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Assessment of the impact of biological and chemical factors on the growth and pathogenicity of fungi associated with yellow maize crops in Muthanna governorate.

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Abstract

The study was conducted in the laboratory of the Badia and Sawa Lake Studies Center in 2025 with the aim of testing the efficiency of some biological and chemical factors in inhibiting the growth of some fungi associated with yellow corn crops and the germination of their seeds in Al-Muthanna Governorate / Iraq. The results showed the superiority of the alcoholic plant extracts (*Heliotropium bacciferum* and *Achillea virescens*) in giving the least growth of the pathogenic fungi *Fusarium solani* and *Fusarium phialophorum*. *Alernaria tenuissima* showed growth rates of (1.0, 1.0, and 1.3) cm, and (3.2, 3.7, and 4.1) cm respectively at a concentration of 7.5% for both species. The extracts also provided protection for maize seed germination in media contaminated with pathogenic fungi, yielding germination rates of (100, 100, and 75)%, and (75, 75, and 62.5)% respectively for the extracts at the same concentration. We also note a significant decrease in the growth of the three fungal isolates when using the five bacterial isolates at varying rates, but the *Streptomyces griseus* isolate stood out by giving the lowest average growth of (2.5, 0.9 and 2.2) cm respectively and protection rates for the germination of yellow corn seeds of (75.5, 100 and 62.5)% against the three fungal isolates respectively. As for the fungicide Othello Top 32.5% SC, it reduced the growth of pathogenic fungi with diameter areas of (1.7, 1.9 and 1.5) cm respectively at a concentration of 1.5%.

Keywords: Biological factors, yellow maize, Al-Muthanna Governorate.

Introduction

Yellow corn *Zea mays* L. is one of the most important agricultural crops after wheat and barley. It is grown in two seasons, autumn and spring, and constitutes 78% of animal feed, as it is the main component in animal feed and poultry rations (Uppal et al., 2014).

In the autumn season, especially in Iraq, the yellow corn crop is exposed to infection by many pathogens, the most important of which are fungi, at different stages, whether before or after harvest, and during transport and storage (Kabak, 2009). The harvest period coincides with the rainy season and the high humidity, which constitutes the most important basic factors that prepare for infection. The lack of modern scientific methods in agriculture, crop storage and management in developing countries makes it more susceptible to contamination by fungal pathogens compared to other crops, and consequently a decrease in the nutritional value of the corn crop and the significant losses it causes in the crop, poultry and animal husbandry and human consumption (Wagacha and Muthami, 2008).

In recent years, many diseases of rot and late wilt caused by the fungus *Fusarium* sp. have emerged. Due to the lack of knowledge of farmers regarding prevention and control methods, they may resort to using chemical pesticides that are fast-acting and give effective results (Hu et al., 2012). However, they cause many diseases in animals, poultry, and human consumption due to the slow-decomposing toxic substances (Zain, 2011). Therefore, the research aimed to study the effectiveness of some biological control agents, such as the use of plant extracts and bacteria, as alternatives to chemical substances, and to measure their inhibitory effect on fungal pathogens and the extent to which they can be used on a large scale.

Materials and Methods

1- Sample Collection

Samples of yellow corn plants were collected from farms near the center of Al-Muthanna Governorate (Al-Rumaytha and Al-Majd) in the September of the 2025 agricultural season. The entire plant (vegetative parts) was taken and placed in polyethylene bags and brought to the laboratory for isolation on the same day.

2- Isolation and Identification of Fungal Pathogens

Samples were taken from the leaves and stems of the yellow corn plant and cut into small pieces (1 cm). They were washed thoroughly with sterile distilled water, then sterilized with a 10% sodium hypochlorite solution for two minutes. They were then washed several times with sterile distilled water and placed on filter paper to remove any remaining solution. The samples were transferred to plastic plates with a diameter of (9) cm containing the previously prepared PDA culture medium, at a rate of 5 pieces per plate. The plates were then incubated at a temperature of 25 ± 2 °C for seven days. The fungi *Fusarium solani*, *Fusarium phialophorum*, and *Alernaria tenuissima* were identified morphologically and microscopically, using taxonomic keys, and

assigned the following codes (F1, F2, and A).

3- Preparation of Plant Extracts

The aqueous extract (hot and cold) of the leaves of *Achillea virescens* and *Heliotropium bacciferum* was prepared according to Al-Mansour's method (1995). The leaves were collected, washed thoroughly under running water, then with distilled water, and left to dry. They were then cut into small pieces and air-dried away from sunlight. The mixture was then placed in an electric oven at 50°C for two hours. Afterward, the components were crushed and ground in an electric grinder. Fifty grams of the dried plant material were placed in one liter of distilled water, shaken for half an hour, and left to stand for 24 hours. The solution was then filtered several times through filter paper and poured into test tubes. These were centrifuged for 10 minutes at 3000 rpm. The precipitate was discarded, and the filtrate was collected in glass dishes and placed in an electric oven at 50°C until completely dry. As for the alcoholic extract of the two plants, the same previous method was used, with the solvent (water) being replaced by ethanol at a concentration of 70%. Then we weighed the extract and obtained a weight of 25 grams of dry extract. Then we prepared different concentrations of it (2.5%, 5% and 7.5%) by dissolving (2.5, 5 and 7.5) grams each separately in 97.5, 95 and 92.5 ml of sterile distilled water and kept it in the refrigerator until use.

4- Bacterial isolates used as a biological agent

The bacterial isolates used in the study were obtained by Professor Dr. (Sofia Jabbar Jassim) of the Badia and Lake Sawa Studies Center / Al-Muthanna University, and were previously molecularly identified by her, as follows: (*Bacillus paramycoides*, *Bacillus cereus*, *Streptomyces griseus*, *Kiebsilla aerogenes*, and *Citrobacter freundii*), where they were given the symbols (B1, B2, S, K, and C).

5- Othello Top 32.5% SC fungicide used in the study

Othello Top 23.5% SC, a preventative fungicide with systemic activity against many fungi, was obtained from an agricultural office in Al-Qadisiyah Governorate and was used according to the recommended instructions. It was prepared in three concentrations (0.5, 1.0, 1.5) ml/L for testing in subsequent experiments.

6- Inhibitory Effect of Plant Extracts on *F. solani*, *F. phialophorum*, and *A. tenuissima*

A laboratory experiment was conducted to assess the inhibitory effect of aqueous and alcoholic extracts of the plants (*A. virescens* and *H. bacciferum*) at three concentrations (paragraphs 3) against fungal isolates of (F1, F2 and A) . The toxic culture method (Ligocka et al., 2002) was used. PDA culture medium was prepared and sterilized in an autoclave at 121°C and 15 psi for 20 minutes. It was then divided into 250 ml flasks and allowed to cool slightly. The plant extracts were then added according to their type and concentration. The medium was poured into Petri dishes. The center of each dish was inoculated with a 0.5 cm diameter

disc containing the aforementioned fungal isolates grown on PDA medium at six days old. A control treatment was performed by inoculating the center of each dish with the fungal isolates individually, with three replicates of each isolate. The dishes were incubated at 25 ± 2°C for six days, and the diameters of the growing fungi were measured six days after the treatment.

7- Inhibitory effect of bacterial species on *F. solani, F. phialophorum* and *A. tenuissima*

The experiment was carried out to estimate the inhibitory effect of bacterial isolates (*B. paramycoides*, *B. cereus*, *S. griseus*, *K. aerogenes* and *C. freundii*) at a concentration of 1×10^{-3} against fungal isolates (F1, F2 and A), following the same method mentioned in paragraph (6).

8- Inhibitory effect of Othello Top 32.5% SC fungicide on *F. solani, F. phialophorum* and *A. tenuissima*

Three concentrations of the fungicide Othello Top 23.5% SC (0.5, 1.0, 1.5) ml/L were prepared. One milliliter of each concentration was added to empty Petri dishes separately. Sterile PDA culture medium was then poured into the dishes containing the fungicide and stirred in a counterclockwise circular motion to ensure even distribution of the fungicide. The mixture was left to solidify. The center of each dish was inoculated with a 0.5 cm diameter disc containing the fungal isolates (F1, F2 and A), each at six days old, with three replicates for each isolate and each concentration. A control treatment was also performed, which involved adding the fungus to the PDA culture medium without the fungicide. The dishes were incubated at 25 ± 2 °C for six days. The diameters of the growing fungi were measured at six days of maturity in the control treatment.

9- The efficacy of plant extracts in protecting yellow corn seeds against the fungal pathogens

The seeds of the yellow corn variety (Al Maha) were sterilized with 70% ethanol for two minutes and then washed several times with distilled water. The seeds were then soaked in aqueous and alcoholic extracts of the plants (*A. virescens* and *H. bacciferum*) separately and at three different concentrations for six hours. After that, the seeds were transferred to plates containing PDA culture medium contaminated with fungal suspensions of (F1, F2 and A) separately, with three replicates for each treatment and 8 seeds per plate. It was emphasized to carry out a control treatment, which ensured the cultivation of seeds soaked in the alcoholic extract only, without adding the fungal isolates, on the aqueous agar medium. The plates were incubated at a temperature of 25±2°C for 10 days, after which the number of germinated seeds was counted and compared to the control treatment.

10-Efficiency of bacterial isolates in protecting yellow corn seeds against fungal growth

The yellow corn seeds of the same variety (Al Maha) were sterilized with 70% ethanol for two minutes, then washed several times with sterile distilled water. The seeds were then soaked in the bacterial suspension of

the isolates (*B. paramycoides*, *B. cereus*, *S. griseus*, *K. aerogenes* and *C. freundii*) at a concentration of 1 x 10^{-3} for six hours, each separately. They were then transferred to Petri dishes contaminated with the fungi (F1, F2 and A) each separately, and the same method mentioned in paragraph (9) was followed.

Results

1- The efficacy of plant extracts in inhibiting the growth of pathogenic fungi

The results in Table (1) showed that the plant extracts were significantly superior at all concentrations used in inhibiting the growth of the pathogenic fungi under study, as the alcoholic extract of *H. bacciferum* at a concentration of 7.5% gave the highest percentage in inhibiting the growth of the fungi (F1, F2 and A) with an average diameter of (1.0, 1.0 and 1.3) cm respectively, followed by the alcoholic extract at a concentration of 5% with an average growth of fungal colony diameter of (1.5, 1.5 and 2.0) cm for the same fungal isolates respectively. The concentration of 2.5% was the least effective within the alcoholic extract with an average growth of (2.2, 2.0 and 2.7) cm respectively. As for the aqueous extracts of the plant *H. bacciferum*, their highest effect was at a concentration of 7.5% for both types (cold and hot), where the percentages reached (3.9, 5.0 and 3.5) and (3.2, 4.5 and 4.4) cm respectively for the same fungal isolates. The alcoholic extract of *A. virescens* had a lower effect than the alcoholic extract of *H. bacciferum*, with growth diameters of (3.2, 3.7, and 4.1) cm respectively at a concentration of 7.5%. The growth diameters of the fungal isolates increased as the concentration of the extract decreased, reaching a concentration of 2.5% for the cold extract, which gave the lowest inhibition rate of the growth of the fungal isolates, with growth diameters of (7.0, 7.0, and 8.5) cm respectively. We note that all treatments were significantly superior in inhibiting the growth of the pathogenic fungi under study compared to the control treatment, in which the average colony diameter was (9) cm for both types of extracts.

Table (1): Effect of plant extracts in inhibiting the growth of pathogenic fungi

Extract	%Concentration	%Average diameter of fungal isolates after six days of testing								
		Cold water extract			**hot water extract**			**ethanolic extract**		
		F1	F2	A	F1	F2	A	F1	F2	A
H. bacciferum	0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	2.5	5.5	7.0	5.5	4.9	6.5	6.5	2.2	2.0	2.7
	5	5.0	5.5	4.2	4.2	5.3	5.0	1.5	1.5	2.0

	7.5	3.9	5.0	3.5	3.2	4.5	4.4	1.0	1.0	1.3
	average	5.8	26.6	5.55	5.32	6.32	6.22	3.42	3.37	3.75
A. virescens	0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	2.5	7.0	7.0	8.5	6.5	7.0	8.0	5.0	5.0	5.5
	5	6.4	7.0	7.0	5.9	6.2	7.0	4.0	4.3	4.9
	7.5	6.0	6.5	6.5	5.1	5.6	6.2	3.2	3.7	4.1
	average	7.1	7.37	7.75	6.62	6.95	7.55	5.87	5.5	5.3
	L.S.D $_{0.05}$	0.1148 = E			0.1148 = F		0.1325 = C		0.0937 =E	

E = Plant extract // C = Concentrate // F = Fungi

2- The efficiency of bacterial isolates in inhibiting the growth of pathogenic fungi

Table (2) shows that all bacterial treatments were superior in inhibiting the growth of pathogenic fungi, albeit to varying degrees. The results showed that treatment with *S. griseus* (S) had the highest effect in reducing the diameter of *F. solani*, *F. phialophorum*, and *A. tenuissima* by percentages of (2.5, 0.9, and 2.2) cm, respectively, on the sixth day of treatment. This was followed by treatment with K. aerogenes and C. freundii (K and C), which had a significant and clear effect in reducing the growth of fungal colonies by percentages of (4.2, 1.0, and 3.1) and (1.0, 3.5, and 3.7) cm respectively for the previously mentioned fungal isolates. As for the two isolates, *B. paramycoides* and *B. cereus* (B1 and B2), they occupied the last place in their effect on the diameter growth of pathogenic fungi, with growth percentages of (4.3, 2.0, and 3.2) and (2.7, 2.2, and 4.0) cm respectively, compared to the control treatment, which reached (9) cm in the diameters of the growth of fungal colonies for all fungal isolates.

Table (2): Effect of bacterial isolates in inhibiting the growth of pathogenic fungi

Fungi	**Diameter (cm) growth of the fungus after six days in the presence of bacteria**					Control
	B1	B2	S	K	C	
A	3.2	4.0	2.2	3.1	3.7	9.0
F 1	2.0	2.2	0.9	1.0	3.5	9.0
F 2	4.3	2.7	2.5	4.2	1.0	9.0
Average	3.1	2.9	1.8	2.7	2.7	9.0

L.S.D $_{0.05}$	0.357 =F×B	0.206 =B	0.146 = F	

F = Fungal isolation // B = Bacterial isolation

3- The effectiveness of the fungicide Othello Top 32.5% SC in inhibiting the growth of pathogenic fungi

The results in Table (3) show that the use of Othello Top 32.5% SC fungicide as a chemical resistance agent had a significant effect in reducing the growth rate of pathogenic fungi *F. solani*, *F. phialophorum*, and *A. tenuissima* to varying degrees depending on the concentration of the fungicide used. The 1.5% concentration gave the highest percentage of inhibition of fungal growth, with colony diameters of (1.7, 1.9, and 1.5) cm respectively. The 1.0% concentration ranked second in reducing fungal colony growth, with growth rates of (2.2, 2.0, and 2.4) cm respectively. These rates then decreased at the 0.5% concentration, resulting in fungal growth rates of (3.0, 3.0, and 2.7) cm respectively. We observe an inverse relationship between pesticide concentration and fungal growth rate; the growth rate decreases with increasing pesticide concentration compared to the control treatment.

Table (3): Effect of the fungicide Othello Top 32.5% SC in inhibiting the growth of pathogenic fungi

Pesticide concentration%	Diameter of fungal growth (cm(Six days after treatment			Average
	F1	F2	A	
0	9.0	9.0	9.0	9.0
0.5	3.0	3.0	2.7	2.9
1.0	2.2	2.0	2.4	2.2
1.5	1.7	1.9	1.5	1.7
Average	3.97	4.07	3.80	
L.S.D $_{0.05}$	F = 0.173	P = 0.200	F×P =0.347	

F = Fungal isolation // P = pesticide

4- The effectiveness of plant extracts in protecting yellow corn seeds against fungal growth

The results in Table (4) show significant differences in the germination rates of yellow corn seeds treated with plant extracts against the pathogenic fungi under study. We also note that there is a direct relationship between the concentration of the extract used and the germination rate, Treatment with the alcoholic extract of the plants (*H. bacciferum* and *A. virescens*) gave a germination rate of (100, 100 and 75) and (75, 75 and 62.5)% respectively at a concentration of 7.5% for the fungal isolates *F. solani, F. phialophorum* and *A. tenuissima* respectively. Then, germination rates began to decrease at the lowest concentration (2.5%), giving low germination rates of (62.5, 37.5, and 37.5) and (50, 50, and 37)% in the alcoholic extract for both plant species, respectively, compared to the aqueous extract (cold and hot) at the same concentration, which showed germination rates of (0.0)% for both species, respectively, These results are similar to the control treatment (without using the extract), and the germination rates increased when the concentration of aqueous extracts increased when compared to the control treatment in which the germination rates reached (0.0)% for both types of extract.

Table (4): Efficiency of plant extracts in protecting yellow corn seeds against fungal pathogens

Extract	concentra % tion	%germination seed OF Yellow corn								
		Cold water extract			**hot water extract**			**ethanolic extract**		
		F1	F2	A	F1	F2	A	F1	F2	A
H. bacciferum	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.5	0.0	0.0	0.0	0.0	0.0	0.0	62.5	37.5	37.5
	5	12.5	12.5	12.5	37.5	37.	37.5	87.5	75.0	75.0
	7.5	20.0	20.0	20.0	50.0	50.0	37.5	100.0	100.0	75.0
	Average	8.12	8.12	8.12	21.87	21.75	18.75	62.50	53.12	46.87
A. virescens	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.5	0.0	0.0	0.0	0.0	0.0	0.0	50.0	50.0	37.5

	5	12.5	12.5	12.5	37.5	20.0	20.0	62.5	62.5	50.0
	7.5	20.0	20.0	37.5	37.5	37.0	50.0	75.0	75.0	62.5
	Average	8.12	8.12	12.50	18.75	14.37	17.50	46.87	46.87	37.50
L.S.D $_{0.05}$	E= 0.071	F= 0.086	E×F= 0.122							

*The data were analyzed after being converted to angular values.

E = Plant extract // F = Fungi //

5- The efficiency of bacterial isolates in protecting yellow corn seeds against fungal growth

Table (5) showed highly significant differences in the germination rate of yellow corn seeds when treated with different bacterial isolates in the presence of fungi. Treatment with S. griseus (S) bacteria provided protection against the pathogenic fungi *F. solani*, *F. phialophorum*, and *A. tenuissima*, giving the highest germination rate of yellow corn seeds, which reached (75.5, 100, and 62.5)% respectively. As for the isolates of *B. paramycoides* and *C. freundii*, the germination rate reached (12.5, 50, and 37.5) and (50, 37.5, and 12.5)% respectively in the presence of the previously mentioned pathogenic fungi. As for the isolates of *B. cereus* and *K. aerogenes*, they had the least effect among the bacterial isolates used, with germination rates reaching (37.5, 37.5, and 12.5) and (12.5, 12, and 50)% respectively in the presence of the pathogenic fungi.

Table (5): Efficiency of bacterial isolates in protecting yellow corn seeds against fungal growth

Fungi	**%Germination seeds of yellow corn in the presence of bacterial isolates**					**Control**
	B1	**B2**	**S**	**K**	**C**	
A	12.5	37.5	75.5	12.5	50.0	0.00
F 1	50.0	37.5	100.0	12.5	37.5	50.0
F 2	37.5	12.5	62.5	50.0	12.5	37.5
Average	33.33	29.16	79.33	25.00	33.33	29.16
L.S.D $_{0.05}$	22.37 =F×B		12.92 =B		10.01 = F	

F = Fungal isolation // B = Bacterial isolation

Discussion

The clear effect of the extract of rhizome and kysom (Table 1) in inhibiting the

growth of pathogenic fungi *F. solani*, *F. phialophorum*, and *A. tenuissima* is due to the nature of the variation in the substances and active ingredients in these extracts and their quantities affecting the inhibitory effect (Qasem and Abu-Blan, 2008), *H. bacciferum* contains Achillein and *A. virescens* contains Chamazuline, essential oil, tannins, and flavones. These substances have a chemical structure that is effective in inhibiting the growth and survival of many fungal species. This may be due to a reduction in carbohydrates and total protein content. They also increase the activity of the enzymes Malik, Fumaras, Succnic dehydrogenase, and dehydrogenase, leading to increased toxicity and thus a reduction in fungal growth rates. At the same time, they reduce the activity of the catalase enzyme in *Fusarium* fungi, thus increasing toxicity. This is consistent with (Thobunluepop et al., 2007, and Ismail, 2009). The extracts are also characterized by containing carboxylic acids, antibiotics, and antioxidants, which work to inhibit the growth of fungi. The dissolved compounds vary depending on the solvent used and its effectiveness in dissolving the largest number of compounds. Ethanol is characterized by dissolving the largest number of active compounds present in the extracts. The inhibitory effect on fungal growth is due to the presence of the Pinene-alpha compound and omega derivatives (3,6w) which have antifungal activity (Shahwar et al., 2012).

The ability of bacteria to inhibit fungal growth (Table 2) may be attributed to their ability to produce chitinase, protease, and amylase enzymes, which digest the fungal cell wall (Wu et al. 2019), in addition to their ability to produce indoleacetic acid (IAA) and siderophores, which are closely associated with inhibiting fungal growth (Rashad et al., 2017). S. griseus bacteria can also produce hydrogen cyanide (HCN), a toxic volatile compound that affects the respiration process of pathogenic fungi, leading to inhibition of their growth. These results are consistent with the findings of De et al. (2021), who used S. griseus bacteria as a biocontrol agent against several species of fungi belonging to the genus Fusarium that cause wilt disease in asparagus plants.

In Table (3), we note the efficiency of the pesticide Othello Top 32.5% SC in inhibiting the growth of pathogenic fungi. This is due to the active ingredients in the pesticide, which cause distortions in fungal cells, change the permeability of the cell membrane, and leak its contents outwards (Yin et al., 2020). The results of this study are consistent with Jaber (2020), as he found that complete inhibition of the Fusarium spp fungus was achieved when using the pesticide Beltanol with the active ingredient (Difenoconazole) at a concentration of 1 ml/L. However, the inhibitory effect decreased with some types of pathogenic *Fusarium* spp when used at a concentration of 10% of the recommended concentration, as the inhibitory effect of the pesticide decreased and reached 88.23% with the two pathogenic fungi *F. cerealis* and *F. culmorum*, while the inhibition rate was 0% in the control treatment.

In Table (4), we note that the germination of yellow corn seeds is not affected by pathogenic fungi when treated with plant extracts. This may be due to the active

ingredient contained in each extract, which can bind to the active groups of the fungus, such as enzymes, or through interference with the fungal DNA and inhibition of its growth (Mutlu-Ingok et al., 2020). Alternatively, the ethanolic alcoholic solvent may have accelerated the diffusion of volatile organic compounds and essential oils, thus inhibiting fungal growth and its effect on seed germination by stressing the fungi and reducing their efficiency in producing biomass, and consequently reducing the metabolism of the fungus (Zhang, 2023). These results are consistent with what Borges et al. (2018) indicated, which showed that plants generally contain secondary metabolites responsible for the synthesis of many biologically active substances, which limit the growth of other plants and protect them from fungi and pathogens, thus demonstrating their effectiveness in disease management. Plant extracts contain large quantities of these biologically active substances, such as alkaloids, cyanogenic glycosides, glucosinolates, lipids, phenols, terpenes, polyacetylenes, polythiols, tannins, phenols, resins, and volatile and fixed oils, which are stored in specific plant structures, such as leaves, bark, seeds, fruits, and roots.

The ability of bacteria to inhibit the growth of pathogenic fungi, as shown in Table (5), stems from their capacity to produce antibiotics, break down fungal cell walls, influence respiratory processes, and exhibit hyperparasitism, either alone or in combination with other biotic factors (Bubici, 2018). These bacteria promote plant growth by producing indoleacetic acid, indicating their affinity for the group of bacteria that stimulate plant growth. In addition to their antibiotic production, Streptomyces species are known to induce the expression of genes associated with plant defense mechanisms (Vurukonda et al., 2018). They can directly induce or produce factors that lead to systemic plant resistance against pathogens. Nasr-Eldin et al. (2019) reported that spraying with Streptomyces reduced *Fusarium* infection by approximately 80% by activating the salicylic acid pathway. These results are consistent with those of Vergnes et al. (2020).

Conclusion

The results obtained indicate that pathogenic fungi associated with maize crops can be controlled using plant extracts and certain microorganisms, such as bacteria, as alternatives to chemical pesticides. Chemical pesticides have negative effects due to the accumulation of toxins in the animal or human body, resulting from their slow decomposition and long persistence. Therefore, I recommend conducting further studies on the use of plant extracts as an antifungal agent against various types of fungi.

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