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EFFECT OF PLANT EXTRACTS AND BACTERIA ON PRODUCTIVITY, QUALITY, AND CONTROL OF FIRE BLIGHT OF PEAR

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Pears are challenged with many serious biotic stresses that cause significant crop losses. One of the most important biotic stresses in Egypt is fire blight. The objective of this work is to test the impact of applying plant extracts and bacteria on the yield quality and fire blight disease of the Le-Conte cultivar of pear trees. The following ten treatments were given: Garlic extract at (2, 4 and 6%) named (T_1 , T_2 and T_3) and ginger root extract (2, 4 and 6%) named (T_4 , T_5 and T_6), mixture of *Bacillus pseudomycoides, Bacillus amyloliquefaciens* and *Pseudomonas taiwanensis* that prevents blight in concentration (10^8 cfu/ ml, 10^{10} cfu/ ml and10^{12} cfu/ ml) named (T_7 , T_8 and T_9) and control treatment (spraying with water) named (T_{10}). From January until the harvest in August, all treatments were applied once a month. The results indicated that all treatments effectively stimulated fruit measurements, natural and chemical characteristics of fruits, leaf mineral contents and protection from fire blight. Generally, T_1 increased yield/ tree, No. of fruits/trees, fruit length, diameter, weight, total soluble solids (TSS), total sugar, reducing and non-reducing sugars, improved leaf mineral content, gave the highest efficacies against fire blight disease and lowest percent disease incidence.

Keywords: pear, garlic, ginger, *Bacillus* sp., fire blight, *Erwinia amylovora*

INTRODUCTION

Pears are one of the most popular fruits in areas with moderate climates. It ranks as the third deciduous fruit worldwide and the fourth among all fruit harvests sold on the international market. Pear is the primary cultivar farmed in Egypt. However, because of the fire blight outbreak, the overall area under cultivation for pears has varied significantly during the past few decades. *Erwinia amylovora* is a (Gram-negative) bacterium. It is the leading cause of fire blight infection in pear trees (Pel et al., 2021). When watered, infected plant portions invariably generate a sticky amber-colored drop of slime which turns dark green, wilts and eventually turns brown (Vrancken et al., 2013). *Erwinia amylovora* is found in over 50 countries worldwide, relying on the availability of adequate environmental conditions, the value of primary inoculum and pathogen virulence and the sensitivity of hosts (Mendes et al., 2024). In Egypt, the most devastating signs of this disease were blight lesions that resulted in the loss of 75% of tree flowers/trees. Chemical remedies have had limited success because of their toxicity, human health effects and environmental pollution. Researchers are looking for innovative environmentally acceptable approaches with no residue, such as using nonpathogenic microorganisms and plant extracts as bioagents (Anuj et al., 2019). Since the market for organic fruit production has been growing significantly in recent years, many fruit crop farmers are concentrating on applying natural goods in horticultural ways rather than synthetic chemical items (Dimitri and Oberholtzer, 2006).

The extract of garlic (*Allium sativum*) contains many chemical compounds and enzymes, although some of its volatiles like allicin, which gives garlic its antibacterial qualities, are more significant. Its higher concentrations of sulphur and volatile chemicals place both at the top because of their genuine and crucial roles in the growth of different crops. Furthermore, includes essential oils, minerals, flavonoids, ascorbic acid and sulphur (El-Desouky et al., 1998). Furthermore, "Canino" apricot trees cultivated in mild winter climates responded favourably to a 4% garlic extract spray by increasing fruit quality and productivity (Abd El-Razek et al., 2011). Garlic extracts are past prepared from fresh garlic enhance quantity and fruit quality when used for peach, according to similar findings published in earlier studies (Ahmed, et al., 2009). Furthermore, extracts from garlic increased the quantity of fruits, total soluble solids (TSS) and yield of mango trees according to Chowdhury et al. (2007). Mango anthracnose was less common when garlic extract was used Chowdhury (2005). Abd El-Razek et al. (2013) recorded that the quantity and fruit quality of pear trees in winter circumstances in Egypt can be enhanced by using garlic extract at 8% in combination with gibberellic acid (GA) at 100 ppm. On Le-Conte "pear" trees, the maximum percentage and quantity of healthy fruits were produced by garlic extract at 4% (Abd El-Hamied and El-Amary, 2015).

Ginger (*Zingiber officinale*) is one of the most widely used culinary condiments. Ginger root extract has antibacterial, anti-inflammatory, analgesic and antioxidant qualities (Sharma et al., 2013; Nikoli et al., 2014 and Amri and Touil-Boukoffa, 2016). According to Wang et al. (2014), Ginger rhizome contains high phenolic compounds that have a range of biological activity. The primary bioactive ingredient, gingerol has been shown by researchers to prevent the growth of a variety of bacteria (Park et al., 2008 and Karuppiah and Rajaram, 2012). Ginger is rich in magnesium, potassium, copper, manganese and vitamin C and B6.

In recent years, investigations for eco-friendly biological alternatives to manage fire blight disease have focused on applying heartening herb extracts with high antibacterial activity (Arafat et al., 2015). Antagonistic microorganisms found on plants' insides (endophytes) can produce antimicrobials. Chen et al. (2009) found that *Bacillus amyloliquefaciens* for example, produces antimicrobials such as difficidin and bacilysin, which are potent for *Erwinia amylovora*. *Pseudomonas fluorescens* is utilized to suppress *Erwinia sp.* and its effectiveness can be improved through nutritional augmentation and osmo-adaptation in special culture medium (Cabrefiga and Montesinos, 2017). Doolotkeldieva and Bobusheva (2016) reported that *Streptomyces* sp. can inhibit the *Erwinia sp*. at the leaf level by 70%.

Pseudomonas aeruginosa releases butenoic acid, which functions as an antimetabolite for *Erwinia sp*. (Lee et al., 2013). They discovered many *Pseudomonas* from phyllosphere in apple effective antagonists of *Erwinia amylovora* (Habibi et al., 2024).

This study aims to examine how bacteria and plant extracts affects fruit quality, pear tree yield and Le-Conte cultivar fire blight infection.

MATERIALS AND METHODS

The work was done in two consecutive growing seasons in 2023 and 2024 on 10-year-old Le-Conte "pear" trees that were 4 x 4 meters apart, budded on *Pyrus communis* rootstock that was grown in sandy soil (Table 1 and 2) and irrigated with a drip irrigation system (Table 3) at Abo Ghaleb Road, which is located on the Egypt Alexandria Desert Road (68 kilometres from Cairo) in Giza Governorate. The nominated trees were uniform in shape and applied to the prevalent horticultural practices. The study involved 10 treatments were established as follows: garlic extract at (2, 4 and 6%) (T_1, T_2 and T_3) and ginger root extract (2, 4 and 6%) (T_4, T_5 and T_6) mixture of bacteria that prevents blight in concentration (10^8 cfu/ml, 10^{10} cfu/ ml and10^{12} cfu/ml) named (T_7, T_8 and T_9) and control treatment (spraying with water) (T_{10}) to investigate study the spraying natural plant extracts affects fire blight infection, fruit quality, and yield in pears. From January to harvest (August) all treatments were sprayed once a month.

The analysis in Table 1, 2 and 3 was carried out in the soil and water laboratory of the central laboratory, Faculty of Agriculture, Ain Shams University.

To create the 2, 4 and 6% garlic extract, 20 g, 40 g and 60 g of cloves were blended with 1L of distilled water, frozen and melted twice then diluted with distilled water to create 1L (Table 4) (El-Desouky et al., 1998).

Table (1). The physical characteristics of soil.

Soil depth cm	Partical size							
	C. Sand %	F. Sand %	Silt %	Clay %	F.C %	W.P %	B.D g/cm^3	Texture
0 – 30	92.8	3.7	2.0	1.5	10	4.8	1.83	Sandy
30 – 60	91.5	1.8	0.2	6.5	11	6.3	1.79	Sandy
60 – 90	93.1	0.6	0.4	5.9	13	5.5	1.72	Sandy

Table (2). The chemical properties of soil.

Soil depth cm	pH	EC ds/m	TDS ppm	Soluble Cations (meq/L)				Soluble Anions (meq/L)			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	CL^{-}
0 – 30	6.9	2.5	1600	9.52	1.3	13.88	0.3	--	0.8	8.97	15.23
30 – 60	7.1	3.03	1939.2	9.6	6.9	13.6	0.2	--	1.8	4.7	23.8
60 – 90	7.3	2.48	1587.2	10.2	3.21	11.2	0.19	--	0.8	7.6	16.4

Table (3). The irrigation water's chemical composition.

pH	EC ds/m	TDS ppm	Soluble Cations (meq/L)				Soluble Anions (meq/L)			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	CL^{-}
6.9	3.26	2086.4	12	1.22	19.28	0.1	-	0.8	9.8	22

Table (4). Garlic cloves' chemical components, as determined by the agricultural arid land research unit according to El-Desouky et al. 1998.

Components	Concentration	Components	Concentration
GA_3*	1.632 mg /l00 g F.W	Mg	1.230%
IAA**	-	SO_4	0.181%
ABA***	-	Mn	94.3 ppm
Ca	1.363%	Zn	66.6 ppm

*GA_3: Gibrillic acid, **IAA: Indole acetic acid, ***ABA: Absisic acid

The ginger root extract was carried out as Shabana et al. (2017) stated. Ginger rhizomes were pounded into a fine powder after being air-dried. One hundred gram of this powder was extracted using 80% ethanol; filtered three times using Whatman No. 1 and then dried using a rotary evaporator at 40°C at decreased pressure. Ultimately, three concentrations 2, 4 and 6% were employed (Table 5).

Table (5). Chemical Analysis of Ginger Root (*Zingiber officinal Rose*) according to Latona et al. (2012).

Components	Concentration (%)	Components	Concentration (mg/100 g)
Crude protein	34.13	Zn	64.0
Ether extract	4.07	Mn	5.90
Crude fiber content	4.02	Cu	8.80
Moisture content	13.75	Fe	279.7
Ash content	7.64	Ca	280.0
Vitamin C	1.036	P	8068.0

1. Bio-control Agents

In this study, three isolates of bioagents (antagonistic bacteria) were obtained from previous studies: *Pseudomonas taiwanensis* strain Pst1 (OP984768) (Badran et al., 2023), *Bacillus pseudomycoides* (Bp1) (OQ629426) (ElSharawy et al., 2023) and *Bacillus amyloliquefaciens* BMAT1 (PP940139) (Eid et al., 2024). *Bacillus pseudomycoides* and *Bacillus amyloliquefaciens* isolates were cultivated individually on nutritional glucose broth medium, whereas *Pseudomonas taiwanensis* was cultured on King's B medium then inoculated at 28 °C for 48 h. Following the incubation time, the bacterial growths were combined. Before use, all bacterial cells were centrifuged and suspended in sterile saline solution (0.85% NaCl) and the concentration was adjusted to $3*10^8$ (T7), $3*10^{10}$ (T8) and $3*10^{12}$ (T9) colony forming units (cfu/ml) as assessed by a standard curve based on absorbance at 620 nm.

2. The Parameters Determined During Two Seasons

1. Total chlorophyll value: Minolta meter SPAD-502 was used to measure leaves in the field at the end of August
2. Leaf area (cm^2) was determined with a leaf area meter.
3. Macro and micronutrients in leaves: thirty leaves per tree, representing the four primary directions, were gathered at the conclusion of the trial season (end of September). Gathered samples were processed and examined for macro and micronutrients in accordance with Jones et al. (1991) and Peterburgski (1968). Calorimetric methods are used to determine total NPK, as explained by Cottenie et al. (1982).
4. The number of fruits/tree and the tree yield (Kg/tree) were determined.
5. Fruit parameters: Fruits were compiled during harvest to measure their physical characteristics, including their diameter (cm), length (cm), weight (g) and shape (fruit length ÷ diameter).
6. Fruit quality: at harvest time, ten mature fruits from each tree were sampled in order to determine the chemical properties, such as TSS%) by a refractometer. In accordance with A.O.A.C. (1995) the percentages of total sugars, reducing and non-reducing sugars were calculated.

3. Pathological Studies

3.1. Sampling

Diseased pear leaves, branches and fruitlets exhibiting characteristic fire blight signs collected samples were transported to the laboratory in plastic bags and stored in ice trays with each sample placed separately in a plastic bag.

3.2. Isolation of *Erwinia amylovora*

The isolation method was carried out from all affected samples shortly after being brought from orchards. Pieces of sick tissues were macerated in 2 ml of sterile water for 30 min. According to Miller and Schroth (1972), a loopful of suspension was streaked on Miller and Schroth medium (MS) as a highly selective medium for *Erwinia amylovora*. Dishes were incubated at 28°C for 2-3 days, resulting in the reddish-orange-colored colonies with deep orange centers characteristic of *Erwinia amylovora.* Single colonies of developing bacteria were transferred to nutrition glucose agar (NGA) slant medium for preservation until used in following assays.

3.3. Pathogenicity test

Pure cultures of *Erwinia sp.* were examined for their capacity to cause disease symptoms. Schaad (1980) evaluated thirteen isolates for pathogenicity on pear fruitlets. Fruitlets were surface sterilized by soaking them in a 0.5% NaOH solution for 10 min. Fruitlets were placed in sterilized plates and injected by stabbing them with a needle containing a 24-hour culture of the bacteria. Incubated at 28ºC for 3-5 days, each plate included four infected fruitlets. Wet cotton pieces were used to maintain high humidity. Control pear fruitlets were injected with sterile media. Pathogenicity tests were performed twice on all isolates.

3.4. Identification of *Erwinia amylovora*

All isolates that exhibited pathogenicity to pear fruitlets were thoroughly identified. The cultural, morphological, physiological and biochemical traits suggested by Schaad (1980), Lelliot and Stead (1987), Dye (1968), Fahy and Persley (1983) and Abd El-Ghafar (1988) were considered as follows:

3.4.1. Cultural and morphological characteristics of *Erwinia amylovora*

These comprised the isolated bacterium's colony type on nutrient agar (NA) medium and MS medium as a selective medium, bacterial cell shape, sporulation and Gram stain reactivity.

3.4.2. Characteristics of *Erwinia amylovora*

These reactions included 3% KOH, urease, oxidase, catalase production, gelatin liquification, starch hydrolysis, Voges-Proskauer (VP), nitrate reduction, levan and indole production, H_2S from cysteine, production of fluorescence pigment of King's B medium (KB), growth on 5% NaCl, production of pink pigment on yeast extract-dextrose-$CaCO_3$ (YDC) medium, acid production from L (+) arabinose and D (-) arabinose.

3.4.3. Molecular identification of *Erwinia amylovora*

To molecularly identify *Erwinia amylovora*, the segment of interest was amplified with forward AGAGTTTGATCATGGCTCAG and reversed ACGGTTACCTTGTTACGACTT. *Erwinia amylovora* was discovered using the 16S rRNA sequencing. Cell DNA extraction was carried out (Feng et al., 2011) and 16S rDNA amplification by Phanse et al. (2013).

3.5. In-vitro test

Garlic extract (2, 4 and 6%) (T_1, T_2 and T_3), ginger root extract (2, 4 and 6%) (T_4, T_5 and T_6) and three antagonistic bacteria isolates (T_7, T_8 and T_9) were examined for their capacity to avoid the growth of pathogen on KB medium. A loopfull of antagonistic bacteria (24-hour-old culture) and filter paper discs (5 mm) soaked with various concentrations of plant extracts were placed on plates containing media previously seeded with *Erwinia amylovora* and inoculated with suitable amounts of 24-hour-old broth. The control treatment (T_{10}) consisted of sterile distilled water. Then, incubated at 28°C for 72 hours. Five replicates of each bioagent isolate were used. The inhibitory zone besetment bioagent growth was evaluated following the incubation period.

3.6. In orchard

3.6.1. Disease assessment

Disease incidence was measured at three pear trees for each treatment when the fruit set was complete. The percentage of disease incidence (DI) was estimated using the following formula: (Mohd Nadzir et al., 2019)

$$DI (\%) = (I / L) \times 100$$

Where, I: length of the infected region (cm), L: overall length of the shoot (cm)

The percentage efficacy of the applications (E) was estimated using the formula (Abbott, 1925):

$$E (\%) = (C - T) / C \times 100$$

Where, C: the % disease incidence in untreated fruit, T: the % disease incidence in treatment.

3.7. Statistical Analysis

The experiment was established up with three trees and three replicates in a completely randomized block design. Duncan's multiple range was employed to differentiate between means, as outlined by Duncan (1955). Significant differences between treatments were assessed using ($P<0.05$).

RESULTS AND DISCUSSION

1. Leaf Total Chlorophyll (SPAD) and Leaf Area (cm²)

Concerning the results in Table (6) chlorophyll and leaf area were affected significantly by all applying treatments during two seasons. T_1 showed the best chlorophyll (53.13 in 2023 and 53.23 in 2024). T_1 and T_2 gave the highest leaf area (38.06 cm^2 and 38.26 cm^2 in both years) (38.00 cm^2 and

38.20 cm^2 in seasons one and two, respectively). Conversely, in both seasons, T_{10} provided the lowest significant results for chlorophyll and leaf area.

Table (6). Effect of plant extracts and bacteria on leaf total chlorophyll and leaf area of pear during 2023 and 2024 seasons.

Treatments	Leaf total chlorophyll (SPAD)		Leaf area (cm^2)	
	2023	2024	2023	2024
T_1	53.13 a	53.23 a	38.06 a	38.26 a
T_2	52.13 b	52.23 b	38.00 a	38.20 a
T_3	49.13 e	49.23 e	35.20 d	35.40 d
T_4	47.16 h	47.26 h	32.10 g	32.30 g
T_5	48.20 f	48.30 f	34.20 e	34.40 e
T_6	48.12 g	48.22 g	33.10 f	33.30 f
T_7	47.13 h	47.23 h	31 10 h	31.30 h
T_8	50.17 c	50.27 c	37.06 b	37.26 b
T_9	49.66 d	49.76 d	36.10 c	36.30 c
T_{10}	46.13 i	46.23 i	30.10 i	30.30 i

T_1: garlic extract at 2%, T_2: garlic extract at 4%, T_3: garlic extract at 6%, T_4: ginger root extract 2%, T_5: ginger root extract 4%, T_6: ginger root extract 6%, T_7: mixture of bacteria at a concentration of 10^8 cfu/ ml, T_8: mixture of bacteria at 10^{10} cfu/ ml, T_9: mixture of bacteria at 10^{12} cfu/ml and T_{10}: control. No statistically significant difference between values with the same letters in the same column in each season.

2. Leaf Mineral Content

2.1. Nitrogen, phosphorus and potassium (%)

In two seasons, all spraying treatments had a substantial impact on the leaf macro components shown in Table (7). Whoever, T_1 produced the highest nitrogen content (2.9% in 2023 and 3.0% in 2024), phosphorus content (1.02 and 1.22% in both seasons, respectively) and potassium content (2.23 and 2.33% in both seasons, respectively). On the other side, in two seasons, T_{10} provided the lowest results for nitrogen, phosphorus and potassium content.

2.2. Iron, copper, zinc and manganese content in leaves (ppm)

Items shown in Table (8) leaf micro elements were affected remarkably by all treatments in two seasons. Whoever, T_1 produced the highest iron content (346 ppm in 2023 and 346.1 ppm in 2024) and copper content (40.0 ppm and 40.1 ppm in the both season, respectively). In addition, T_1 and T_2 gave the highest value on zinc and manganese content in both seasons. Opposite those, T_{10} gave the lowest significant values for iron, copper, zinc and manganese content in both seasons.

Garlic extracts remarkable effects on leaf area, macro, micro and chlorophyll pear tree Tables (6, 7 and 8) may be due to minerals, flavonoids, saponins, sulfur and allyl groups (H_2CHCH_2), primarily diallyl disulfide, are all present in garlic extract. Additionally, a phytoalexin known as allixin has been discovered. These results agree with those of Botelho (2007) on apples.

Abd El-Hamied and El-Amary (2015) on pears, El-Sharony et al. (2015) on mangoes and Wanas et al. (1998) on squash, El-Salhy et al. (2017) on grapevines and El-Amary and Abd El-Hamied (2018) on grapes. Garlic extract was found to improve vegetative growth by previous investigators.

Table (7). Effect of plant extracts and bacteria on some leaf macro elements of pear trees during 2023 and 2024 seasons.

Treatments	N (%)		P (%)		K (%)	
	2023	2024	2023	2024	2023	2024
T_1	2.9 a	3.0 a	1.02 a	1.22 a	2.23 a	2.33 a
T_2	2.8 b	2.9 b	0.96 b	1.16 b	1.98 b	2.08 b
T_3	2.6 d	2.6 d	0.68 e	0.88 e	1.91 c	2.01 c
T_4	2.3 f	2.3 f	0.59 g	0.79 g	1.67 f	1.77 f
T_5	2.4 e	2.5 e	0.63 f	0.83 f	1.86 d	1.96 d
T_6	2.4 e	2.5 e	0.62 f	0.82 f	1.81 e	1.91 e
T_7	2.1 g	2.2 g	0.56 h	0.76 h	1.43 g	1.53 g
T_8	2.6 c	2.7 c	0.88 c	1.08 c	1.98 b	2.08 b
T_9	2.6 cd	2.7 cd	0.78 d	0.98 d	1.92 c	2.02 c
T_{10}	2.1 g	2.1 g	0.32 i	0.52 i	1.33 h	1.43 h

T_1: garlic extract at 2%, T_2: garlic extract at 4%, T_3: garlic extract at 6%, T_4: ginger root extract 2%, T_5: ginger root extract 4%, T_6: ginger root extract 6%, T_7: mixture of bacteria at a concentration of 10^8 cfu/ ml, T_8: mixture of bacteria at 10^{10} cfu/ ml, T_9: mixture of bacteria at 10^{12} cfu/ ml, and T_{10}: control. No statistically significant difference between values with the same letters in the same column in each season.

Table (8). Effect of plant extracts and bacteria on some leaf micro elements of pear trees during 2023 and 2024 seasons.

Treatments	Fe (ppm)		Cu (ppm)		Zn (ppm)		Mn (ppm)	
	2023	2024	2023	2024	2023	2024	2023	2024
T_1	346.0 a	346.1 a	40.0 a	40.1 a	32.0 a	32.2 a	52.0 a	52.1 a
T_2	328.0 b	328.1 b	38.0 b	38.1 b	32.0 a	32.2 a	51.0 a	51.1 a
T_3	297.0 e	297.1 e	32.0 c	32.1 c	26.0 c	26.2 c	43.0 c	43.1 c
T_4	213.0 h	213.1 h	28.0 d	28.1 d	22.0 de	22.2 de	33.0 e	33.1 e
T_5	289.0 f	289.1 f	31.0 c	31.1 c	23.0 d	23.2 d	42.3 c	42.4 c
T_6	257.0 g	257.1 g	29.0 d	29.1 d	22.0 de	22.2 de	38.0 d	38.1 d
T_7	211.0 i	211.1 i	26.0 e	26.1 e	21.0 e	21.2 e	31.0 f	31.1 f
T_8	311.0 c	311.1 c	37.0 b	37.1 b	28.0 b	28.2 b	48.0 b	48.1 b
T_9	306.0 d	306 1 d	32.0 c	32.1 c	28.0 b	28.2 b	47.0 b	47.1 b
T_{10}	191.0 j	191.1 j	26.0 e	26.1 e	18.0 f	18.2 f	28.0 g	28.1 g

T_1: garlic extract at 2%, T_2: garlic extract at 4%, T_3: garlic extract at 6%, T_4: ginger root extract 2%, T_5: ginger root extract 4%, T_6: ginger root extract 6%, T_7: mixture of bacteria at a concentration of 10^8 cfu/ ml, T_8: mixture of bacteria at 10^{10} cfu/ ml, T_9: mixture of bacteria at 10^{12} cfu/ ml, and T_{10}: control. No statistically significant difference between values with the same letters in the same column in each season.

2.3. Fruit weight (g), number of fruits/trees and yield (Kg/ tree)

As shown in Table (9) fruits weight and number of fruits/tree were increased remarkably by all spraying agents in two seasons. Whoever, T_1 gave the best fruit weight (162.6g in 2023 and 163.6g in 2024), number of fruits/tree (373 and 372 in two seasons) and yield (61.02 kg and 60.48 kg in two seasons). T_{10} exhibited the lowest significant values for fruit weight and number of fruits/tree and yield in two seasons.

Table (9). Effect of plant extracts and bacteria on fruit weight, number of fruits/trees and yield of pear trees during 2023 and 2024 seasons.

Treatments	Fruit weight (g)		N. of fruits/tree		Yield (Kg/ tree)	
	2023	2024	2023	2024	2023	2024
T_1	162.6 a	163.6 a	373 a	372 a	61.02 a	60.48 a
T_2	141.7 b	142.7 b	347 b	346 b	49.51 b	49.02 b
T_3	132.2 e	133.2 e	261 e	260 e	34.76 e	34.37 e
T_4	107.8 h	108.8 h	152 h	151 h	16.53 h	16.27 h
T_5	126.2 f	127.2 f	203 f	202 f	25.82 f	25.49 f
T_6	123.6 g	124.6 g	160 g	159 g	19.93 g	19.65 g
T_7	103.6 i	104.6 i	142 i	141 i	14.85 i	14.60 i
T_8	137.3 c	138.3 c	339 c	338 c	46.88 c	46.40 c
T_9	134.3 d	135.3 d	288 d	287 d	38.96 d	38.54 d
T_{10}	90.8 j	91.8 j	85 j	84 j	7.80 j	7.62 j

T_1: garlic extract at 2%, T_2: garlic extract at 4%, T_3: garlic extract at 6%, T_4: ginger root extract 2%, T_5: ginger root extract 4%, T_6: ginger root extract 6%, T_7: mixture of bacteria at a concentration of 10^8 cfu/ ml, T_8: mixture of bacteria at 10^{10} cfu/ ml, T_9: mixture of bacteria at 10^{12} cfu/ ml, and T_{10}: control. No statistically significant difference between values with the same letters in the same column in each season.

2.4. Fruit length (cm), fruit diameter (cm) and fruit shape

Resulted in Table (10) fruit length, diameter and shape were increased remarkably by all applying treatments in two seasons. T_1 showed the best fruit length (7.9 cm in 2023 and 8.7 cm in 2024), fruit diameter (6.9 cm and 7.9 cm in both seasons, respectively) and fruit shape (1.4 in 2023 & 1.3 in 2024). T_{10} showed the lowest values for fruits parameters in the two seasons.

Garlic extract's positive benefits on fruit weight, yield, Number of fruits/tree, length, diameter and shape pears' increased concentration of sulfur Tables (9 and 10). Proteins and cystene, cysteine and methionine as amino acids are made of sulfur. They have specific functions in lowering phenols and ABA and increasing the production of GA_3, indoles and the majority of organic foods (Kubota et al., 2000).

Extract of garlic enhanced growth, fruit yield and quality of apple, pear and flame seedless grapevines (Abd El-Razek et al., 2013; Mostafa and El-Yazal, 2013 and El-Amary and Abd El-Hamied 2018).

Table (10). Effect of plant extracts and bacteria on fruit length, fruit diameter and fruit shape of pear trees in 2023 and 2024

Treatments	Fruit length (cm)		Fruit diameter (cm)		Fruit shape	
	2023	2024	2023	2024	2023	2024
T_1	7.9 a	8.7 a	6.9 a	7.9 a	1.4 a	1.3 a
T_2	7.7 b	8.7 a	6.7 b	7.7 a	1.3 ab	1.2 b
T_3	7.6 bc	8.6 ab	6.0 cd	7.2 bc	1.2 b-d	1.2 bc
T_4	7.2 d	8.2 cd	5.9 d	6.9 cd	1.2 d-f	1.1 de
T_5	7.5 c	8.5 ab	6.0 d	7.0 b-d	1.2 c-e	1.2 bc
T_6	7.3 d	8.3 bc	5.9 d	6.9 cd	1.2 c-e	1.1 cd
T_7	7.2 d	8.2 cd	5.8 d	6.8 d	1.2 ef	1.1 ef
T_8	7.7 b	8.6 ab	6.2 c	7.3 b	1.3 bc	1.2 bc
T_9	7.6 bc	8.6 ab	6.2 c	7.2 bc	1.2 b-d	1.2 bc
T_{10}	6.9 e	7.9 d	5.4 e	6.4 e	1.1 f	1.0 f

T_1: garlic extract at 2%, T_2: garlic extract at 4%, T_3: garlic extract at 6%, T_4: ginger root extract 2%, T_5: ginger root extract 4%, T_6: ginger root extract 6%, T_7: mixture of bacteria at a concentration of 10^8 cfu/ ml, T_8: mixture of bacteria at 10^{10} cfu/ ml, T_9: mixture of bacteria at 10^{12} cfu/ ml, and T_{10}: control. No statistically significant difference between values with the same letters in the same column in each season.

2.5. TSS, total sugars, reducing sugars and non-reducing sugars (%)

According to Table (11) TSS, total sugars, reducing sugars and non-reducing sugars were affected remarkably. T_1 and T_2 gave the best T.S.S in two seasons. Furthermore, T_1 and T_9 in both seasons, T_6 in first season and T_7 in the second season gave the highest total sugars. In addition, T_1 showed the highest reducing sugars in two seasons. T_1 and T_2 produced the lowest non-reducing sugars in both seasons. On the other side, T_{10} exhibited the minimum significant values for T.S.S, total sugars, reducing sugars and the maximum values of non-reducing sugars in both seasons.

Because garlic includes non-volatile sulfur, which has antibacterial, antioxidant and antitumor-promoting qualities, these substances might work well. Additionally, it suppresses aflatoxin B1 metabolism and mutagenesis DNA (Yamasaki et al., 1991). Extracts of garlic also demonstrated antibacterial performance for microorganisms found in aquaculture farms. According to Abd El-Hamied and El-Amary (2015) the plant's constituents also provide antibacterial, antifungal and antiprotozoal effects.

The extract of garlic improved plant tolerance to various stressors and increased cell elongation and division. The nutritional state of the vine and growth were improved by garlic extract, which tipped the scales of competition in favor of the reproductive organs. Furthermore, the beneficial effects of these extracts on increasing sugar biosynthesis are undoubtedly evident in the improvement of fruit quality and maturation Gouda (2016) and Rizkalla (2016). In general, the present study showed that natural garlic extract significantly enhanced the quality of the fruit.

Table (11). Effect of plant extracts and bacteria on T.S.S, total sugars, reducing sugars and non-reducing sugars of pear during 2023 and 2024 seasons.

Treatments	T.S.S (%)		Total sugars (%)		Reducing sugars (%)		Non-Reducing sugars (%)	
	2023	2024	2023	2024	2023	2024	2023	2024
T_1	13.8 a	14.2 a	11.3 a	11.8 a	7.5 a	7.6 a	3.8 ef	4.2 e
T_2	13.7 a	14.2 a	10.2 c	10.7 cd	6.3 b	6.4 b	3.9 e	4.3 e
T_3	13.1 b	13.7 d	10.7 b	11.6 b	6.3 b	6.4 b	4.4 d	5.2 c
T_4	12.3 d	13.2 f	10.7 b	11.6 b	6.3 b	6.4 b	4.4 d	5.2 c
T_5	12.7 c	13.4 e	10.1 c	10.8 c	5.3 d	5.4 d	4.8 c	5.4 b
T_6	12.6 c	13.2 f	11.2 a	10.8 c	5.8 c	5.9 c	5.4 a	4.9 d
T_7	12.2 d	13.1 g	9.8 d	11.8 a	6.3 b	6.4 b	3.5 f	5.4 b
T_8	13.2 b	14.1 b	9.9 d	10.8 c	5.3 d	5.4 d	4.5 d	5.4 b
T_9	13.2 b	13.8 c	11.2 a	11.7 ab	6.2 b	6.3 b	5.0 bc	5.4 b
T_{10}	12.2 d	12.8 h	9.7 d	10.6 d	4.5 e	4.6 e	5.2 ab	5.9 a

T_1: garlic extract at 2%, T_2: garlic extract at 4%, T_3: garlic extract at 6%, T_4: ginger root extract 2%, T_5: ginger root extract 4%, T_6: ginger root extract 6%, T_7: mixture of bacteria at a concentration of 10^8 cfu/ ml, T_8: mixture of bacteria at 10^{10} cfu/ ml, T_9: mixture of bacteria at 10^{12} cfu/ml and T_{10}: control. No statistically significant difference between values with the same letters in the same column in each season.

2.6. Isolation of *Erwinia amylovora*

The causative organism, *Erwinia amylovora* was recovered from pear samples (leaves, cankerous branches and fruitlets). On MS media, thirteen isolates from infected pear samples formed reddish-orange colonies with deep orange cores, indicating the presence of *Erwinia amylovora*.

2.7. Pathogenicity test

Thirteen isolates (*Erwinia amylovora*) were tested for pathogenicity on immature pear fruitlets. The findings of the pathogenicity test revealed that four isolates (EA4, EA6, EA8 and EA 12) were pathogenic on immature pear fruitlets (Table 12) with no significant variation in degree of oozing.

2.8. Identification of the Causal Organism

2.8.1. Morphological and cultural characters

Pathogenic isolates EA4, EA6, EA8 and EA12 were short-rod, non-sporeformers and gram-negative. Their colonies on (NA) medium were round, convex, translucent, creamy white, with a soft surface and full edge. In the meantime, these colonies on MS media were circular and cambered a reddish-orange center and a transparent entire edge.

Table (12). Pathogenicity test for isolated bacterium from pear samples with a typical fire blight symptom, during 2023.

Isolate code	Pathogenicity test
EA1	-
EA2	-
EA3	-
EA4	+
EA5	-
EA6	+
EA7	-
EA8	+
EA9	-
EA10	-
EA11	-
EA12	+
EA13	-

2.8.2. Biochemical and physiological characters

Pathogenic isolates EA4, EA6, EA8 and EA12 tested positive for 3% KOH, catalase and gelatin liquification, Voges-Proskauer (VP), levan formation, a sucrose-reducing chemical and growth on 5% NaCl. In the meanwhile, these isolates showed a negative oxidase reaction. Urease production, starch hydrolysis, methyl red (MR), nitrate reduction, indole generation, H_2S production, fluorescent pigment on King's B (KB) medium and pink pigment on yeast extract-dextrose-$CaCO_3$ (YDC) agar medium. All isolates were capable of using L (+) arabinose, glucose, sucrose, sorbitol, mannitol and trehalose as carbon sources. These isolates were unable to use D (-) arabinose, cellobiose, lactose, maltose, mannose, xylose, aesculin, salicin or μ-methyl glycoside as carbon sources. There was no variation observed between the isolates. The results revealed that the EA4 isolate's 16S rDNA sequencing shared 100% identity with *Erwinia amylovora*. The phylogenetic tree was constructed by matching sequences from NCBI GenBank and the sequence was submitted to NCBI GenBank under accession number PQ222636 (Fig. 1).

2.9. Disease Control

2.9.1. In-vitro test

Effect of natural plant extracts and bacteria on growth of *Erwinia amylovora* in-vitro. Six concentrations of two natural plant extracts (garlic and ginger) (T_1, T_2, T_3, T_4, T_5 and T_6) and three concentrations of antagonistic bacteria (T_7, T_8 and T9) were tested individually for antibacterial activity against *Erwinia amylovora*. The results demonstrated significantly substantial antibacterial activity of garlic extract T_1, T_2 and T_8 (45, 43 and 41 mm) inhibitory zone compared to all other treatments, accordingly Table (13) and Fig. (2). Data are identical with Islam et al. (2014), who discovered that *A.*

sativum extract has potent efficacy against *Erwinia amylovora*. Data are corresponding with Hussein et al. (2019), who discovered that *Pseudomonas fluorescens* L18 and *Bacillus subtilis* K3 have high activity against *Erwinia amylovora*.

Garlic extract exhibited the strongest effect on *Erwinia amylovora*, with an inhibition zone of 34 mm. Ali (2010) found a similar conclusion, observing that garlic and thyme water extracts were more effective at suppressing *Erwinia amylovora* growth. Thymol (purified from garden thyme) was found to inhibit pathogen development at all concentrations tested. Furthermore, all amounts of sulfur compounds found in garlic proved to impede the growth of *Erwinia amylovora* (Ali, 2010).

Although the exact active components of the extracts that demonstrated these effects have not been identified, the antibacterial efficacy of garlic and thyme may be refer to the presence of active components such as sulfur compounds in garlic and thymol in thyme (Ali, 2010).

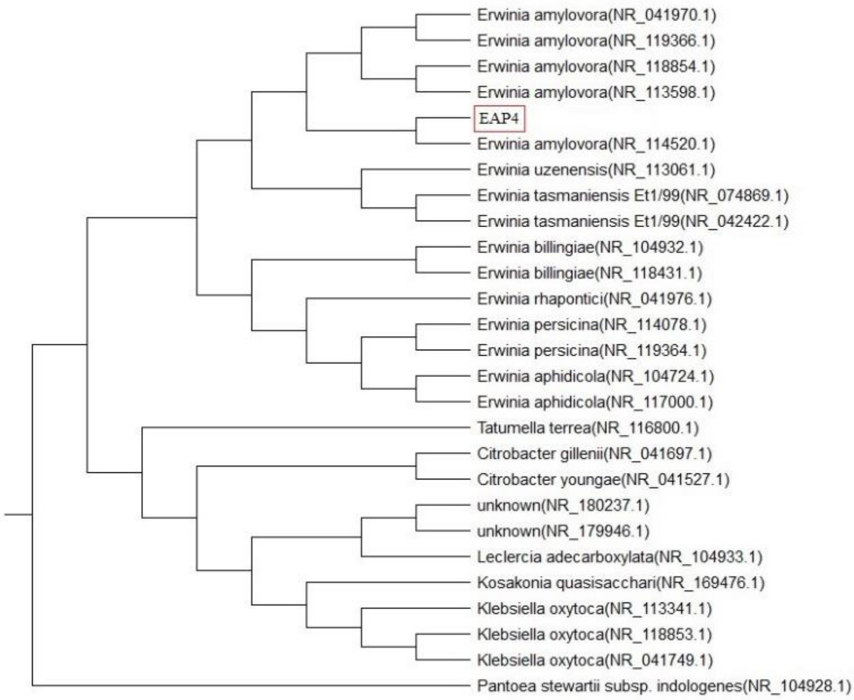


Fig. (1). A phylogenetic tree summary was generated using 16S rRNA gene to offer the link between isolate EAP4 and matched species. This isolate was quite similar to *Erwinia amylovora* strain EA4.

Table (13). Effect of plant extracts and bacteria on growth of *Erwinia amylovora* (Inhibition zone (mm)) in-vitro

Treatment	Inhibition zone (mm)
T_1	45 a
T_2	43 b
T_3	38 d
T_4	20 fg
T_5	27 e
T_6	21 f
T_7	40 c
T_8	41 c
T_9	19 g
T_{10}	16 h

T_1: garlic extract at 2%, T_2: garlic extract at 4%, T_3: garlic extract at 6%, T_4: ginger root extract 2%, T_5: ginger root extract 4%, T_6: ginger root extract 6%, T_7: mixture of bacteria at a concentration of 10^8 cfu/ ml, T_8: mixture of bacteria at 10^{10} cfu/ ml, T_9: mixture of bacteria at 10^{12} cfu/ ml and T_{10}: control. No statistically significant difference between values with the same letters in the same column in each season.

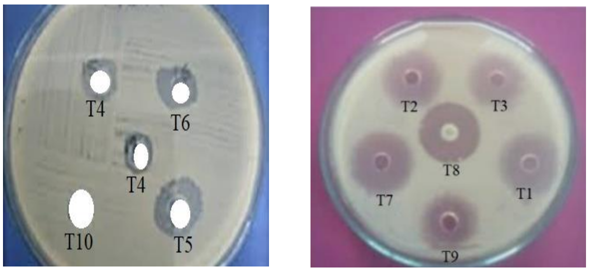


Fig. (2). Impact of bacteria and plant extracts on growth of *Erwinia amylovora* (Inhibition zone (mm)) in-vitro.

2.9.2. In Orchard

Testing the effect of mixed cultures of antagonistic bacteria and plant extracts on disease incidence

Three concentrations of garlic extract (T_1, T_2 and T_3), three concentrations of ginger root extract (T_4, T_5 and T_6) and three concentrations of mixed antagonistic bacterial cultures (T_7, T_8 and T_9) were used as foliar treatments in the 2023 and 2024 seasons. In this study, T_1 had the lowest percentage of disease incidence (16.3% in 2023 and 15.2% in 2024). They were followed by T_2 (16.9% in the first season and 15.2% in the second). These therapies were the most effective against fire blight disease. T_1 demonstrated the highest efficacy (80.9% in 2023 and 82.3% in 2024). Furthermore, T_8 reached an advanced position in efficacies against fire blight disease (79.8% in 2023 and 81.2% in 2024) (Table 14). Our findings are consistent with Bastas (2020), who discovered that *Syzygium aromaticum* and

Thymus vulgaris extracts had the maximum efficacy in reducing fire blight induced by *Erwinia amylovora* of by 67.81 - 64-12%, respectively.

Antibiotics and copper are mostly used to control pathogenic microorganisms, which can be hazardous to the climate and humans and accumulate in nature. Furthermore, bacteria frequently develop durability to bactericides due to their continued use. Plant-derived compounds have no known harmful effects on human or climate. Naturalistic products are exploited to generate new agrochemicals, particularly biopesticides (Gwinn, 2018). The use of plant extracts to control fire blight disease appears auspicious, given the scarcity of efficient drugs for copper and the absence of commercially available resistant cultivars (Gwinn, 2018).

El-Hamid (2016) asserts that extracts of plants have the capability to block the specific triggered genes during bacterial infection. Modifying virulence genes is an important method for modulating bacterial pathogenicity. Plant extract-based antibacterial medicines reduce bacterial disease by inhibiting numerous positive negative and gram bacteria from developing biofilms and utilizing the quorum sensing (QS) mechanism. These mechanisms describe how phenolics, polyphenols in plant extracts interact with bacteria (Vieira et al., 2017) Furthermore, plant extracts of plant are significant natural compounds that promote systemic acquired resistance (SAR) in tissues, are toxicologically unharmed, can be used in small quantities, do not cause pathogens to develop resistant races and can be useful in combating for a variety of pests and diseases (Baysal and Gursoy, 2003).

Xanthomonas campestris pv. *citri* was utilized to assess the antibacterial activities of several aromatic plant oil extracts. Chudasama and Thaker (2013) discovered that both *Syzygium* sp. and *Thymus* sp. had robust inhibition zones of 24.33 and 23.66 mm, respectively. The antibacterial action of *Syzygium* sp. extract on *Xanthomonas* sp. was also found to be very consistent with the findings of Benchouikh et al. (2016). According to Ibrahim and Abu-Salem (2014) methanol extracts of *Syzygium* sp. have high antibacterial activity against *Salmonella typhi, B. cereus* and *Staphylococcus aureus.*

Sharma et al. (2014) and Benchouikh et al. (2016) discovered that phenolic acids in *Syzygium aromaticum*, such as eugenol and eugenyl acetate, exhibit antibacterial properties. Soltani and Aliabadi (2013) report that the extracts' antibacterial action is linked to numerous flavonoids and phenolic chemicals in pure form. Thyme essential oil's antibacterial properties are mostly due to its active monoterpene phenolic components. Terpene phenols change the permeability of bacterial membranes leading to bacterial mortality (Saraç and Uğur, 2008). *Thymus vulgaris* (Karami-Osboo et al., 2010), which was evaluated for *Erwinia* sp. in-vitro exhibits considerable pathogen suppression effects with *Thymus vulgaris* essential oil content remarkably inhibiting pathogen more than its extract composition.

Table (14). Effect of plant extracts and antagonistic bacteria on disease incidence of pear fire blight during 2023 and 2024 seasons.

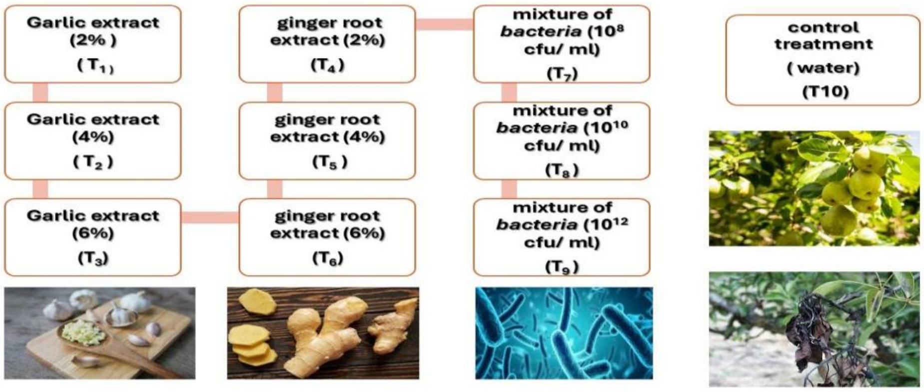
Treatment	Disease incidence (%)		Efficacy (%)	
	2023	2024	2023	2024
T_1	16.3 i	15.2 i	80.9 a	82.3 a
T_2	16.9 h	15.7 h	80.1 b	81.7 b
T_3	20.3 f	20.1 f	76.1 e	76.6 e
T_4	42.1 c	40.4 c	52.4 h	53.1 h
T_5	30.1e	29.3 e	64.6 f	65.9 f
T_6	39.3 d	86.0 a	53.8 g	38.9 i
T_7	50.8 b	52.5 b	40.4 i	38.9 i
T_8	17. 2 h	16.1 h	79.8 c	81.2 c
T_9	17.8 g	16.8 g	79.1 d	80.4 d
T_{10}	85.2 a	86.0 a	-	-

T_1: garlic extract at 2%, T_2: garlic extract at 4%, T_3: garlic extract at 6%, T_4: ginger root extract 2%, T_5: ginger root extract 4%, T_6: ginger root extract 6%, T_7: mixture of bacteria at a concentration of 10^8 cfu/ml, T_8: mixture of bacteria at 10^{10} cfu/ml, T_9: mixture of bacteria at 10^{12} cfu/ml and T_{10}: control. No statistically significant difference between values with the same letters in the same column in each season.

CONCLUSION

Given the prior results, it appears appropriate to indicate that foliar application with garlic extract at 2, 4% and mixture of *Bacillus pseudomycoides, Bacillus amyloliquefaciens* and *Pseudomonas taiwanensis* at a concentration of 10^{10} cfu/ ml improved the quality, productivity and growth, gave the highest efficacies against fire blight disease and the lowest disease incidence of pear tree. Furthermore, an economic analysis of the costs and advantages of high-performing organic treatments would be useful. Also, reducing production costs and thereby increasing income.

Model figure of study



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تأثير المستخلصات النباتية والبكتيريا على الإنتاجية والجودة ومكافحة مرض اللفحة النارية للكمثرى

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تواجه الكمثرى العديد من الإجهادات الحيوية الخطيرة التى قد تسبب خسائر كبيرة فى المحصول. يعتبر مرض اللفحة النارية من أخطر الإجهادات الحيوية التى تواجه الكمثرى فى مصر. الغرض من هذه الدراسة هو معرفة تأثير رش المستخلصات النباتية والبكتريا على محصول أشجار الكمثرى وجودة الثمار والإصابة بمرض اللفحة النارية. أجريت عشر معاملات على النحو التالي: مستخلص الثوم بنسبة (٢، ٤ و٦٪) (T_1، T_2 وT_3) ومستخلص جذور الزنجبيل بنسبة (٢، ٤ و٦٪) (T_4، T_5 وT_6)، وخليط من البكتيريا mixture of *Bacillus pseudomycoides, Bacillus amyloliquefaciens* and *Pseudomonas taiwanensis* المانعة للإصابة باللفحة النارية بتركيز (10^8 وحدة تشكيل مستعمرة/مل، 10^{10} وحدة تشكيل مستعمرة/مل و10^{12} وحدة تشكيل مستعمرة/مل) (T_7، T_8 وT_9) ومعاملة المقارنة (الرش بالماء) (T_{10}). تم رش جميع المعاملات مرة واحدة كل شهر بدءًا من شهر يناير وحتى موعد الحصاد (أغسطس). أظهرت النتائج المتحصل عليها أن جميع المعاملات كانت فعالة جدًا في تحفيز قياسات الثمار والخصائص الطبيعية للثمار والخصائص الكيميائية للثمار والمحتوى المعدنى للأوراق (N و P و K و Ca و Mg و Mn و Fe و Zn) والوقاية من اللفحة النارية للثمار. بشكل عام، أدى T_1 إلى زيادة المحصول لكل شجرة، وعدد الثمار لكل أشجار، وطول الثمرة، وقطرها، ووزنها، والمواد الصلبة الذائبة الكلية، والسكريات المختزلة وغير المختزلة، وتحسين محتوى المعادن فى الأوراق، وأعطى أعلى فعالية ضد مرض اللفحة النارية وأقل نسبة حدوث للمرض.