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The combined allelopathic effect of wheat plant residues with doses of mineral fertilizer nitrogen (N) on yield of sunflower (*Helianthus annus* L.) crops.

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Abstract

This study was conducted on a farm associated with the Agricultural Extension Directorate of Residues Governorate during the 2023 agricultural season. The study aimed to determine the differential effect of wheat plant residues alone and with different fertilizer treatments on selected argemone characteristics of Sunflower (Agrico cultivars). The research included the evaluation of four different fertilizer treatments: no fertilization, nitrogen fertilizer at a rate of 80 kg/ha, nitrogen fertilizer at a rate of 120 kg/ha, wheat residues at a rate of 1400 g/m^2m^2, and wheat residues at a rate of 1400 g/m^2 combined with nitrogen fertilizer at 120 kg/ha).

The experiment used a split-plot design, with three replicates for each treatment. The following parameters were examined: Plant height (cm), Flower disc diameter (cm), Average dry weight of the disc (g), Average seed weight per disc (g), Average number of seeds per disc (seed), Average weight of 100 seeds (g), Biological yield (kg/ha), Yield from Seeds (kg/ha) and Harvest factor (%).

The results demonstrated a significant superiority of the mineral fertilization treatment (120 kg/ha) alone or with wheat residues at 1400 g/m2 concentration in most of the studied indicators over the other treatments. This was evident by the increase in the flower disk (13.21), the dry weight of the flower disk (78.06 grams), and the weight of seeds in the plant (41.45 grams). Additionally, the weight of 100 seeds was (4.947 grams), the biological yield was (27,541 kg/ha), and the seed yield was (3316 kg/ha).

Regarding the plant height characteristic, the organic fertilization treatment of 120 kg/ha alone or with wheat residues at 1400 g/m2 concentrations showed superiority. This was followed by treating wheat residues at 1400 g/m^2 (173.3,168.3) cm, respectively. Furthermore, the harvest index was significantly higher in the 120 kg/fertilization treatment, either alone or with wheat residue at a rate of 1400 g/m^2.

Keywords

Allelopathic; wheat; mineral fertilizer; sunflower (*Helianthus annuus* L.) crops

Introduction

The Sunflower (*Helianthus annuus* L.) belongs to the family Asteraceae of crops. The strategy is widely adapted to different environments worldwide, and it is a dual-purpose crop, as its oleaginous varieties are used to

manufacture vegetable oils, soap, inks, dyes, etc. (1).

As for the oleaginous varieties, their seeds are used by humans after being roasted because they are palatable and have a distinctive flavor, in addition to their high nutritional value due to the presence of carbohydrates (75%), proteins (16%), and elements (18%) such as calcium, phosphorus, iron, potassium, fiber, vitamins, and others (2). Due to their high financial returns and the presence of factories specialized in roasting and packaging seeds, the demand for them has increased recently, which has prompted specialists to pay attention to these varieties, expand their cultivation horizontally and vertically, and introduce the necessary improvements in their cultivation technology to stimulate their genetic and physiological ability to adapt themselves to the environment. Where it is planted better to improve seed growth and development and reduce the percentage of empty seeds, as well as increase its specific weight to fill the shortfall in its productivity per unit area, especially since sunflower productivity in Iraq is still low compared to global production, according to the Central Bureau of Statistics (3). Sunflower productivity is obtained through several methods, through controlling the quality and quantity of fertilization, as well as involving some agricultural methods with plants in the field through the use of plant residues, which is one of the effective methods for raising the efficiency of the plant by investing in growth factors such as water and nutrients available in the soil solution by inhibiting weeds (4,5) and benefiting from it to increase the density of vegetative cover exposed to sunlight towards improving the efficiency of the carbon assimilation process for producing dry matter and storing it in estuaries and increasing the yield rate (6).

This suggests that allelopathy could be the mechanism responsible for reducing weed growth and population. The differences among stands could be due to differences in the allelopathic potential, which directly or indirectly increases agricultural yields through the use of agrarian plant residues, which is considered one of the essential methods due to its role in improving the physical, chemical, and biological characteristics of the soil as well as having an inhibitory effect on the growth of the weeds accompanying the crop (7-10).

Based on the above, this experiment was carried out to determine the combinations of mineral fertilizer with or without wheat residue on the growth of the sunflower crop and on some growth characteristics.

Materials and Methods

Plant material

Sunflower cultivars, the Asgaro variety, were used in the study. The variety was procured from the genetic bank of the General Authority for Scientific Agricultural Research in Iraq. Table 1 shows some characteristics of the type studied.

Field experiment site

The field experiments were carried out in the fields of the Agricultural Extension Department, Wasit Governorate, which are located at longitude 32° 34¯N, 45° 50¯E. During the agricultural season of spring 2023, the soil was characterized as loamy soil with a high nitrogen, phosphorus, potassium, organic matter, and a weak alkaline medium, and the soil salinity was average, with physicochemical characteristics listed in Table 2. The climate data (Table 3) indicates that the temperatures were high during the growing season, but they were not stressful for the plants.

Studied fertilizer Treatment

Control treatment without fertilization

- Mineral nitrogen fertilizer at a rate of 80 kg/ha = 171.6 kg/ha urea
- Mineral nitrogen fertilizer at a rate of 120 kg/ha = 257.6 kg/ha urea (this quantity was calculated based on the percentage of nitrogen in the urea of 46.6%
- Wheat plant Residues at a concentration of 1400 g/m^2
- Nitrogen fertilizer at a concentration of (120 kg/ha with wheat residues at a concentration of 1400 g/m^2)

Cultivation method and statistical analysis

Field plots (1.5m x 1.5m) were made randomly in a field heavily infested with weeds on February 25, 2023. The plots were plowed by a spade to a depth of 30 cm and received Nitrogen as NP (46%N) at 240 kg/ha (50% before planting and 50% after two weeks of planting) and P as

Table 1: Some morphological characteristics of the Asagrio genotype of Sunflower

Varieties	Average plant height (cm)	Average weight of 100	Average productivity (kg/ha)	seeds weight of seeds per plant (g)	Average number of days of flowering	Average number of days to maturity (day)
Value	142	5.6	2560	33.6	68	100

Table 2: Physical and chemical properties of the soil at the field experiment

	Physical properties			Chemical properties		
Varieties	sand (%)	Silt (%)	Glay %	N (%)	P_2O_5 (ppm)	K_2O (ppm)
Value	43.28	32.5	23.62	0.13	28.6	315

Table. 3. Climatic data at the location during the 2013 sunflower crop growing season

Month	Minimum air temperature °C	Maximum air temperature °C
February	16.00	34.53
march	17.66	36.65
April	18.07	42.67
May	18.97	43.03
Average	17.67	39.22

triple superphosphate (46% P_2O_5) at 240 kg ha^{-1} at planting time (11).

Seeds of sunflower genotypes (Asagrio) were sown manually on their respective plots in rows with a distance of 25 cm between seeds and 50 cm between rows. The plots were selected for a split-plot design with three replications. At the end of crop maturity, Sunflower plants were harvested. The analysis was done through a particular statistical program (Genstat), and the arithmetic means of the coefficients were compared using the least significant difference (L.S.D.) test at the 5% level (12).

Studied indicators

The indicators were studied on an average of five plants from each plate and at a rate of 3 replicates.

Plant height: Plant height represents the total length of the plant in cm from the base of the stem to the beginning of the flower disc. It was recorded after the disc had completed growing.

The diameter of the flower disc (cm) was measured in cm

The average dry weight of the flower disc (g) was measured using a weighing scale

The average number of seeds per disc (seed) was manually counted and recorded for each disc separately

Average weight of 100 seeds (g): 100 seeds were weighed using a weighing scale

Biological yield (kg/ha): The dry weight of whole plants with seeds present was measured as $1m^2$ and then mathematically converted to kg/ha.

Seed yield (kg/ha): Seeds were weighed in plants per square meter and converted mathematically to kg/ha.

Harvest index % = seed yield / biological yield ×100

Results and Discussion

Plant Height

The statistical analysis results in (Table 4) illustrate significant differences in the plant height characteristics of the different fertilization treatments of the sunflower variety, Asgaro. It was observed that the mineral fertilization treatment of 120 kg N/ha of wheat residues with a concentration of 1400 g/m^2 was superior to plant height (173.3 cm).

There were significant differences in the treatment of adding residues alone (168.3 cm). In comparison, the control treatment without fertilization recorded the lowest significant values in this characteristic of plant height (124.2 cm). This means that the addition of fertilizer, whether mineral or organic residues, leads to an increase in plant height compared to the control treatment. The positive effect is mainly on vegetative growth and an increase in the number of leaves in the plant, and consequently on the amount of dry matter manufactured and used to increase the growth rate, which increases the height of the plant. This is consistent with what was mentioned by (13). Also, the role of the residues inhibited the growth of the surrounding weeds, which reflected positively on the lack of competition for energy sources for plants. The fact that wheat residues reduced weed density and dry weight in the last stages of the crop's life cycle may give a positive indication in reducing its competition with the crop in the critical stages of pod formation and seed filling, which is one of the essential components in increasing economic yield. The significant decrease in weed density and dry weight during the growth stages of the crop may be the result of the release of some allelopathic compounds, such as phenolic acids from crop residues, the effect of which increased with the increase in the weight of residues added to the soil (9).

Flower disc diameter

The diameter of the floral disc is one of the essential indicators in determining seed yield, as the quantity or number of seeds is positively related to the diameter of the floral disc (13). The statistical analysis results showed significant differences in the character of the flower disc

Table .4 .Effect of wheat residues and different fertilization treatments on some agronomic traits of Sunflower Asgaro

Treatment*	Plant height (cm)	Flower disc diameter (cm)	Average dry weight of disc (g)
Control treatment without fertilization	124.2	10.73	44.18
80 kg/ha	151.7	10.9	56.21
120 kg/ha	160.8	11.31	59.41
Wheat residue concentration 1400 g/m	168.3	12.77	55.53
Wheat residue + 120 kg/ha	173.3	13.21	78.06
L.S.D	13.26	1.864	9.81

* Each an average of three replicates.

diameter between the treatments (Table 4). Regarding the fertilization treatments, we note that the mineral fertilization treatment of 120 kg per ha with wheat residue was significantly superior to the rest of the fertilization treatments studied in the flower disc diameter of 13.21 cm). In contrast, this characteristic's treatment without fertilization recorded the lowest significant values (10.73 cm). It is noted that the studied mineral fertilizer additions or organic residues led to an increase in the diameter of the floral disc compared to the control treatment, and this is consistent with the results reached by (14).

Also, wheat residues affect the growth and number of weeds by releasing inhibitory allelopathic compounds from wheat residues due to microorganisms present in the soil. Research indicates that wheat residues contain allelopathic compounds of a phenolic nature that have a high inhibitory capacity for weeds (15, 16). The ability of these compounds to dissolve in water helps in their absorption into the seeds, reducing the rate of germination and seedling growth and then reducing the density of the weeds and their growth above the soil surface (17). The reason for the decrease in the germination and development of the weeds is attributed to the disturbances caused by phenolic compounds in metabolic processes such as the absorption of ions (18), the construction of chlorophyll (19), the stability of the cell membrane (20), and the construction of hormones, proteins, and enzymes (21,22).

Average dry weight of disc

The statistical analysis results showed significant differences in the average dry weight of the disc between the studied treatments (Table 4). Regarding fertilization treatments, we note that the mineral fertilization treatment is 120 kg/ha with wheat residues was significantly higher than the rest of the fertilization treatments in the average dry weight of the flower (78.06 g). The lowest value was recorded in the control treatment (44.18 g).

Increasing the proportion of mineral nitrogen readily available to the plant leads to a noticeable improvement in the average dry weight of the flower disc (23-25). Also, the results show that the apparent reduction in weed density and dry weight has positively impacted the yield of sunflower plants in terms of dry matter, grains, and grain yield components. The reason for this is that this reduction has led to the growth of few and weak plants, making them lose their ability to compete for water, nutrients, and other factors.

Average weight of whole seeds per plant

The results of the statistical analysis showed that there were significant differences in the average seed weight per plant (Table 5). As for fertilization treatments, we note that the mineral fertilization treatment is 120 kg. h^{-1} with the addition of wheat residues, it was significantly higher than the other fertilization treatments studied regarding the average seed weight per plant (41.45), followed by the fertilization treatment with the 120 kg fertilization treatment. Meanwhile, the control treatment without fertilization was the least significant in this trait (23.14 g). Fertilizer additions led to an increase in the amount of dry matter manufactured in the plant. Many studies (26) have indicated the significant impact of nitrogen fertilization on the sunflower plant, as the rate of growth and development of vegetative (leaves) and reproductive (flowers and seeds) growth is greatly affected by a lack of nitrogen, as Nitrogen deficiency during the early growth period causes a decrease in the percentage of leaves and a delay in their growth and thus results in a reduction of the leaf area index (LAI) and therefore a reduction in the rate of receiving solar radiation, and consequently the amount of dry matter manufactured and transferred to the seeds in the seed filling stage, and this is consistent with the results reported by (26) and on the contrary, (27).

The average weight of 100 seeds

The final seed weight is determined by the amount of assimilates prepared from the source and the filling capacity of the seed, which begins after the completion of the set and ends at the plant's physiological maturity stage (28) and may be affected by environmental and biological factors. The effect of wheat residues on the seed weight rate and the presence of an apparent increase in seed weight when adding restudy with mineral fertilizer 120 kg/ha. In contrast, the addition of residues alone showed a significant effect on increasing seed weight.

The statistical analysis results showed that the type was treated with added fertilization and residues. Treatment 120 kg. h^{-1} With the addition of wheat residues, it was significantly superior to the rest of the treatments in terms of the weight of 100 seeds (Table 5). As for

Table.5. Effect of wheat residues and different fertilization treatments on Sunflower's yield components under field conditions.

Treatment*	Weight of whole seeds per plant (g)	number of seeds per floral disc (seed):	weight of 100 seeds (g):	Yield kg .h^{-1}
Control treatment without fertilization	23.14	537.5	3.243	1851
80 kg/ha	29.61	701.5	3.767	2369
120 kg/ha	33.47	735.6	3.94	2678
Wheat residue concentration 1400 g/m	30.22	621.5	3.75	2658
Wheat residue + 120 kg/ha	41.45	874.3	4.947	3316
L.S.D	5.512	691	0.039	441

* Each an average of three replicates.

fertilization treatments, we note that the mineral fertilization treatment exceeds 120 kg/ha with the addition of wheat plant residues significantly higher than the rest of the fertilization treatments studied in the average weight of 100 seeds (4.947) (g), followed by a mineral fertilization treatment of 120 kg/ha (3.94). At the same time, the lowest value was recorded in the average weight of 100 seeds in the control treatment (3.243 g). This also means that the fertilizer addition, whether mineral or organic, led to an increase in the weight of 100 seeds as a result of the positive effect of nitrogen fertilization on the vegetative system of the plant and thus on the amount of dry matter manufactured in the leaves and transferred to the seeds. This is consistent with what was mentioned by (29).

The achieved increase in seed weight may result from decreased weed density in the treatments to which wheat residues were added. Competition for essential growth elements was reduced, and seed preparation increased, reflected in an increase in seed weight. Also, the residues added to the soil may improve its nutritional status by adding nutrients resulting from the decomposition of these residues. (30) reported that plowing white corn residues accelerates their decomposition in the soil when appropriate moisture and microscopic revival are available and also helps eliminate the effect of compounds. Allelopathic inhibits the growth of many crops (31).

Average number of seeds per floral disc /seed

The number of seeds per pod represents one of the components of yield that is more related to the variety's genetic characteristics than the variety affected by environmental factors. It is considered an essential criterion in selecting highly productive varieties. This characteristic may be inversely related to the weight of the seed in the pod. Increasing the number of seeds increases the competition between seeds, mainly when it corresponds to a decrease in the processing rates of photosynthesis products and mineral elements. The average weight of one seed decreases due to the distribution of nutrients to a more significant number of seeds. Therefore, the seed-filling rate in varieties whose pods contain three seeds is higher than in those with five seeds (32). The number of seeds in the disk is an essential component of yield, and the statistical analysis results indicated significant differences in the average number of seeds in the studied treatments (Table 5). The study showed that mineral nitrogen fertilization treatments 120 kg/ha with wheat residue have significantly outperformed the rest of the fertilization treatments studied in terms of the average number of seeds per flower disk (874.3) seeds/ disc, while the control treatment was the least significant in this trait (537.5) seeds/disc. The most important effect was mineral fertilization, where nitrogen is easily absorbed. This was reflected positively in the plant's growth, especially in the early stages and the stage of flower and node formation, which was reflected positively in the number of seeds in the disc (32).

The results in Table indicate a significant effect of wheat residues added to the soil on increasing the number of seeds per pod.

Biological yield

The statistical analysis results showed significant differences in the biological yield characteristics between the different fertilization treatments for sunflowers (Table 5). As for fertilization treatments, we note that the nitrogen fertilization treatment exceeds 120 kg/ha - with the addition of residues significantly compared to the rest of the fertilization treatments studied (27,541 kg/ha), where the release of mineral nitrogen in a large amount led to a noticeable increase in the mass of the vegetative system of the whole plant.

This is consistent with the findings of (33), while the treatment without fertilization was the least significant in this trait (12811 kg/ha) From this, the role of residues in reducing weed density and improving plant growth is clear, and this is what (34) found when sunflower residues were added with the pesticide Terflan to combat weeds in the bean crop. Also, adding residues at a rate of 350 or 760 $gm^{-}2$ alone in the treatments from which weeds were removed until the end of the season (without weeds) in the first season increased the dry weight of the plant by 27 and 30% compared to the treatment without the jungle itself and without the addition of residues. This may give a positive indication that adding residues improves crop growth through its role in improving soil properties and nutritional status (35).

Yield from seeds

The results of the statistical analysis showed that there were significant differences in seed yield for all treatments (Table 5). As for fertilization treatments, it was observed that the mineral fertilization treatment exceeded 120 kg/ ha with the addition of residues was significantly superior to the rest of the fertilization treatments studied, followed by the 120 kg fertilization treatment 120 kg/ha, (3316, 2678 kg/ha) respectively). Adding arrowroot through mineral fertilizer increases the abundance of elements for the plant from the early stages of growth, which leads to the formation of a good shoot and leaf area that is effective in the process of photosynthesis and, thus, the accumulation of dry matter and its transfer to the seeds along with abundant water through provision. This increased the number of seeds and the weight of 100 seeds, reflected in the increased seed yield. The mixed fertilization also gave a reasonably good result, as organic fertilizer leads to a slow release of nutrients and improves the efficiency of using mineral fertilizer, positively impacting the yield and its components. This is consistent with the findings of (25).

The results show a significant effect of adding wheat residues and mineral fertilizer addition treatments. In general, by observing the results of the weed-free treatment for the length of the season, it is clear that the wheat residues alone improved the growth and yield of the Sunflower, which led to achieving the highest yield when adding the residues. It increased the yield, which indicates that reducing the number of weeds and inhibiting their growth in these treatments made them lose their ability to compete with the sunflower crop and

saved some growth factors, including nutrients, water, and other things that would have been spent on growing the weeds. In addition, the decomposition of wheat residues will add more seed. Organic matter will improve the physical and chemical properties of the soil, and all of this will reflect positively on the growth of the bean crop and improve its productivity. The decrease in weed density is due to the release of some allelopathic compounds that inhibit the growth of many types of weeds, which are known for their adverse effects on many plant metabolic processes, such as the absorption of nutrients, the construction of chlorophyll, proteins, hormones, cell division, and cellular components (36). Most of these compounds have a high solubility in water, which helps their absorption into the seed and reduces the germination rate and seedling growth.

Conclusion

1. Wheat residues alone or combined with nitrogen (120 kg) appeared more effective on growth than the sole treatments.
2. Integration of wheat residues at 1400 gm /m^2 with 120 kg/ha is significantly superior to the fertilizer treatments that improve sunflower crops.
3. Wheat residues showed allelopathic inhibition of companion weeds.

Recommendations: According to the results of this study, the following points are recommended:

1. Considering the allelopathic phenomenon as an agricultural practice to reduce the weed population and decrease herbicide dependence.
2. Use Wheat residues to control weeds in heavy weed-infested soil.
3. More screening programs on allelopathic crops, including Sunflower, should be conducted to find genotypes with superior allelopathic potential to be used for weed control.

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Authors' contributions

AK carried out the agriculture experiment of this paper, the spilt plot design, and the study design and performed the statistical analysis, in addition to reading and approving the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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