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INTEGRATED WEED CONTROL IN THE POTATO PLANT AND ITS EFFECT ON PRODUCTIVITY

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May 2023

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

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ABSTRACT

INTEGRATED WEED CONTROL IN THE POTATO PLANT AND ITS EFFECT ON PRODUCTIVITY

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This study was conducted on one of the farms affiliated with Heet District, Anbar Governorate, for the spring season of 2022 to study the efficiency of metribuzin herbicide alone or with mulching black plastic and hoeing in controlling potato weeds and the role of the factors mentioned in the vegetative characteristics of potatoes and yield according to the RCBD. The results indicated the effect of metribuzin at a rate of 400 g/ha with mulching by reducing the total weed density and their dry weight by 19.0 plants per m^2 and 43.0 g, respectively. It did not differ significantly from metribuzin at a rate of 800 g/ha with 16.0 plants per m^2 and 29.7 g, respectively. The study showed the efficiency of metribuzin at a rate of 400 g/ha in combination with one or two hoeings to reduce the weed density to 19.3 and 10.6 plants per m^2, respectively, and dry weights of 30.0 and 24.3 g. The effect was reflected in plant heights and vegetative dry weight. The integration treatment between the herbicide at half the recommended rate and mulching achieved an increase in the rates and gave 82.3 cm and 63.3 g, respectively. It did not differ from the herbicide treatment at the recommended rates of 79.0 cm and 60.3 g, respectively. Also, the efficiency of metribuzin combined with one or two hoeings in plant height and total vegetative dry weight of 73.6 cm is 1 and 57.3 g per one hoeing, respectively, and 70.6 cm and 53.0 g for the two hoeings, respectively, reflecting on yields by increasing this weight. The integration treatment between the herbicide at half the recommended rate and mulching increased the rates and gave 41.1 tons/ha, which did not differ significantly from the herbicide treatment at the recommended rate of 44.9 tons/ha. While the use of metribuzin at half the recommended rate in combination with one or two hoeings affected the total yield by giving 41.0 tons/ha for one hoeing and 45.8 tons/ha for the two hoeings, the results indicate that the positive effects have been associated with an increase in plant protein and chlorophyll content.

2023, 85 pages

Keywords: Metribuzin, Mulching, Hoeing, Weed density, Total yield

ÖZET

PATATES BİTKİSİNDE ENTEGRE YABANCI OT KONTROLÜ VE VERİMLİLİK ÜZERİNDEKİ ETKİSİ

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Bu çalışma, 2022 bahar sezonu için Anbar Valiliği'ne bağlı bir çiftlikte yapılmış olup, Metribuzin herbisiti tek başına veya siyah plastik örtü ile birlikte kullanılarak patates yabancı otlarını kontrol etme konusunda çapalamaya ek olarak patates bitkisinin bitki özellikleri ve verimindeki etkisini araştırmak için yapılmıştır. Sonuçlar, 400 g/ha dozunda Metribuzin kullanımının örtüleme ile birlikte yabancı ot yoğunluğunu 19.0 bitki/m²'ye ve kuru ağırlıklarını 43.0 gram/m²'ye kadar azaltma etkisi gösterdiğini, 800 g/ha dozundaki Metribuzin kullanımıyla karşılaştırıldığında farklılık göstermediğini ortaya koymuştur. Ayrıca, Metribuzin'in bir veya iki çapalama ile birlikte 400 g/ha dozunda kullanımı, yabancı ot yoğunluğunu sırasıyla 19.3 bitki/m² ve 10.6 bitki/m²'ye kadar azaltarak etkisini göstermiştir. Bitki boyu ve bitki kuru ağırlığına yansımıştır. Herbisitin yarısı önerilen dozu ve örtüleme arasındaki entegrasyon işlemi, 82.3 cm ve 63.3 g'lik artış sağlamıştır. Bitki boyu ve bitki kuru ağırlığı açısından önerilen dozdaki herbisit işleminden farklılık göstermemiştir. Ayrıca, Metribuzin ile bir veya iki çapalama uygulaması, bitki boyu ve toplam bitki kuru ağırlığı açısından sırasıyla bir çapalama işleminden 73.6 cm ve 57.3 g, iki çapalama işleminden sırasıyla 70.6 cm ve 53.0 g verim artışı sağlamıştır. Bu, ağırlığın artırılması verime yansımıştır. Önerilen dozun yarısı ile örtüleme arasındaki entegrasyon işlemi, 41.1 ton/ha'lık bir artış sağlamıştır. Önerilen dozdaki herbisit uygulamasından farklılık gözlemlenmemiştir. Bununla birlikte, önerilen dozun yarısı ile bir veya iki çapalama uygulaması toplam verimi etkilemiş olup, sırasıyla bir çapalama işleminde 41.0 ton/ha ve iki çapalama işleminde 45.8 ton/ha verim artışı sağlamıştır. Sonuçlar, bitki protein ve klorofil içeriğindeki artışla ilişkili olarak pozitif etkilerin olduğunu göstermektedir.

2023, 85 sayfa

Anahtar Kelimeler: Metribuzin, Malçlama, Çapalama, Ot yoğunluğu, Toplam verim

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Anmar Khalid Nassar NASSAR
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LIST OF SYMBOLS

ºC	Celsius Degrees
da	Decare
dS	Desisiemens
EC	Electrical Conductivity
g	Gram
ha	Hectare
in	Inches
kg	Kilogram
mm	Millimeter
ppm	Parts per million
%	Percentages

LIST OF ABBREVIATIONS

CO	Control
HO	Hoeing
IWM	Integrated weed management
M	Metribuzin
MU	Mulching
TSS	Percentage of total soluble solids
USDA	U.S. Department of Agriculture
H.W	Weeding

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1. INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to the family Solanaceae and includes more than 2000 species and 90 genera. It is one of the most important crops in the world due to its abundant yield and diversity of growth in different conditions (Ganainy *et al.*2022). It ranks third as a strategic and economic crop after wheat and rice (Eriksson *et al.*2016). Where it constitutes the daily diet of more than 90% of the diet of countries (Duguma *et al.*2019). Although the environmental conditions in Iraq may be suitable for the growth of the crop, the productivity of the crop is still low. The reason for this is the farmers' lack of interest in the process of crop management, especially in the field of weed control, as the weeds cause great losses that sometimes lead to the loss of the entire crop, and this depends on the type and density of the weeds in the field. Most researchers have confirmed that weeds cause great losses in the percentage of the total yield, reaching 30–50% and sometimes reaching 70% (Al-rajbo *et al.*2022). The weeds' competition for the potato crop is not limited to light, water, nutrients, and production alone but also affects the quality of the tubers, as the weeds cause holes and deformations in the potato tubers and produce tubers of small size that are undesirable for the consumer and cause great losses to the farmer, and some weeds secrete toxic substances that cause crop damage and contribute significantly to the decline in production in quantity and quality (Xie *et al.*2021).

The cultivation of the potato crop at the global level is exposed to many problems, including the weed that competes with the crop and reduces its productivity, as weed control is a basic and necessary process to reduce the negative effects of its competition for the potato crop and then achieve high productivity and quality. Relying on one method for controlling weeds in crops in general and potatoes in particular is not sufficient and efficient in controlling weeds, as it does not prevent the subsequent growth of the weeds, especially during the flowering period, and thus may be a cause of the transmission of viral diseases or the emergence of their spread in subsequent years (Li *et al.*2019).

The farmers follow the method of chemical control of the weeds accompanying the potato crop in Iraq by using one of the recommended herbicides, including metribuzin. This method is not sufficient or effective enough to get rid of weeds. In addition, the continuous use of specific types of herbicides in the potato fields helped develop some weeds' resistance to them. Therefore, the method of integration in the control and the application of what is available from mechanical, biological, and chemical methods are the best methods for improving the control of the weeds, increasing the efficiency of control, and reducing the types and quantities of herbicides used. This is reflected in their effect on the environment, especially the residues remaining in the soil on subsequent crops (Caputo 2021).

Therefore, the study aimed at the following:

1. Identification of the types of weeds accompanying the potato fields during the season in the experimental field.

2. Studying the effect of the two processes of mulching with black plastic or hoeing (agricultural methods) in controlling the weed accompanying the potato crop and its effect on a number of vegetative, productive, and chemical characteristics compared with the use of metribuzin herbicide alone.

3. Attempting to reduce the rates of metribuzin spraying in potatoes by following the method of integration in the control between the use of the herbicide and the process of mulching with black plastic or the process of hoeing on the above-mentioned characteristics.

2. LITERATURE REVIEW

2.1 The Economic Importance of The Potato Crop

At the beginning of the seventies, and on a global level, the issue of food emerged when the world was alerted to the dangers of the increasing gap between the rates of demand for food and the rates of production, as the vegetation cover represents a large part of the nature surrounding us and is one of the necessities of human life. The hand of man has been extended since ancient times by research and exploration. In the plant, there are nutritional, medicinal, and other secrets (Barbas *et al.*2020).

Potatoes are one of the most important crops in the world due to their high nutritional value. Potatoes began to be cultivated in Europe and spread mainly among them. It was considered a luxury commodity, but due to the success of its cultivation, the promotion of its use among the poor, and its consideration as the food of choice for them, its level as a luxury commodity fell by the nineteenth century among Europeans (Salmensuu 2021).

It is popularly known as "the king of vegetables," as it is the most productive vegetable in the world. It is an important and necessary source of nutrition and income for many populations and communities, and its dry matter contains energy and protein, which makes it of good nutritional quality. In many countries, the potato crop gives the highest yield per hectare compared to other food crops (Duguma *et al.*2019). They are mainly consumed as human food because they contain a high percentage of carbohydrates and proteins compared to grains, and they also contain vitamins such as vitamin B and vitamin C and various minerals (Jennings *et al.*2020).

2.2 Origin of Potato and Cultivation Dates

The Andes Mountains in Bolivia and Peru in South America are the original homelands of the potato, from which it spread to different regions of the world (Javaheri *et* *al.*2012). They made from it a fine, light material called shono and used this material instead of wheat in making bread (Stokstad 2019).

The Spanish explorers were the first Europeans to eat potatoes, and they brought them with them to Europe in the mid-16th century AD. At the same time, the English explorers brought the potato to England, from which it was transported to Ireland, where it grew well. The potato became known in some Western countries as the Irish potato because a large part of the Irish depended on it in their diet (Eriksson *et al.*2016). It is believed that the potato moved to North America at the beginning of the seventeenth century AD, but it did not become an important food crop until the Irish immigrants brought it, when they settled in New Hampshire in 1719 AD. As a result of infection with late blight and due to the appearance of the Colorado potato beetle, the potato crop in Ireland was scarce between 1845 and 1847 AD, so about 750,000 Irish died as a result of disease or starvation. Hundreds of thousands of people left Ireland and settled in other countries, especially the United States. It resulted from the progress that occurred in food manufacturing during the twentieth century through the use of potatoes in the products of making chips and crispy potatoes (Bodensten 2021). The cultivation of this crop in developed countries has rapidly developed in terms of production and quality thanks to intensive scientific research in the field of potato varieties and their agricultural pests and production technology, from preparing the land to harvesting and marketing the crop (Duru 2017).

2.3 Cultivated Area and Global Production

Potato (*Solanum tuberosum L.*) is considered one of the main nutrients and the fourth largest food in the world; it was originally cultivated in South America and spread to many countries of the world (Mu and Li 2019). In addition, potatoes are considered the main crop in many countries of the world, with an annual production of nearly 300 million tons. Potatoes are one of the main products in the world (Rajendran 2018).

The global trend in potato production has led to a decline in developed countries and accelerated growth in developing countries, especially in Asia and Africa, as these two regions of the world contain a greater number of undernourished people. Thus, the high availability of potatoes per capita in these areas may justify the nutritional needs of the population. And that the nutritional value of the potato is so great that it may be the only human food for some time without harming public health (Wichrowska 2022).

The global production of potatoes amounted to 376.875 million tons annually worldwide, with 50% of it distributed in the continent of Asia and 30% in Europe, while it reached 11% and 8%, respectively, in America and Africa. China leads the ranking of potato-producing countries with nearly 100 million tons, a quarter of the world's production, followed by India with about 45 million tons, then Russia with about 31 million tons, with a combined share of 46% of global production, followed by Ukraine, the United States, Bangladesh, Germany, Poland, and France, which together accounted for 24%. The total volume of production increased at an average annual rate of 1.6% in the last ten years (Atlasbig 2021).

Potato is one of the main food crops in the world and the most important vegetable crop in terms of quantities produced and consumed, and it is popularly known as "the king of vegetables" (Singh *et al.*2020). Being the most productive vegetable in the world, it provides an important and essential source of nutrition and income for many populations and societies (Shehata 2019), and its dry matter contains energy and protein, making it of good nutritional quality. The potato alone contributes about 21% of the total vegetable area and 26% of its total production (FAO 2018).

According to the statistics of the Directorate of Agricultural Statistics, Central Statistical Organization, Iraq, the area planted with potatoes and productivity in various seasons in 2020 are as follows:

2.3.1 First-production

The production of the potato crop was estimated at 674.8 thousand tons for the year 2020, an increase of 282.5 thousand tons compared to the 2019 season, which was estimated at 392.3 thousand tons, and the rate of increase was estimated at 72.0% as in Table 2.1.

2.3.2 Second-cultivation area

The total area planted in Iraq with the potato crop for the year 2020 for the spring and autumn seasons was estimated at 96.5 thousand acres, an increase of 40.1 thousand hectares over the 2019 season, which was estimated at 56.4 thousand acres, and the rates of increase were estimated at 71.1%, as shown in Table 2.1.

2.3.3 Third- average production

The average yield of an acre of the potato crop for the spring and autumn seasons during the year 2020 AD was estimated at 6994.6 kg per acre based on the total cultivated area, with an increase of about 0.5% compared to the 2019 season, which was estimated at 6957.5 kg per acre, as shown in Table 2.1 (Agricultural Statistic Directorate 2021)

Table 2.1 Cultivated area, total production and average yield of potato crop in Iraq for the year 2020

Crop	Cultivation area (acre)	Production (ton)	Average production (kg per acre)
Potato	96.5	674.8	6994.6

2.3.4 Usage and Nutritional Value

Potatoes are one of the main crops in the world. They are essential and cheap food for many; they are used in many food industries; and they provide a larger amount of energy than other crops (Paixão e Silva *et al.*2021). Potato tubers are used for direct food and in the food industry as processed materials such as chips (Górska-Warsewicz *et al.*2021). Irish farmers consumed potatoes in the eighteenth and nineteenth centuries at a rate of 4 kg per person per day, and this quantity is sufficient to provide the human being with all his daily needs of calories, proteins, minerals, and vitamins except for vitamins A and D (Simakov *et al.*2021).

However, potato protein contains a large number of amino acids, as potatoes contain 18 amino acids out of the 20 essential amino acids necessary for building the human body. This gives it a high biological value because it is present in varying quantities of amino acids such as tyrosine, lysine, arginine, and histidine, while potatoes are considered poor in the amino acids methionine and cysteine (Rasulu *et al.*2021). Potato tubers are also used for various industrial purposes through the extraction of flour and starch, as well as in the fermentation industry to extract alcohol and some organic acids, in addition to their use in animal feed for easy digestion because they have a laxative effect (Bongaarts 2021).

Potatoes yield more dry matter and protein per unit area than a similar area of major cereal crops on which the world depends (Leonel *et al.*2017). But a person needs to consume three times more potatoes than grains in order to get the same number of calories because of the lower percentage of dry matter in potatoes compared to cereals (Bongaarts 2021).

The chemical composition of potato tubers varies with different varieties, the degree of maturity of the tubers, the prevailing conditions for tuber formation, as well as agricultural operations and storage conditions. A total of 100 grams of peeled potato tubers contains, on average, 22 grams of the dry matter, giving 76 calories, and it contains 17 grams of carbohydrates, 2 grams of protein, 0.5 grams of fiber, 1.0 grams of fatty materials, and 9.0 grams of ash. It also contains a group of important mineral salts, including 400 mg potassium, 55 mg phosphorous, 22 mg magnesium, 7 mg calcium, 3 mg sodium, and 6.0 mg iron, in addition to a group of vitamin B (0.1 mg B1, 0.4 mg B2, and 1.5 mg B5) and small amounts of pyridoxine (B6), biotin, inositol, and pantothenic acid (B3). Potato tubers also contain a small amount of vitamin C, ranging from 15-20 mg, and traces of vitamin A in white pulp varieties (Barbaś and Sawicka 2020).

Table 2.2 Nutritional value of potato (100 g fresh) USDA 2019

Sl. No.	Particulars	Nutrient value
1	Energy	Energy 77 kcal
2	Water	2. Water 79.25 g
3	Carbohydrate	3. Carbohydrate 17.49 g
4	Sugars	0.82 g
5	Starch	15.29 g
6	Dietary fibres	2.1 g
7	Fat	0.09 g
8	Protein	2.05 g
9	Vitamin c	19.7 mg
10	Calcium	12.0 mg
11	Iron	0.8 mg
12	Magnesium	23 mg
13	Phosphorus	57 mg
14	Potassium	425 mg

2.4 Harmful Weed

Despite the role that the weed plays in maintaining soil moisture and improving soil qualities by increasing the percentage of organic matter and preventing it from eroding, many areas of weed growth are considered natural pastures. However, at the same time, it causes great losses that far outweigh the losses caused by the rest of the pests, and the evidence for this is that the use of weed herbicides has exceeded the use of all other pesticides, especially in recent years. At the same time, it is clear evidence that the traditional control methods, by adopting mechanical and agricultural methods, have become secondary means in the field of weed control to be ahead of chemical control, especially since there are many studies that confirm that chemical control of the weed is more efficient than the use of agricultural and mechanical methods such as hoeing operations and others (Vilà *et al.*2021).

The number of harmful and competitive weeds for economic crops is about 30,000 species, which constitute about 10% of the total plants in the world; more than 1800 species cause economic losses in agricultural production; and 200 plant species of them constitute about 95% of the problems of the weed in the field of agricultural investment and more. The dangerous species are about 12, and these constitute 70% of the weed problems (Pala *et al.*2018).

The weeds are considered one of the most important problems faced by man since he started planting seeds until harvesting the crop, as they adapt environmentally and biologically to the growth of economic plants (Haq *et al.*2021). The weed increases the costs of various agricultural operations, and this, in turn, leads to a decrease in the return on capital for the agricultural investor. This is reflected in the decrease in the value of the land on which the bush is located, especially perennial plants, and thus leads to a decrease in demand for it (Bodensten 2021). Moreover, harmful weeds have spread everywhere, including in uncultivated areas and between residential communities and new cities, and this distorts the general view of cities and spoils the beauty of nature when it is present in these areas. The weed also creates other problems, such as obstructing the view outside the roads, and is considered a source of ignition for fires (Guerra *et al.*2022). The bush is currently spread in different parts of the world, and the number of its species reaches tens of thousands, and some of them are ancient, such as *Stellaria media* L. and *Polygon aviculare* L., whose studies have proven its existence 600,000 years ago, as it maintains its vitality for long periods and grows everywhere, and it varies according to the nature of its growth (Yadav *et al.*2021).

This has led to a change in the species composition of this weed and its economic importance over time in different ecological zones. The density and danger of many species have decreased, and some dangerous species have appeared as a result of the change in agricultural techniques, including the use of chemical fertilizers, seed cleaning for cultivation, and pest control methods, including the use of selective weed herbicides. Some weeds were not harmful in their native environments, such as *Convolvulus arvensis* L. in Europe, but became harmful when they moved to North America (Skiba *et al.*2021).

Harmful weeds have acquired with the development of agriculture some characteristics that distinguish them from economic crops, as they are characterized by their high ability to adapt and withstand changing bad environmental conditions, shortening their life cycle, and producing large numbers of seeds that retain their vitality for several years, as this enhances their competitiveness with economic crops, which grow at their expense and productivity (Mangold *et al.*2021). The weed differs in the degree of its adaptation and its ability to compete, as the broad-leaved annual weeds are more adaptive and competitive than the narrow-leaved weeds because their seedlings are more visible and germinate faster, especially in the early stages of crop growth (Skiba *et al.*2021).

The damage of the weed may not be apparent on the surface when it is in the range of 10–20% (Barker 1990). But it can cause significant damage and losses that may reach about 28.7% of the total losses caused by pests in important crops around the world and may reach 41%, thus exceeding the damage of other pests (Fried *et al.*2019).

The researcher Cramer (1967) estimated that the global average loss in yield due to the weed ranged between 6.8% and 15.7% of the productivity in different regions, and this constituted 25%-33% of the total loss caused by various other agricultural pests (Skiba *et al.*2021). The damage to the weed may be greater when fertilizer is used without accompanying the weed control process, as research indicates the possibility of a negative impact of fertilization on agricultural production when neglecting the control of the weeds. Fertilization encourages the growth of the crop and the bush, but the possibility of the bush benefiting from the nutrients is greater, so it grows faster to become in a better competitive position than the crop (Guerra *et al.*2022).

In general, weeds are a major problem in potato production all over the world, as they play a role in reducing the yield in terms of quality and quantity (Ross 2015), shading crops, and causing direct competition for light, water, and nutrients. In addition to the toxic compounds secreted by the weeds, which have an inhibitory effect on the germination and growth of the crop, there is direct damage to the quality of the tubers through the roots of some types of bush that penetrate the tubers adjacent to the potato in the soil. It causes deformation of the tubers due to these roots and reflects on their quality (Sabzi *et al.*2018). But according to statistics, there was a discrepancy in the amount of damage caused by the bush between developing and developed countries. The amount of damage was about 25% in developing countries; this percentage decreased in developed countries to 5%, and the damage of the weeds does not depend on the quantity of production alone; it affects the number and size of tubers and leads to obtaining smaller tubers of poor quality with less dry matter content (Mangold *et al.*2021). The size of the decrease in yield depends on the density of the bush and its ability to compete, and this decrease in the presence of the bush ranges between 16% and 76%, and each additional 10% increase in the dry weight of the bush led to a decrease in the yield of 12% to 18% (Yadav *et al.*2021).

Among the weeds are those that are toxic to humans and animals, in addition to being hosts to many agricultural pests such as rodents and insects such as green peach aphids (*Myzus persicae*), which are responsible for transmitting many potato viruses such as mosaic virus and leaf curl (Wichrowska 2022). The weeds are also a host for many fungal pathogens; moreover, the weeds impede the uprooting (harvesting) of potatoes and reduce their efficiency, such as the bush of *Arvensis convolvulus* L., which is a major problem in potato fields because it interferes with the potato shoot and hinders the harvest process (Fried *et al.*2019). In addition to the above, the weeds caused significant losses in the potato crop, which represented about 34.4%–86.0%. The growth of weeds during the growing season of the potato crop leads to a significant decrease in the number of tubers and the dry weight of leaves (Shehata *et al.*2019). Yohannes (2011) found that the height of potatoes and the number of stems per plant were significantly reduced compared to the control treatment (weed-free) due to weed competition for plants. The weeds also affected the chlorophyll content in plant leaves, the quality of the tubers, and their nutritional content.

2.5 Harmful Weed Competition for Potato Plants

The appearance of weeds, which are particularly harmful at the start of the growing season (primary infestation of weeds) and at the end of the season (secondary infestation of weeds), is one of many factors that limit potato cultivation (Abdallah *et al.*2021). The primary infestation in the weeds reduced the yield by 54% and, before harvest, by 16%. The weeds are characterized by having the highest production reduction rate of 34% compared to other pests 18%. The sum of weed damage losses usually exceeds that of other pests (Attri *et al.*2022). The extent of competition between agricultural plants and weeds depends on the types of weeds, the forms of their communities, their level of density, the type of crop, climatic conditions, the nature of the soil, the quality of agricultural operations, production techniques, and their requirements (Shen *et al.* 2019). The competitive ability of each crop and weed is determined by the speed of germination, growth, and development of the vegetative and root systems of its plants, and the competition between the weeds and crops for nutrients is most intense in the early stages of growth, especially the first four weeks of crop growth, especially on nitrogen, which is not available in the same amount and speed that it is consumed by the weeds from the soil, which leads to damage that will continue until the time of harvest (Argüelles and March 2021). Good use of herbicides makes it possible to eliminate the competitive effect of harmful weeds on arable crops from the beginning of potato germination as well as reduce the emergence of later weeds (secondary infestation) (Barbaś and Sawicka 2020). Hall *et al.* (1999) indicate that the harmful weeds compete with the potato crop for light, nutrients, water, and space, and the competition for nutrient consumption is one of the most prominent manifestations of competition between agricultural crop plants and weeds, the most obvious and sharpest compared to the competition for water consumption. Since the nutrients are often limited in quantity in the soil, the rate of water loss from the soil is governed more by the surrounding medium conditions than it is by the type of plant. It is often difficult to accurately interpret the results of competition experiments because the elements of competition interact and influence weed growth and crop productivity at different levels of soil fertility (Zarzecka *et al.*2016).

The most dangerous period of competition between the weeds and the crop is at the beginning of the season, which requires controlling the weeds during this period, and this competition reduces the possibility of the crop obtaining the elements necessary for growth and thus affects productivity (Abdallah *et al.*2021). GeiseI (2004) indicates that the period of competition between the weeds and the potato starts from the date of planting until the crop grows above the surface of the soil, i.e., a period of 6 to 7 weeks, as the weed that appears later after this period will not be harmful as long as the potato crop plants appear in abundance (Bongaarts 2021). Note that potatoes appear above the surface of the ground 15-30 days after planting, and this creates competition in favor of the crop, which is considered one of the appropriate solutions to avoid competition between them (Sabzi *et al.*2018).

The weeds often pose a serious problem in the potato crop; despite the crop being distinguished by a strong and fast-growing vegetative group, it turns into a weak competitor with the weeds for nutrients, space, light, and moisture. Moreover, it is considered a host for many insects and plant pathogens, and the most common types of weeds spread in potato fields are narrow-leaved weeds such as *Cyperus rotundus*, *Phalaris minor*, *Spergula arvensis*, *Polypogon monspeliensis*, *Rumex dentatus*, *Avena fatua*, *Hordium spontaneum*, and *Cynodon dactylon*. In addition to broad-leaved weeds such as *Medicago polymorpha*, *Chenopodium album*, *Convolvulus arvensis*, and *Anagallis arvensis* (Gupta *et al.*2019).

2.6 Weed Control

Weed control is an important process in changing the ecosystem, creating ideal conditions for agricultural development, stabilizing the economic production of agricultural products, and increasing their productivity. Here, the idea of complete eradication of the weeds must be avoided because the possibility of getting rid of the weeds completely is difficult to achieve, knowing that the complete removal of harmful weeds can cause problems for other pests such as insects that consider the weeds a host to complete their life cycle (Chacko *et al.* 2021).

2.7 Methods of Weed Control

The weeds reduce crop productivity by 45%-95%, as well as its quality, and increase production costs as they host insects and plant pathogens as a shelter to complete their life cycle, which increases the need for and costs of controlling them. Weed management may include different methods. The decision of the method to be used depends on the environmental conditions, available labor, and number of weeds, so treatment must be done using the integration of different control methods (Attri *et al.* 2022). There are many ways to control the weeds, and they are classified according to their importance and use as follows:

2.8 Use of Chemical Herbicides

That is through the use of chemicals to control weeds, and the chemicals used for this purpose are divided according to the nature of the herbicide's action and methods of application into main sections. The chemical herbicides used to control weeds, including what is considered a non-selective for plants, kill any plant on which this herbicide is applied. Some of them are specialized in their effect (selective) so that they kill a specific type of plant (the weeds) and do not harm the other type (the crop) (Yadav *et al.*2015). The idea of using chemical herbicides in weed control is not new; for more than a century, some chemicals have been used to control weeds on railways and public roads, including copper salts, petroleum, sulfuric acid, and others, which are non-specialized substances (non-selective) that kill all plants without discrimination. Therefore, researchers began, in 1900, to search for chemicals that have an optional character and specialize in the extermination of some plants but not others. Nowadays, there are several herbicides that specialize in controlling a particular group of weed plants (Kalkhoran *et al.*2021). Chemical weed herbicides are the latest research findings for effective means of weed control, and if these compounds are used correctly, they give guaranteed results. It is considered one of the most effective means of controlling the various types of weeds, whether it is with agricultural crops, on irrigation channels, drainage, and roadsides, or in agricultural lands such as airports, oil fields, and factories (Belirlenmesi 2020).

2.9 The Importance of Chemical Control and Its Impact on the Potato Crop

Chemical control is one of the main and important methods of weed control, as the control allows to reduce the number of times the manual hoeing process is done during cultivation, and even dispensing with it sometimes, for example, a study was conducted by a number of researchers in Egypt to find out how to compare the effect of metribuzin with the process of hoeing and sawdust, the results showed the effectiveness of the herbicide in weed control and it reduced the density of the weeds and the control rate reached more than 90%, this was significantly reflected in an improvement in the growth parameters of potatoes and its components, and at a lower financial cost than the process of hoeing and sawdust (Abdallah, *et al.*2021). It is widely known that the losses caused by the weeds have exceeded the losses caused by other pests, as the losses in crop productivity were sometimes estimated without controlling the weeds to be about 43%.

2.10 The Use of Metribuzin

This herbicide was known by the trade names Sencor and Vapcor, and it is a selective systemic herbicide used before planting, before germination, or after. It is used to control broad-leaved weeds and some Gramineae weeds in the fields of soybeans, potatoes, sugar cane, alfalfa, tomatoes, corn, and lentils (Ara *et al.*2016). It kills the weeds by interfering with the electron transfer process in the photosynthesis process (Al-Adil 2006).

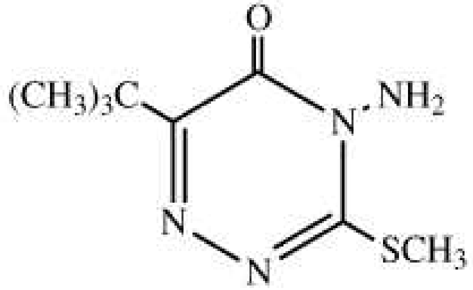

Figure 2.1 The structure of the active ingredient of metribuzin

2.10.1 Effect of metribuzin on the total weed density and dry weight

The characteristics of dry weight and total weed density are good indicators for measuring the percentage of weed control and determining the efficiency and effectiveness of the herbicide; that is, they give a clear indication of the ability of competition between the crop and weeds to extract growth requirements and the reflection of this competition on the ability to accumulate dry matter (Minin *et al.*2020). It is noticed from the studies and research that were conducted that all herbicide treatments have reduced the dry weight of the weeds and inhibited the accumulation of dry matter in them in different proportions, and that this allows the crop to grow without stress, which is the competition for different growth requirements. The reason for the decrease in dry weight of the weeds was attributed to the effect of the herbicide in reducing the accumulation of dry matter (Al-Naqeeb *et al.*2010).

Habib *et al.* (1989) showed that the use of metribuzin at a rate of 0.75 kg active ingredient per ha before potato germination was effective in controlling broad and narrow-leaved weeds. The number of weeds that were counted after 6 weeks of germination decreased significantly in the herbicide treatment compared to the weedy treatment, and it gave a density of 3 plants per m^2 compared to 38 plants per m^2 for the weedy treatment. This was reflected in its dry weight, which gave a weight of 24.4 g/m^2 compared to 95.5 g/m^2 in the weedy treatment. In an experiment in which metribuzin was used at a concentration of 1 kg of active ingredient/ha for the 2011 and 2012 seasons, it reduced the number of weeds of *Plantago major, Polygonum alatum,* and *Oxalis corniculata* as broad-leaved weeds and *Cyperus cyperoides, Imperata cylindrica,* and *Digitaria adscendens* as narrow-leaved weeds in potato fields after 90 days from planting. The weed's density was 12.8 and 12.0 plants per m^2, respectively, and the control rate was 66.8 and 66.9%, respectively, while it reached 28 and 27.5 plants per m^2 in the weedy treatment, and it was reflected in their dry weight, which gave a weight of 8.4 and 8.2 g/m^2, respectively, compared with 14.6 and 14.1 g/m^2 in the weedy treatment (Yadav *et al.*2015).

Mishra and Jamliya (2018) found that using metribuzin herbicide at a rate of 0.350 and 0.525 active substances per kg/ha to control weeds in the soybean crop *Glycine max* L. had a significant effect on reducing the dry weight of the weeds Echinochloa crusgalli, *Parthenium hysterophorous*, and *Celotia argentia* after harvest. It gave a weight of 149.8 and 141.9 kg ha1, respectively, compared with 470.2 kg ha1 in the weedy treatment. Treating with herbicide Sencor 70 WG at a rate of 1 kg/ha before potato germination reduced the number of companion weeds, *Echinochloa crus-galli, Chenopodium album, Stellaria media, Lycopsis arvensis,* and *Viola arvensis*, which reached a density of 19.2 plants m^2 and achieved a minimum dry weight of 76.6 g m^2 before harvesting the tubers. While the control treatment recorded the highest number density of 46 plants per m^2 and a dry weight of 236.7 g per m^2 (Barbaś and Sawicka, 2020). Bankoti *et al.* (2021) mentioned the importance of controlling *Cyperus rotundus, Eleusine indica, Digitaria sanguinalis, Medicago denticulata, Chenopodium album,* and *Amaranthus virdis* spread in potato fields and their effect on the control rate and its dry weight when treated with Metribuzin at a rate of 350 g/ha after germination. It gave a control ratio of 46.42% and 43.28% for the narrow and broad leaf weeds at the harvest period, respectively, and this reflected on its dry weights, which amounted to 9.90 and 12.70 g/m^2 compared to the weedy treatment of 18.60 and 22.30 g per m^2, respectively. Shafiq and Kaur (2021) also found that the use of metribuzin at a rate of 350 g/ha before germination in the potato crop gave a controlled rate after 21 days of treatment of 74% for *Rumex dentatus*, 45% for *Eleusine indica,* and 30% for *Cyperus rotundus*, while it gave 100% to the weeds *Coronopus didymus*, *Medicago denticulate,* and *Anagallis arvensis*. While the dry weights after 60 days of treatment were 28.9 g/m^2 compared with 81.1 g/m^2 of the weedy treatment

2.10.2 Effect of metribuzin on some vegetative traits

The vegetative characteristics of the plant are greatly affected by the external factors surrounding it and affecting the vegetative growth, so the weeds compete with the main plant for the growth requirements, whose deficiency leads to a decrease in the rate of photosynthesis, which reduces the plant height, the number of leaves of the plant, the total dry weight of the vegetative, and the chlorophyll. The growth of any crop requires complex functional processes that may be related to the nature of the surrounding environmental factors during its different stages of growth, such as temperature, humidity, light, and nutrients (Ahlqvist and Ahlqvist 2019).

It was mentioned by Shehata *et al.* (2019) in a study conducted for two seasons in the Arab Republic of Egypt when Metribuzin was used at a rate of 714 g/ha before germination of the potato crop when controlling the most prevalent broad-leaved weeds, namely *Medicago hispida, Chenopodium album* L., *Emex spinosa* (L.), and *Sisymbrium irio,* and the only narrow-leaf Phalaris minor found in the experimental field, which gave a controlled rate of 100%, which was positively reflected in the improvement of some vegetative characteristics, including plant height, number of stems, and total wet and dry weight of the vegetative, which gave 45 cm and 4.4 stems per plant and 158.1 g and 16.2 g, respectively, compared to 40 cm and 3.3 stems per plant and 102.9 g and 8.9 g, respectively, in the weedy treatment.

Sharmu *et al.* (2021) also found that the weeds *Cyperus rotundus, Eleusine indica, Digitaria sanguinalis, Medicago denticulata, Chenopodium album,* and *Amaranthus virdis* spread in potato fields when treated with metribuzin at a rate of 350 g/ha after germination. It gave plant height and a number of potato leaves of 299.3 cm and 25.9 leaves per m^2 after 60 days of treatment and 37 cm and 316 leaves per m^2 at harvest, compared with 25.3 cm, 32.1 cm, 277.3 leaves per m^2, and 297 leaves per m^2 in the weedy treatment, respectively. The control of the weeds of *Chenopodium album, Sisymbrium irio, Coronopus* sp., *Cichorium pamilum, Malva parviflora,* and *Sonchus oleraceus* accompanying the potato crop using Metribuzin herbicide at a rate of 504 g/ha achieved a controlled rate of 100%. As well as an increase in the improvement of some characteristics of vegetative growth, including the characteristics of plant height, the number of stems, and the wet and dry weight of the vegetative system with 84.3 cm, 7 stems per plant, 512.6 g, and 65.6 g, respectively, compared with 50.8 cm, 3.3 stems per plant, 116 g, and 22.01 g, respectively, in the weedy treatment (El- Abdallah, *et al.*2021).

Shafiq and Kaur (2021) showed that the herbicide metribuzin was very effective at getting rid of the weeds Rumex dentatus, Eleusine indica, Cyperus rotundus, Coronopus didymus, Medicago denticulate, and Anagallis arvensis. The herbicide was used at a rate of 350 g/ha before the potato seedlings sprouted, which caused the plants to grow taller and have more leaves.

2.10.3 Effect of metribuzin on some chemical properties

Many studies and research have confirmed the importance of the effect of metribuzin in controlling weeds and its reflection on some chemical characteristics due to its effectiveness and speed of effect. Sharshar et al. (2015) say that in a study done in the Arab Republic of Egypt during the 2011–2012 season, the herbicide metribuzin was used after 5% emergence of the potato crop and at a rate of 300 g/fed. After 80 days of treatment, it gave 6.77 mg/g of chlorophyll and 22% of dry matter, while the weedy treatment only gave 3.95 mg/g of chlorophyll and 18% of dry matter. Shehata et al. (2019) also mentioned in a study conducted in 2016 and 2017 when metribuzin was used at a rate of 714 g/ha in controlling potato weeds. It achieved a significant increase in the percentage of total soluble sugars (TSS) and the percentage of chlorophyll, as the herbicide treatment gave 1.6% TSS and the percentage of chlorophyll was 1.094 mg/g, compared with the weedy treatment's 1.0% and 0.702 mg/g, respectively. After the use of Sencor 70 WG herbicide at a rate of 2 kg/ha before emergence to monitor the effect of the herbicide on some chemical characteristics of two potato cultivars, Irga and Balbina, it was found that there was a decrease in the percentage of total sugars and the percentage of reduction in sugars in the weedy treatment, which gave an average of 0.652% and 0.351%, respectively. While the percentage increased with weed control by the herbicide and gave 0.652% and 0.353%, respectively. There were no significant differences between the two cultivars for all studied traits (Zarzecka *et al.*2017). El-Abdallah *et al.* (2021) pointed out that the weed control accompanying the potato crop using Metribuzin herbicide at a rate of 504 g/ha achieved a significant effect on the percentage of dry matter of the potato crop and gave a percentage of 36.8% compared with 37.02% in the weedy treatment. This was reflected in the percentage of total chlorophyll in the herbicide treatment, which gave 0.36 mg/g, while the control treatment gave 0.30 mg/g.

2.10.4 Effect of metribuzin on the total yield and its components

Weed control is a basic and necessary process to reduce the negative effects of its competition with the potato crop and then achieve a high yield and a high degree of quality. The losses of the potato crop affected by the weed competition for its plant needs range from 13-85% depending on the weed density and types, especially at the beginning of its growth, as it is sensitive to the weed because of its competition for the necessary requirements for growth (Carvalho *et al.*2007). The results of Habib *et al.* (1989) indicated that the use of metribuzin at a rate of 0.75 kg active substance per ha was effective in controlling the weeds of *Chenopodium album* L., *Chenopodium murale* L., *Scorpiorus muricatus* L., L. *malva parvifllora, Convolvulus arvensis* L., and *Cyperus rotundus* L. Before potato germination, it led to a significant increase in the production of tubers, as it gave a yield of 16.31 tons per ha, compared to 11.1 tons per ha of the incubated treatment. In an experiment in which Metribuzin was used at a concentration of 1 kg of active ingredient per ha for the 2011 and 2012 seasons to control Plantago major, *Polygonum alatum, Oxalis corniculata, Cyperus cyperoides, Imperata cylindrica,* and *Digitaria adscendens* in the potato field after 90 days of planting, it gave an average yield of 26.8 tons per hectare for the two seasons of the experiment treated with the herbicide, compared to 18.1 tons per hectare in the weedy treatment (Yadav *et al.*2015).

Shehata et al. (2019) also showed that metribuzin, when used at a rate of 714 g per ha in 2016 and 2017, was effective at getting rid of the weeds M*edicago hispida, Chenopodium album L., Emex spinosa (L.), Sisymbrium irio,* and *Phalaris minor* that grew in the field of experiments before the potato crop sprouted. It achieved a significant increase in the rate of fresh weight of the tuber and the number of tuber plants, and it gave a mean of 575.9 g and 8 tuber plants, respectively, compared to 316.4 g and 5.1 tuber plants, respectively, in the weedy treatment. This was reflected in the total yield, which was 33.8 tons per hectare for the herbicide treatment, while the control treatment gave a yield of 17.9 tons per hectare. The use of Sencor 70 WG herbicide at a rate of 1 kg commercial substance per ha after germination and 0.5 kg per ha before emergence to control the weeds *Echinochloa crus-galli, Chenopodium album, Stellaria media, Lycopsis arvensis,* and *Viola arvensis* associated with the potato crop This led to a significant increase in the total yield of 28.2 and 32.5 tons per ha, respectively, while the weedy treatment gave a yield of 27.4 per ha (Barba and Sawicka, 2020). The control of the weeds of *Chenopodium album, Sisymbrium irio, Coronopus* sp., *Cichorium pamilum, Malva parviflora,* and *Sonchus oleraceus* accompanying the potato crop using Metribuzin herbicide at a rate of 504 g per ha achieved a significant increase in the growth and yield of the potato crop. It gave 20 tubers and 75.7 g per plant for the number of tubers and their average weight, respectively, compared to 5 tubers and 25.2 g per plant in the weedy treatment, and this was reflected in the total yield, which gave 36.9 tons per ha for the herbicide treatment, while the control treatment gave a yield of 8.4 tons per ha (El- Abdallah, *et al.*2021).

Shafiq and Kaur (2021) also found that the use of metribuzin at a rate of 350 g per ha was efficient in controlling the weeds *Rumex dentatus, Eleusine indica, Cyperus rotundus, Coronopus didymus, Medicago denticulate,* and *Anagallis arvensis* accompanying the potato crop before its germination, which led to an increase in the yield of potatoes to 21.7 tons per ha compared to the weedy treatment of 14.6 tons per ha.

2.11 Hoeing

The process of uprooting by hand or using some machines is useful and effective in order to get rid of the weeds in the crop fields. This is still a common method of controlling weeds in many countries, despite the high cost and scarcity of labor. In addition to the problems of using herbicides, including environmental pollution and a reduction in the quality of treated crops (Shehata *et al.*2019). The process of uprooting is very successful for controlling annual and biennial weeds, as this method does not leave a trace of the roots in the soil and they cannot grow again, but in the case of perennial weeds, the method of uprooting is completely ineffective because the process of uprooting these plants does not eradicate all the plant residues in the soil. There is a possibility that parts of it will remain in the ground, and after a while, it will grow again. In order to eliminate it, the uprooting process must be repeated several times (Al-Gburi 2018). With regard to the potato crop, the hoeing process is carried out for two main purposes: to get rid of the weeds and to fill in the backfill around the plants. The most important thing that must be taken into account when hoeing is that the axe or the mechanical hoe must be away from the plants and that this distance increases with the age of the plants, and usually two or three hoeings are sufficient for annual and perennial weeds because a lot of hoeing helps to increase the spread of viral infections in the field. Hoeing must stop when the ground is free of weeds or when the plants are large in size so as not to damage the roots and vegetative growth. Also, the frequent passage of tractors leads to the compaction of the surface soil in the case of mechanical hoeing (Melander and McCollough 2021). Whereas for the perennial weeds, the hoeing process must be repeated several times during one season, after 2-3 weeks of the plants regaining their growth, in order to deplete the nutrients stored in their parts under the soil, as is the case with the weeds *Imperata cylindrica* and the wild reeds *Phragmitis australis*. It is a successful method of controlling perennial weeds because of the availability of cheap labor (Shehata et al.2019).

2.11.1 Effect of hoeing on the total density and dry weight of weeds

Many studies and research conducted confirmed the importance of the hoeing method in weed control for its effectiveness and speed of impact on the total density and dry weight of the weeds. This allows the potato crop to grow without stress. Sharshar *et al.* (2015) found in a study conducted in the Arab Republic of Egypt during the 2011-2012 season using 2 and 3 hoes that it was efficient and effective in controlling the weeds scattered in the potato fields after 60 and 90 days of planting. It significantly affected the fresh weight of the weeds and gave a weight of 84.9 and 131.1 g per m^2 after 60 days and 197.2 and 71.8 g per m^2 after 90 days, compared to 747.5 and 1629.5 g per m^2 in the weedy treatment, respectively. It was also found that the use of two hoes after 20 and 40 days of germination during the seasons of 2011 and 2012 led to a reduction in the total number of weeds (*Plantago major, Polygonum alatum, Oxalis corniculata,* *Cyperus cyperoides, Imperata cylindrica,* and *Digitaria adscendens)* that were diagnosed in the potato field after 90 days from planting. The weed density was 17.3 and 16.6 plants per m2, respectively, while it reached 28 and 27.5 plants per m^2 in the weedy treatment, and it was reflected on their dry weight, giving a weight of 8.9 and 8.6 g per m^2, respectively, compared with 14.6 and 14.1 g per m^2 in the weedy treatment (Yadav *et al.*2015).

Shehata *et al.* (2019) also showed in a study that two hoes were used during the season, which were efficient and effective in controlling the broad and narrow-leaved weeds such as *Medicago hispida, Chenopodium album* L., *Emex spinosa* (L.), *Sisymbrium irio, and Phalaris minor* scattered in the potato field. This significantly affected the relative efficiency of the control compared to the weedy treatment, and gave a controlled rate of 100%. The use of two hoes during the season was efficient and effective in controlling narrow and broad-leaved weeds when harvesting potatoes, as it significantly affected the dry weight of weeds for an area of one square meter and gave a weight of 20.84 and 24.10 g per m^2 for narrow leafweeds and broad-leaved, respectively, compared with 115.82 and 129.72 g per m^2 in the weedy treatment (El-Metwally and El-Wakeel 2019).

In an experiment carried out by Al-rajbo *et al*. (2022), it was found that the total density of weeds and the percentage of its control when conducting the first hoeing to control weeds accompanying the potato crop were 170.6 plants per m^2 and 92.1%, respectively, when the germination of 50% of the potato, 61.8 plants per m^2, and 97.4% when the germination of 100% of the potato crop compared with the weedy treatment. One hoeing of the weeds of *Chenopodium album, Sisymbrium irio, Coronopus* sp., *Cichorium pamilum, Malva parviflora,* and *Sonchus oleraceus* accompanying the potato crop two weeks after germination achieved a controlled rate of 72% compared to 100% of the treatments sprayed with chemical herbicides (El- Abdallah *et al.*2021).

The hoeing process to control the weeds *Chenopodium album, Sisymbrium irio, Coronopus* sp., *Cichorium pamilum, Malva parviflora, Sonchus oleraceus, Avena fatua, and Lolium* sp. spread within the potato crop gave a controlled rate of 72% for broad-leaved weeds and 59.1% for narrow-leaved compared with 97.5% and 95.1% when treated with Clomazone herbicide used at a rate of 1152 g active substance per ha (El-Ganain *et al.*2022).

2.11.2 Effect of hoeing on some vegetative traits

The weeds compete with the crops planted with them in the same space for nutrients, water, and light, and when the weeds are left without control, it will lead to a decrease in their production in quantity and quality. Therefore, it must be controlled because the growth of the weeds and their survival with potato plants lead to a decrease in the number of leaves, plant height, number of stems, and chlorophyll content through their competition. For the crop to obtain the necessary growth requirements for photosynthesis (Shehata *et al*, 2019).

Sharshar *et al. (*2015 found that in a study conducted in the Arab Republic of Egypt during the 2011–2012 season, using 2 and 3 hoes during the season was efficient and effective in controlling the weeds scattered in the potato fields. It significantly affected the height of the plant and the number of stems and gave 27.5 cm and 2.3 stems per plant, respectively, when performing the two hoeings and 27.3 cm and 2.3 stems per plant, respectively, when three hoeings were done, compared to 22.3 cm and 1 stem per plant in the weedy treatment.

El-Metwally and El-Wakeel (2019) also indicated that the use of two hoes during the season was efficient and effective in controlling the weeds with narrow and broad leaves, as it achieved a significant increase in plant height and an average number of leaves for the potato crop when harvesting the potato crop and gave 51.21 cm and 28.19 leaves per plant, respectively, compared with 44.31 cm and 20.13 leaves per plant in the weedy treatment. The use of two hoes during the season was efficient and effective in controlling the weeds *Medicago hispida, Chenopodium album* L., *Emex spinosa* (L.), *Sisymbrium irio, and Phalaris minor that* spread in the potato crop field. It significantly affected the improvement of vegetative characteristics, including plant height, number of stems, and wet and dry weight of the vegetative system compared to the weedy treatment after 75 days of planting, and it gave 45.4 cm and 4.7 stems per plant, 166.3 g and 14.3 g, respectively, compared to 40 cm and 3.3 stems per plant and 102.9 g and 8.9 g, respectively (Shehata et al, 2019).

The process of hoeing to control the broad and narrow leaves accompanying the potato crop gave a significant increase in some vegetative characteristics of the crop, including plant height, fresh and dry weight of the vegetative parts, and the number of stems per plant: 73.5 cm, 330.16 g, 51.37 g, and 6.3 stems per plant, respectively, compared with 50.8 cm, 116.02 g, 22.08 g, and 3.3 stems per plant, respectively, in the weedy treatment (El-Ganain *et al.*2022).

2.11.3 Effect of hoeing on some chemical properties

Sharshar et al. (2015) found that in a study conducted during the 2011-2012 season, using 2 and 3 hoes during the season was efficient and effective in controlling the weeds spread in potato fields, as it significantly affected the percentage of chlorophyll compared to the weedy treatment after 80 days of treatments. It gave 6.55 and 6.32 mg per g, respectively, for chlorophyll after 2 and 3 hoeing, and 19 and 19% as percentages of dry matter, compared with 3.95 mg per g and 18% in the weedy treatment.

Also, Shehata *et al.* (2019) showed in a study that two hoes were used during the season, which were efficient and effective in controlling the broad-leaved and narrow-leaved weeds such as *Medicago hispida, Chenopodium album* L., *Emex spinosa* (L.), *Sisymbrium irio, and Phalaris minor* scattered in the potato field. It achieved a significant increase in the percentage of total soluble sugars (TSS) and the percentage of chlorophyll, which gave 1.5% TSS and a chlorophyll content of 1.047 mg per g compared with the weedy treatment of 1.0% and 0.702 mg per g, respectively. The control of the weeds of *Chenopodium album, Sisymbrium irio, Coronopus* sp., *Cichorium pamilum, Malva parviflora,* and *Sonchus oleraceus* associated with the potato crop using one hoeing had a significant effect on the percentage of dry matter and chlorophyll content of the potato crop, which gave 36.78% and 0.44 mg per g, respectively, compared to the control treatment, which gave 37.02% and 0.30 mg per g, respectively (El-Abdallah, *et al.*2021).

The process of hoeing to control the broad and narrow-leaf weeds accompanying the potato crop gave a significant increase in some chemical characteristics of the crop, including the chlorophyll content, carotenoids, starch, and total sugars, as it gave 0.29%, 0.049%, 26%, and 17 mg per g, respectively, compared with 0.16%, 0.054%, 12%, and 8 mg per g, respectively, in the weedy treatment (El-Ganain *et al.*2022).

2.11.4 Effect of hoeing on the total yield and its components

Several studies and research have indicated that weeds cause a percentage of yield losses, and these percentages vary depending on the density of the growing weeds with the crop. Uremis *et al*. (2009) found a significant effect when treated with a weed hoe twice during the potato season. Compared with the weedy treatment, an increase in potato tuber yield reached 22.85 tons per ha compared to 16.66 tons per ha in the control treatment.

Sharshar *et al*. (2015) also found in a study conducted during the 2011-2012 season using 2 and 3 hoes during the season that they were efficient and effective in controlling potato weeds, as they significantly affected the improvement in some characteristics of the yield components, including the number of tubers per plant and tuber weight compared to with the weedy treatment after 80 days of the treatment, and it gave 6.5 tubers per plant and 6.32 g when making two hoes during the season, 8.5 tubers per plant and 111.6 g when making three hoes during the season, compared with 5.25 tubers per plant and 84.1 g, respectively, in the weedy treatment. It was positively reflected in the yield of potato tubers, and the two hoeing treatments gave a yield of 12.9 tons per feddan and 12.6 tons per feddan for three hoeings, while the control treatment gave a yield of 6.8 tons per feddan.

In a study, it was shown that when using two hoes during the season, they had good efficiency against the weed control plants *Medicago hispida, Chenopodium album* L., *Emex spinosa* (L.), *Sisymbrium irio, and Phalaris minor* accompanying potatoes. It achieved a significant increase in the components of potato yield represented by the number of tubers per plant and the fresh weight of the tuber, and it gave 8.4 tubers per plant and 613.6 g compared to 5.1 tubers per plant and 316.4 g, respectively, in the control treatment. This was reflected in the yield of potatoes, and the hoeing treatment gave a yield of 37.6 tons per hectare, compared to 17.9 tons per hectare in the weedy treatment (Shehata *et al.*2019). El-Metwally and El-Wakeel (2019) also showed that the use of two hoes during the season was efficient and effective in controlling narrow and broad-leaved leaves, as it obtained a significant increase in the components of potato yield represented by the average tuber weight, tuber diameter, and tuber length, as it gave 181 g, 7.20 cm, and 12.3 cm, versus 145.7 g, 5.65 cm, and 9 cm, respectively, in the weedy treatment, and this reflected positively in the yield, as the yield of tubers with the hoeing treatment amounted to 39 tons per ha compared to 24.25 tons per ha in the control treatment.

The control of the weeds of *Chenopodium album, Sisymbrium irio, Coronopus* sp., *Cichorium pamilum, Malva parviflora,* and *Sonchus oleraceus* associated with the potato crop using one hoe had a significant effect on increasing the components of the potato yield. The length of the tuber was 72.6 mm, the diameter of the tuber was 64.7 mm, the tuber weight was 98.1 g, and the number of tubers per plant was 12.25 tubers per plant, while the control treatment gave 66.4 mm, 43.2 mm, 25.2 g, and 5 tubers per plant, respectively, and it was positively reflected in the yield of potato tubers. The hoeing treatment gave 33.3 tons per ha compared to 8.4 tons per ha in the weedy treatment (El-Abdallah *et al.*2021). The process of hoeing to control weed spread in the potato crop field achieved a significant increase in the components of the potato yield, including tuber weight and the number of tubers per plant: 39.1 g, 12.25 tubers per plant, compared with 25.2 g, 5.0 tubers per plant in the weed treatment. This was reflected in the total yield of the crop, and the hoeing treatment gave a yield of 33.3 tons per ha, in contrast to 8.4 tons per ha in the control treatment (El-Ganain *et.al*., 2022).

2.12 Mulching with Black Plastic

Covering the soil with black plastic (mulching) is one of the most important agricultural operations, as it limits the growth of the weeds that compete with the main crop for water, minerals, and sunlight. It also maintains the necessary moisture and prevents it from leaking into the outside atmosphere through evaporation (Amare and Desta 2021). Black plastic is also used to block light and sterilize the soil, as the plastic cover is effective in reducing weed growth and works to homogenize the ground moisture under the cover, as well as make the salts move towards the edges of the cover when salinity rises (Pathak and Singh 2021). Cover can have various beneficial effects on the cropping system, such as increasing soil nutrient content and suppressing harmful weeds, and mulching is an option available for safe control of the weeds. It has many advantages, such as accelerating growth that leads to early maturity and enhancing vegetative growth in the potato crop. The mechanism of the effect of the plastic cover on the growth of the weeds is by preventing the formation of aerial roots on the stems of plants above the soil surface, as these roots increase the size of the root system at the expense of the floral and fruiting systems, which affects the amount of the total yield per plant. This is due to the efficient consumption of nitrates formed from the liberation of nitrogen oxide gases resulting from the oxidation of nitrogen fertilizer under the plastic. The first experiments were carried out using black plastic to cover the soil (mulching) in one of the research centers in Germany in 1933, where it was used to cover the soil before planting it with the potato crop (Albadree *et al.*2016).

2.12.1 The effect of mulching on the total weed density and its dry weight

Many studies have confirmed the importance of weed control by using different methods, including the mulching method for its effectiveness and speed of impact on the weeds, as it reduces the density of the weeds and inhibits their dry weight. Khan *et al.* (2008) found that the use of mulching with plastic covers was effective in controlling the weeds of album *Chenopodium*, *Amaranthus viridis*, *Cyperus rotundus*, and *Eleusine indica* associated with potato crops during the 2006-2007 season after 90 days of planting and gave a control ratio of 31% by reducing the total density of the weeds by 15.9 plants per m^2 and its reflection on their dry weight of 31.86 g/m^2. While it increased to 19.30 plants per m2 and 38.27 g/m^2 in the weedy treatment, respectively. According to Diyanat and Baziar (2020), during the 2015 growing season, the use of black plastic significantly reduced the total weed density (18.66 plants per m^2) and their dry weight (3.8 g/m^2), as determined within the cultivation of Valeriana officinalis L.

after 30 days of use, and 8.97 plants per m^2 and 4.5 g/m^2 at harvest. Whereas, the control treatment gave a total weed density of 23.59 plants per m^2 and a dry weight of 9.25 g/m^2 after 30 days and 66.93 plants per m^2 and 14.25 g/m^2 at harvest. The use of different types of mulching to control the narrow and broad-leaved weeds accompanying the potato crop, including black plastic covers, rice straw covers, and guava leaves, proved their efficiency in controlling the weeds after 70 days of planting potatoes by reducing their dry weight. The plastic sheets outperformed the other types used and gave a dry weight of 3.69 g/m^2 compared to 18.67 and 11.54 g/m^2 of covers with rice straw and guava plants, respectively, whereas all types of mulching outperformed the control treatment by 117.29 g/m^2 (El-Metwally and El-Wakeel 2019).

As explained by Dvořák and Král (2019), when applying two types of covers to control the weeds spread within the potato crop, which are plastic covers and covers from weed residues in different proportions: *Dactylis glomerata* (5%), *Festuca pratensis* (40%), *Lolium perenne* (20%), *Poa pratensis* (20%), and *Alopecurus pratensis* (10%), the mulching with plastic covers outperformed by reducing the dry weight of the weeds on the mulching with weed residue, and it gave 7.31 g/m^2 compared with 31.6 g/m^2, while the quality of the covers exceeded that of the weedy treatment (175.94 g/m^2).

Shehata *et al.* (2019) also indicated the effective effect of using different types and colors of covers in controlling the weeds of *Medicago hispida*, *Chenopodium album* L., *Emex spinosa* (L.), *Sisymbrium irio, and Phalaris minor* spread in the potato field. The covers used achieved relative efficiency in weed control after 90 days of planting. The black cover of the plastic gave a relative efficiency of 98.1%, the white cover 89.6%, the blue cover 83.7%, and the rice straw cover 90.4%, and it was found that all types of covers used were efficient and effective compared to the weedy treatment.

Gupta *et al*. (2019) found that when using different cover colors and straw to control the weeds diagnosed in the experimental site of potato crop *Phalaris minor* L., *Spergula arvensis* L., *Cynodon dactylon* L., *Rumax dentatus* L., *Hordium spontaneum*, *Chenopodium album* L., and *Convolvulus arvensis* L. after 60 days of cultivation, it reduced the percentage of weed density to 48.11%, 57.73%, and 61.26% for white and black plastic covers and straw coverage, respectively, and this reflected on the percentage of decrease in their dry weight, which gave 45.83%, 46.61%, and 20.30%, respectively.

2.12.2 The effect of mulching on some vegetative characteristics

The use of plastic types is one of the important factors in increasing the vegetative characteristics of the potato crop, as its increase causes an increase in its nutritional content and an improvement in the productive characteristics of the plant. Metwally and El-Wakeel (2019) found the use of different types of covers to control weeds accompanying the potato crop, including covers with black plastic and covers with rice and wheat residues. It proved its efficiency in weed control by improving some vegetative characteristics, including plant height and number of leaves per plant, and these types of covers outperformed the control treatment. The height and number of leaves of the plant were 56.16 cm and 31.11 leaves per plant for using black plastic, respectively, and 50 cm and 28.15 leaves per plant for covering rice waste and 54.45 cm and 28.15 leaves per plant for wheat waste, compared with 44.31 cm and 20.13 leaves per plant for weedy treatment. This was reflected in the total dry weight of the potato plant, giving a weight of 30.90, 25.07, and 29.21 g/m^2, respectively.

Shehata *et al.* (2019) also indicated the effective effect of using different types and colors of covers in controlling the weeds that existed in the potato crop field, as the covers used achieved improvement in some vegetative characteristics, and the black plastic cover gave 51.5 cm height of the plant and 204.5 g and 20.1 g for the wet and dry weight of the shoot, respectively, and 4.8 stems per plant, while the white cover gave 46.8 cm, 171.4 g, 17.8 g, and 4.7 stems per plant, respectively. Whereas, the vegetative characteristics of the blue cover were 54.4 cm, 164.6 g, 14.4 g, and 4.7 stems per plant, respectively, and all cover colors were superior to the weedy treatment of 40 cm, 102.9 g, 8.9 g, and 3.3 stems per plant, respectively.

Bhatta *et al.* 2020 noted the efficiency of using different types and colors of covers for some vegetative characteristics of potato crops after 75 days of planting. The black plastic was 60.10 cm in height, 362.0 leaves for the experimental unit, and 13.46 mm in diameter of the stem, and the silver plastic was 61.55 cm in height, 394.7 leaves for the experimental unit, and 14.45 mm in diameter, respectively. While the white plastic gave 59.28 cm in height, 362.15 in the number of leaves per experimental unit, and 14.33 mm in stem diameter, all covering colors outperformed the weedy treatment by 55.20 cm, 229.45 in the number of leaves per experimental unit, and 12.24 mm, respectively. It was also found that covering with black plastic gave a height of 21.57 cm and 55.45 cm for potato plants after 75 days of planting, and silver coverings gave 21.57 cm and 41.0 leaves per plant, while it reached a height of 16.12 cm and 27.55 leaves per plant with covers with plant residues, while the weedy treatment gave 16.12 cm and 32.52 leaves per plant (Ghimire 2021).

Dinu *et al.* (2022) showed that the use of plastic covers affected the average root weight of the two potato cultivars, Pumpkin and Chestnut, which led to a decrease in weight to 260.4 and 348.7 g, respectively, in the control treatment (without covers), while the rate of the roots in the two potato cultivars was 294.5 and 370.2 g, respectively.

2.12.3 The effect of mulching on some chemical properties

Shehata *et al*. (2019) indicated the effectiveness of using different types and colors of mulch in controlling the weeds detected in the potato field. The mulching was used to improve some chemical properties, and the black plastic cover gave 1.137 chlorophyll, 1.3 TSS, and 5.43% for the percentage of total soluble sugars. While the white cover gave 1.042, 1.5 TSS, and 4.0%, respectively, while the blue cover gave 54.4 cm, 0.941, 1.6 TSS, and 4.52%, respectively, all the colors of the mulching outperformed the weedy treatment by 0.702, 1.0 TSS, and 3.65%. The use of different types of mulching to control the identified weeds in the potato crop field, including black plastic mulching and rice and wheat waste mulching, proved their efficiency by reducing the value of TSS and the percentage of total carbohydrates to 5.39 TSS and 71.35%, respectively, in the control treatment. While the plastic mulching gave 5.55 TSS and 82.11%, respectively, and the mulching with rice residues gave 5.67 TSS and 77.75 percent, and wheat waste gave 5.77 and 77.30 percent, respectively (Metwally and El-Wakeel, 2019). Dinu *et al*. (2022) also showed that the use of plastic mulching affected some of the chemical properties of two potato varieties, pumpkin and chestnut, as there was a decrease in TSS in the control treatment by 13.6%, while the value in the two potato varieties increased to 14.1% and 14.7%, respectively, as well as in the proportion of the amount of starch, as the ratio ranged between 13.7-14.6% in the control treatment and 14.3-16.0% for the two potato cultivars.

2.12.4 The effect of mulching on the total yield and its components

Black plastic plays an important role in the potato crop, as its use leads to an increase in the total yield, and its components provide appropriate conditions for plant growth and reduce weed competition for the crop. Khan *et al.* (2008) found that the use of plastic mulching was effective in controlling the weeds accompanying the potato crop during the 2006–2007 season, and it gave a total yield at harvest of 24.36 tons per ha. While it decreased in the weedy treatment to 13.30 tons per ha. Masud *et al. (2002)* also found that when using two types of plastic mulching, black and white, and a third type, mulching with weed residues within the potato crop, when the crop was harvested, the white plastic polyethene caused an increase in the yield of 60.45% and the black plastic of 49.04%, while the control treatment gave a percentage of 43.20%.

Dvořák and Král (2019) showed that when applying two types of mulching to control weeds spread within the potato crop, they are black plastic and plant residues. The plastic mulching outperformed by increasing the total yield to 36.43 tons per hectare; this was followed by the treatment of mulching with plant residues, with a yield of 35.82 tons per hectare, and the yield decreased to 32.62 tons per hectare in the control weedy treatment. The use of different types of mulching to control weeds accompanying the potato crop, including black plastic mulching and mulching with rice and wheat residues, proved their efficiency by improving some characteristics of the yield and its components, including the average tuber weight, tuber diameter, and total yield. These types of covers outperformed the control treatment and gave the tuber weight and tuber diameter amounts of 207.0 g and 8.42 cm for the use of black plastic, respectively, and 145.9 g and 6.20 cm for mulching with rice residues and 181.7 g and

8.12 cm for wheat residues, compared with 145.7 g and 5.65 cm for the weedy treatment (Metwally and El-Wakeel 2019).

The mulching used in controlling the potato weeds achieved this by improving the rate of tubers per plant and the total yield; the black plastic mulching gave 8.6 tubers per plant and 40.9 tons per ha, whereas the white mulching gave 7.7 tubers per plant and 36.7 tons per ha, respectively. While the blue mulching gave 7.8 tubers per plant and 40.5 tons per ha, respectively, and all mulching colors outperformed the weedy treatment by 5.1 tubers per plant and 17.9 tons per ha (Shehata et al. 2019).

Bhatta *et al.* (2020) noted that the use of different types and colors of mulching affected some components of the yield of potatoes, and black plastic gave 107.13 g of average tuber weight and 64.50 tubers per m^2 and 5.17 kg/m^2 plant yield per square meter,and silver plastic gave 105.55 g, 63.00 tubers per m2, and 5.67 kg/m^2, respectively,while white plastic gave 89.26 g, 68.25 tubers per m^2, and 5.48 kg/m^2, and that all the mulching colors outperformed the weedy treatment at 61.70 g, 56.0 tubers per m^2, and 4.15 kg/m^2, respectively. Mulching with black plastic gave 8.28 tubers per plant and a yield of 470.0 g per plant, and silver mulching gave 14.5 tubers per plant and 507.5 g, respectively. While mulching with plant residues gave 7.75 tubers per plant and 342.5 g yield per plant, the weedy treatment gave 5.70 tubers per plant and 257.5 g plant yield, respectively. Whereas the total yield was 39.17, 42.29, and 28.54 tons per hectare for black, silver, and plant residues, respectively, and the weedy treatment gave a yield of 21.46 tons per hectare (Ghimire 2021).

2.13 Integrated Weed Control of the Potato Crop

Agriculture all over the world has relied entirely on weed herbicides as the most effective weed control measure for decades. However, the long-term use of herbicides has had a negative impact on the environment and human health, while at the same time creating a global problem of herbicide resistance (Babalola *et al.*2021). Therefore, Europe has developed special laws and legislation for the use of herbicides and the approval of certain groups of herbicides for use in weed control, with the aim of producing healthy and safe food through the increasing change in the behavior and life of weed plants and the increase of tolerant species from them. Researchers' interest in that has increased recently, so there is an increasing awareness of the need to use new weed herbicides and to integrate different agricultural methods with those herbicides through the weed management system (Pavlović *et al.*2022).

In view of the large number of weed species and the great variation in the nature of their growth and reproduction, it is difficult to control them by adopting one method without resorting to the correct integration method between the means of control, taking into account all the biological characteristics, climate, and soil conditions (Yadav et al.2015). It is preferable to develop a long-term plan in the weed management program by using herbicides and physical control, with an emphasis on not repeating the use of the herbicide but rather the use of herbicides belonging to different groups in integration with the use of agricultural rotations (Ahlqvist 2019).

Integrated Weed Management (IWM) is defined as the use of multiple methods of weed control from the field with a group of effective methods of weed control, including preventive, agricultural, mechanical, chemical, and biological operations (Figure 2.2). The preventive method is defined as the contamination of the equipment used in the field with harmful weed seeds. Where agricultural equipment, manure, fodder, and crop seeds are the main sources for the spread of harmful weeds in the field. Weed control first begins with cleaning all equipment used in crop fields (Figure 2.3) (Korres et al. 2019).

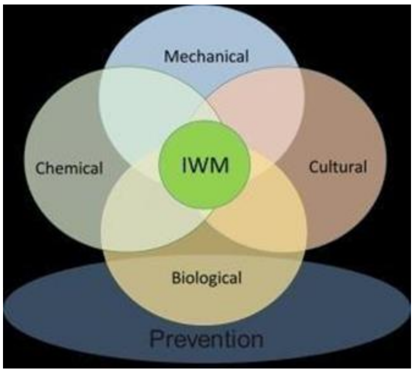

Figure 2.2 Integrated weed control methods

The optimal use of field agricultural operations is more effective than the control of chemical herbicides by making crop management decisions in the process of weed control, which helps the effectiveness of chemical weed control applications. The most important of these agricultural operations are the appropriate selection of row distance, the use of crop rotation, the selection of appropriate varieties, the appropriate planting date, and the use of mulching (Gupta *et al*. 2022).

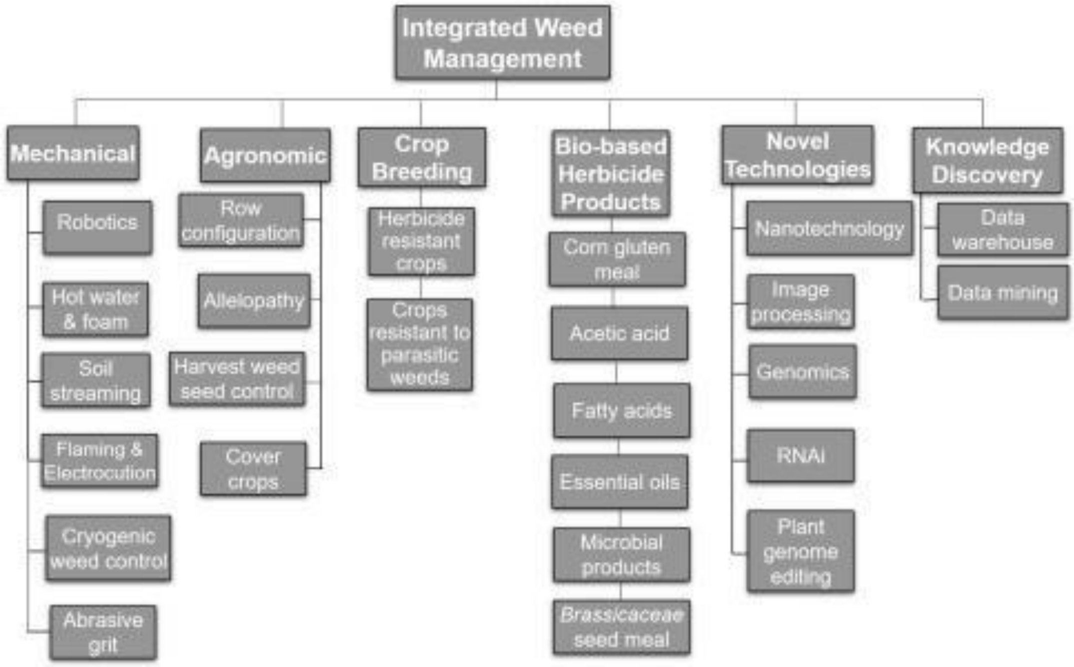

Figure 2.3 Components of Integrated Weed Management (IWM) (Korres *et al.*2019)

Some farmers complain that metribuzin is no longer satisfactory for weed control throughout the season; moreover, negative effects may occur on some potato varieties, and the poor efficiency of the herbicide can be attributed to weed resistance. Therefore, in order to achieve sustainable management of the weeds, the current use patterns of weed herbicides must be changed by adopting more sustainable methods of weed control, such as the integration of weed herbicides with mechanical practices, which in turn leads to effective weed control, yield production, and environmental preservation (Abdallah, Atia, *et al.*2021).

Studies indicate that field agricultural operations for weed control are the appropriate choice for integration with herbicides. Khan (2008) reported that using Ronstar herbicide after 7 days of planting, mulching with Water Hyacinth residues in addition to one hoeing after 25 days of planting, reduced the density of the weeds to 9.23 plants per m^2, and the control rate was 78% after 90 days of planting, were effective methods for controlling the weeds found in the potato field. While the treatment of mulching with one hoe only gave a weed density of 12.10 plants per m^2 and a controlled rate of 62%, This was reflected in the total yield of the crop, which was 29.58 tons per ha for the spraying treatment with mulching and hoeing and 27.88 tons per ha for the mulching treatment with one hoe, compared with 18.36 plants per m^2 and 13.30 tons per hectare for the weedy treatment.

Yadav *et al.* (2015) indicate that the use of metribuzin at a rate of 1 kg of active substance per ha alone or in combination with one hoeing after 20 days of planting was efficient in controlling potato weeds and had an impact on production by reducing weed density and dry weight. The herbicide treatment gave the weed density with one hoeing of 9.7 plants per m^2 and a dry weight of 8.9 g/m^2, and the herbicide alone was 12.5 plants per m^2 and 8.2 g/m^2, respectively. This was reflected positively in the yield, giving 25.9 tons per ha for the herbicide treatment with one hoeing and 25.8 tons per ha for the pesticide alone, while the weedy treatment gave 27.5 plants per m^2, 14.1 g/m^2, and 17.2 tons per ha, respectively. It was also found that the use of metribuzin at a rate of 500 g/ha in combination with one hoeing after 40 days of planting and mulching with wheat residues with one hoeing after 20 days of planting gave a weed reduction rate of 69.71% for the herbicide with one hoeing and 74.99% for the treatment of mulching with one hoeing; this is reflected in the percentage decrease in their dry weight, which amounted to 13.56% and 30.71%, respectively. This affected the total yield by giving 22.39 tons per hectare of the herbicide with one hoeing and 25.39 tons per hectare for mulching with hoeing, compared with the weedy treatment of 14.20 tons per hectare (Gupta *et al.* 2019).

Shafiq and Kaur (2021) showed that the efficiency of metribuzin herbicide used at a rate of 275 g/ha pre-emergence with paddy straw mulch was more effective in controlling the weeds associated with the potato crop than using the herbicide alone (350 g/ha). Through the indices of the percentage of weed control after 60 days of planting and at harvesting potatoes, which reached 93.7% and 90.0%, respectively, compared to herbicide use alone at 64.4% and 23.9%, respectively, and its reflection on the total production, 31.67 tons per hectare were produced when using the herbicide with mulching compared with 21.74 tons per hectare when using the herbicide alone.

3. MATERIALS and METHOD

3.1 Study Site

The experiment was carried out in one of the farms affiliated to Heet District - Anbar Governorate for the spring season of 2022 to study the efficiency of Metribuzin pesticide alone or in integration with some agricultural methods represented by mulching and hoeing in controlling potato weeds, in addition to the role of thefactors mentioned above in some vegetative and chemical characteristics of the potato crop yield.

3.2 Land Preparation

The field soil for the experiment was prepared by plowing, smoothing, and leveling well and homogeneously, then the land was divided into three blocks (replicates), and each replicate consisted of 13 experiment units in which experimental treatments were randomly assigned to the experimental units in each replicate. Each experimental unit contains four furrows, with a distance of 75 cm between furrows and a distance of 25 cm between plants in each furrow, leaving 0.75 m between the experimental units to prevent interference between the treatments. The area of the experimental unit was 4.5 x 4 = 18 m^2.

3.3 Soil Analysis

Samples of field soil were taken from different areas before the start of the experiment, down to a depth of 30 cm, then air dried and ground; after grinding, it passed through a sieve with a diameter of 2 mm, was preserved in plastic containers, and was transferred to the laboratories of the Anbar Agriculture Directorate, Anbar Governorate, to perform the required analyses. Of the physical and chemical properties of the soil of the field on which the experiment will be carried out, as shown in Table 3.1.

Table 3.1 Physical and chemical properties of the experimental field soil

<table>
<tr><td colspan="3">Physical and Chemical Properties of the Soil
physical and chemical properties of experiment soil</td><td>Unit
Units</td></tr>
<tr><td rowspan="3">Soil parts</td><td>Sand</td><td>56</td><td>%</td></tr>
<tr><td>Silt</td><td>28.4</td><td>%</td></tr>
<tr><td>Clay</td><td>15.6</td><td>%</td></tr>
<tr><td colspan="2">Electrical conductivity (Ec)</td><td>2.53</td><td>Ds/m</td></tr>
<tr><td colspan="2">Organic Matter (OM)</td><td>1.05</td><td>%</td></tr>
<tr><td colspan="2">Soil Ph</td><td>7.31</td><td>-</td></tr>
<tr><td rowspan="2">Chemical properties</td><td>Gypsum</td><td>40</td><td>%</td></tr>
<tr><td>Lime</td><td>27</td><td>%</td></tr>
<tr><td>Soil texture</td><td colspan="2">Sandy loam</td><td>-</td></tr>
</table>

On January 1, 2022, Nahar Al-Awrad Company for Potato Trade and Agricultural Supplies imported and planted potato seeds of the Arizona variety (Figure 4), Class: Elite, in a field with sandy loam soil. After preparing the land well by plowing twice perpendicularly to a depth of 30–40 cm, the experiment was fertilized with poultry manure as the fertilizer approved for the cultivation of potatoes in the region by farmers for its ease of decomposition, its ability to provide the nutritional needs of the plant, and its high content of the necessary nutrients, especially nitrogen, phosphorous, potassium, and calcium. In addition, balanced chemical fertilizer (N. P. K. 15 15 15) was used, which is one of the most widely used triple compound mineral fertilizers in all crops in the form of granules. As 100 kg contains 15 kg of pure nitrogen, 15 kg of phosphorous in the form of P_2O_2 and 15 kg of potassium in the form of K_2O, the moisture content in it does not exceed 2.5%, which encourages the growth of the vegetative part of the plant and allows the absorption of CO_2 from the atmosphere. In addition, fertilization after planting is done by adding nitrogen fertilizer in the form of urea in two batches, the first after germination is complete and the second at the beginning of the formation of tubers. The treatment was carried out with Metribuzin before emergence at a rate of 400 and 800 g/ha, and agricultural operations included mulching with black plastic (thickness 8.0 microns) and hoeing operations, as shown in the experiment scheme in Table 3.2.

Figure 3.1 Arizona potato variety

Table 3.2 The pilot scheme shows a potato field in Heet District, Anbar, for the spring season of 2022.

R1	R2	R3
Weedy	Black Plastic	M.800 g/ha + Two Hoeing
Hand Weeding	Two Hoeing	M.400 g/ ha + 1 Hoeing
Metribuzin 800 g/ha	One Hoeing	M.800 g/ha + Black Plastic
Metribuzin 400 g/ha	M.400 g/ha + Two Hoeing	M.400 g/ha + Black Plastic
M.800 g/ha + Black Plastic	M.800 g/ha + Two Hoeing	M. 800 g/ha + 1 Hoeing
M.400 g/ha + Black Plastic	M.400 g/ha + 1 Hoeing	Metribuzin 400 g/ha
M. 800 g/ha + 1 Hoeing	M. g/ha + 1 Hoeing	Metribuzin 800 g/ha
M.400 g/ha + 1 Hoeing	M.400 g/ha + Black Plastic	Hand Weeding
M.800 g/ha + Two Hoeing	M.800 g/ha + Black Plastic	Weedy
M.400 g/ha + Two Hoeing	Metribuzin 400 g/ha	Black Plastic
One Hoeing	Metribuzin 800 g/ha	Two Hoeing
Two Hoeing	Hand Weeding	One Hoeing
Black Plastic	Weedy	M.400 g/ha + Two Hoeing

3.4 Prevalent Climatic Conditions

Temperature is one of the most important elements of the climate and is characterized by its variation during the day and night in Iraq, meaning there is a difference in temperature. As shown in Table 3.3.

Table 3.3 Average maximum and minimum temperatures during the experiment implementation period

Temperature ° C		Rainfall (inches)	Month	Growing season
Max.	Min.			
15.5	3.0	0	January	Spring 2022
21.0	6.8	0	February	
21.6	8.3	0	March	
32.4	14.8	0	April	
34.5	21.0	0	May	

Agricultural operations and their implementation date:

Table 3.4 The dates of the works carried out at the trial site during the spring season of 2022

Pesticide spraying time		14/2/2022
History of manual weeding		12/3 – 13/4 - 3/5/2022
Fertilization	Before planting	Poultry manure 10 tons/ha
	After planting	Urea – NPK 15-15-15
Hoeing	First hoeing	18/3/2022
	Second hoeing	18/4/2022
Irrigation		12 times
Planting date		18/1/2022
Tuber harvested		30/5/2022
Variety		Arizona
Growing season		2022
Planting season		Spring

3.5 Characters Studied

Diagram below shows the characteristics studied.

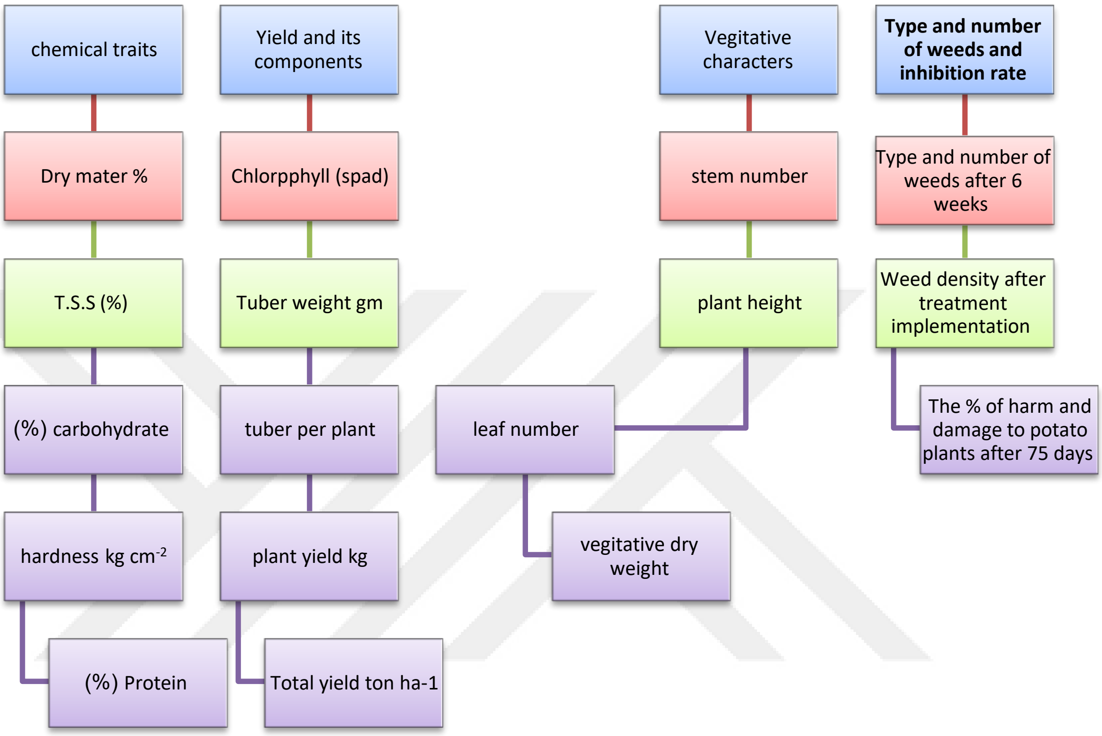

Figure 3.2 Studied characteristics of the weed and the potato crop

3.5.1 Characteristics of the weed growth

3.5.1.1 Types and total density of the weeds and the control percentage

The types of weeds that prevailed in each treatment were diagnosed, and the total numerical density of the total weeds within one square meter was calculated at the end of the growing season. Using a wooden square with dimensions of 100 cm x 100 cm for four different locations from each experimental unit at random.

The percentage of weed control was determined according to the following equation:

$$Weed\ control\ \% = \frac{No. of\ weeds\ in\ control\ treatment - No. of\ weeds\ in\ herbicide\ treatment}{No. of\ weeds\ in\ control\ \ treatment} \times 100$$

3.5.1.2 The dry weight of the weeds (g) and the percentage of inhibition

The weeds were dried naturally by placing the weeds to be dried in a ventilated room with continuous stirring for 8-12 days until their weight was stable, and then their weight was taken.

3.5.1.3 Percentage of weed inhibition

The percentage of weed inhibition was determined from the following equation:

$$Inhibition\ \% = 100\ \frac{A}{B} \times 100$$

A: dry weight of the weeds in the herbicide treatment.
B: dry weight of the weeds in the control (weedy) treatment.

3.5.2 Percentage of harm and damage to potato plants after metribuzin

The phytotoxicity was evaluated on the Arizona potato cultivar based on the system proposed by the European Herbal Research Society (EWRS), represented by a logarithmic scale ranging from 1 to 9 degrees, where the number 1 represents healthy plants unaffected by pesticides and the number 9 represents the maximum degree of impact and plant death. The safest pesticides in terms of phytotoxicity are those on the lowest scale. There was no harm or damage to the potato plant after 6 weeks of applying the treatments, as the damage rate was 0%.

3.5.3 Plant height (cm)

Three plants were selected from each experimental unit of the middle furrow, and the length of the plant was taken. The measurement was carried out using a metric ruler from the surface of the soil to the highest peak of the plant.

3.5.4 Leaf number (Plant)

Three plants were selected from each experimental unit of the middle furrow, and the number of leaves was counted.

3.5.5 Stem number (Plant)

Three plants were selected from each experimental unit of the middle furrow, and the number of stems was counted.

3.5.6 Vegetative dry weight (g per plant)

The plants were dried naturally by placing the plants to be dried in a ventilated room with continuous stirring for 8–12 days until the weight was stable, and then their weight was taken.

3.5.7 Dry matter percentage (%)

The percentage of dry matter was estimated by placing a known weight of the cut tubers in an electric oven at a temperature of 75 °C for a period of 72 hours (until the weight was stable), and it was estimated according to the following equation: (Al-Sahaf 1989).

$$Dry\ mater\ (\%) = \frac{Tuber\ dry\ weight}{Tuber\ fresh\ weight} \times 100$$

3.5.8 Chlorophyll content in leaves (SPAD unit)

The chlorophyll content in potato leaves was estimated by using a chlorophyll meter type SPAD 502 supplied by the Japanese company Minolta, taking the readings from 10 plants for each experimental unit, and then taking the average (Minnotti *et al.*1994).

3.5.9 Tuber number (tuber plant)

The average number of tubers per plant was counted by taking 10 plants from each treatment after the tubers were harvested.

3.5.10 The average weight of tubers per plant (g per plant)

The weight of tubers was taken for ten plants for each treatment from each replicate, and then the average yield of one plant was calculated.

3.5.11 The average tuber weight (g)

According to the average tuber weight, by weighing the yield of one plant for ten randomly selected plants from each treatment, then dividing the yield of the plant by the number of its tubers, and extracting the average tuber weight in grams using a sensitive scale.

3.5.12 Total yield (tons/hectare)

It was calculated after harvesting by calculating the total yield of the experimental unit and then proportioned to hectares according to the following equation:

$$Total\ yield\ hectares^{-1} = \frac{Yield\ of\ the\ experimental\ unit}{Area\ of\ the\ experimental\ unit} \times 10000\ m^2$$

3.5.13 Carbohydrate percent (%)

The percentage of carbohydrates was estimated using the Infralyzer-400 device.

3.5.14 Percentage of total soluble solids (T.S.S)

Total soluble solids represent all of the sugars, organic acids, and other dissolved substances in the juice of the tubers. It was calculated by placing a piece of the tuber in a hand press and then taking several drops of it to be placed on the hand refractometer to read it. The reading was repeated for many pieces and for many tubers (Al-Ani 1985).

3.5.15 Tuber hardness (kg/cm^2)

The tuber hardness was measured using a penetrometer as a light layer was removed from the outer shell of the tuber, and then the tuber was punctured by means of a plunger with a diameter of 0.5 cm more than once to be read (Al-Ani 1985).

3.5.16 Protein (%)

The percentage of protein was measured by estimating total nitrogen according to the Kjeldahl method using the Micro Kjeldahl device (Al-Ani, 1985), and the percentage of protein was calculated on the basis of wet weight as in the following equation: (Brucker and Morey 1988)

$$protein\ on\ the\ basis\ of\ dry\ weight\ (\%) = percentage\ of\ total\ nitrogen\ \times 7.5$$

3.6 Statistical Analysis

After collecting and tabulating the data for the different treatments, the data were statistically analyzed for the studied traits according to the RCBD (randomized complete block design), with three replications, and using the Genstat program. The least significant difference (LSD) test was used at a probability level of 0.05 to compare the arithmetic means of the studied traits.

4. RESULTS and DISCUSSION

4.1 Diagnosis of the Weeds Accompanying the Potato Crop During the Spring Season of 2022

When diagnosing the types of weeds spread in the potato crop during the spring growing season, it was noted that weed types reached 13, including 8 broad-leaved (Table 4.1), represented by the plants of sweet clover, wild radish, white top, and lamb quarter, which were the most prevalent among the other types of weeds, while a few types of weeds of yellow safflower, mallow, and redroot pigweed, while the narrow-leaved weeds reached 5 species, including rigid ryegrass, wild oats, and large carb grass, through their presence in general much less compared to in broad weeds.

Table 4.1 Types of weeds accompanying the potato crop during the spring season of 2022

English name	Scientific name	Family
Rigid rye grass	*Lolium rigidum* L.	Poaceae
Sweet clover	*Mililotus indicus* Mill	Fabaceae
Wild radish	*Raphanus raphanistrum* L.	Compositea
Wild safflower	*Carthamus oxyacanthus*	Asteraceae
Mallow	*Malva rotunbifolia* L.	Malvaceae
Redroot pigweed	*Amaranthus reteroflexus* L.	Amaranthaceae
White top	*Cardaria dropa* Desv	Brassicaceae
Bermuda grass	*Cynodon dactylon* L.	Poaceae
Lambs quarter	*Chenopodium album* L.	Chenopodiaceae
Annual darnel	*Lolium temulentum*	Poaceae
Wild Oat	*Avena fatua* L.	Poaceae
Large carb grass	*Digitaria sanguinalis* L.	Poaceae
Field bindweed	*Convolvulus arvensis* L.	Convolvulaceae

4.2 Effect of Metribuzin Herbicide Alone or in Combination with Plastic Mulching and Hoeing on Weeds Associated with Potato Crop and Its Dry Weight

4.2.1 Total weed density (m^2)

The number of all weeds significantly decreased for all treatments compared to the weedy treatment (194.2 plants/m^2). This is summarized in Table 4.2, which shows the general rates of weed numbers from the application of treatments and their dry weight at harvest. The treatment of integrating black plastic strips with metribuzin at the recommended rate (800 g/ha) and the half-rate treatment (400 g/ha), which gave the lowest numbers of weeds of 5.3 and 19.0 plants/m^2, respectively, and the reflection of this on the control percentage of 97.2 and 92.2%, respectively, significantly decreased the total weed density. It did not differ significantly from the treatment of metribuzin at the recommended rate without mulching 16 plants/m^2, which gave a controlled rate of 91.7%. While it differed significantly from the treatment of mulching with black plastic alone, the number of weeds amounted to 62.3 plants/m^2, and the control rate was 67.9%. As for the treatments of hoeing, the results of the same table indicate that there are significant effects in the number of weeds per square meter; it was significantly decreased by the treatment of integration by hoeing with Metribuzin at the recommended rate, giving a number of weeds of 6.0 and 4.0 plants/m^2 and a control ratio of 96.7 and 97.7% for the treatment of one and two hoeing, respectively. It did not differ significantly from the treatment of integration by hoeing once and two hoeing with half the recommended rate of the herbicide, which gave 19.3, 10.6 plants/m^2 and the control rate of 90.0 and 94.5%, respectively, and they did not differ significantly from the treatment of two hoeing without herbicide, 7.3 plants/m^2 and 96.2%. Whereas, all hoeing treatments in combination with the herbicide differed significantly from the one hoeing treatment without herbicides in terms of the number of weeds and the control ratio of 73.6 plants/m^2 and 61.1%, respectively.

This result indicates the effectiveness of the herbicide metribuzin alone or with some agricultural methods implemented, including the use of black plastic mulching or the hoeing process that affects the vital activities of the weeds and the subsequent growth processes in plants, which leads to the death of the weeds, or it may also be due to the use of more than one method in the control procedure, which leads to a multiplicity of the mechanisms of action of these methods with their response to the herbicide.

These results were in agreement with the results reached by Khan (2008), Yadav *et al*. (2015), Gupta *et al.* (2019), and Shafiq and Kaur (2021) on the efficiency of herbicides with the use of agricultural methods such as black plastic mulching and weed hoeing.

The extent of competition between agricultural plants and weeds depends on the types of weeds, the forms of their communities, the level of their density, the type of crop, and climatic conditions (Mangold *et al.*2021). As the competitive ability of the crop and weeds is determined by the speed of germination, growth, and development of the vegetative and root systems of their plants, the competition between the weeds and crops for nutrients is intense in the early stages of growth, especially in the first four weeks of crop growth (Argüelles and March 2021). The good use of herbicides makes it possible to eliminate the competitive effect of harmful weeds on arable crops from the beginning of potato germination as well as reduce the emergence of later weeds (Barbaś and Sawicka 2020).

Mulching the soil with black plastic is an important agricultural process. It is used to block the light and sterilize the soil, and the plastic mukching is effective in reducing the growth of weeds and works to homogenize the ground moisture under the cover (Pathak and Singh, 2021). The hoeing process is also useful and effective in order to get rid of weeds in crop fields, and it is considered very successful for controlling annual and biennial weeds as this method does not leave a trace of the roots of the weed in the soil and it cannot grow again (Al-Jubouri, 2002; Shehata *et al.*2019).

4.2.2 Weeds dry weights (g m^2)

It is also noted from the results of Table 4.2 that the dry weight of the weeds was 28.7 and 43.0 g/m^2 in the treatment of integration with black plastic mulching with metribuzin at the recommended rate and half the rate, respectively, and its reflection on the percentage of inhibition with a rate of 95.9% and 91.9%, respectively. It did not differ significantly from the treatment of metribuzin at the recommended rate without mulching at 29.7 g/m^2, which gave an inhibition rate of 95.7%, which differed from the treatment of mulching with black plastic at only 184.7 g/m^2, where the inhibition rate is 73.3%.

The results also show that there are significant effects of the hoeing treatments in combination with the herbicide on the dry weights and their inhibition rates. The dry weights decreased significantly with the hoeing treatment with metribuzin at the recommended rate of giving them a dry weight of 18.0 and 11.7 g/m^2, and the inhibition rate was 97.4 and 98.3% for the one and two hoeing treatments, which did not differ significantly from the treatment of integration. They did not differ significantly from the treatment of the two hoes without herbicides (21.7 g/m^2 and 97.0%). Whereas all hoeing treatments in combination with the herbicide differed significantly from the single hoeing treatment by giving dry weight and an inhibition rate of 182.01 g/m^2 and 73.7%, respectively.

The dry weight of the weeds is clear evidence of a decrease in their competitiveness compared to the crop's ability. The low dry weight gives a clear indication of the effectiveness of these treatments and their impact on the vital activities of the weeds, and that the demolition process has outperformed the construction process. This was evident in the increase in dry weight in the weedy treatment and its decrease in the herbicide treatments. The herbicide metribuzin makes many changes in the physiological processes within the plant body. The main effect is the inhibition of photosynthesis, as the herbicide enters the chloroplast, and when it reaches the active sites within the second photosystem, it inhibits the water photolysis step (Hill reaction), as well as impeding the light reactions by stopping the growth and formation of chlorophyll in many plant species, as it causes them to swell and quickly break down after that, by preventing the stomata from bulging, which indicates that this herbicide killed the important living tissues in photosynthesis. This indicates that the process of demolition outperformed the process of building in plant tissues (Gupta *et al.*2022). The results obtained show the significant effect of metribuzin on agricultural operations by reducing the dry weight of the weeds and their ability to compete with the crop. It is a clear reflection of the high relative efficiency of weed control and the reduction of weed density in potato fields. This finding is in agreement with Gupta *et al.* (2019) Barbaś and Sawicka (2020) and Bankoti *et al.* (2021).

Table 4.2 Effect of the herbicide metribuzin alone or in combination with black plastic mulching and hoeing on the total weed density and its dry weight

Treatments	**Weed Growth Characteristics**			
	Total weed density m^2	**Control %**	**Dry weight g.**	**Inhibition rate in dry weight %**
Weedy	194.2f	0.0f	693.3e	0.0 e
Hand Weeding	0.0a	100a	0.0 a	100a
Metribuzin 800 g/ha	16.0b	91.7b	29.7 b	95.7b
Metribuzin 400 g/ha	96.0e	50.5e	204.0 d	70.5d
M.800 g/ha + Black Plastic	5.3a	97.2a	28.7 b	95.9b
M.400 g/ha + Black Plastic	19.0b	92.2b	43.0 b	91.9b
M. 800 g/ha + 1 Hoeing	6.00a	96.7a	18.0 a	97.4a
M.400 g/ha + 1 Hoeing	19.3b	90.0b	30.0 b	95.4b
M.800 g/ha + Two Hoeing	4.00a	97.9a	11.7 a	98.3a
M.400 g/ha + Two Hoeing	10.6ab	94.5ab	24.3 ab	96.8ab
One Hoeing	73.6d	61.1d	182 c	73.7e
Two Hoeing	7.3a	96.2a	21.7 a	97.0a
Black Plastic	62.3c	67.9c	184.7 c	73.3c
L.S.D. $P<0.05$	4.3	——	15.0	——

4.3 Effect of Metribuzin Alone or in Combination with Black Plastic Mulching and Hoeing on Some Vegetative Characteristics of Potato Plant Growth.

4.3.1 Plant height (cm)

The results indicate that there is a significant effect of metribuzin treatment according to the rates used alone or in combination with the black plastic mulching process or the hoeing process on the average plant height compared to weedy treatment, which gave the lowest value of 54.6 cm (Table 4.3). The treatments of Metribuzin (800 g/ha) with plastic mulching outperformed, and it gave a plant height rate of 84.3 cm and 82.3 cm for the herbicide treatment (400 g/ha) over the treatment of using plastic only (64.0 cm), while it did not differ significantly from the treatment of using the herbicide at the recommended rate (79.0 cm). The results also indicated the superiority of metribuzin herbicide treatments according to the rates used with the one and two hoeing processes (Table 4.3), giving an average height of 77.3 cm and 73.0 cm for herbicide treatment of 800 g/ha with one and two hoeing, respectively, and 73.6 cm and 70.6 cm for herbicide treatment of 400 g/ha with one and two hoeing, respectively, on the treatment of using only one hoeing (61.6 cm). However, it did not differ significantly from the treatment of the two hoes alone (67.3 cm). The reason for the superiority of all treatments in the average plant height compared to the weedy treatment may be attributed to the effect of treating the herbicide alone or with some agricultural methods on reducing the competition between the weeds and the potato plant on the main growth requirements and thus increasing the height of the potato plants. These results agree with Stachowski (2006). or perhaps through improving the growth of seeds and accelerating the emergence and then improving plant growth in the field, and this is the result of the agreement between the treatments, which led to the inhibition of harmful weeds and their inability to compete for nutrients with the crop. This helped in the processes of carbon metabolism, respiration, and the protoplasmic building process. As it is included in the synthesis of nucleic acids (DNA and RNA) necessary for cell division and then the increase in plant height (Al-Ani 1985). No significant differences were observed between the herbicide treatments or the integration with mulching and hoeing in the number of stems for each plant compared to the weedy treatment, which indicates the absence of an inhibitory effect of the herbicide according to the rates used and agricultural methods on this trait (Table 4.3).

4.3.2 Leaf number (leaf plant) and vegetative dry weight (g)

The results indicate metribuzin treatments (800 g/ha) with mulching with black plastic were outperformed, and it gave the number of leaves per plant and the vegetative dry weight of 99.3 leaves per plant and 65.0 g, respectively, and 125.0 leaves per plant and 63.3 g, respectively, for the herbicide treatment (400 g/ha), the treatment of using plastic only (47.0 leaves per plant and 50.3 g), respectively (Table 4.3), while it did not differ significantly from the treatment of using the herbicide at the recommended rate (123.7 leaves per plant and 60.3 g).

The results also indicate that there are significant effects in the hoeing treatments in combination with the herbicide in the number of leaves per plant and the total dry weight of the vegetative, as the treatment of Metribuzin (800 g/ha) with the hoeing process increased significantly with 105.0 leaves per plant, 58.7 g per hoeing, and 110.0 leaves per plant, 66.7 g for two hoeings, respectively. Followed by the herbicide treatment (400 g/ha) in one and two hoeing, which gave the number of leaves as 106.3 and 117.3 leaves per plant and the total vegetative dry weight as 57.3 and 53.0 g, respectively. They did not differ significantly from the treatment of the two hoes without the herbicide (89.3 leaves per plant) and 53.0 g, respectively.

The absence of weeds and their lack of competition for the potato crop in the treatment of the absence of weeds or their scarcity in the various treatments contributed to allowing the crop plants to grow without competition and to obtain the requirements for growth without stress, and then the increase in the outputs of the photosynthesis process, which was positively reflected on the increase in the vegetative growth of the plant, represented by the plant height, and then the increase in the dry weight of the plant, compared to what was recorded by the weedy treatment (Pathak and Singh 2021 Abdallah *et al.*2021), The increase in the dry weight of the vegetative total in the experimental treatments may be attributed to a significant increase in the accumulation of processed materials inside the plant, which helped to raise the dry weight rate in the plant (Farrag *et al.*2016).

Table 4.3 Effect of Metribuzin alone or in combination with black plastic mulching and hoeing on some vegetative characteristics of potato plants

Treatments	Vegetative characteristics of potato plant growth			
	Plant height Cm	**Stem number plant**	**Leaf Number per plant**	**Vegetative dry weight g**
Weedy	54.6 f	2.0a	45.7d	41.3f
Hand Weeding	84.6 a	3.0a	132.0a	75.0a
Metribuzin 800 g/ha	79.0 ab	2.3a	123.7a	60.3bed
Metribuzin 400 g/ha	69.3 cde	4.0a	52.0d	39.7f
M.800 g/ha + Black Plastic	84.3 a	3.0a	99.3bc	65.0ab
M.400 g/ha + Black Plastic	82.3 a	2.6a	125.0a	63.3abc
M. 800 g/ha + 1 Hoeing	77.3 abc	3.0a	105.0abc	58.7abc
M.400 g/ha + 1 Hoeing	73.6 bcd	3.0a	106.3abc	57.3bcd
M.800 g/ha + Two Hoeing	73.0 bcd	2.3a	110.0abc	66.7bcd
M.400 g/ha + Two Hoeing	70.6 cd	2.3a	117.3abc	53.0ab
One Hoeing	61.6 e	2.0a	64.3d	44.7def
Two Hoeing	67.3 de	2.3a	89.3c	53.0drf
Black Plastic	64.0 e	3.0a	47.0d	50.3cde
L.S.D. $P<0.05$	8.2	N.S	29.1	11.8

4.4 Effect of Metribuzin Alone or in Combination with Black Plastic Mulching and Hoeing on the Total Yield and Its Components of Potato Plants and the Chlorophyll Content

No significant differences were observed between herbicide treatments or integration with mulching and hoeing in the number of tubers per plant compared to the weedy treatment, which indicates the absence of an inhibitory effect of the herbicide according to the rates used and agricultural methods on this trait (Table 4.4). The results also showed that the treatments of Metribuzin (800 g/ha) with black plastic mulching were superior in that the average weight of the tuber and the yield of one plant amounted to

128.2 g, 933.6 g per plant, respectively, and 120.2 g, 774.9 g per plant, respectively, for the herbicide treatment (400 g/ha) on the treatment of using plastic only (125.4 g, 682.6 g per plant), while it did not differ significantly from the treatment of using the herbicide at the recommended rate (139.0 g, 848.4 g per plant). This was reflected in the total yield of the potato crop (tons/ha), which gave a yield weight of 49.4 and 41.1 tons per hectare for herbicide treatment according to the rates of 800 and 400 g/ha used with plastic mulch, respectively, while the herbicide treatments without mulching gave 44.9 and 32.6 tons/ha, respectively.

The results also indicated the superiority of metribuzin herbicide treatments according to the rates used with the one-hoeing and two-hoeing processes by giving the average tuber weight and yield of one plant, which amounted to 160.5 and 980.3 g per plant for the herbicide treatment at a rate of 800 g/ha with one hoeing and 152.6 and 878.0 g per plant with two hoeing, respectively. It did not differ significantly from the herbicide treatment at a rate of 400 g/ha, with 158.0 g and 774.1 g per plant with one hoeing and 144.6 g and 864.4 g per plant with two hoeings. While it differed significantly from the treatment of using one hoe only (123.7 g, 656.1 g per plant), it did not differ significantly from using two hoes only (157.1 g, 872.1 g per plant). This was reflected on the total yield of the potato crop (tons/ha), which gave a yield weight of 51.9, 45.8 tons/ha for the herbicide treatment according to the rates of 800 and 400 g/ha with one hoeing process, respectively, and 46.5, 45.8 tons/ha with the two hoeing processes on some vegetative characteristics of potato plants.

Table 4.4 Effect of metribuzin alone or in combination with black plastic mulching and second hoeing on the total yield and its components in potato plants

Treatments	Total yield and its components for potato crop			
	Tuber no. Per plant	**Tuber weight gm**	**Plant yield Gm**	**Plant yield Ton/ ha**
Weedy	5.8a	70.0e	472.2e	25.0e
Hand Weeding	6.2a	173.0a	1123.3a	**59.5a**
Metribuzin 800 g/ha	6.1a	139.0b	848.4abc	**44.9abc**
Metribuzin 400 g/ha	6.0a	103.0cd	616.7cd	32.6cd

M.800 g/ha + Black Plastic	6.9a	128.2bc	933.6a	**49.4a**
M.400 g/ha + Black Plastic	6.9a	120.2c	774.9bc	41.1bc
M. 800 g/ha + 1 Hoeing	5.8a	160.5a	980.3a	**51.9a**
M.400 g/ha + 1 Hoeing	5.8a	158.0a	774.1h	41.0h
M.800 g/ha + Two Hoeing	7.6a	152.6b	878.0a	46.5a
M.400 g/ha + Two Hoeing	5.7a	144.6b	864.4abc	45.8abc
One Hoeing	5.2a	123.7c	656.1cd	34.7cd
Two Hoeings	5.6a	157.1a	872.1ab	46.2ab
Black Plastic	5.3a	125.4bc	682.6bc	36.1bc
L.S.D. $P<0.05$	n.s	19.0	85.9	4.5

The use of metribuzin herbicide alone or in combination with black plastic mulching and hoeing processes in controlling potato weeds led to reducing competition for nutritional and light requirements and making it confined only to the nutrition of the plant itself. This was reflected in an increase in the ability of the root system of the crop to absorb water and mineral elements and an increase in the accumulated carbohydrates and their transfer to the leaves and then to the tuber as the main consumer (Majeed, 2010; Yadav et al.2015). The increase in the weight of the tubers in the experimental treatments can be attributed to the increase in the leaf area of the potato plant and its positive reflection on the activity of photosynthesis, which leads to an increase in the manufacture of carbohydrates transferred to the tubers, which leads to an increase in their weight (Javaheri et al.2012).

The superiority of the treatments over the control weedy treatment in yield may be due to the effect of the treatments on the availability of nutrients in the soil solution and their slow release and absorption by the plant for a longer period and not losing them by providing the harmful weeds with nutrients, which led to an increase in the quantities of nutrients absorbed without competition by the roots of the plant, as the nutrients were available to the plant without the harmful competition of the weeds and then stimulated the absorption of water and growth, which has an important role in the various metabolic processes of the plant (Kharmashou 2018). This finding is in agreement with what was reported by Yadav et al. (2015) Shafiq and Kaur (2021) and Gupta et al. (2019) on the possibility of controlling weeds accompanying the potato crop by using metribuzin or integrating it with some agricultural operations.

The results showed that there were significant differences in the chlorophyll content in potato leaves between the rates of use of metribuzin alone or in combination with the plastic mulching and the control weedy treatment that gave the lowest content of 40.7 SPAD units (Fig. 4.1). The average chlorophyll content was 48.6 SPAD units for metribuzin treatment at 800 g/ha with black plastic mulching and 44.6 SPAD units for 400 g/ha, compared with 40.7 and 42.7 SPAD units for the weedy treatment and black plastic mulching only, respectively. The results also indicate the superiority of metribuzin herbicide treatments according to the rates used with the one and two hoeing processes with chlorophyll content in the leaves: 44.1 and 46.4 SPAD units for the herbicide treatment at a rate of 800 g/ha with one and two hoeing processes, respectively, and 48.1 and 45.3 SPAD units for the herbicide treatment at a rate of 400 g/ha with one and two hoeing processes, respectively. Whereas the treatment of one hoe gave 42.3 units of SPAD, the treatment of two hoes gave 43.7 units of SPAD.

The increase in the total content of chlorophyll may be attributed to the effect of the treatments on increasing the availability of the elements N and Mg, which have an important effect through their presence in the center of the chlorophyll molecule (Addiscott, 1974). This finding is in agreement with Sharshar *et al.* (2015) El-Abdallah *et al*. (2021) and Shehata *et al*. (2019). The use of metribuzin in the mulching and hoeing processes has an effective role in increasing the chlorophyll content in potato leaves.

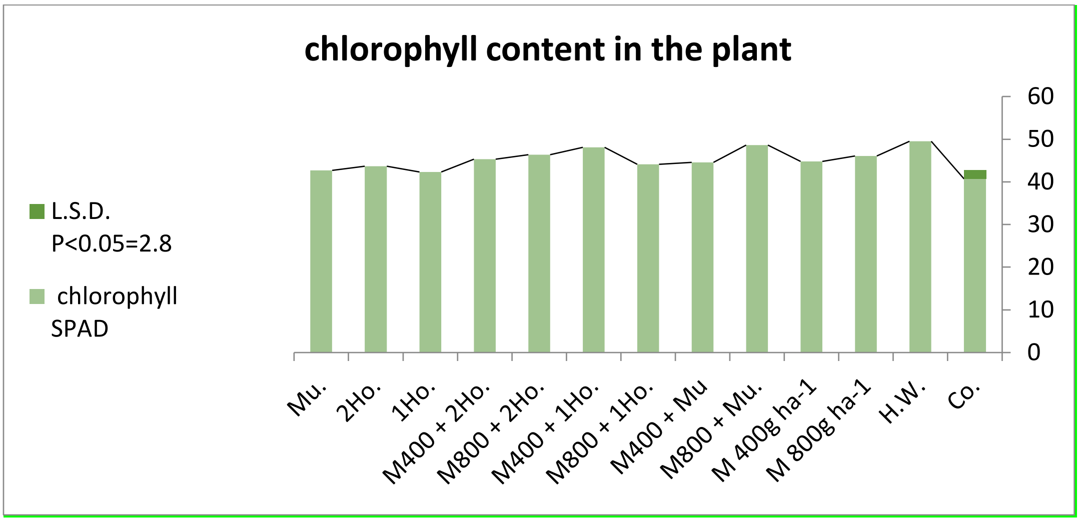

Figure 4.1 Effect of metribuzin alone or in combination with black plastic wrap and a hoe on the chlorophyll content of potato plants (Ho= hoeing, Mu= mulching, M= metribuzin, HW= hand weeding and Co= control)

4.5 Effect of Metribuzin Alone or in Combination with Black Plastic Mulching and Hoeing on Some Chemical Properties of Potato Plants

The weeds greatly affect agricultural production in terms of quantity and quality, so the weed control program is successful whenever the number of weeds per unit area decreases and thus increases the competitiveness of the potato crop, and this reflects the chemical characteristics of growth represented by the percentage of dry matter, TSS, carbohydrates, tuber hardness, protein, and others.

The percentage of dry matter in leaves and TSS in tubers significantly decreased in the overgrown treatment compared to all treatments (13.5 and 5.4%, respectively) (Table 4.5). The above-studied traits were significantly increased by the treatment of mulching with black plastic with the use of metribuzin herbicide at rates of 800 and 400 g/ha, giving the highest percentages of 16.6 and 5.5%, respectively, while the lowest percentages were recorded in the treatment of mulching at only 13.6 and 5.6%, respectively. Whereas, for hoeing treatments, the results indicate that there are significant effects in the percentage of dry matter and TSS with the use of metribuzin herbicide at a rate of 800 g/ha, giving it the highest percentage of 15.8 and 6.3% for one hoeing and 14.8 and 6.5% for two hoeings, respectively. Followed by the hoeing treatment with the use of herbicide at a rate of 400 g/ha, 15.8 and 5.9% for one hoeing and 15.9 and 6.3% for the two hoeings, while it decreased in the single hoe treatment without the use of herbicide by 14.4 and 5.6%, respectively.

Metribuzin alone with some agricultural methods led to a significant increase in the percentage of dry matter and TSS compared to the weedy treatment. This may be due to its role in controlling the weeds accompanying the crop, which provided a suitable local environment for the growth of potato plants, as well as its impact on the physical and biological activities of the soil, which results in an increase in the absorption of nutrients and their accumulation in the leaves (Shehata *et al.*2019). The increase in these percentages can also be explained by the fact that proteins, sugars, acids, and other soluble salts are important components of total soluble solids. The little change in the treatments may have occurred due to the low osmotic capacity that facilitated the accumulation of soluble solids (Kharmashou 2018).

The results indicate the significant superiority of the mulching treatment with 800 and 400 g/ha of Metribuzin herbicide application in increasing the percentage of carbohydrates by 11.6 and 11.3%, respectively, and tuber hardness by 10.1 and 11.6 kg/cm^2, respectively, compared to the weedy treatment, in which the percentages decreased to 9.3 and 9.5 kg/cm^2, respectively. The effect of hoeing treatments on the percentage of carbohydrates and tuber hardness did not show any significant difference between the 800 g/ha herbicide treatment and hoeing, reaching 11.3 and 9.2 kg/cm^2 for one hoe and 9.9 and 11.5 kg/cm^2 for two hoes. While it gave 11.0 and 10.8 kg cm^2 for one hoe and 11.6 and 11.3 kg/cm^2 for two hoes with 400 g/ha of the herbicide, respectively, which significantly increased the percentage over the rest of the treatments, this percentage decreased in the treatment of one hoe to 9.7 and 9.9 kg/cm^2, and 10.0 and 9.9 kg/cm^2 for the two hoes, respectively.

The use of metribuzin alone or with the methods of mulching and hoeing led to an increase in the total soluble carbohydrate content of the tubers compared to the weedy treatment. This may be due to the fact that this technique contributed to changing the root circumference of the potato plant after removing the weeds and creating the appropriate conditions for plant growth, thus facilitating the process of absorbing water and nutrients and securing the plant's needs from them, which paved the way for the photosynthesis process to take its right course completely (Azad *et al.*2015). Also, the hardness of the tubers may be attributed to an increase in the efficiency of the photosynthesis process and an increase in the proportion of soluble sugars, free amino acids, and proline, thus reflecting the hardness (Poddar *et al.*2017).

Table 4.5 Effect of metribuzin alone or in combination with black plastic mulching and hoeing on some chemical characteristics of potato plants

Treatments	**Chemical properties of potato plants**			
	Dry matter %	**T.S.S %**	**Carbohydrate %**	**Hardness Kg/cm^2**
Weedy	13.5g	5.4k	9.3k	9.5abc
Hand Weeding	16.3b	6.4b	11.9a	11.8a
Metribuzin 800 g/ha	15.1d	6.0e	10.6e	10.4a
Metribuzin 400 g/ha	14.6ef	5.8g	10.2f	10.6a
M.800 g/ha + Black Plastic	16.6a	5.5j	11.6b	10.1ab
M.400 g/ha + Black Plastic	16.4ab	6.2d	11.3c	11.6a
M. 800 g/ ha + 1 Hoeing	15.8c	6.3c	11.3c	9.2abc
M.400 g/ha + 1 Hoeing	15.8c	5.9f	11.0d	10.8d
M.800 g/ha + Two Hoeing	14.8e	6.5a	9.9h	11.5a
M.400 g/ha + Two Hoeing	15.9c	6.3c	11.6b	11.3a
One Hoeing	14.4f	5.6i	9.7i	9.9abc
Two Hoeings	14.7e	5.7h	10.0g	9.9abc
Black Plastic	13.6g	5.6i	9.5j	9.5abc
L.S.D. $P<0.05$	0.2	0.06	0.1	1.5

The results indicate that there are significant differences in the percentage of protein content in potato tubers between the herbicide dose used of Metribuzin alone or in integration with the plastic mulch and the control weedy treatment that gave the lowest content of 5%; the content rate reached 7% for Metribuzin treatment at a rate of 800 g/ha with black plastic mulching and 6.8% for the herbicide at a rate of 400 g/ha, compared with 5 and 5.2% for the weedy treatment and black plastic mulch only, respectively (Figure 4.2). The same figure also indicated the superiority of metribuzin herbicide treatments according to the rates used with the single and two hoeing processes by giving the protein content in the tubers 7.1 and 5.7% for the herbicide treatment at a rate of 800 g/ha with one and two hoeing processes, respectively, and 6.8

and 7.1% for the herbicide treatment at a rate of 400 g/ha with one and two hoeing processes, respectively. While the treatment of one hoe yielded 5.4% and the two hoeing treatments yielded 6.2%.

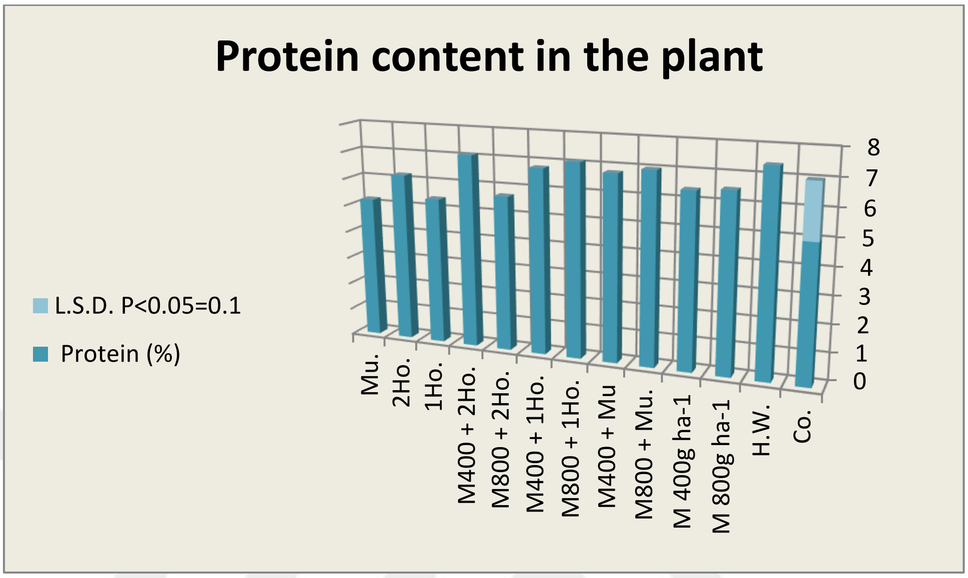

Figure 4.2 Effect of metribuzin alone or in combination with black plastic mulching and hoeing on protein content of potato plants (Co= control, Mu= mulching, M= metribuzin, H.W. = hand weeding, Ho= hoeing)

The effective role of the studied treatments on the percentage of protein in the crop is clear compared to the weedy treatment. This is due to the fact that the treatments have contributed to providing nutrients for the plant by not competing with the weeds. As it contributed to the formation of strong vegetative growth and thus affected the products of photosynthesis and the amount of nitrogen absorbed, which will be reflected in the percentage of proteins that are formed in the resulting tubers (Al-Ani 1985). It may also be attributed to the influential and effective role in protein formation as a result of the transformation of amino acids, which are subsequently transferred from the places of manufacture in the leaves to the places of storage in the tubers. It also helped to speed up the absorption of nutrients, which in turn leads to an increase in the speed of growth and an increase in yield and chemical characteristics such as protein and starch through activating the process of photosynthesis (Science 2019).

5. CONCLUSION

1. The presence of the weeds of sweet clover, wild radish, white top, lamb's quarter, and field bindweed broad-leaved was diagnosed in the field of the most widespread experiment, compared to other broad-leaved weeds such as wild safflower, mallow, and redroot pigweed, while the weeds of wheat, Bermuda grass, annual darnel, wild oats, and large carb grass, where leaf weeds were much less than broad-leave.

2. The use of metribuzin herbicide according to the recommendation (800 g/ha) alone, in combination with black plastic mulching, or with hoeing was effective in weed control, and this was reflected in the yield, components, and chemical properties of the potato crop.

3. The integration between mulching with black plastic or hoeing with a low dose (400 g/ha) of metribuzin was efficient in controlling the weeds and the studied traits during the growing season of the potato crop.

4. The treatment of the two hoes alone was efficient and effective in controlling the weeds and the characteristics studied above.

6. RECOMMENDATIONS

1. The possibility of using metribuzin pesticide at half the recommended rate with integration by mulching with black plastic or hoeing for one time is a good economic orientation to weed control in the potato crop by reducing the recommended rate of the herbicide and its reflection on the ecosystem.

2. The possibility of using the hoeing process twice only to control the weeds in small areas and in the early stages of potato growth.

3. Conducting subsequent studies on the use of the herbicide with other non-plastic mulching operations that had an effective role during the review of the literature.

4. Conducting subsequent studies on the use of other types of herbicides with other more effective and less costly agricultural operations.

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APPENDICES

APPENDIX 1. Pictures of master thesis study


M1+H2


M1


Weedy
M2+Mu
M2
M2+H1


H2


H1


M_2+H_2


APPENDIX 2. Sources of variance, degrees of freedom and mean squares for the studied characteristics

		Total weed density m^2	Dry weight g	plant height cm	Stem number Per plant	Leaf number per plant	Vegetative dry weight g	Tuber no. Per plant	Tuber weigh g	Plant yield g
S.O.V	d.f	M.S	M.S	M.S	M.S	M.S	M.S	M.S	M.S	M.S
R	2	14.050	166.85	56.31	0.3077	372.1	85.26	0.2412	49.0	121
T	12	9292.103	107269.03	249.92	0.9145	2899.0	324.41	1.3774	2319.7	87267
Error	24	6.706	80.04	23.92	0.8632	298.1	49.23	0.6635	128.2	2603
Total	38									

		Plant yield Ton/ha	Chlorophyll SPAD	Dry matter %	T.S.S %	Carbohydrate %	Hardness Kg/cm^2	Protein %
S.O.V	d.f	M.S	M.S	M.S	M.S	M.S	M.S	M.S
R	2	0.339	0.028	0.12428	0.023726	0.060687	0.9837	0.18692
T	12	245.180	19.945	3.11046	0.417215	2.355908	2.3586	1.85701
Error	24	7.312	2.781	0.02578	0.001531	0.008671	0.7925	0.01220
Total	38							

CURRICULUM VITAE

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Education

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Work Experience

Year	Institution	Position
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2011- Present	Assistant Director of Anbar Municipality	

Academic Activities