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Research Article

Effect of date vinegar spraying on the growth and resistance of cucumber plants (*Cucumis sativus* L.) infected with vascular wilt caused by the fungus *Fusarium oxysporum*

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Abstract

This study investigated the efficacy of different concentrations of date vinegar in inhibiting the growth of the phytopathogenic fungus *Fusarium oxysporum*. The results demonstrated that date vinegar suppressed fungal growth, with the 20% concentration achieving complete inhibition (100%) compared with the control treatment, which exhibited no inhibition (0%). The findings also revealed that the germination percentage of cucumber seeds after 10 days increased with increasing concentrations of date vinegar compared with the treatment inoculated with the pathogen alone. The highest germination percentage (95.14%) was recorded in the 15% and 20% date vinegar treatments. Furthermore, the seedling mortality rate was reduced to 0% in all treatments containing date vinegar, whereas the treatment inoculated solely with the pathogenic fungus exhibited a seedling mortality rate of 100% after 14 days. The greenhouse experiment further demonstrated the beneficial effects of date vinegar application on the vegetative growth characteristics of cucumber plants cultivated in plastic pots. Significant improvements were observed in plant height, fresh and dry biomass, and leaf area compared with the pathogen-inoculated treatment. In addition, date vinegar treatments reduced disease severity caused by the pathogenic fungus, resulting in improved plant growth and vigor. These findings indicate that date vinegar has considerable potential as an ecofriendly and sustainable alternative for the management of fungal diseases in cucumber plants. The results of the present study represent a promising step toward sustainable agricultural development and environmental protection by reducing dependence on synthetic chemical pesticides that may adversely affect ecosystems and human health.

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1. INTRODUCTION

Sustainable agriculture is essential in our growing world, where traditional agriculture cannot meet all the requirements [1]. This type of agricultural activity makes the most of the available natural resources [2]. These strategies benefit the environment and ensure the safety of agricultural products for humans. The continued use of pesticides, chemical fertilizers, and herbicides has led to low soil fertility, substandard agricultural production, and poor economic returns, harming the environment through their toxic effects on the biosphere, killing non-target organisms, and the emergence of resistance to those pesticides in the targeted pest, in addition to their toxic effects on humans and animals [3]. The use of these chemicals in agricultural activities directly affects the quantity and quality of agricultural products due to the close relationship between agriculture and the environment [1]. In recent years, researchers have paid great attention to natural plant extracts, especially in the manufacture of fungicides, as potential agents to combat plant pathogens in the field. This is due to their antimicrobial properties and the presence of a variety of secondary metabolites, such as phenols, polyphenols, tannins, flavonoids, alkaloids, glycosides, and other compounds. Numerous studies have demonstrated the effectiveness of plant extracts against various pathogenic fungi, including the fungal species *Alternaria* spp. and *Fusarium* spp. [4] and [5]. Fungal diseases are among the most serious biologic undefined stresses, causing significant crop damage in many countries [6]. In light of climate threats and the spread of pathogens, improving agricultural crop production is essential because it constitutes a major concern for the agricultural sector, especially by avoiding the use of chemical pesticides and replacing them with natural pesticides, such as natural vinegar [7]. Vinegar is a natural product resulting from two stages: the first is anaerobic, through the conversion of fermentable sugars into ethanol, and the second is aerobic, through the conversion of ethanol into acetic acid by bacteria of the genus Acetobacter during the oxidation process [8], as acetic acid is considered the main product of the fermentation process [9].

Therefore, the current study aimed to study the effect of different concentrations of natural date vinegar in stimulating the growth and resistance of cucumber plants (Cucumis *sativus* L.) infected with vascular wilt caused by the fungus *Fusarium oxysporum***.**

2. MATERIALS AND METHODS

a. Pathogenic fungus *Fusarium oxysporum*

A ready-made isolate of the pathogenic fungus *Fusarium oxysporum* (F017) was obtained from the Mycology Laboratory of the Department of Biology, College of Education for Pure Sciences, University of Diyala. Isolates were cultured on PDA medium. Plates were incubated at 25°C for 7 days.

1) Laboratory experiments

To test the effect of different concentrations of natural date vinegar on Cucumis sativus L. cucumber seeds infected with the pathogenic fungus *F. oxysporum* (F017), an experiment was conducted in 9-cm diameter Petri dishes under laboratory conditions. The effects of different natural vinegar concentrations (0%, 5%, 10%, 15%, and 20%) were tested according to the method described by El Helaly et al. [10]. The PDA medium was prepared according to the manufacturer's instructions, sterilized in an autoclave, and allowed to cool to 40°C. Subsequently, 5, 10, 15, and 20 mL of date vinegar were added as v/v (95, 90, 85, and 80 mL) of culture medium to complete the volume to 100 mL. After that, it was poured into the dishes and mixed by hand to mix the extract with the medium and left to cool. Cucumber seeds were pre-sterilized with a 1% sodium hypochlorite solution for 2 min., incubated in a suspension of the pathogenic fungi *F. oxysporum* (F017), and then transferred to Petri dishes at a rate of one seed per dish, with three replicates for each concentration. The control treatment was left untreated without vinegar addition. After 10 days, the following measurements were taken:

Percentage inhibition

Percentage inhibition = (CT/C) × 100.

C = diameter of fungal culture in the control group

T = diameter of fungal culture for processing (vinegar)

- Germination rate

The germination rate was calculated using the following equation:

Germination ratio = (number of germinated seeds / total number of seeds) 100

- Percentage mortality of seedlings

As for the death of seedlings, the reading was taken after 15 days of growth, and the percentage of seedling death was calculated according to the method of Kipngeno et al. [1] using the following equation:

Seedling death rate = (number of dead seeds / total number of seeds) 100

b. Pots experiment

An experiment was conducted in the greenhouse of the College of Education for Pure Sciences, University of Diyala. A potting experiment was conducted at the end of August during the 2024-2025 agricultural season. The aim of the experiment was to study the effect of different concentrations of date vinegar on the resistance and growth of cucumber plants grown in plastic pots against the pathogenic fungus *F. oxysporum* (F017). A mixture of sandy loam soil and peat moss (1:3) was used in this experiment. The soil was sterilized using a vacuum sealer at a temperature of 121°C and a pressure of 1.2 kg/cm² for 30 min, and the process was repeated three times. The soil was placed in sterilized 3 kg plastic pots and planted with surface-sterilized cucumber seeds, three seeds per pot. These seeds were then thinned to one plant per pot after germination.

The experiment was conducted in two phases. The first phase included four treatments at concentrations of 5%, 10%, 15%, and 20%, in addition to a control treatment of uninfected plants. The second part included the same treatments at its concentrations (5, 10, 15, and 20%), along with the control treatment for the infected plant. Three replicates were performed for each treatment. Fungal infection occurred 30 days after planting by spraying the vegetative system with fungal suspensions. Then, the treatments were covered with plastic bags and left for 2 days to achieve fungal infection. The treatments were then sprayed with the abovementioned concentrations of vinegar. The spraying process was repeated three times, with five days between each spray. Data were then collected for all treatments and replicates after the final spray. The same treatments were repeated but without the pathogenic fungus, bringing the total number of treatments and replicates to 15 experimental units. The treatments were distributed within the greenhouse according to a completely randomized design: vegetative growth characteristics, fresh and dry weight of plant, plant height (cm), number of leaves, and leaf area (cm²) measured using ImageJ software according to the Pedro and Danita method [12].

c. Statistical analysis

A factorial experiment was conducted using an RCBD. The results were statistically analyzed using SPSS. The differences between the means were tested using the differences between the range tests at a p value of 0.05.

3. Results

3.1 Laboratory experiment

The results shown in Table 1 show the inhibitory effect of natural date vinegar on the diameter growth of the pathogenic fungus *Fusarium*, where the highest inhibition rate reached 100% at 20% concentration with an inhibitory diameter of 0.00 mm compared to the control treatment, where the diameter of the fungal culture reached 9 mm, while the lowest inhibitory diameter was at 5% concentration with an inhibition rate of 66%, followed by treatments of 15% and 10% with an inhibition rate of 76.66% and 71.55%, respectively, as shown in Figure 1. Treatment with natural vinegar at different concentrations inhibited the growth of *Fusarium* fungi.

The results of the laboratory experiment to test the effect of treatment with different concentrations of date vinegar on the growth of cucumber seedlings growing in plastic dishes in the presence or absence of the pathogenic fungus (Table 2) showed a significant increase in the percentage of cucumber seed germination after 10 days of growth. Also, the results showed that the germination percentage increased with increasing vinegar concentration compared with the pathogen treatment only without adding vinegar. The 15% and 20% concentration treatments recorded the highest germination percentage of 95.14%, followed by the 10% concentration treatment, which was 90.42%. As for the 5% treatment, there were no significant differences between it and the pathogenic fungus treatment without vinegar, and the germination percentage for them was 85.71%, as for the control treatment without adding vinegar and without the pathogen, the germination percentage was 100%. The results in the table also show that the seedling death rate became 0% when treated with different concentrations of date vinegar, compared to the treatment with the pathogenic fungus only, in which the seedling death rate after 14 days was 100%. (Table 3), (Table 4)

Table 1. The effect of treatment with different concentrations of natural date vinegar on the diameter growth of the pathogenic fungus *Fusarium oxysporum*.

Concentration	Colony diameter (cm)	Inhibition rate (%)
5%	3.06	66
10%	2.56	71.55
15%	2.10	76.66
20%	0	100
Control	9	0
P value at 0.05	0.001	0.001

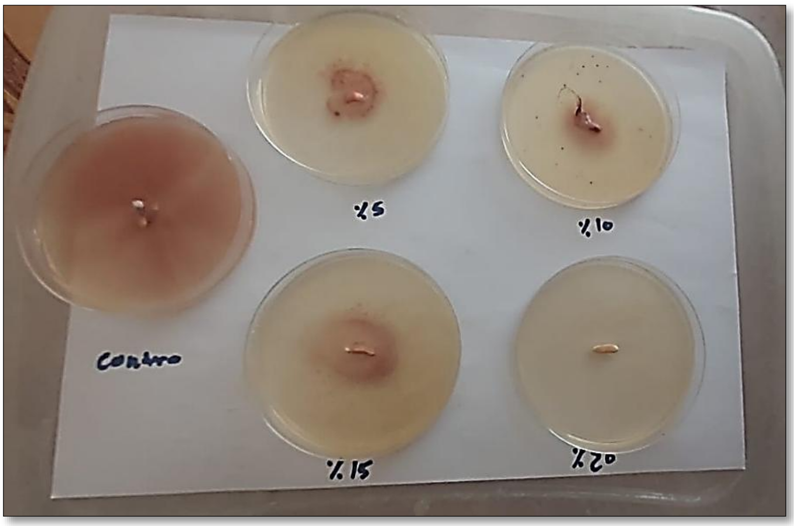

Figure 1: Effect of treatment with different concentrations of natural date vinegar on the growth of *Fusarium oxysporum* on PDA medium

Table 2: Effect of treatment with different concentrations of natural date vinegar on the germination and seedling death rates of *F. oxysporum*-infected cucumber plants

Concentration	Germination rate (%) after 10 days	Seedling death rate (%) after 14 days
5%	85.71 d	0
10%	90.42 c	0
15%	95.14 b	0
20%	95.14 b	0
Control (with the pathogen)	85.71 d	100
Control (without pathogen)	100 a	0
P value at 0.05	0.00	-

3.2 Pot experiment

Table 3 shows the positive effect of natural date-vinegar spraying on the height of cucumber plants growing in plastic pots in the presence or absence of pathogenic fungi. We note from the table that spraying vinegar at a concentration of 20% recorded the highest height among healthy plants, which was 42.33 cm. This concentration also recorded the highest height in vegetative growth in infected plants, which was 40.66 cm, compared to the control treatment without addition and the treatment of the plant infected with the pathogenic fungus, which were 38.33 and 30.53 cm, respectively. As we note from the table, both the fresh and dry weights of cucumber plants infected with pathogenic fungi increased with increasing vinegar spray concentration, and the weights reached their highest level in the spray treatment at 20% concentration, which was 34.33 and 5.72 gm. All vinegar spray treatments, whether in the presence or absence of pathogenic fungi, outperformed the control treatments in the absence of pathogenic fungusence of pathogeni. The table shows 22.40 and 6.08 gm., respectively, for fresh and dry weights consecutively.

The results in Table 5 and Fig. 2 indicate a clear response in the plants infected with the pathogenic fungus in the leaf area trait of cucumber plants. We note from the table a decrease in the leaf area of cucumber plants with increasing vinegar spray concentration compared with the infected plant without treatment, which was 15.486 cm². As for the treatments of healthy plants, the leaf area of cucumber plants also decreased with increasing vinegar spray concentration compared with the control treatment, which was 13.185 cm2.

Table 3. Effect of natural date vinegar treatment on plant height (cm) of cucumber plants infected with the pathogenic fungus *Fusarium oxysporum*.

Concentration	Plant height (cm)	
	Without pathogen	With pathogen
0% (control)	38.33 ab	30.53 b
5%	36.66 ab	30.66 b
10%	42.00 a	31.37 b
15%	42.00 a	32.08 b
20%	42.33 a	40.66 a
P value at 0.05	0.006	

Table 4. Effect of natural date vinegar treatment on plant weight (gm) of cucumber plants infected with the pathogenic fungus *Fusarium oxysporum*.

Concentration	Fresh weight (gm.)		Dry weight (gm.)	
	Without pathogen	With pathogen	Without pathogen	With pathogen
0% (control)	28.40 cde	22.40 f	6.08 b	4.43 cd
5%	30.37 cd	23.04 ef	6.23 b	4.17 d
10%	38.33 ab	25.03 def	6.53 b	5.17 bcd
15%	37.70 ab	32.53 c	6.48 b	5.45 bcd
20%	39.50 a	34.33 abc	7.82 a	5.72 bc
P value at 0.05	0.001		0.001	

Table 5: Effect of treatment with different concentrations of natural date vinegar on leaf area (cm^2) of cucumber plants infected with the pathogenic fungus *Fusarium oxysporum*.

Concentration	Leaf area (cm2)	
	Without pathogen	With pathogen
0% (control)	13.185	15.486
5%	15.958	15.333
10%	15.873	13.391
15%	14.937	11.883
20%	13.264	10.545
P value at 0.05	0.093	

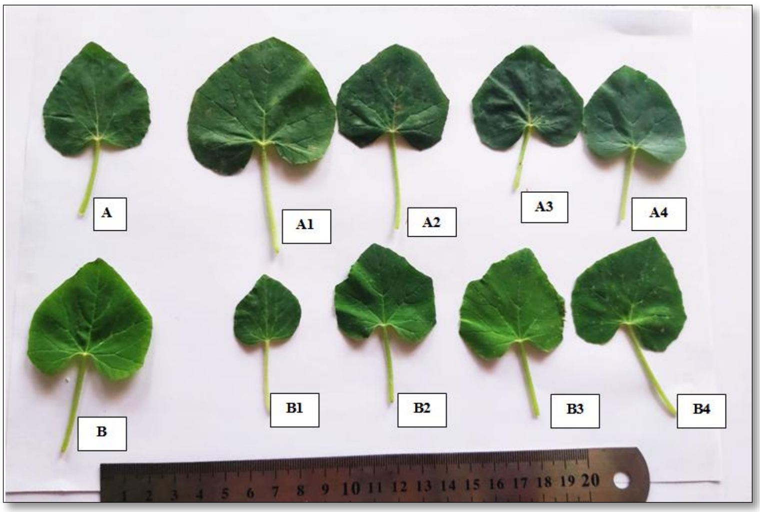

Figure 2. Treatment with vinegar in healthy plants and plants infected with pathogen. (A) represents control treatment, A1: 5%, A2: 10%, A3: 15%, A4: 20%. (B) represents the pathogenic fungus, B1: 5%, B2: 10%, B3: 15%, B4: 20%.

4. Discussion

The research results show the positive effect of date vinegar in inhibiting pathogenic fungi growth under laboratory conditions. Treatment with different concentrations of date vinegar also improved the germination rate of cucumber seeds and reduced the seedling death rate to 0%. The greenhouse experiment confirmed this positive effect of spraying with vinegar in improving plant growth on the one hand and increasing the plant's resistance to pathogenic fungi on the other. The reason is that natural vinegar (acetic acid) is an organic compound that can directly affect fungal pathogens that infect plants. This was confirmed by some studies, as [13] and [14] stated that organic acids showed good results in inhibiting the activity of pathogens, and this is consistent with the results of the current study. As is well known, the primary component of vinegar is acetic acid, which has been found to degrade the cell wall of fungal cells and inhibit some of their metabolic functions [15]. Vinegar is also an antifungal that inhibits the growth of many plant-pathogenic fungi, as confirmed by numerous studies [16]-[18]. Some studies have indicated the importance of vinegar treatment in improving plant growth by enhancing nutrient availability in the soil [19].

5. Conclusions

Studies investigating the effects of using natural vinegar are still limited. Therefore, more comprehensive research is recommended to evaluate its effects on different plant species using various application methods and concentrations. However, laboratory studies, including this one, have shown that spraying with vinegar inhibits the growth and pathogenicity of plant pathogenic fungi, including *Fusarium oxysporum*. These results indicate that natural vinegar is a promising and environmentally friendly alternative for combating fungal diseases that affect plants.

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