Assessment of the Effectiveness of Selected Eco-Friendly Alternatives for Controlling the Disease Complex of *Pectobacterium atrosepticum* and Potato virus Y (PVY) in Two Potato Cultivars

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Abstract

This study was conducted in Al-Alam District, Salah Al-Din Governorate, during the autumn growing season of 2025 on potato crops. The objectives were to identify the soft rot bacterium causing blackleg disease using the Polymerase Chain Reaction (PCR) technique and to evaluate the efficacy of some safe alternatives in controlling the disease complex of *Pectobacterium atrosepticum* and Potato virus Y (PVY) on two potato cultivars. Molecular identification was performed using amplification of the 16S rRNA geneconfirmed the presence of *P. atrosepticum*, while a 350 bp sequences of PYV-O gene confirmed infection with the PYV^{O} strain of PVY. The study evaluated the effects of *Thuja orientalis* extract, *Cordia myxa* fruit extract, the resistance inducer Bion, and a culture of the alga *Ch. turgidus*. Results indicated that disease severity was lowest in the *Ch. turgidus* treatment (0.40) for the cultivar Naima, whereas the bacterial-only treatment recorded the highest severity (0.70) for the same cultivar. The cultivar Naima showed the lowest overall disease severity. The *Ch.turgidus* treatment also resulted in the highest leaf area and shoot dry weight for Naima, while the combined infection treatment produced the lowest values. Naima showed significant superiority in mean leaf area and dry weight. In terms of total yield, the *Ch. turgidus* treatment achieved the highest yield for Naima, compared with 520.7 kg under the combined control. Naima also recorded the highest average yield among cultivars. Plant height was greatest under the *Thuja orientalis* extract treatment (81.66 cm) and lowest under the combined control for Naima, with no significant differences between cultivars for this trait. These results indicate that *Ch. turgidus* is a promising safe alternative for reducing disease severity and improving growth and yield of potato under combined bacterial and viral infection conditions.

Introduction

Potato (*Solanum tuberosum L.*) is one of the most important food and strategic crops worldwide, ranking fourth in economic importance and human consumption after wheat, rice, and maize. It is rich in carbohydrates, proteins, minerals, and vitamins (4). Potato crops are exposed to a wide range of bacterial, fungal, and viral diseases that negatively affect growth, productivity, and marketability. Among the most serious bacterial diseases is blackleg, caused by *Pectobacterium atrosepticum*, formerly known as *Erwinia carotovora*. This bacterium is Gram-negative, rod-shaped, and motile by means of peritrichous flagella, and is classified as a soft rot bacterium due to its ability to secrete cell wall–degrading enzymes, leading to tissue maceration and cell death (38)(24).

In addition, potato crops, like other agricultural crops, are affected by viral diseases, among which Potato virus Y

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(PVY) causes significant economic losses in both yield and quality. Numerous studies have reported that more than 50 plant viruses infect potato plants worldwide; however, only a few of these, including PVY, are responsible for substantial economic losses in potato production (35).

In recent decades, increasing attention has been directed toward the search for environmentally friendly and safer alternatives for plant disease control, particularly the use of plant extracts. Medicinal and aromatic plants contain a wide range of secondary metabolites such as phenols, flavonoids, alkaloids, and terpenes, which have demonstrated high antimicrobial activity and growth-inhibitory effects against pathogenic fungi, bacteria, and viruses (15). The induction of systemic resistance in plants through the use of *Thuja orientalis* extract, commonly known as the tree of life and belonging to the family Cupressaceae, has been widely studied due to its antibacterial, antiviral, antioxidant, and antifungal properties (25).

Cordia myxa, one of the largest genera in the family Boraginaceae, is considered a rich source of antioxidants (36). During the past three decades, several environmentally friendly chemical compounds have been evaluated;(27) reported that acibenzolar-S-methyl (ASM) is an effective plant resistance inducer that enhances plant protection against viral, bacterial, and fungal pathogens. ASM also helps maintain postharvest quality, delays senescence, and controls fruit and vegetable deterioration after harvest.(18) reported that species of the alga *Ch.turgidus* are abundant in freshwater, aerial, and soil environments and have the ability to improve plant growth by significantly increasing vegetative biomass and yield, due to their content of essential nutrients. From an applied perspective, studying the interaction between bacterial and viral pathogens represents an important step in developing integrated resistance strategies aimed at enhancing plant immunity against dual infections, which pose an increasing challenge in Iraqi potato fields.

2.Materials and Methods

2.1.Sample collection and bacterial isolation from infected potato tubers (*Pectobacterium atrosepticum*)

The method described by(14) was followed with some modifications. A number of potato tubers showing soft rot symptoms were collected from local markets for laboratory isolation and purification of bacterial isolates. The tubers were thoroughly washed with tap water to remove adhering soil particles. They were then immersed in a sodium hypochlorite (NaOCl) solution diluted at a ratio of 1:5 with water for three minutes, followed by rinsing to remove residual disinfectant. A portion of the macerated tissue from the infected area of the tuber cross-section was aseptically taken using a sterile loop and streaked onto solid Potato Dextrose Agar (PDA) medium. In addition, other isolates were cultured on Nutrient Agar (NA) and incubated at 27 °C for 24 hours. Subsequently, the bacterial inoculum was prepared using Nutrient Broth (NB), and serial aqueous dilutions of the bacterial isolate were performed. Potato plants were then inoculated with the prepared isolate.

2.2 Detection of Pectobacterium atrosepticum using PCR

Genomic DNA was extracted from 24-hour-old bacterial cultures using a Chelex® 100 kit (Bio-Rad, USA). A small amount of bacterial colonies was collected using a sterile loop and transferred into a 1.5 mL Eppendorf tube containing 200 µL of Chelex® 100 and 100 µL of TE buffer.

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The tubes were then placed in a water bath at 95 °C. After 10 minutes, the samples were removed and centrifuged at 16,000 × g for 10 minutes. The supernatant containing DNA was carefully transferred to 0.5 mL tubes and stored at −4 °C until use. PCR amplification of the 16S rRNA gene was performed using the universal primers 27F and 1492R, which amplify approximately a 550 bp fragment. The PCR reaction mixture and cycling conditions were carried out according to standard protocols.

2.3. Polymerase Chain Reaction PCR

Table (1). Universal primers used for amplification of the 16S rRNA gene for molecular identification of Pectobacterium atrosepticu

Product Size	Sequence	Primer name
550 base pair	5′- GTG TAG CGG TGA AAT GCG -3′	F-27
	5′- ACG GGC GGT GTG TAC AA 3′	R-149

2.4 Inoculation of potato tubers with the bacterial inoculum

The surface of the tubers was disinfected using sodium hypochlorite (NaOCl) solution diluted from a commercial bleach solution with a concentration of 6% at a dilution ratio of 4:1. The tubers were then thoroughly rinsed several times with sterile distilled water to remove any traces of the disinfectant. Afterward, sterile superficial wounds were made on the tuber surface, and the tubers were inoculated with the freshly prepared bacterial suspension at a concentration of 1×10^4 (3).

2.5 Plant sample collection and virus detection.

Potato plant samples showing symptoms suggestive of Potato virus Y (PVY) infection were collected from infected potato fields in Salah Al-Din Governorate. Symptoms included clear mosaic patterns, leaf necrosis, and severe stunting in some seedlings, in addition to a high population density of the main vector, the green peach aphid (Myzus persicae). Preliminary diagnosis was performed based on symptoms in the Virology Laboratory, College of Agriculture, Tikrit University. The virus was maintained in living plants and subsequently detected using multiplex Polymerase Chain Reaction (PCR). The isolate was renewed in pots (10 pots) until the start of the field growing season.

2.6 Mechanical transmission of Potato virus Y (PVY^O).

One gram of potato leaves randomly collected from infected fields, after diagnosis, was macerated in a porcelain mortar with phosphate buffer solution (prepared by adding 1.36 g/L of $KH_2\ PO_4$ and 1.42 g/L of $NaHPO_4$, pH 7.0). The homogenate was filtered through a double layer of gauze into a beaker to obtain a clear extract. Leaves of potato plants at the fourth true-leaf stage were gently dusted with an abrasive (carborundum). The index finger was dipped into the viral extract, and the leaf was supported with the palm of the hand and gently rubbed in one direction. The leaves were then rinsed with distilled water to remove residual inoculum and abrasive material. Symptom development was monitored one week after inoculation (32).

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2.7 Polymerase Chain Reaction PCR

Table (2) Specific primers used for detection of the PVY-O strain.

Product Size	Sequence	TM (°C)	GC (%)	Primer name
335 base pair	5′- GCACGTTCCAAGGTTACC-3′	56.0	56 %	F-PYV
	5′-TCGCTTAGCATGATATTCCCT-3′	55.9	43%	R-PYV

3 .Preparation of experimental treatments

The treatments used in the field experiments included:

1.Alcoholic plant extracts:

a. Fruit extract of *Thuja orientalis*

b. Fruit extract of *Cordia myxa*

2.The chemical compound Bion (Acibenzolar-S-methyl).

3.A culture of the alga *Ch. turgidus*.

Fresh fruits of *Thuja orientalis* and *Cordia myxa* were collected from trees in Al-Alam District. The fruits were thoroughly washed to remove dust and impurities, then placed in an oven in the Virology Research Laboratory for 7 days at a temperature of 40–45 °C for complete drying. The dried samples were ground using an electric grinder and sieved through a 1.5 mm mesh sieve. The powdered samples were then collected, placed in polyethylene bags labeled with the plant name and weight, and stored until use in the field experiments.

3-1 Alcoholic extraction of plant samples

The plant extracts mentioned above were prepared in the Virology Laboratory, Department of Plant Protection, College of Agriculture, Tikrit University, using the method described by(22) as cited in(20). Forty grams of each powdered plant sample were placed in a 500 mL glass flask, and 400 mL of the alcoholic solvent (methanol) was added. The mixture was then placed on a magnetic stirrer hot plate for 15 minutes and subsequently kept in a dark place for 24 hours. The extract was filtered through two layers of muslin cloth, and the filtrate was further filtered through Whatman No. 1 filter paper. The filtrate was transferred into plastic tubes and centrifuged at 3000 rpm for 10 minutes to obtain a clear supernatant. The supernatant was then freeze-dried using an ALPHA 1–2 LDplus lyophilizer to obtain the dry extract, which was stored in sterile, tightly sealed containers at 4 °C until field application.

3.2 Preparation of *Ch. turgidus* culture medium

The algal isolate *Ch. turgidus* was obtained from the College of Science, University of Anbar, and its identity was confirmed by the supervising professor. The specific culture medium was prepared according to the manufacturer's instructions by adding the ready-made BG11 broth at a concentration of 1.627 g per liter of distilled water. The medium was sterilized in an autoclave at

121 °C and 1.5 kg/cm² pressure for 15 minutes (5).

3.3 Field experiments and experimental design

The study site was selected in the agricultural fields of Al-Alam District, Salah Al-Din Governorate, at coordinates 34.6734° N latitude and 43.59° E longitude. Land preparation involved several steps, starting with plowing using a moldboard plow, followed by soil leveling and smoothing to prepare the field for planting. Row spacing was set at 2 m, and plant spacing within rows was 30 cm. The designated area was planted on 15 February 2025.

Table (3). Potato cultivars used in the experiment

The producing company	Origin	Class characteristics	Class name	Sequence
Solawest	France	The shell is white and medium-sized.	ELBEIDA	1
Germicopa	France	The peel is white, medium to large in size.	NAIMA	2

4 :Calculation of PVY Disease Severity

Disease severity was assessed using a symptom severity scale according to(30), based on the visual progression of PVY symptoms on the three tested cultivars. The number of infected plants at each severity score (0, 1, 2, 3, 4, 5) was recorded, and disease severity was calculated using the following formula .

1-A: Table (4) Pathological evidence of progression of PVY virus infection severity

Injury Appearance	Injury Description	Number
	Healthy plant	**0**
	Light mosaic	1
	Intense mosaic and beginning to wrinkle	**2**

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	Reduction in leaf Previous area and leaf curling along with the aforementioned symptoms	**3**
	Symptoms include severe yellowing and leaf distortion with the onset of tissue death	**4**
	Tissue death and wrinkling along with the aforementioned symptoms	**5**

5 .Measurement of leaf area (cm^2 $plant^{-1}$)

Leaf area was calculated according to the method described by(39) based on fresh weight. Five leaves were collected from each plant (upper, middle, and lower canopy), with three plants sampled per treatment. The leaves were punched using a circular metal disc with an area of 0.75 cm^2 to determine the area of each leaf and calculate the average. This value was then multiplied by the total number of leaves per plant to obtain the total leaf area per plant. The following equation was applied.

Leaf area = (Leaf weight (g) × Area of punched discs (mm^2)) / Disc weight (g)

6 .Percentage of dry matter in the plant shoot system(%)

Shoot dry matter was determined by randomly sampling five plants from each experimental unit. The samples were weighed fresh using an electronic balance and then air-dried under ambient conditions for 14 days until a constant weight was achieved. The percentage of dry matter in the shoot system was calculated using the following equation

Dry matter percentage of the shoot system (%) = (Dry weight of sample / Fresh weight of sample) × 100

7 . Plant yield (kg $plant^{-1}$)

The yield per plant for each experimental unit was calculated using the following equation:

Plant yield (kg $plant^{-1}$) = Total yield of five plants (kg) ÷ 5

8. Plant height (cm $plant^{-1}$)

Plant height was measured at the stage of full vegetative growth and physiological maturity using a standard measuring tape. Five plants were randomly selected from each experimental unit, and measurements were taken from the soil surface at the stem base to the highest growing point .

9 .Statistical analysis

The field experiment was conducted using a Randomized Complete Block Design (RCBD) as described above. Mean comparisons were performed using Duncan's Multiple Range Test at a probability level of 0.05, using the SAS software package (10).

10. Results and Discussion

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1.Molecular detection of *Pectobacterium atrosepticum* in potato

The results of gel electrophoresis showed that DNA extracted from bacterial colonies was successfully amplified using PCR with species-specific primers. Amplification produced a DNA fragment of 550 base pairs in infected samples corresponding to the target gene. Clear bands were observed in the positive (+) samples at the same position as the standard marker, whereas no bands appeared in the negative (−) control. The PCR products were visualized on a 1.5% agarose gel stained with ethidium bromide and photographed under ultraviolet light. These results are genetically consistent with those reported by (23).

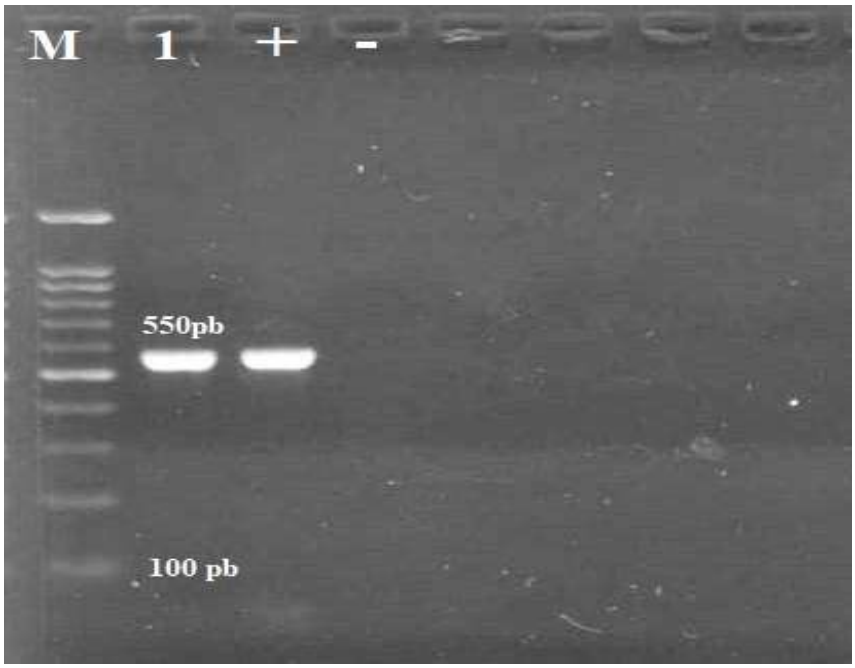

Figure (1) Molecular detection of bacterial isolate using a 550pb primer

https://www.ncbi.nlm.nih.gov/nuccore/PX121750

Figure (2) Registration of the isolation in the gene bank for bacterial isolation

2 .Molecular detection of Potato virus Y (PVY^O)

The results of gel electrophoresis obtained from the examination of potato plant samples exhibiting PVY symptoms showed clear bands resulting from the amplification of a portion of the viral coat protein gene using PCR. Although several samples exhibited typical viral symptoms, most of them did not produce detectable bands. Molecular analysis revealed the presence of the virus at a fragment size of 335 bp, which was clearly observed on a 1.5% agarose gel under an electric field of 5 V/cm using TBE buffer for 1 hour. The genetic bands showed high similarity to the results reported by (33).

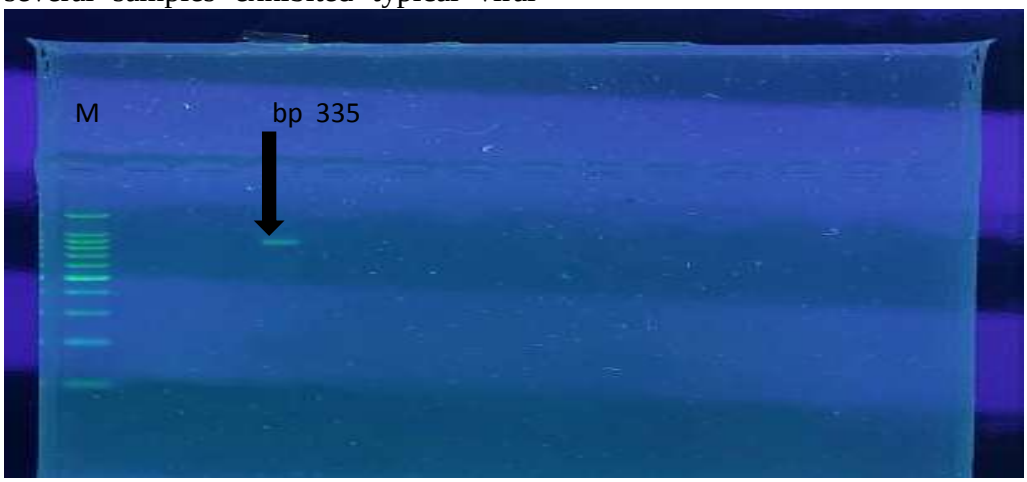

Figure (3) Results of the molecular detection reaction for the local isolate of potato virus Y(PVY^O) at the bp 335 band

3.Effect of treatments on disease severity of blackleg (*Pectobacterium carotovorum*) in potato under co-infection with Potato virus Y

The results presented in Table (5) showed that combined infection with the bacterium and virus resulted in significant differences among treatments. The lowest disease severity was recorded in the *Ch. turgidus* treatment, indicating its high efficacy in reducing disease severity, with a value of 0.40 for the cultivar Naima, followed by the Bion treatment (0.44). In contrast, the bacterial-only treatment recorded the highest severity (0.70) for the same cultivar.

Regarding cultivar effects, the results in the table indicated that the cultivar Naima was the least susceptible, with a mean infection rate of 55.11, whereas the cultivar Elbeida exhibited the highest infection rate (57%). This suggests the presence of genetic variation among cultivars in their response to combined infection and biological treatments, as cultivars differ in the composition of defensive proteins, cell wall structure, and the speed of immune response.

It can be concluded that the superiority of the *Ch. turgidus* treatment contributed to the reduction in disease severity through its ability to activate systemic acquired resistance (SAR) mechanisms within the plant. Algal components stimulate the production of internal defensive compounds such as phytoalexins and oxidative enzymes, including peroxidase and polyphenol oxidase, as well as increasing the accumulation of phenolic compounds, which are among the most important defensive components against pathogens.

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These findings are consistent with those reported by(7) and (28).

This variation reflects differences among cultivars in their level of resistance to the pathogen and is likely due to genetic differences in immune response, such as the speed of defensive compound production or the plant's ability to restrict the virus to limited tissue areas and prevent its spread, in agreement with the findings of (9).

Table (5). Effect of treatments on disease severity of potato infected with blackleg under co-infection with Potato virus Y.

coefficients Average	NAIMA	ELBEIDA	Items / Transactions
0 .71 a	0 .70 b a	0 .72 a	Treatment with bacteria
0. 61 c	0. 65 b	0. 65 b	Infected with bacteria and then PVY virus
0.00 g	0.00 h	0.00 h	Intact control treatment
0. 46 e	0. 44 g e f	0. 48 d e f	Bion compound
0 .51 d	0. 50 d e	0 .53 d c	Thuja fruit extract
0 . 66 b	0 .67 b a	0. 65 b	Cordia myxa fruit extract
0. 41 f	0. 40 g	0. 42 g f	*ch.turgidus*
	55.11 b	57.94 a	Average of the two classes

- Values followed by the same letters in the same row (or column or both) are not significantly different at P=0.05 based on to Duncan's multiple range test.

4 . Effect of treatments and cultivars on leaf area (cm²) of potato infected with blackleg bacterium under co-infection with Potato virus Y

The statistical analysis of the data presented in Table (6) showed significant effects of the different treatments on leaf area. The *Ch. turgidus* treatment recorded the highest mean leaf area (34.00 cm²), followed by the Bion treatment, which resulted in 31.66 cm² for the cultivar Naima. In contrast, the combined infection treatment produced the lowest leaf area (20.66 cm²) for the same cultivar. With respect to cultivar effects, the results indicated a significant superiority of Naima, with a mean leaf area of 28.76 cm², compared with Elbeida, which recorded 27.61 cm².

The significant increase in leaf area observed under the *Ch. turgidus* treatment reflects its efficiency in enhancing vegetative growth, due to its richness in bioactive compounds such as amino acids, polysaccharides, vitamins, and certain phenolic compounds, which contribute to improved physiological activity of plant cells and enhanced resistance to infection. In contrast, the combined infection treatment caused a

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marked reduction in leaf area. These findings are consistent with those reported by(29).

The present results support previous studies indicating that the application of algal treatments and the compound Bion can induce systemic resistance in plants and reduce the severity of combined infections in potato through activation of plant defense pathways such as the salicylic acid and jasmonic acid signaling pathways, as reported by (12). (8)and)(31) also reported that treatment of plants with the alga Spirulina platensis improved vegetative growth parameters, including leaf area, under infection with Bean yellow mosaic virus (BYMV).

Table (6). Effect of treatments on leaf area of potato infected with blackleg under co-infection with Potato virus Y.

coefficients Average	NAIMA	ELBEIDA	Items / Transactions
22.66 e	23.66 f	21.66 f g	Treatment with bacteria
19.83 f	20.66 g h	19.00 h	Infected with bacteria and then PVY virus
35.33 a	35.33 a	35.33 a	Intact control treatment
30.83 c	31.66 b c	30.00 c d	Bion compound
27.83 d	27.33 e	28.33 d e	Thuja fruit extract
27.66 d	28.66 d e	26.66 e	Cordia myxa fruit extract
33.16 b	34.00 a b	32.33 b c	*ch.turgidus*
	28.76 a	27.61 b	Average of the two classes

- Values followed by the same letters in the same row (or column or both) are not significantly different at P=0.05 based on to Duncan's multiple range test.

5. Effect of treatments on shoot dry weight of potato plants infected with blackleg bacterium under co-infection with Potato virus Y

The data presented in Table (7) indicate significant differences among the applied treatments. The *Ch. turgidus* treatment produced the highest shoot dry weight, with a significant difference compared to the other treatments, reaching 73.66 g, followed by the fruit extract of *Thuja orientalis* with 70.66 g for the cultivar Naima. In contrast, the combined control treatment recorded the lowest shoot dry weight (54.33 g) for the same cultivar. Regarding cultivar effects, Naima exhibited a higher dry weight (70.14 g), outperforming Elbeida, which recorded a lower value of 66.28 g.

These results indicate that the reduction in bacterial and viral disease severity can be attributed to the effectiveness of *Ch.*

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turgidus in producing bioactive antibacterial compounds and inducing plant resistance, leading to increased vegetative growth and improved growth traits, and consequently a higher shoot dry weight. This finding is consistent with that reported by(1).(5)also reported that treatment with the alga Spirulina platensis reduced disease severity caused by Cucumber mosaic virus (CMV) through the induction of systemic resistance (ISR) during infection, or due to the presence of cytokinins in Spirulina platensis, which positively influence the biosynthesis of amino acids, mRNA, RNA, and DNA, thereby compensating for imbalances in nitrogenous bases caused by viral infection and reducing the virus's ability to express itself within infected plant cells.

The tannins present in *Thuja orientalis* extract contribute to reducing disease severity through their inhibitory activity against pathogenic bacteria and viruses via mechanisms associated with their antioxidant properties and the reduction of oxidative stress, which alleviates disease pressure on the plant and results in increased vegetative growth. This is consistent with the findings of (37)and(11).

Table (7). Effect of treatments on shoot dry weight of potato infected with blackleg under co-infection with Potato virus Y.

coefficients Average	NAIMA	ELBEIDA	Items / Transactions
58.83 e	60.66 h g	57.00 h i	Treatment with bacteria
51.66 f	54.33 i	49.00 j	Infected with bacteria and then PVY virus
92.16 a	95.66 a	88.66 b	Intact control treatment
68.00 c	70.00 c d e	66.00 e f	Bion compound
69.50 c	70.66 c d	68.33 d e	Thuja fruit extract
64.83 d	66.00 e f	63.66 f g	Cordia myxa fruit extract
72.50 b	73.66 c	71.33 c d	*ch.turgidus*
	70.14 a	66.28 b	Average of the two classes

- Values followed by the same letters in the same row (or column or both) are not significantly different at P=0.05 based on to Duncan's multiple range test.

6 . Effect of treatments on plant height (cm) of potato infected with blackleg bacterium under co-infection with Potato virus Y

The results presented in Table (8) showed highly significant differences among treatments in plant height. The *Thuja orientalis* extract treatment recorded the greatest plant height (81.66 cm), with a significant difference compared with the other treatments, followed by the *Ch. turgidus* treatment (74.33 cm). The combined control

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treatment recorded the lowest plant height (41.00 cm) for the cultivar Naima.

Regarding cultivar effects, the results indicated no significant differences between the two cultivars. The mean plant height of Naima was 70.42 cm, whereas Elbeida recorded 68.95 cm.

Thuja orientalis extract is considered a bioactive compound with strong antibacterial properties, as its phenolic constituents contribute to weakening bacterial cell walls and inhibiting essential enzymatic activities. This effect reduces the severity of bacterial infection and improves the physiological status of the plant, thereby enhancing resistance to pathogens and resulting in increased vegetative growth. Plant height is therefore regarded as a key indicator of overall plant vigor (34)and (19).

Table (8). Effect of treatments on plant height (cm) of potato infected with blackleg under co-infection with Potato virus Y.

coefficients Average	NAIMA	ELBEIDA	Items / Transactions
50.50 d	49.33 f g	51.66 f	Treatment with bacteria
42.66 e	41.00 h	44.33 g h	Infected with bacteria and then PVY virus
106.16 a	108.33 a	104.00 a	Intact control treatment
69.66 c	71.00 c d e	68.33 d e	Bion compound
79.33 b	81.66 b	77.00 b c	Thuja fruit extract
68.33 c	67.33 e	69.33 d e	Cordia myxa fruit extract
71.16 c	74.33 c d	68.00 d e	*ch.turgidus*
	70.42 a	68.95 a	Average of the two classes

- Values followed by the same letters in the same row (or column or both) are not significantly different at P=0.05 based on to Duncan's multiple range test.

7 . Effect of treatments on yield per plant (kg) of potato infected with blackleg bacterium under co-infection with Potato virus Y

The results presented in Table (9) indicate the superiority of the *Ch. turgidus* treatment, with a significant difference compared to the other treatments, as it produced a yield of 1215.1 kg for the cultivar Naima, followed by the *Thuja orientalis* extract treatment, which yielded 1115.9 kg. In contrast, the combined control treatment produced only 520.7 kg for the same cultivar. Regarding cultivar effects,

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Naima was superior, with a mean yield of 922.75 kg, whereas Elbeida recorded 901.58 kg.

The marked increase in vegetative growth traits, particularly yield in potato, following treatment with *Ch. turgidus* may be attributed to the presence of plant growth regulators and amino acids in algae, which improve the nutritional and physiological status of the plant, leading to enhanced cell division and increased nutrient uptake rates. This occurs through strengthening of the root system and increasing root surface area, in addition to improving flowering and mobilizing nutrients that are otherwise unavailable in the soil. These effects positively influence photosynthesis and plant growth, thereby increasing yield, in agreement with the findings of (6) and(17).

The superiority of the *Thuja orientalis* extract in increasing yield may be explained by the presence of phytoalexins and pathogenesis-related (PR) proteins, as well as the role of tannins and resins in strengthening plant cell walls against infection. (2) demonstrated in their study on Moringa oleifera extract that it contains tannins and resins that enhance plant resistance and improve yield traits. Moreover, inducing resistance in potato plants against combined infection contributed to reducing disease severity. All these factors clearly explain the observed increase in yield, along with improvements in other growth traits.

The use of algae as effective biostimulants has also shown a clear positive effect on increasing broccoli yield, which is attributed to their role in improving vegetative growth and enhancing physiological efficiency, thereby directly increasing yield, as reported by(21). These results are consistent with those reported by (13) who demonstrated that pest infestation negatively affects potato productivity and yield.

Table (9). Effect of treatments on yield per plant (kg) of potato infected with blackleg under co-infection with Potato virus Y

coefficients Average	NAIMA	ELBEIDA	Items / Transactions
d613.5	573.3 f	653.7 f	Treatment with bacteria
d547	520.7 f	573.3 f	Infected with bacteria and then PVY virus
a1275.0	1350.0 a	1200.0 b c	Intact control treatment
897.8 c	905.0 e	890.7 e	Bion compound
1083.15 b	1115.9 c d	1050.4 d	Thuja fruit extract
801.0 c	779.3 e	822.7 e	Cordia myxa fruit extract
1167.7 a	1215.1 a b	1120.3cd	*ch.turgidus*
	922.75 a	901.58 b	Average of the two classes

- Values followed by the same letters in the same row (or column or both) are not significantly different at P=0.05 based on to Duncan's multiple range test.

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Conclusion

The present study provides the first molecular confirmation in Salah Al-Din Province of the occurrence of Potato virus Y (PVY) and *Pectobacterium carotovorum* , the causal agent of soft rot disease, using PCR assays. Beyond pathogen detection, the findings clearly demonstrated that treatment with the alga *Ch.turgidus* significantly outperformed the other tested treatments in reducing disease severity and enhancing key growth parameters, including leaf area, dry weight, and total yield. Meanwhile, *Thuja orientalis* extract recorded the highest mean plant height among the evaluated treatments.Importantly, this work represents the first documented evidence of employing *Ch. turgidus* as a biocontrol agent against viral diseases. The promising outcomes observed in this study highlight its potential as a sustainable and environmentally friendly approach for viral disease management. These results pave the way for future investigations into its application within organic farming systems and its possible effectiveness against other viral pathogens and across different host plants..

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