall (1997). This indicate that sunflower contains bioactive allelochemicals, especially phenolics and terpenoids, which would be involved in this suppressing effect. Sunflower shows inhibitory effects on a relatively wide range of weeds (dicots and grasses) as assayed under laboratory, greenhouse and field conditions. Allelopathy could be exploited for biocontrol in several ways, among others as biologically active mulch either scattered over the soil surface or mixed into the soil. Sunflower root exudates also inhibit weed seedling growth, but are less effective than leaf and stem tissue leachates (Leather, 1983)

Antibiotic compounds are found in different parts of the sunflower parts and their quantity and concentration increase according to the age of the plant. leaves of the sunflower are a basic and important source for the production of antagonistic compounds. Through its important role in the photosynthesis process, and by containing plant toxins that settle in the soil under field conditions for a certain period and reach the level of toxicity. Also, the stems of plants contain substances that have an antagonistic inhibitory effect, and in other cases, the stems are the main source of inhibition (El Marsni *et al.*, 2015).

2.8 Sunflower Residues as natural herbicides

The allelopathic potential of sunflower *Helianthus annuus* L. can be used for controlling weeds in sunflower crop and other crops. Terpenes and phenolic compounds comprise the important allelochemicals in sunflower plants. Residues from sunflower plants possess a strong allelopathic activity and can be used to suppress weeds in various agricultural settings by either scattering them in the form of a layer over the soil surface or mixing it in the soil. Weeds growing in sunflower plants can be suppressed by cultivating sunflower cultivars that could express an allelopathic activity (Jabran, 2017).

Sunflower is thermo and photo-insensitive, hence it can be grown round the year in sub-tropics, hence, fits well in multiple cropping systems. However, the yield of some crops following sunflower plants is lower than normal, possibly because of allelopathic inhibition. In sunflower plants, several substances (phenolic compounds, diterpenes and triterpenes) with allelopathic properties have been isolated and chemically characterized (Macias *et al.*, 1999). More than 200 allelopathic compounds have been isolated from different cultivars of sunflower. Studies indicated that extracts and leachates of residues or plant parts are added to the soil for assessing their allelopathic potential (Kamal and Bano 2008).

Results indicated that application of sunflower water extracts reduced weed density by 5–26% and weed biomass by 9–31%, while sunflower residue incorporation (4 to 6t/ha) caused a 44 –57% reduction in weed density and 58–70% reduction in weed biomass compared with the control (Ullah *et al.,* 2018).

Allelopathic sunflower grown in rotation with other crops can also help to achieve natural weed control. Although the allelopathic potential of sunflower is well established, there is a great opportunity to explore the role of sunflower as mulch and rotation allelopathic crops (Jabran, 2017).

2.9 Sunflower Residues as green manures

Green manure can be defined as the practice of plant cultivation until the flowering stage or until the incomplete development of seeds, with subsequent cutting or incorporation of their biomass into the soil. The decomposition consists in the physical fragmentation process of the organic residues into smaller particles, which is a process performed by components of the soil macro-, meso-, and microfauna. Physical fragmentation of residues provides an increase in surface area, facilitating microbial colonization and subsequent hydrolysis by microbial extracellular enzymes. Thus, complex polymers are degraded into monomeric compounds and ions, which can be absorbed by microbial cells or plants. The factors that can affect the direction and magnitude of the decomposition process are the nutrient content and biochemical composition of the crop residues or green manure added to the soil, the nature and abundance of the present microbial communities, Soil moisture, temperature, aeration, pH, the carbon/nutrient ratios of the soil organic matter (SOM) and the presence or absence of inhibitor substances (Lamparter *et al.,* 2009 and Poirier *et al.,* 2013). Biochemical composition influences plant residue decomposition and microbial communities in the soil. Plant residues consist basically of the same components, but the proportions can vary between species, plants of the same species, organs of the same plant, and crop conditions (Sariyildiz and Anderson, 2003)

Genotypic variation, growing conditions and various plant organs, such as leaves, stems and inflorescences may influence the allelopathic activity of sunflower, which can be both stimulatory and inhibitory (Gawronska *et al.,* 2007)

Einhellig and Waller (1999) indicated that all plants produce and store large amounts of primary and secondary metabolites, These compounds are different in their chemical composition, concentration, and the type of plant tissue from which they are released, and that these compounds are often unstable under environmental conditions and are easily biodegradable. These compounds are often soluble in water.

2.10 Bioherbicidal Potential of Sunflower residues on weeds

Residues from sunflower plants possess a strong potential to inhibit weeds (Morris and Parrish 1992). The allelopathic potential of sunflower plants can be manipulated to control weeds under field conditions. This may be achieved by growing cultivars of sunflower possessing an allelopathic activity and suppressing weeds under field conditions. Sunflower seeds are used for obtaining oil; however, their allelopathic herbage may be incorporated into the soil to suppress weeds. The other way is to collect the sunflower herbage, chop it into pieces, and use it in other fields for suppressing weeds.

In the experiment of Alssdawi *et al* (2011),Which aims to find out the effect of mixing the remains of eight sunflower cultivars with the soil and its effect on the growth of the weed accompanying the wheat that is often planted after the sunflower in Iraq and its impact on productivity. The sunflower cultivars Zahrat Al-Iraq, Coupon, Sin-Altheeb, Shabah and Flammy recorded a reduction in the number of weeds by 67.0, 46.1, 50.5, 86.8 and 63.7%, respectively, while the two cultivars Euroflor and Shumoos had the least reduction in the number of weeds, reaching 21.59 and the two cultivars Coupon and Sin-Altheeb gave the highest inhibition rate in the dry weight of the weed 80.79 and 74.23% respectively, while the inhibition rate of Shumoos and Shabah cultivars was 33.67 and 60.81% respectively.

2.11 Allelopathic potential of sunflower residues on Successive Crops

Many researchers confirmed that sunflower residues contain many allelopathic compounds that affect the germination and growth of many crops when mixed with the soil. Purvis *et al.* (1990) reported that sunflower crop residues reduced wheat germination and growth by 4- 33%. As for the remaining sunflower residues on the surface of the soil left without plowing, it often reduced the growth of the crops successive , compared to the removal of residues or traditional plowing, while the productivity of wheat increased in the non-cultivated treatments, as it reached 5.2 ton ha^{-1} when mixed with soil and plowing, the productivity decreased to 4.9 ton ha^{-1}.

The sunflower crop residue in the soil reduced harmful weed growth early and when mixed with soil reduced the yield of later crops (Cenusko *et al.,* 1992).

Hozayn *et al.* (2011) found that the addition of sorghum and sunflower residues (roots and shoots) reduced the germination and growth of wheat, except for sunflower root residues, which had abortive effect on wheat. The study showed a selective presence in the effect of the residues in certain types of weed. The sorghum rootstock residues achieved the highest reduction in the number of seedlings and their dry weight after 60 days for Abu Damim weed by 72 and 13.08% respectively, and for wild oats by 43.55 and 62.20%, respectively, compared to the treatment comparison (without adding residues), While the sunflower root residues achieved the highest decrease in the density and dry weight of clover earring *Medicago minima* by 90.19 and 82.76 %, respectively, compared to the comparison. It was concluded from the study that the allelopathic effort of crops varies according to the different plant parts, the sensitivity of the receiving species to them, the amount of residues added to the soil, and the elective influence attributed to the allelopathic compounds released from the plants and their concentration in the residues. Radical antibiotics inhibitors are found in the roots in a lesser amount compared to what the leaves contain in general, and in some cases, they were on the contrary (Jabran, 2017).

Sadeghi *et al.,* (2010) found in their study the allelopathic effect of sunflower residues on the germination and growth of some weeds and crops and the chemical properties of the soil that the effect of the residues on the growth of plant species was more evident than in the germination of seeds, and the growth of wheat and barley crops decreased significantly when adding the residues, especially at high concentration, while the effect was not significant on the Bean yield for both used concentrations, and this is an indication of the resistance of the bean crop to the phytotoxins released from the sunflower residue, while the addition of residues significantly affected the dry weight of all types of broad and thin-leaved weeds in different proportions according to the number of residues and the plant species.

3. The Successive Crops

3.1 Wheat

Wheat (*Triticum aestivum)* is the most important staple crop in temperate zones and is in increasing demand in countries undergoing , urbanization and industrialization. In addition to being a major source of starch and energy, wheat also provides substantial amounts of a number of components which are essential or beneficial for health, protein, vitamins dietary fiber, and minerals (Shewry and, Hey 2015).

Iraq's total production of this crop in 2021 was 4,234,000 tons (Central Organization for Statistics 2021). In cereal crops, the need for suitable tools for weed management has an outstanding relevance. Indeed, competition with weeds not only is one of the biggest causes of yield losses, but also an issue for quality achievement . weed control bears a deep importance in ensuring a high-quality level product Additionally, the present large demand of organic cereals, associated with the establishment of a public compensation payment system, create a favorable context to promote organic arable farming systems. These systems will face technical problems such as weed control which affect economic viability and may greatly influence cereals quality (Jabran *et al.,* 2017).

3.2 Broad Bean

Broad bean crop, *Vicia faba L,* is one of the crops known for its nutritional importance. It is one of the winter crops belonging to the legume family, Fabaceae, whose seeds contain a high percentage of protein estimated at 25-30% What increased the importance of this crop is its high nutritional value, as it It is a cheap source of protein compared to animal protein (Abdul Halitan, 2010). China is one of the most productive and consuming countries for legumes, with an estimated production of about 2.7 million tons per year. In the Arab world, Egypt leads, with a production of about 262 thousand tons per year. In Iraq, production rates are low per unit area, as the cultivated area reached (9382). dunums, and the total production reached (4947) thousand tons of seeds, with a productivity rate of 527.4 kg. dunums-1, Iraq's total production of this crop in 2021 was 33354 tons.

One of the problems faced by farmers in the world is the weeds of both broad and thin leaves that accompany the bean crop and their competition for nutrients, water and light. By increasing the number and diversity of bushes. It leads to significant losses in the quantity and quality of the crop, as well as the negative effects it produces on the production process (Shehata and Sahar, 2005).

3.3 Flax

Flax Linum usitatissimum L is one of the most important winter oil crops in the world. This crop is grown as a dual-purpose crop, as it is important in the production of fiber, and flax oil is also considered one of the best oils Flax is one of the crops that is highly affected by weeds, and the affected rate may reach 85%.The weeds affect the quantity and quality of the yield. The oil content and the commercial value of the flax are also affected.(Bakry et al 2015).

Flax cultivation was concentrated in a limited number of countries in the world, and the production of the former Soviet Union and Poland accounted for about 80% of the total global production of flax. Flax can also be grown in many countries with temperate climates and under different environmental conditions (FAO, 2017).

Materials and Methods

CHAPTER THREE

3. Materials and Methods

3.1 Trail location

Field trail was carried out in Alhamdhia Research Station belonging to College of Agriculture / University of Anbar located in Alramadi, western Iraq (latitude 43º39´ N, longitude 33º44´ E). during the agricultural season (2021 - 2022). Allelopathic potential from residues parts of three sunflower cultivars *Helianthus annuus* L. namely Sakha, Akmar and Ishaqi were evaluated under field conditions against weed flora associated with crops; Wheat *Triticum aestivum*, broad bean *Vicia faba* and flax *Linum usitatissimum* which are cultivated usually after the sunflower crop as successive crops. After getting seed from Sunflower crop, plant parts were chopped and incorporated with field soil using a rotavator. Simple experiment was conducted in a randomized complete block design (RCBD) with three replicates.

Table 1. Soil Component Analysis

Property	Value	Unit
pH	7.7	
Ec	2.4	$ds\ m^{-1}$
SOM%	0.69	
CEC	20.1	$Centimol\ kg^{-1}$
CA2+	7.5	$mEq\ liter^{-1}$
MG2+	5.0	$mEq\ liter^{-1}$
NA+	8.7	$mEq\ liter^{-1}$
K+	2.1	$mEq\ liter^{-1}$
$SO4^{-2}$	12.8	$mEq\ liter^{-1}$
HCO3	2.0	$mEq\ liter^{-1}$
CI-	10.0	$mEq\ liter^{-1}$
N	56.0	$mg\ Kg^{-1}$
P	12.5	$mg\ Kg^{-1}$
K	286.0	$mg\ Kg^{-1}$
Fe	2.73	$mg\ Kg^{-1}$
Soil type	Lomy soil	
Sand	42.4	$mg\ Kg^{-1}$
Clay	13.6	$mg\ Kg^{-1}$
Silt	44.0	$mg\ Kg^{-1}$

3.2 Cultivation of Sunflower Cultivars

Area of experimental unit which sunflower cultivars were grown is 27 m^2 each experimental unit ($3 * 9m^2$). Distance between each two lines was 70 cm, and distance between one plant and another was 25 cm. As for the subsequent crops, they were sown on experimental units measuring (2 * 3m). Wheat was planted in 8 lines per unit at a seeding rate of 140 kg ha^{-1} with a weight of 7.5 g per line, and the distance between lines was 20 cm. As for the broad beans, 5 lines were planted with a distance of 40 cm between one lines and a distance of 25 centimeters between one plant and another with a final density of 100000 plants per ha^{-1}. Flax was planted in 8 lines per unit with a weight of 80 kg ha^{-1} as 5 g per line, with a distance of 25 cm between one line and another.

Table 2 Types of weed flora found in the experimental field

Local name	Common name	Scientific name	Family
الشعير البري	wild barley	*Hordeum jubatum*	Poaceae
الحنيطة	Rigid grass	*Lolium rigidum*	Poaceae
الشوفان البري	Wild oat	*Avena fatua*	Poaceae
السليجة	Wild beets	*Beta valgaris*	Asteraceae
الخباز	Mallow	*Malva parviflora*	*Malvaceae*
الجنيبرة	Hoary cross	*Cardaria draba*	Brassicaceae
الجرجير	Eruca	*Eruca stiva* millar	Malvaceae
الفجيلة	Wild radish	*Raphanus raphanistrum*	Brassicaceae
ام الحليب	Annual snow thistle	*Sonchus oleraceus*	Brassicaceae
الحندقوق	Sweet clover	*Melilotus indicus L.*	Fabaceae
المديد	Field Bindweed	*Convolvulus arvensis L.*	Convolvulaceae

3.3 Determination of Total Phenolic Compounds

Total phenolic compounds exudates from sunflower residues were determined by modified method of McDonald *et al.* (2001) using Folin-Ciocalteu reagent with slight modifications. Soil field samples were taken from each plot to determine total Phenolics at 0-30cm depth as three samples from each plot mixed well. 5gm of soil sterilized for 10 minutes in the oven at 50 C° and then mixed with organic solvent (50% ethanol 99% and 50% alcoholic ether) and at a rate of 1 soil / 5 solvent and left overnight in the darkroom. Extract was filtered with filter paper. 0.5 ml of the filtrate was added to it 2.5 ml of Folin and Ciocalteu′s phenol reagent 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. Absorbance of phenolic compounds was measured with a UV spectrophotometer with a wavelength of 765 nm. Concentration of total phenolic compounds was estimated basis on a standard curve of gallic acid (figure 1) at concentrations of 100, 200, 300, 400 and 500 ppm as linear regression equation ($y = 0.0022x + 0.0586$ $R^2 = 0.873$).

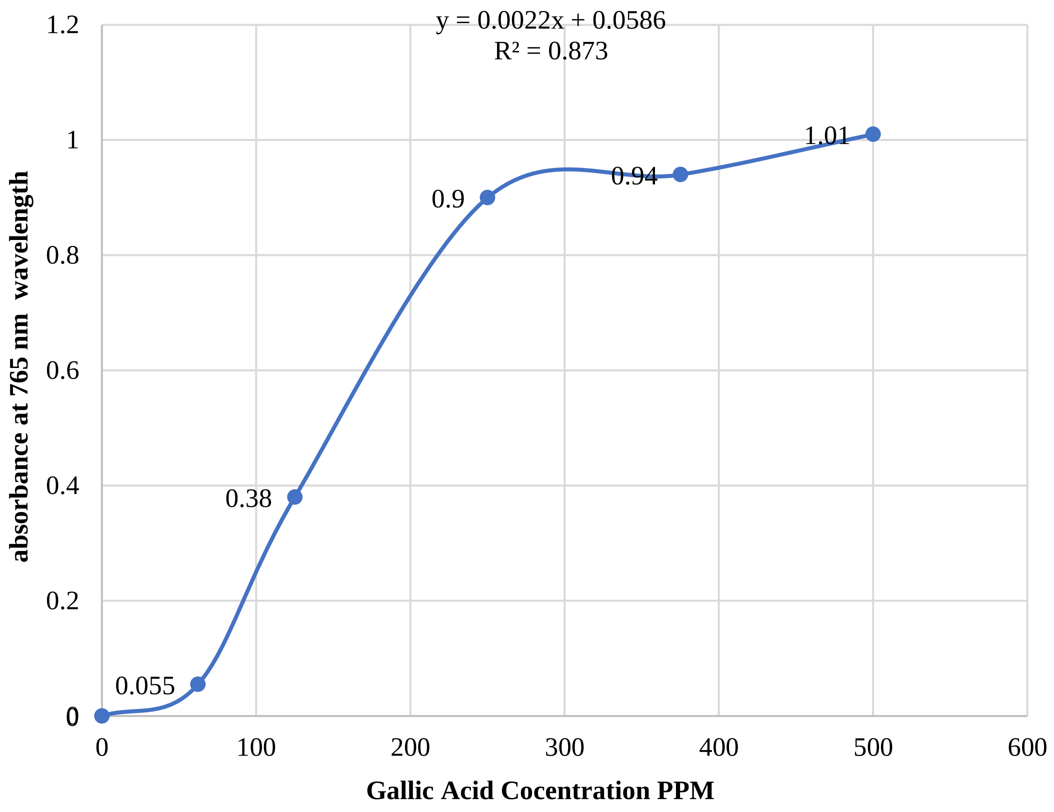

Figure 1 : Gallic acid calibration

3.3 Analysis of soil content

Soil samples were taken from soil of field four weeks after mixing with sun-flower crop residue at depth of 0 to 30 cm to evaluate variation of soil nutrients compared to control treatment. Analysis was conducted in central lab belonging to college of Agriculture- University of Anbar.

3.4 The Studied traits

3.4.1 Crop Injury Symptoms

Crop injury symptoms of successive crops were estimated once a week beginning from emergence stage until the fifth week from emergence by visual 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.

3.4.2 Weed properties

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

3.4.3. Growth parameters and yield components of successive crops

3.4.3.1 Successive crop، growth parameters

Plant height (cm)

Wheat plant height was measured from base of the plant to the end of the spike of the main stem. Regarding the broad bean and flax plants the height was measured from the base of the plant to the top end of stem. Plant height was taken as an average of (10) plants per experimental unit. (Khan and Spilde ،1992) .

Wheat flag leaf area (cm^2)

Flag leaf area was measured when flowering was completed by calculating the average leaf area for 10 random plants from the midlines of each experimental unit according to the following equation Flag leaf area = leaf Length × Maximum Width × 0.95 (Thomas ،1975).

Broad bean Leaf area (cm^2)

Leaf area was measured in the flowering stage by the weighted method for (20) leaves and was punctured with a diameter of (1 cm) and the dry weight of the leaves and discs was taken and the area of one disk was calculated for the area of the leaf by applying the equation mentioned by (Watson, 1958) and as follows.

$$\text{Leaf area} = \frac{\text{leaf dry weight (gm)}}{\text{disk dry weight (gm)}} \times \text{disk area } (cm^2)$$

The leaf area of one plant was calculated as in the following equation:

Leaf area per plant = leaf area x number of leaves

Broad bean leaf area index

Leaf area index is a result of dividing the leaf area by the area of land occupied by given plant.

Number of flax leaves per plant

Leaves of 10 plants were taken randomly from midlines at the beginning of flowering.

Number of flax branch (branch plant)$^{-1}$

It was calculated as an average of 10 plants randomly drawn from the midlines of each experimental unit in the harvest phase.

Dry weight of vegetative parts (gram)

Ten random plants were taken from each experimental unit at 100% flowering stage and placed in perforated paper bags after cutting them and then put into an electric oven at a temperature of 65 °C for 48 hours and then for 3 hours at 105 °C until the weight is stable and then they were weighed with a sensitive scale.

Spike/ pod and lengths (cm)

Wheat spike and broad bean pod length were measured from a random sample for each experimental unit as an average of 10 spikes from the base to the end.

Number of spikes/pod and capsules per m^2

Number of wheat spikes, broad bean pods and flax capsules for the plants harvested group were calculated from an area of square meters from the medium lines.

Weight of 1000 grain (g)

A random sample of grains was taken for each experimental unit and 1000 grains were counted from them as their weight was extracted.

Number of grains/ seed per spike/pod and capsules It was calculated as an average number of grains/ seeds in ten spike/pod and capsules.

Biomass (Ton ha^{-1})

It was estimated from the weight of the harvested plants from the same area taken to study the yield and based on (ton ha^{-1}), which included the weight of the total dry matter of grain and straw.

Harvest Index (%)

Harvest Index was calculated as in the following equation(Donald ، 1962).

$$\text{Harvest Index} = \frac{\text{seed yield}}{\text{Biomass}} \times 100$$

Total yield (Ton ha^{-1})

After conducting the threshing process of the sample harvested from a square meter area, then separating the straw and weighing the grains, then converting the weight to tons.

3.5. Experimental data analysis

Experimental data were subjected to analysis of variance (ANOVA) using the SAS system, version (9). Experiment was conducted in (RCBD) design with three replicates. Differences between mean values were determined using L.S.D range test ($P \leq 0.05$).

Results and Discussions

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Total phenolic content isolated from sunflower residues into the field soil

Results were derived from a calibration curve ($y = 0.0022x + 0.0586$ $R^2 = 0.873$) of gallic acid (100–500 ppm) as shown in (Figure 1) and total phenolic compounds isolated from soil mixing with sunflower residues as shown in (Table 3). Most treatments of sunflower residues have differed significantly from each other in the case of their content from phenolic compounds. Highest content observed in soil field mixed with Sakha cultivar in the 4th week after mixing recorded $(1.48\text{mg g})^{-1}$ while the phenolic content at the control treatments (soil without residues) recorded the lowest content in most of the week measured.

Table3.Total Phenolics of sunflower exudation for eight weeks after mixing sunflower plant parts with the field soil

Sunflower Cultivars	Weeks							
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8thweek
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

Many studies indicated that sunflower contains various phenolic compounds in different plant parts such as study by (Liang, *et al.,* 2013; Liang *et al.,* 2015 and Mehmood *et al.,*2018). These studies 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 by Ghafa *et al.* (2001) which was conducted to identify the total phenols in sunflower, has found the total phenols in the leaves were more as compared to the stem which was, $(0.0316\ \text{and}0.016\text{mM g})^{-1}$ respectively.

As can be observed from data presented in (figure 1), Phenolic content released from sunflower cultivars to soil field began to be increased gradually from first week of mixing until reached highest content in 4th week then decreased progressively. Many environmental factors can affect the decomposition of phenolic compounds such as the pH of the soil, temperature, oxygen, and soil substance (Freeman *et al.,* 2015)

4.2. Soil nutrient Analysis

Averages are presented in Table 4. show some soil properties for the experimental field according to samples taken at 2, 4 and 6 weeks after mixing sunflower residues compared with the controls. As can be seen, most of the treatments have differed significantly as compared with controls. Sunflower residues enhanced soil properties by increasing the essential nutrient’s NPK. Moreover, organic matter increased in soil and increase ranges from 44 to 143%. The same is true for the organic carbon and C/ N ratio which witnessed a significant increase in all treatments.

Table 4. Soil properties of the study field according to the samples taken at 2, 4 and 6 weeks after mixing sunflower residues compared with the controls

cultivars	Duration	K mg.kg^{-1}	p mg.kg^{-1}	N µg.kg^{-1}	Organic Matter	Organic Carbon	C/N Ratio
Sakha	**2nd Weeks**	434	50.0	1843	1.11	5.16	19.1
Akmar		343	50.0	2396	1.16	4.53	18.5
Ishaqi		401	64.6	2796	1.40	6.10	39.5
Sakha	**4th Weeks**	521	49.7	1256	1.19	5.60	39.8
Akmar		405	26.5	1555	2.00	5.00	32.0
Ishaqi		394	29.0	1549	2.10	8.30	31.3
Sakha	**6th Weeks**	432	43.0	2422	1.30	5.60	31.0
Akmar		419	70.0	1430	1.54	7.90	35.0
Ishaqi		418	71.0	1177	1.61	6.20	37.3
Control		17.6	16.2	92.00	0.67	2.42	14.5
L.S.D. : 0.05		174	24.2	361	0.38	1.48	14.3

The sunflower residues were able to increase the amount of the essential nutrients for plant growth (NPK) as well as those necessary nutrients useful for the activity of microorganisms and their proportions. The results come in line with the results of Ullah *et al.,* (2018) which conformed that sunflower residue incorporation at 6 ton ha^{-1} improved soil health, suppressed weeds and resulted in better seed yield of spring-planted mung bean. Returning soil fertility naturally is desirable as it is one of the promising strategic solutions to provide soil fertility naturally without the use of chemical fertilizers, which negatively affect the properties of the soil (Gunfer, 2021).

4.3. Crop Injury Symptoms

Injury symptoms of 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 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 cultivars.

Various crop sensitivity to the sunflower residues 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 its effect was dependent upon the concentration of the dissolved sunflower biomass in the field soil (Abbas *et al.,* 2021).

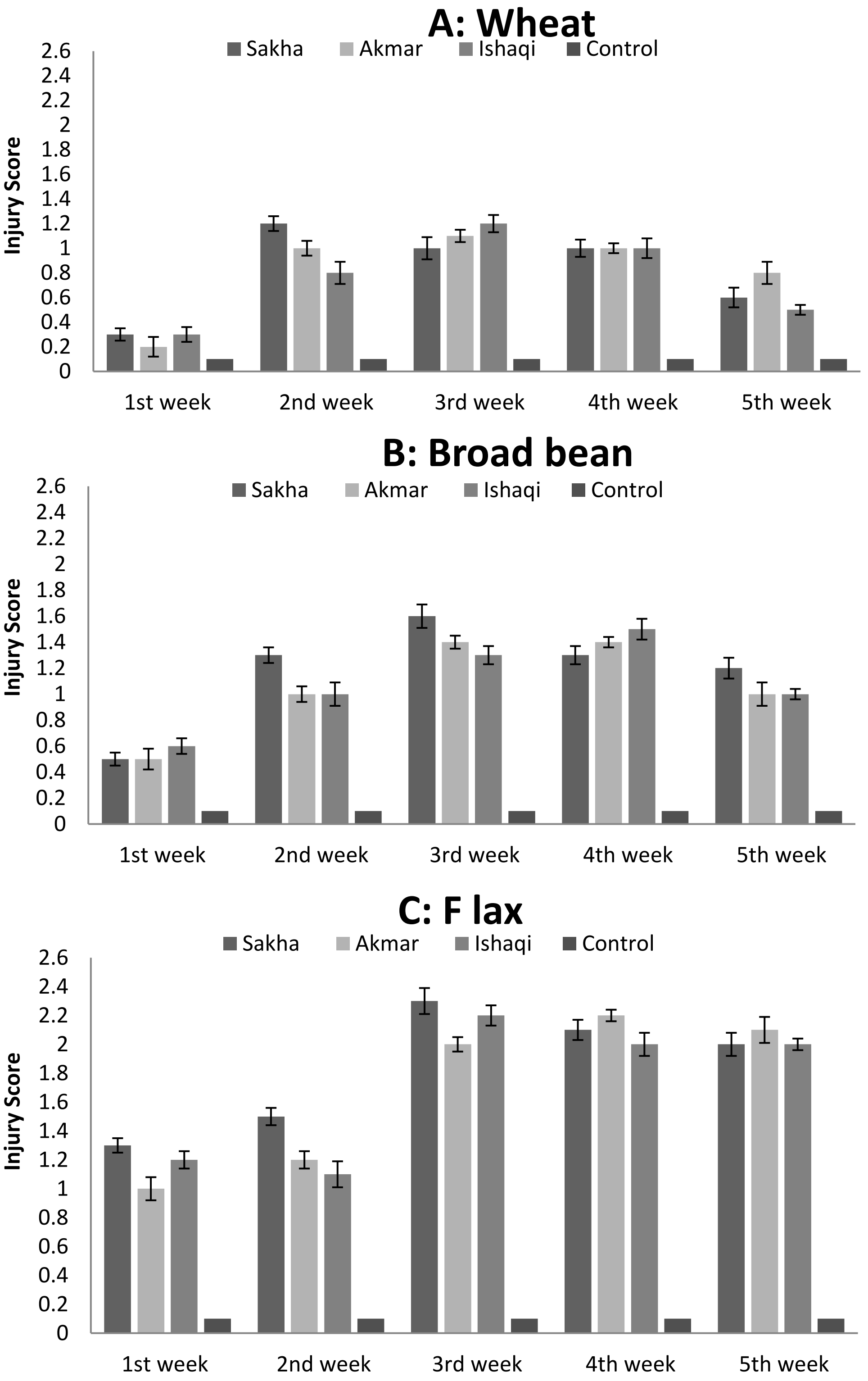

Figure 2. Injury symptoms of proposed successive crops affected by residues of the three sunflower cultivars mixed with field soil A: Wheat B: Broad bean C: Flax

4.4. Allelopathic potential of three sunflower cultivars on weeds companion with proposed successive crops

Weed Density (Plant m)$^{-2}$

Weed density per m^2 at 30 and 60 DAC of weed population affected by the residues of the three sunflower cultivars are shown in Table 5. 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 as the comparison on control.

Improvement in efficacy of sunflower residues has also been reported earlier by studies such as Rawat *et al.* (2017) who mentioned that the Rhizosphere soil of sunflowers drastically smothered the weed germination, population, and biomass. Residual suppression effect of sunflower 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 (Alsaadawi *et al.,* 2012).

Best allelopathic effects of sunflower cultivars 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 Lam *et al.* (2012) which indicated that wheat has 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 5- Allelopathic potential of sunflower residues on density and dry matter of weed companying with the successive crops

Sunflower cultivars	Successive crops	Weed density 30 DAC Plan m^2	Weed density 60 DAC Plan m^2	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

Weed Dry matter (g m^{-2})

Allelopathic effects of the sunflower residues of three cultivars on the weed population under open field conditions are summarized in Table 5. All the traits of the sunflower residues showed desired reduction against weed dry matter when differed significantly from the control trait. Result came in line with results of Ullah *et al.* (2018) when they found that sunflower residue incorporation caused a 44-57% reduction in weed density and a 58-70% reduction in weed dry weight compared with the control. However, similar to results of 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 growth of the weed growing with it and ranged according to its severity. Wheat tolerance against weeds has also been confirmed by Lemerle *et al.* (2006) who 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.

4.5. Allelopathic potential of the three sunflower cultivars on growth parameters and yield components of wheat crop

4.5.1. Wheat growth parameters

Wheat plant height (cm)

Data presented in Table (6) shows allelopathic potential of the three sunflower cultivars on growing traits of wheat crop cultivated as successive crop. As can be seen from the data, the trait of plant high did not differ significantly between the studied treatments. However, the plant height recorded highest level in the treatment of weedy check which was 91.6 cm.

Flag leaf Area

Leaves are the main parts of plant that occur in photosynthesis activities. Flag leaf in cereal crops is considered the most contributing leaf to the grain yield, as it is in a big way in the fullness of grain during A flowering period.

Table 6. Allelopathic potential of the three sunflower cultivars on growth parameters of wheat crop season 2021 – 2022

Treatment	Plant Hiegh cm	Flag leaf Area cm^2	dry matter of vegetative parts	Spike Length cm
Sakha	76.7	31.43	10.81	12.00
Akmar	74.17	33.23	10.75	11.86
Ishaqi	80.43	31.73	11.86	11.84
Weedy Check	91.60	29.36	7.98	10.57
Free Weed	79.49	34.03	12.57	12.00
L.S.D: 0.05	N.S.	N.S.	2.1	0.7203

It is also considered one of the most critical factors affected by weed competition for field crops. The results obtained from Table (6) indicate that there are no significant differences between the studies' treatments for this trait. Although there were clear differences in the area of the flag leaf, the highest value for this trait was for the free weed treatment, which amounted to 34.03 cm^2, while the lowest value of the weedy check treatment was only 29.36 cm^2.

Dry matter of vegetative parts $(\mathbf{Ton\ ha})^{-1}$

plant dry weight is known as the most characteristic influenced by the biological plant processes such as respiration, photosynthesis, and others. The increase in photosynthesis in the plant means an increase in the construction of organic compounds in the plant cells and this increase is embodied in the dry weight of the plant, which includes the components of leaves, stems and some reproductive parts.

Results in Table (6) indicate that there are significant differences between treatments in the rate of plant dry weight, where the highest value was shown in the free weed treatment, at a rate of (12.57) ton h^{-1}, while the lowest value was (7.98) tons per hectare in the weedy check. Wheat plant that was planted after inverting sunflower cultivars into the soil were also recorded a significant increase in comparison with the controls when the dry matter weight achieved for 11.86, 10.81 and 10.57-ton h^{-1} for Akmar, Sakha and Ishaqi cultivars, respectively.

These results agrees with what was reached by Tawfiq and Alsaadawi (2015) when they found that the use of two sunflower cultivers residues (Shamoos and Sun Altheeb) contributed to an increase the dry matter of the later crop (Mung bean) compared to control treatment.

Spike Length (cm)

Length of spike is often positively correlated with the components of the yield when number of flowers it bears in increasing with the increase in its length. The results observed in Table (6) showed that there were slight significant differences amongst treatments in terms of spike length, where the highest length was (12) cm in sunflower residues of Sakha cultivar and the free weed treatments followed by Akmar Ishaqi treatments (11.86) (11.84). Length of spike decreased in the weedy check treatment and was recorded 10,57 cm. This is consistent with what was reached by Almarie (2009) when found that the absence of the weeds was significantly affected the length of the spike.

4.5.2. Wheat yield and yield components

Number of spikes (Spike m^{-2})

The characteristic of the number of spikes of a plant is one of the important components of the yield, and it is positively related to the yield, which is indicated during the beginning of the crops life, and its number is determined by the number of stalks. The abundance of new growth factors, including competing the weed plants during an early stage of the crop’s growth, has important effects in determining number of plants bearing fertile spikes.

The results of Table (7) showed a significant difference in the number of spikes per square meter between the different studied treatments in this study. All the treatments concerned with the sunflower residues did not differ significantly from the free weed treatments which were achieved with the Ishaqi cultivar. Highest average of spikes was 349 spike /m^2, followed by Sakha and Akmar 344 and 340 spike per meter square The lowest value was in the weedy check (280) spikes/ m^2. This is due to the fact that the absence of the weed and preparing the crop with an acceptable amount of nutrients released from the sunflower residues allows the crop to grow without relative tension, which is reflected in an increase in the efficiency of photosynthesis. Our result agreed with Khan *et al.* (2007) who indicated that the highest number of spikes was achieved in the absence of the competition factor between the crop and the accompanying weed plant.

Weight of 1000 grain (g)

Results of the experiment shown in Table (7) indicate that sunflower residues improve wheat crops growth resulting in achieving the desired amount of this treatment. Sakha cultivar recorded highest value was (37.53) grams, while the lowest weight was (31.99) grams in the weedy check treatment. The average weight of 1000 wheat grains of the other treatments arranged from 35.91 to 34.34 grams. The reason for these results comes from the absence of weeds which led to inhance the wheat plants to perform their metabolic processes better than the plants in weedy plots in addition to the nutrients that were added to the soil after the decomposition of the sunflower residues.

Table 7. Allelopathic potential of the three sunflower cultivars on wheat yield and yield components in season 2021 – 2022

Treatments	**number of spikes per m^2**	**Weight of 1000 grain (g)**	**Number of grains in the spike**	**Biomass Ton ha^{-1}**	**Harvest index (%)**	**Total yield Ton ha^{-1}**
Sakha	344	35.91	49.3	17.3	30.75	5.32
Akmar	340	37.53	48.9	16.4	32.37	5.31
Ishaqi	349	35.27	49.57	16.9	30	5.07
Weedy Check	280	31.99	42.66	15.4	29.68	4.11
Free Weed	349	34.34	50.43	19.7	25.22	4.97
L.S.D: 0.05	35.99	1.89	3.72	1.64	4.45	0.82

Number of grains per spike

Providing the appropriate environment for wheat plants to grow without competing on growth requirements, positively reflects the various growth activities by greater amount of food produced due to these processes and thus going to the growing grains and reducing their abortion and finally increasing their number in the spike.

The data obtained from Table (7) showed significant differences in the average grain number per spike through their influence on the study factors. It can be noted that the highest value was (50.43) grains in the free weed treatment, while the lowest value was in the weedy check treatment, which amounted to (42.66) grains/spike.

furthermore, the treatments that were sown after inverting sunflower residues were slightly different, as the amount of treatment planted with wheat after the Ishaqi variety was (49.57), and the treatment served after turning the residues of Sakha cultivar (49.3) and the treatment that was sown after the Akmar variety was (48.9) . This is consistent with what was reached by Alsalmane et al. (2016) when outperformed free weed treatment by manual weeding on weed plants in the average number of grains per spike.

Biomass (Ton ha^{-1})

Results of the experiment are shown in Table (7)appearing significant differences between the treatments. Highest biomass average in the free weed treatment was (19.7) tons, and lowest average for this trait was (15.4) tons in the weedy check. As for the cultivars that were planted after turning the sunflower residues, it ranged between (17.3) tons for the cultivar that was planted with wheat after turning the residues Sakha cultivar and (16.9) tons for the cultivar that was sown with wheat after inverting Ishaqi residues, and (16.4) tons for the cultivar that was sown with wheat after overturning Akmar residues. This result is consistent with what was reached by (Tawfiq and Alsaadwi 2015) when they found that the use of sunflower residues for the two cultivars Shamoos and Sun Altheeb contributed to an increase in the biomass of the subsequent crop compared to the overgrown treatment.

Harvest index (%)

Results in Table (7) indicate the superiority of the treatments planted with wheat after turning the residues of the variety Akmar achieved the highest harvest index of (32.37%) compared to the other treatments, while the free weed treatment recorded the lowest harvest index of (25.28%) , the increase in the harvest index for the treatment of the absence of weeds may be due to the increase in both grain yield and Biomass Table (6).

As for the treatments that were sown after turning over the remnants of the sunflower cultivars, they were slightly different, as the amount of the treatment that was sown after the Sakha cultivar was (30.75%) and the Ishaqi cultivar (30%), while the weedy check treatment amounted to (26.68%).

Total yield (Ton ha^{-1})

The final outcome of all metabolic activities of any plant is the plant’s productivity of grains or seeds, and the source from which the metabolic materials are made and accumulated is their final estuary in the grain or seed.

The data presented in table (7) compared the average of the studied treatments where the highest yield rate was given in the treatment plant with wheat after cultivar Sakha (5.32 Ton ha^{-1}) which didn't differ significantly from the other treatments, including the free weed. This may be due to a significant reduction in the number of weeds, in addition to the elements and nutrients that were found in the soil due to the decomposition of the sunflower residues. The lowest yield was in the weedy check treatment which was achieved only (4.11 Ton ha^{-1}). These results agree with many researchers who mentioned that wheat crops cultivated after adding sunflower residues showed significant improvement in grain yield (Alsaadawi and Al-Temimi, 2011).

As for the free weed treatment, it was (4.97) Ton/ha-1 and for the treatments that were planted after overturning the other sunflower cultivars, Akmar and Ishaqi, they were (5.31) and (5.07)Ton/ ha^{-1}, respectively.

4.6. Allelopathic potential of the Residues three sunflower cultivars on growth parameters yield and yield components of the broad bean crop

4.6.1. Broad bean growth parameters

Broad bean plant height (cm)

Results of the experiment in table (8) did not show any significant differences between the studied treatments in terms of broad bean plant height. Despite the presence of slight differences in the plant height rates, the lowest height was observed in the treatment of Akmar sunflower residues which amounted to only 57.8cm. The other treatments including free weed treatment ranged from (62.33 to76.86 cm).

Table 8. Allelopathic potential of the three sunflower cultivars on growth parameters of Broad bean crop season 2021 – 2022.

Treatment	Plant Height cm	Leaf Area cm^2	Leaf Area Index	dry matter of vegetative parts	Pod length cm
Sakha	62.33	2277	2.5	11.98	10.5
Akmar	57.8	2390	4.4	7.75	13.7
Ishaqi	76.26	2328	3.93	7.01	13.8
Weedy Check	85.33	2162	3.2	6.44	10.32
Free Weed	76.86	2669	5.06	7.62	15.4
L.S.D: 0.05	N.S.	218.6	1.26	1.32	0.93

As for the weedy check treatment, it reached a maximum height of (85.33) cm. This increase can be attributed to the increase in weed density leads to an increase in competition between plants for growth requirements. in addition to this, increasing weed density which leads to an increase in shading among plants, and this encourages auxin and gibberellins to increase the elongation of internodes, which increases plant height (Abdelgadir, 2016).

Broad bean’s Leaf Area (cm^2)

The results of the experiment in Table (8) showed significant differences between the treatments, where the lowest average leaf area in the weedy check treatment was (2162)cm^2 and the sunflower residues treatments recorded (2277) cm^2 for the Sakha cultivar, (2328) cm^2 for the Ishaqi cultivar and (2390) for the Amar cultivar. As for the free weed treatment; It achieved the highest hight of (2669)cm^2.

This increase in the leaf area of the broad bean shows a positive effect when growing without weed which affected the physiological processes in providing the opportunity for the bean crop plants to absorb water and nutrients, especially the nitrogen element (Alawisi, 2019).

Broad bean’s Leaf Area Index

The absence or lack of competition from the weeds to the crop leads to an increase in its ability to obtain the full nutritional requirements. This leads to a difference in the length of the vegetative growth period, and the increase in the concentration of bio-contrasting compounds reflected on the intensity of the nutrient density during the period of vegetative growth.

The results shown in Table (8) indicated the superiority of the free weed treatment in this trait, as the amount of leaf area index was (5.06), while the leaf area rates for the other treatments ranged between (4.4) for the treatment served with beans after turning the residues of the cultivar Akmar in the soil and (3.93) for the treatment served with broad bean after turning the residues of the cultivar Ishaqi. As for the weedy check treatment, it achieved (3.2) and the lowest amount in this characteristic was for the treatment that was planted with the broad bean after turning the residues of the cultivar Sakha, as it reached (2.5) This result agrees with what was reached by, Alawisi (2019) study.

Dry matter of vegetative parts of the broad bean crop

Dry weight of the plant is one of the most influential characteristics of the vital processes that take place inside the plant, such as respiration, photosynthesis, and others, and any effect on these processes appears in another way on the final yield.

The increase of photosynthesis elevale in the production of organic compounds in the plant cells This increase is embodied in the dry weight of the plant, which includes the components of leaves, stems and some reproductive parts.

The results in Table (8) show the superiority of the treatment served with the broad bean crop after turning the residues of the cultivar Sakha in this trait, as the dry weight of the bean was 11.98 ton ha^{-1}, while the weedy check treatment was the lowest, reaching (6.44) ton ha^{-1}. The other sunflower cultivars were (7.01, 7.75 and 7.62 ton ha^{-1} for the treatments of Ishaqi, Akmar and the free weed treatment respectively. How the crop is affected by the external environment, especially the released contents of the previous crop, affect negatively or positively the growth and development of this crop (Kubure *et al.,* 2016).

Broad bean's pod length (cm)

The results of the experiment in table (8) showed that treating Sakha cultivar residues by decreasing the average broad bean pod length when reached the lowest average at 10.5 cm while the largest pod length was 15.4cm in the free weed treatment, followed by the weedy check treatment with an average length of 10.32cm. In terms of other sunflower cultivars, Ishaqi and Akmar recorded an average length which was at 13.8 and 13.7cm respectively. Although the sunflower residues treatments increased significantly as compared with the weedy check treatment due to the absence of weeds, they did not reach the significant level in the free weed treatment, which explains the allelopathic effects that determine the growth and development of the crop despite the availability of nutrients (Zimdahl, 2018).

4.6.2. Broad bean yield and yield components

Number of pod\ m^2

Results of the experiment in Table (9) showed that there were no significant differences between the treatments, despite the superiority of the free weed treatment in this trait. As the maximum number of pods per square meter; is 274 pods.m^2, the treatment served with the broad bean crop after turning the residues of the variety Akmar in the soil 234 pods.m^2 , then the weedy check treatment 233 pods.m^2. The treatment that was planted after turning the residues of the cultivar Ishaqi 226 pod .m^2 and the least number of pods was in the treatment that was planted after turning over the residues of the cultivar Sakha 200 pod .m^2.

Weight of 100 seed

As shown in the data obtained in table(8), the free weed treatment showed significant superiority in comparison with the other treatments which achieved 138.43g for 100 broad bean seeds.

As can see from the same table, treatments of sunflower residues did not differ significantly from the weedy check in terms of the weight of 100 seed, although the number of weeds decreased in these treatments as shown in table (5). The reason mostly is due to the negative effects of these residues in determining the growth of the crop and the effect on its vital processes, including the process of seed filling. These results are in agreement with the findings of many researchers such as (Alsaadawi *et al.,* 2012).

Table 9. Allelopathic potential of the three sunflower cultivars on yield and yield components of Broad Bean crop season 2021 – 2022.

Treatments	**number for pods\m^2**	**weight of 100 pulse**	**number of grains in pod**	**Biomass Ton ha^{-1}**	**Harvest index**	**Total yield Ton ha^{-1}**
Sakha	200	133.8	3.86	10.94	26.96	2.95
Akmar	234	135.06	5.0	11.44	33.74	3.86
Ishaqi	226	133.76	4.1	11.64	39.77	4.63
Weedy Check	233	133.14	4.2	10.07	41.70	4.2
Free Weed	274	138.43	4.37	12.93	40.9	5.3
L.S.D: 0.05	N.S.	2.18	N.S.	0.83	4.73	1.2

Number of seed in pod

The results of the experiment as Shown in table (9) did not show any significant differences between the treatments. However, the lowest value was in the treatment served with broad bean after turning the residues of the cultivar Sakha in the soil, where the average number of seeds per pod was 3.86 seed followed by the treatment that was planted after turning the residues of the variety Ishaqi 4.1 seed then the treatment of weedy check 4.2 seed and the treatment free weed 4.37 seed. The highest number of seeds per pod was observed at the treatment of Akmar residues at a rate of 5 seeds per pod.

Biomass (Ton ha^{-1})

The results of the experiment shown in Table (9) showed that there were significant differences in the trait of the Biomass among the treatments. The highest rate of the Biomass was in the free weed treatment at 12.93 Ton ha^{-1} followed by the treatment of Ishaqi residues at a rate of 11.64 Ton ha^{-1} then the treatment of Akmar and Sakha residues at a rate of 10.94 and 11.44 Ton ha^{-1} ,respectively. The lowest rate was in the weedy check treatment which was 10.07 Ton ha^{-1}. The current results agreed with the results of Alsaadawi *et al.* (2011) who found that Sunflower residues led to an increase in the biomass of the broad bean plants planted as a successive crop.

Harvest index (%)

The results in table (9) showed that there were significant differences between the treatments, where the largest rate of the harvest index was in the weedy check treatment 41.70% followed by the free weed treatment 40.9% and the ishaqi treatment 39.77%. Regarding Akmar and Sakha residues, it recorded a lower value of 33.74 and 26.96%. This may be due to the effect of allelopathic effects of sunflower cultivars and increasing phenolic content released from these cultivars which characterized the highest range of phenolics as shown in (Table2).

Total yield (Ton ha^{-1})

The seed yield is related to the components of the yield, which is the final outcome of the ability of the plant species to produce the largest amount of photosynthetic materials and convert them to estuaries early in the life cycle of the crop.

The results of the experiment in the table (9) showed that there were significant differences between the different treatments, where the highest rate was in the free weed treatment and amounted to (5.3) Ton ha^{-1}.

It was observed that there was an undesirable decrease in the final yield of broad bean plants planted after sunflower residues to the extent that the two cultivars Sakha and Akmar residues recorded the lowest rates despite the supply of the soil with the essential nutrients. The decreased percentage of broad bean yield was 44.4, 27.2 and 12.7% as compared with the free weed, which is an economically considered unacceptable loss rate.

The harmful effects of sunflower plants in crop rotations are mentioned by Azania *et al.* (2003) and the reason is attributed to the release and accumulation of root exudates during crop growth in soil. The soil incorporation of its green manure or dry biomass in the soil is inhibitory to both crops and weed species.

4.7. Allelopathic potential of the three sunflower cultivars on growth parameters of the Flax crop

4.7.1. Flax plants growth parameters

Flax plant height (cm)

Flax crop *Linum ustatissmim* L. is an annual plant ranging in height from 50 to 120 cm and thickness from (1.5) to (3) mm, depending on the variety and the environmental conditions in which the crop grows.

Results of experiment as shown in Table (10) indicate that there were significant differences of 5% between the treatments in terms of flax plant high. Highest height in the free weed treatment reached 104.3 cm, followed by the weedy check treatment at 96 cm.

Sunflower residues recorded the lowest high of flax plants which were 62.3,58.1 and 55.8 cm for Sakha, Akmar and Ishaqi cultivars, respectively. The sunflower residues, it is attributed to the allelopathic effect of sunflower residues. Flax crop is considered a sensitive crop that is characterized by slow growth and small vegetative parts, which makes it vulnerable to being affected by external conditions, especially the previous crop and the soil contents in which it is grown (Patrcia *et al.*, 2014). These findings are supported by many researchers such as Walsh *et al.* (2014), who found canola *Brassica napus* leaf washing reduced the germination.

Table 10. Allelopathic potential of the three sunflower cultivars on Flax crop growing parameters season 2021 – 2022

Treatment	**Plant High**	**Number of leaves per plant**	**number of branches per plant**	**Dry matter of vegetative part**
Sakha	62.3	85.0	1.03	2.35
Akmar	58.1	94.0	1.10	2.40
Ishaqi	55.8	84.3	1.00	2.47
Weedy Check	96	114.0	1.20	3.73
Free Weed	104.3	166.7	1.63	11.33
L.S.D: 0.05	13.65	20.94	N.S.	0.7

Number of leaves per plant

Results of the experiment showed that there were significant differences in the number of flax leaves per plant by the variation of treatment. The largest number of leaves was in the free weed treatment, which amounted to 166.7 leaves followed by the weedy check treatment with 114 leaves. similary with the trait of plant high, the sunflower residues recorded the lowest rate of leaves; 94, 85 and 84.3 leaf per plant for Akmar, Sakha and Ishaqi cultivars respectively. Reason for this may be due to the allelopathic effect of the remaining sunflower cultivars, which led to reducte the number of leaves in these treatments, compared to the free weed treatment. This result is in agreement with the findings of Puhup and Dwivedi (2019)study.

Number of branches per plant

Number of branches in the plant is one of the characteristics of vegetative growth, which is important, for the flax crop, as it reflects the possibility of producing largest number of capsules which leads to increased productivity.

Results of the experiment in the table (10) did not show that there were differences between the treatments, and the largest number of branches was in the free weed treatment, which amounted to (1.63) branches, followed by the weedy check treatment (1.2) leaves, then the treatment that was planted with flax crop after turning over the residues of the cultivar Sakha (1.03) branching and the treatment that was planted with flax crop after turning over the residues of the variety Akmar (1.1) branching. The least number of branches was in the treatment that was planted with the flax crop after turning the residues of the variety Ishaqi (1) branching. This may be due to allelopathic effect of the sunflower residues This result is in agreement with the findings ,Chhaganiya *et al.(*2018) study.

Dry matter of vegetative parts

The results of the experiment in table (10) showed that there were differences between the treatments, and the largest dry matter weight was in the free weed treatment, which amounted to (11.33) tons, followed by the weedy check treatment (3.73) tons, then the treatment planted with flax crop after turning over the residues of the Ishaqi variety (2.47) tons and the treatment planted with flax after turning the residues of the variety Akmar (2.4) tons, the lowest weight was in the treatment served with the flax crop after turning the residues of the variety Sakha (2.35) tons. With the previous characteristics, the height of the plant, the number of branches and the number of leaves, led to a decrease in the dry weight of the plant.

4.7.2. Flax seed yield and yield components

Capsules per plant

The results of the experiment shown in Table (11) reviewed that there significant between the treatments, the highest number of capsules per plant was in the free weed treatment; 11.33 capsule followed by the weedy check treatment 6.73capsule. The treatment planted with flax crop after the sunflower recorded the lowest number of capsules per plant when flax plants grown after Ishaqi sunflower variety came in 5.27 capsule Akmar variety 5.33capsule. The lowest number of capsules per plant was in the treatment flax plant grown after the Sakha variety which came in 5.23 capsule only. This may be due to the effect of weed competition for flax and this is what Singh. *et al.* (2019)

The number of capsules per m^2

The results of the experiment shown in Table (11) reviewed that there were differences between the treatments. The large number of capsules per plant in the free weed treatment was 997 capsule followed by the weedy check treatment containing 888 capsule. This may be due to the presence of the weed. This is in consistent with the findings of Abd-El-daiem (2015) Who showed that removing the weed leads to an increase in the number of pods. The treatments of flax plants grown after sunflower residues did not reach to the significant level which achieve only 692, 623.3 and 611.4 capsule for Ishaqi, Sakha and Akmar, respectively. The negative effect of sunflower residues was appearing clearly in most of the flax yield traits, including the trait under study.

Table 11. Allelopathic potential of the three sunflower cultivars on yield and yield components of Flax crop season 2021 – 2022 .

Treatments	The number of capsules per plant	Number for capsules per m^2	Weight of 1000 grain	Number of seeds per capsule	Biomass Ton ha-1	Harvest index	Total yield Ton ha^{-1}
Sakha	5.23	623.3	5.98	5.2	3.19	26.23	0.837
Akmar	5.33	611.4	6.14	4.93	3.62	27.04	0.979
Ishaqi	5.27	692.0	5.90	4.3	3.29	25.62	0.843
Weedy Check	6.73	888.0	5.11	7.2	3.83	19.68	0.754
Free Weed	11.33	997.0	7.11	6.7	5.11	27	1.38
L.S.D: 0.05	2.41	282.8	0.81	0.86	0.67	4.27	0.406

Weight of 1000 seed

The results of the experiment shown in Table (11) indicate that there were differences between the treatments, and the largest weight was in the free weed treatment, which amounted to 7.11g grams followed by the treatment of Akmar 6.14 grams, then the weedy check treatment, 5.11g, The other sunflower treatments of Sakha and Ishaqi recorded the lowest weight of 1000 seed reaching only 5.98 and 5.90g, respectively. Reducing competition, by decreasing the number of weed plants per area may not be sufficient to improve the yield and yield components due to the presence of other obstacles such as an effect of allelopathic compounds released from previous plant residues.

Number of seeds per capsule

The results presented in Table (11) showed that there were significant differences between the treatments, and the largest number of seeds per capsule was in the weedy check treatment, which amounted to 7.2 seed, followed by the free weed treatment of 6.7 seed. The treatments of sunflower residues amounted to 5.2 4.93 4.3 seed for Sakha, Akmar and Ishaqi respectively. This may be due to the small number of capsules per square meter, as well as in the plant, which caused an increase in the number of seeds in the weedy check treatment, in contrast to the free weed treatment, in which the number of capsules per plant and the number of capsules per square meter excelled in characteristics. As for the cultivars that were planted after the sunflower cultivars, they may have been affected by the allelopathic effect of the remaining sunflower parts in the soil.

Biomass Ton ha^{-1}

Results of the experiment in Table (11) showed that there were significant variations between the treatments. The treatments of sunflower residues did not reach the significance level and it was less than the value of the free weed treatment for this trait when recorded at 3.62, 3.29 and 3.187 Ton ha^{-1} only for Akmar, Ishaqi, Sakha, respectively.

The greatest weight of the biological yield in the free weed treatment was 5.11 Ton ha^{-1} followed by the weedy check treatment (3.83) Ton ha^{-1}. This may be due to weed competition and this in consistent with the findings of (Ozcan *et al.* 2014) who indicated that the decrease in the Biomass was due to the presence of weed.

Harvest index

The results of the experiment showed that there were differences between the treatments, and the greatest value of the harvest index was in the free weed treatment which differed significantly from all other treatments and amounted to 40.56% , followed by the treatment of Akmar residues 27.13% , then the weedy check treatment 26.86%. The other treatments Sakha and Ishaqi were the lowest value of flax harvest index 26.23 25.6%.

This may be due to weed competition and allopathic effects of sunflower residues. These results are in consistent with the findings of Ozcan *et al.* (2014) who indicated low harvest evidence due to the presence of weed accompanying the crop.

Total yield Ton ha^{-1}

The results of the experiment showed that there were considerable differences between the treatments. As presented in the data in Table 11, the highest value of the total yield was in the free weed treatment, which amounted to 1.38 Ton ha^{-1} ، followed by the treatment that was planted with the flax crop after Akmar residues of 0.979 Ton ha^{-1} . These two treatments differed significantly from the other studied treatments. The other treatments of sunflower residues Ishaqi and Sakha recorded 0.843 and 0.837, respectively. The lowest weight was in the weedy check treatment 0.754 Ton ha^{-1}. This may be due to the effect of weed competition as well as the allopathic effects of sunflower residues, This in consistent with the findings of Alam *et al.* (2021) who found a decrease in the total yield due to the presence of weeds.

Although the sunflower residue treatments came with a higher seed yield rate than the weedy check treatment, which explains the harmful effect of these materials on the flax yield which did not reach the rate observed in free weed treatment.

This clearly shows the negative effect of the allelopathic substances on most of the yield components, which led to the deterioration of the final yield.

The results also shown the discrepancy between the sunflower cultivars in their effect on successive crops according to the amount and type of substances released into the soil.

Concussions and Recommendations

CHAPTER FIVE

5. **Concussions and recommendations**

5.1. Conclusions

It can be concluded from the results of the study that:

1. The allelopathic effects of sunflower residues appear clearly in reducing population and weed dry weight due to its content of phenolic compounds.
2. Sunflower residues have succeeded in supplying the soil with a desirable amount of nutrients as well as organic matter.
3. The cultivation of the wheat crop after the sunflower crop gave it an acceptable grain yield, in contrast to the broad bean and flax crops, which were negatively affected.

5.2. Recommendations

It can be recommended that :

1. Sunflower residues can be used in sustainable agriculture as an attractive eco-friendly method to suppress the weed population and supply the soil with the desired amount of essential nutrients.
2. Try not to cultivate the broad bean and flax crops after the land containing the sunflower residues to avoid the unacceptable loss in economic yield.
3. Conduct studies of the effect of sunflower residues on other wheat cultivars.
4. Carry on the research of the sunflower residues on the other proposed successive crops.

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Appendices

Appendix 1: Analysis of variance table for the total phenolic content in the study field soil after mixing sunflower residues (MS)

S.O.V.	DF	Sum of Squares	Mean of Square	F Value	Pr > F
Replicates	3	0.03254215	0.01627107	2.26	0.1131
Treatments	31	10.4386985	0.31731032	44.03	<.0001***
E. error	62	0.44684519	0.00720718		

Appendix 2: Analysis of variance table for soil properties of the study field (MS)

S.O.V.	DF	MS					
		N mg kg^{-1}	p mg kg^{-1}	K mg kg^{-1}	Organic Matter	Organic Carbon	C/N Ratio
Replicates	2	363270*	235.2^{ns}	7725^{ns}	0.0089^{ns}	1.30^{ns}	147.292^{ns}
Treatments	9	1335319**	1064.7**	54223**	0.544**	8.36**	253.44**
E. error	18	44425	198.8	10302	0.049	0.747	69.58

Appendix 3: Analysis of variance table of sunflower residues on density and dry matter of successive crops accompanying with the weeds

S.O.V.	DF	MS		
		Weed density 30 DAC	Weed density 60 DAC	Weed dry matter g m^2
Replicates	2	21340^{*}	30489^{**}	25620^{**}
Treatments	11	76743^{**}	39088^{**}	54249^{**}
E. error	22	3840	4671	2920

Appendix 4: Analysis of variance Table for growth parameters traits and yield components of Wheat crop (MS)

S.O.V.	DF	MS								
		Plant high cm	Flag leaf Area cm^2	dry matter of vegetative parts	Spike Length cm	number of spikes m^2	Weight of 1000 grain (g)	Biomass Ton ha^{-1}	Harvest index (%)	Total yield Ton ha^{-1}
Replicates	2	27.17^{ns}	3.20^{ns}		0.92^{*}	1656 ns	1.01 ns	0.68 ns	6.06ns	0.122ns
Treatments	4	536.3^{ns}	9.73^{ns}		1.11 **	2663^{**}	12.57^{**}	7.65^{**}	10.28^{*}	0.78^{*}
E. error	8	49.88	2.69		0.15	365	1	0.76	2.09	0.19

Appendix 5: Analysis of variance Table for growth parameters traits and yield components of Broad bean crop (MS)

S.O.V.	DF	MS									
		Plant High cm	Leaf Area cm^2	Leaf Area Index	dry matter of vegetative parts	number for pods m^2	weight of 100 grain	number of grains in pod	Biomass	Harvest index	Total yield Ton ha^{-1}
Replicates	2	130.5^{ns}	23448^{ns}	1.512*		247.4^{ns}	0.0748^{ns}	1.394^{ns}	0.02^{ns}	9.298^{ns}	0.119^{ns}
Treatments	4	385.7^{ns}	107402**	2.963**		2107^{ns}	19.54**	0.549ns	3.263**	140.8*	2.553**
E. error	8	217.5	13484	0.2968		695	1.34	0.3505	0.19	27.90	0.406

Appendix6 Analysis of variance Table for growth parameters traits and yield components of Flax crop (MS)

S.O.V.	DF	MS								
		Plant High (cm)	Number of leaves per plant	number of branches per plant	Dry matter of vegetative part	The number of capsules per plant	Number for capsules per m^2	Weight of 1000 grain	Number of seeds per capsule	Biomass
Replicates	2	22.5^{ns}	104.6^{ns}	0.0166^{ns}		3.914^{ns}	23266^{ns}	0.036^{ns}	0.152^{ns}	0.208^{ns}
Treatments	4	847.2**	3569**	0.199**		20.63**	88447*	1.53**	4.66**	1.8856**
E. error	8	43.46	123.7	0.06		1.64	22559	0.185	0.212	0.1273

النمو. نفس التأثير لوحظ على نباتات الباقلاء كما هو الحال في نباتات الحنطة عدا ملاحظة حروق لحواف بعض الاوراق بالمقارنة مع المعاملتين المدغلة والخالية من الادغال والتي لم يضاف اليها مخلفات زهرة الشمس. اما بالنسبة لنباتات الكتان فقد كانت الاكثر تأثرا وتعدى الضرر الى احتراق حواف بعض الاوراق والتقزم.

ادت مخلفات زهرة الشمس الى تحسين صفات النمو لمحصول لحنطة وبالتالي زيادة حاصل الحبوب الكلي وبنسبة زيادة مقداره 22.75, 22.6 و 19% لمخلفات اصناف سخا , اقمار واسحاقي بالمقارنة مع المعاملة المدغلة وبنسبة زيادة معنوية اعلى من المعاملة المدغلة والتي سجلت معدل زيادة 17.1%.

بدى التاثير الاليلوباثي واضحا على محصولي الباقلاء والكتان والذين لم يحققا ارتفاعا في صفات النمو وزيادة في الحاصل على الرغم من تزويد التربة بالمكونات الرئيسية لمتطلبات النمو لاسيما NPK ونسبة الكاربون الى النيتروجين .

الخلاصة

نفذت تجربة حقلية في محطة الحامضية للبحوث الزراعية التابعة لجامعة الانبار / كلية الزراعة خلال الموسم الزراعي 2022/2021 . تم تقييم التاثير الاليلوباثي لمخلفات ثلاثة اصناف من زهرة الشمس وهي سخا , اقمار واسحاقي ضد الادغال النامية مع المحاصيل التي تعقب زراعته وهي الحنطة والباقلاء والكتان وكذلك تقييم التاثير الاليلوباثي على تلك المحاصيل بعد الحصول على البذور من نباتات زهرة الشمس المزروعة في العروة الخريفية للموسم 2021 تم تقطيع وخلط اجزاء المحصول بوسطة الة Rotavator ومن ثم زراعة المحاصيل اللاحقة.

بينت النتائج مايلي:

بلغ اعلى معدل لمركبات الفينولات الكلية والمفروزة من متبقيات زهرة الشمس ولمختلف الاصناف الى التربة خلال الاسبوع الرابع من بعد الخلط وسجل متوسطا قدره (1.48mg/g) في حين سجلت معاملة المقارنة (بدون اضافة) اقل معدل لمركبات الفينول ولكل الاسابيع وتراوح بين (0.05 - 0.12 mg/g).

بين تحليل التربة بأن مخلفات زهرة الشمس قامت برفد تربة الحقل بالعناصر الاساسية للنمو وخصوصا NPK وكذلك زيادة المادة العضوية ونسبة الكاربون الى النيتروجين والتي ازدادت بمعدل يتراوح من 44 الى 143 % ولكافة اصناف زهرة الشمس ولكل فترات القياس مقارنة بالمعاملة المدغلة.

لوحظ انخفاضا كبيرا للكثافة العددية للادغال النامية مع المحاصيل اللاحقة لمخلفات زهرة الشمس بعد 30 و60 يوم من الزراعة نتيجة التاثير الاليلوباثي وكذلك انخفض الوزن الجاف للادغال بنسبة كبيرة. مع ذلك فقد لوحظ تفاوت بين معدل كثافة الادغال ووزنها الجاف اعتمادا على نوع المحصول فقد سجلت الادغال النامية مع محصول الحنطة اقل معدل لكثافة الادغال ووزنها الجاف.

اما فيما يخص درجة الضرر للمحصول اللاحق لمخلفات زهرة الشمس فقد تراوحت بتغيير اللون الاخضر لنباتات الحنطة الى اللون الاخضر الباهت والاصفرار الطفيف في بداية مرحلة

ﭚ ﭛ ﭝ ﭜ

ﮞ ﮟ ﮠ ﮡ ﮈ ﮉ ﮤ ﮥ ﮦ ﮨ ﮩ ﮪ ﮫ ﮬ ﮭ ﮮ ﮯ

ﮰ ﮱ ﯓ ﯔ ﯕ ﯖ ﯗ ﯘ ﯙ ﯚ ﯛ

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
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كلية الزراعة
قسم المحاصيل الحقلية

التأثير الأليلوباثي لثلاثة اصناف من زهرة الشمس على بعض المحاصيل اللاحقة والادغال المرافقة

رسالة مقدمة

الى مجلس كلية الزراعة في جامعة الانبار
وهي جزء من متطلبات نيل درجة الماجستير في العلوم الزراعية

من قبل
تيسير مزهر فليح
بكالوريوس علوم زراعية

بأشراف

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1444هـ **2022م**