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The importance of crop rotation and some inducing factors in indicators of infection of wheat Galls nematode *Anguina tritici*

ABSTRACT

The field experiment was carried out in the fields of a farmer in Kirkuk governorate / Hawija district N 43º36´17.73"E"05.56´ 35º16, and the study included the planting of the crop rotation crops (mung beans, sunflower and sesame and without planting) in the summer For the year 2020, and in the winter season, the wheat crop, Sham 6 variety, was planted in the experimental units planted with the crops of the agricultural rotation, as well as fallow land that was not planted with any previous crop. The wheat crop was treated with inducting factors (atonic, salicylic acid, hydrogen peroxide and organic copper) by two sprays, the first at the branching stage and the second at the end of the elongation stage, for each of the inducting factors, the randomized complete block design was used in the arrangement of the split plot RCBD in split plot), the results of the experiment showed a significant superiority of the induction treatment with organic copper in reducing the infection indicators of wheat plants, as it recorded the percentage of infestation of spikes, the percentage of infected grains and the average weight The gall had the lowest average of 10.92 %, 3.42 %, and 3.91 mg, respectively, and the sunflower treatment showed a significant difference for the characteristics of the percentage of spikes infestation, the percentage of infected grains, and the average weight of the gall. Were 10.39, 4.30%, and 3.83 mg, respectively As for the interaction treatments between inducing factors and the crop rotation, the treatment of (Sunflower + Organic Copper) was superior when it recorded averages of 5.71%, 0.47% and 2.33 mg, respectively.

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INTRODUCTION

Wheat *Triticum aestivum* L., which belongs to the Poacea family, has an advanced position among the strategic grain crops due to the large volume of its trade exchange capacity in global markets, and its nutritional value is high because it contains most of the nutrients needed by the human body (Tony, 2013). Also, wheat contains many nutritional compounds such as carbohydrates, proteins, minerals and some vitamins such as vitamins B and E, and wheat products provide about (20%) of the calories consumed by the human body per day, as they contain 12-17% proteins and 76- 80% carbohydrates and 1.2-1.5 fats (Hussein and Omar, 2007) Wheat is the main source of daily nutrition for most of the world's population, reaching 35%, and thus ranks first in the world in terms of production and demand (Kadum et al, 2019)

The Ear Cockle Disease, caused by *Anguina tritici*, is one of the most important diseases that affect the wheat crop, as it spreads in most countries of the world. The global losses of the disease in wheat production have reached more From 50% (Paruthi et al.,1987) and in Iraq, the first record of the disease was made by the English expert Rao, 1921, in the early twenties of the last century. and that among the safe means is the Crop Rotation, a concept intended The rotation of planting different crops on a specific plot of land (Gowarikar et al., 2009), in a study on the crop rotation system consisting of three levels, the first (mung beans - wheat), the second (maize - wheat)

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and the third (soybean - Wheat), the study showed that the succession system (soybean - wheat) gave the highest production of 6.85 tons. ha^{-1}, and the (mung beans - wheat) system recorded a production of 5.73 tons. ha^{-1}. The Crop rotation system (potatoes - Wheat-without planting) reduced *Globodera heterodera* nematodes in soil to 44.69% (Khniwi et al., 2015). The extract of sunflower leaves on the root knot nematode *Meloidogyne incognita*, at a concentration of 40 mg/kg of sunflower leaves, showed a significant difference in the number of second-stage juvenile in the root after four days of incubation, with an average of 5 juvenile /root compared to the control 40 juvenile / Root (Amulu et al., 2021) .Induced resistance is one of the means of resistance to plant diseases, which has given effective results in many diseases, which is to motivate the plant and push it to resist the disease through the formation of substances responsible for resistance before the occurrence of infection and the speed of the reaction when the injury occurs, which includes the induction of responses Plant defense at the level of tissue systems and organs, building phytoalexin, and building proteins in response to the elicitor factor. Methyl-salicylic acid induced resistance against root-knot nematodes *M. incognita* in tomato, as the number of eggs decreased to 50%, while the number of nematodes decreased by 57% (Molinar and baser, 2010). As shown by El-Saedy et al. (2019), the effect of hydrogen peroxide on citrus nematodes (*Tylenchulus semipenetrans*, Cobb) at a concentration of 20 ml/tree reduced the population density of the pest population to 76%. Because of the importance of this disease and its causing great economic losses in many areas of wheat planting in Iraq, and due to the lack of studies on it, the study aimed to: Field application in some spraying treatments of inducing materials, which include (salicylic acid, hydrogen peroxide, organic copper and atonic) and Apply of the Crop rotation whose succession corresponds to the wheat crop (sesame, sunflower, mung beans, and without planting)

MATERIALS AND METHODS

Collecting galls of wheat

Samples were collected from infested bread wheat grains, which were obtained from some affected fields, as well as from grain purification laboratories for the bread wheat crop. After that, the galls were manually isolated according to the required quantities, and placed in Polyethylene bags until the time for field use.

Crop rotation experience

The experiment of the Crop rotation was carried out during the summer season (2020) in one of the farmers' fields in Hawija district / Kirkuk governorate. The soil of the field, which was fallow land for the previous season, was prepared by tillage twice in an orthogonal way and doing the leveling and smoothing operations well, in order to prepare it for planting The Crop rotation crops in order to know the effect of planting these summer crops on wheat gall nematodes during the growing season

Land division and planting

The land was divided according to the randomized Complete Block Design (RCBD), as it was divided into rectangular plots of (22 x 6 m^2) planted with crops of the Crop rotation and then distributed randomly on the blocks, leaving a space between the panels of 2 meters in order to prevent the transfer of juvenile nematodes from Between the plots and the occurrence of interference between them, the experiment was fertilized according to the fertilizer recommendations recommended by the Ministry of Agriculture for each crop of the Crop rotation.

Factors of the Crop rotation

The experiment of the Crop rotation included four Factors (sesame, mung beans, sunflower and without planting), as the seeds of the Crop rotation crops were obtained from local markets (local varieties), the crops of the Crop rotation were planted in each separate plot from the other and according to the approved field recommendations. By the Ministry of Agriculture, each plot was inoculate with one gall with each grain of wheat that had been collected preset. The experiment was irrigation with a sprinkler irrigation system, according to the plant's need for water. As for the factor without planting, the land was contaminated with galls in equal quantities and left without any agricultural operations.

Induction experience

After the end of the crop rotation, the experiment land was watering the field before planting while keeping 50% of the residues of the previous crop. When appropriate drought, the land was tillaged well and the smoothing and leveling process was conducted for it. The land was divided according to the place of distribution of the Crop rotation experiment Factors. Separate secondary plots were made with dimensions (3 * 1.5 m) with three plots on the width, between them an earthy barrier 50 cm to prevent overlapping of the Factors of the experiment, and six plots on the linear between them is an earthy barrier 1 meter. Note that each experimental unit was planted with crops during the previous

Treatment preparation

Wheat seeds were used, variety Sham 6, which were prepared by the Seed Examination and Certification Authority / Salah El-Din Branch, as the grains were planted in the form of longitudinal Rows between each Row and the last of 25 cm. Hawija district, the experiment was applied by designing the complete random blocks in the arrangement of split plot (RCBD in Split plot), as the crops of the Crop rotation included main plots and induction treatments of secondary plots. After completing the distribution of treatments, DAB fertilizer (P2O546% and N 18%) was added in an amount of (320 kg/ha), and urea fertilizer (N 46%) was added at the beginning of the tillers with an amount (200 kg/ha), Irrigation and Removal of the weeds manually according to the needs of the plants, the experiments included the following treatments: 1. Control treatment which included Inoculation with the pathogen only without the inducing factor, as the soil of each factor of the Crop rotation experiment was inoculated. 2. Control treatment which included sow only wheat without pathogen and inducing factor 3. spraying with salicylic acid at a concentration of 200 ppm. 4. spraying with organic copper of Spanish origin, Disper company, at a concentration of 2 g / liter. 5. The Atonic spray treatment, of Japanese origin, at a concentration of 2 ml / liter 6. spraying hydrogen peroxide at a concentration of 150 ppm.

Statistical analysis

The data of the experiment were analyzed according to the randomized Complete Block Design in a split plot using the Statistical Analysis System (SAS, 2003) and the means were compared for the studied traits using Duncan's Multiple Range Test at a probability level of 0.05.

Field measurements

1. Percentage of infected spikes = Number of infected spikes / Total number of spikes ×100
2. Percentage of infected grains = Number of infected grains / Total number of grains ×100
3. The weight of the gall (mg). The average weight of 20 galls was calculated from each experimental unit.

RESULTS AND DISCUSSION

Effect of induction factors and Crop rotation on infection indicators of wheat plant Sham 6

1. Percentage of infected spikes %

Table (1) shows significant effects of inducing factors at the 5% probability level, as no spikes were infected in the healthy control treatment, followed by the organic copper treatment, which significantly superiority the other induction treatments by reducing the proportion of infected spikes to 10.92%, while the highest incidence of spikes was 17.70%. in atonic treatment, but it reduced the infection ratio compared to the infected control treatment, in which the infection ratio reached 35.54%. As for the Crop rotation treatments, the sunflower treatment superiority when it recorded the lowest infection ratio of 10.39%, while the highest infection ratio for spikes of wheat was in the treatment that was not planted. It has a summer crop (treatment without planting). The results also show that all the interaction treatments for the healthy control treatment recorded an infection ratio of 0.00% and for all the treatments of the Crop rotation, and the interaction treatment (sunflower + organic copper) achieved the lowest infection ratio of 5.71% with a significant difference from all the interaction treatments of the studied factors, as it is noted that all interaction treatments have achieved a lower infection ratio with a significant difference than the infected control treatment and in all treatments of the crop rotation with inducing factors.

Table (1): Effect of inducing factors and Crop rotation on the percentage of infected spikes of wheat variety Sham6

Crop Rotaion / inducing factors	Sunflower	Mung Beans	Sesame	Without Planting	Average Of Effect Inducing Factors
Salicylic Acid	9.54kl	12.30ji	8.70l	23.08f	13.40d
Atonic	11.98j	17.53h	11.62j	29.67c	17.70b
Hydrogen Peroxide	9.77k	13.29i	9.63kl	26.39d	14.77c
Organic Copper	5.71n	11.60j	7.33m	19.05g	10.92e
Control - Infected	25.37e	33.50b	29.40c	53.92a	35.54a
Control -Healthy	0.00o	0.00o	0.00o	0.00o	0.00f
Average Of Effect Crop Rotation	10.39d	14.70b	11.11c	25.35a	

The average carrying similar letters mean that there are no significant differences at the 0.05 level and those carrying different letters mean that there are significant differences between them at the level of significance

2. The percentage of infected grains

The results of Table (2) indicate the effect of inducing factors and the crop rotation on the percentage of infested grains of the Sham 6 wheat plant.

Table (2): Effect of inducing factors and Crop rotation on the percentage of infested grains of wheat cultivar Sham 6

Crop Rotaion / inducing factors	Sunflower	Mung Beans	Sesame	Without Planting	Average Of Effect Inducing Factors
Salicylic Acid	2.10l	6.70h	2.52kl	9.00g	5.07d
Atonic	4.42ji	8.77g	4.57i	13.29	7.76b
Hydrogen Peroxide	2.71k	6.62h	3.96j	11.06f	6.08c
Organic Copper	0.47n	4.95i	1.22m	7.05h	3.42e
Control - Infected	16.16d	23.43b	17.23c	31.77a	22.14a
Control -Healthy	0.00n	0.00n	0.00n	0.00n	0.00f
Average Of Effect Crop Rotation	4.30d	8.41b	4.91c	12.02a	

The average carrying similar letters mean that there are no significant differences at the 0.05 level and those carrying different letters mean that there are significant differences between them at the level of significance

As the healthy control treatment recorded an infection ratio of 0.00% of grains, followed by the organic copper treatment that significantly superiority on the other treatments by recording the lowest percentage of infected grains amounting to 3.42%, while the Atonic treatment recorded the highest percentage of grain infestation amounted to 7.76%, but it significantly superiority the infected control treatment, which recorded a ratio of infection of grain reached 22.14%, and the

Sunflower treatment showed the lowest infection ratio of 4.30% and the highest infection ratio recorded by treatment without planting 12.02%. The results also showed that all the interaction treatments for the healthy control treatment recorded an infection ratio of 0.00% and for all the treatments of the agricultural cycle, followed by the interaction treatment (sunflower + organic copper), which recorded the lowest infection ratio for grains in the wheat plant, which amounted to 0.47%, with a significant difference from all the interaction treatments for the studied factors. It is also noted that all the interaction treatments achieved a lower infection ratio with a significant difference from the infected control treatment and in all the treatments of the crop rotation with the induction factors

3. The weight of the Gall / mg

Table (3) shows the results of the effect of the inducing factors and the crop rotation on the average weight of one gall. The statistical analysis at the probability level of 0.05 showed significant differences between the induction treatments, as the induction treatment with organic copper recorded the lowest average weight of one gall at 3.91 mg, while the Atonic treatment recorded the highest The average weight of the gall was 6.23 mg, but it superiority the infected control treatment with a significant difference, which recorded 11.18 mg, and the sunflower treatment was superior to the rest of the treatments for the Crop rotation when it recorded the lowest average of 4.59 mg, and the treatment without planting recorded the highest average gall weight of 8.51 mg. the results in Table (3) that all the interaction treatments (induction factors + Crop rotation) were superior and significantly different than the infected control treatment, as the (organic copper + sunflower) treatment gave the lowest average gall weight of 2.33 mg, while the treatment recorded (Atonic + without planting) the highest average gall weight was 8.17 mg, which did not differ significantly from the treatment (hydrogen peroxide + without planting).

Table (3): Effect of inducing factors and crop rotation on gall weight/mg of wheat plant Sham 6

Crop Rotaion / inducing factors	Sunflower	Mung Beans	Sesame	Without Planting	Average Of Effect Inducing Factors
Salicylic Acid	3.13m	5.01i	3.94k	6.65g	4.68d
Atonic	5.05i	7.55f	4.16j	8.17e	6.23b
Hydrogen Peroxide	3.33l	5.20i	4.03jk	8.04e	5.15c
Organic Copper	2.33n	4.02jk	3.31lm	6.00h	3.91e
Control - Infected	9.13d	12.17b	9.70c	13.73a	11.18a
Control -Healthy	____	____	____	____	0.00f
Average Of Effect Crop Rotation	4.59d	6.79b	5.02c	8.51a	

The average carrying similar letters mean that there are no significant differences at the 0.05 level, and those carrying different letters mean that there are significant differences between them at the level of significance

The results of Table (1, 2 and 3) showed the effect of the inducing factors and the Crop rotation on the infestation indicators of the wheat plant Sham 6, as the Crop rotation treatment (Sunflower) proved its efficiency in reducing the incidence of spikes, the incidence of grain infestation and the weight of one gall, which amounted to 10.39 , 4,30%,4.59 mg, respectively. The reduction in the infestation ratio in spikes and grains and the weight of the gall may be due to the reduction in the number of second-stage juvenile of the wheat gall nematode *A.tritici* in the treatment of sunflower. This is in agree with Amulu et al. (2021) that the extract of sunflower leaves reduced the number of second-stage juvenile,in This result is in agreement with Aminu-Taiwo and Fawole (2018), who found that the aqueous extract of sunflower leaves at a

concentration of 10% inhibited egg hatching of root-knot nematodes *Meloidogyne incognita* by 97.97% and a killing ratio of 100% after two days of incubation, as agreed with Badr (2019) that *Helianus annus* sunflower extract with a concentration of 100% achieved significant results, as the percentage of larvae/250 soil, number of nodes/root and number of egg sacs (6, 12 and 8), respectively compared to the control, which amounted to 60.06, 65.10 and 40.46 % respectively . The reduction of infection indicators in sunflower treatment may be due to the chemical activity of decomposing substances from the plant such as chromotaline and sesquiterpene lactones, which are likely to be nematicidal substances (Amulu, et al., 2021; Wang et al., 2002;Mcsorly ,2011) and Perez et al,2003) also mentioned that most parts of the plant are rich in compounds such as (tannins, alkaloids and flavonoids), and that these compounds when decomposed in the soil produce ammonia and nitric acid, and these substances are considered toxic to nematodes. The results of table (1, 2, and 3) also showed the superiority of the organic copper treatment in reducing the infection indicators with a significant difference, as the percentage of spike infection, the percentage of grain infection, and the weight of one gall were 10.92 %, 3.42 and 3.91 mg, respectively. This may be due to the fact that the concentration of 2 g/L used in this study was high, which caused the toxicity of the second-stage larvae, and the spraying time may have an effect (the branching period of the wheat plant) during the activity of the larvae and their climbing the plant. This results agree with Mohamed et al. (2019) reported in a study conducted on the effect of using copper nanoparticles in vitro against the second stage larvae of the root knot nematode *Meloidogyne incognita*. When incubating soil saturated with nano-copper at a concentration of 0.2 g/L, second-stage larvae were placed inside it for three days, after which the soil was examined and it was found that the death ratio was 100% for larvae. The mechanism of copper's effect on nematodes is indicated by Hedges (2010) that it causes damage to the nervous system, followed by paralysis of the nematodes. As Bargmann (2006) mentioned that copper causes an increase in the level of calcium through the amphid sense organ located in the front of the nematode body, which is connected to the nerves, so there will be a continuation of the chemical stimulation of the nematode.

The results also show that the dual interaction treatment (sunflower + organic copper) achieved the best results in reducing infection indicators compared to the single treatment of them, and this result may be attributed to the combined effect of the two treatments on wheat gall nematodes

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أهمية التعاقب المحصولي وبعض عوامل الاستحثاث في مؤشرات الإصابة لنيماتودا ثآليل الحنطة *Anguina tritici*

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الخلاصة

نفذت التجربة الحقلية في حقول احد المزارعين في محافظة كركوك/ قضاء الحويجة 35º16´ 05.56"E"17.73´36º43 N, وتضمنت الدراسة زراعة محاصيل الدورة الزراعية (الماش و زهرة الشمس والسمسم وبدون زراعة) في الموسم الصيفي لعام 2020 , وفي الموسم الشتوي تمت زراعة محصول الحنطة صنف شام6 في الوحدات التجريبية المزروعة بمحاصيل الدورة الزراعية كما تمت زراعة ارض بور لم تزرع بأي محصول سابق ,تم معاملة محصول الحنطة بعوامل الاستحثاث (الاتونيك وحامض السالسيلك وبيروكسيد الهيدروجين و النحاس العضوي) بواقع رشتين الاولى عند مرحلة التفرعات والثانية في نهاية مرحلة الاستطالة, وذلك لكل عامل من عوامل الاستحثاث , تم استخدام تصميم القطاعات العشوائية الكاملة بترتيب الالواح المنشقة (plot RCBD in Split) , أظهرت نتائج التجربة تفوق معنوي لمعاملة الاستحثاث بالنحاس العضوي في خفض مؤشرات الإصابة لنبات الحنطة , اذ سجلت نسبة إصابة السنابل و نسبة الحبوب المصابة ومعدل وزن الثؤلولة ادنى متوسط بلغ 10.92 % و 3.42 % و 3.91 ملغم على التوالي , كما أظهرت معاملة زهرة الشمس فرقا معنويا لصفات نسبة إصابة السنابل و نسبة الحبوب المصابة ومعدل وزن الثؤلولة بلغ 10.39 % و 4.30 % و 3.83 ملغم على التوالي , اما معاملات التداخل بين عوامل الاستحثاث والدورة الزراعية فقد تفوقت معاملة (زهرة الشمس + النحاس العضوي) عندما سجلت متوسطات بلغت 5.71 % و 0.47 % و2.33 ملغم على التوالي.

الكلمات المفتاحية:
الحنطة , عوامل الاستحثاث , الدورة الزراعية , مؤشرات الاصابة