The Future of Agriculture

Article

Effect of Foliar Spraying with Chitosan and Moringa Extract on Vegetative Growth, Cluster and Powdery Mildew of Attika Seedless Grapevines

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https://doi.org/10.37229/fsa.fja.2026.08.05

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Future Science Association

Available online free at www.futurejournals.org

Print ISSN: 2687-8151

Online ISSN: 2687-8216

Received: 3 June 2026
Accepted: 25 July 2026
Published: 5 August 2026

Publisher's Note: FA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: This study examined the effects of foliar spray of chitosan and moringa leaf extract (0.2 or 0.4%) either alone or in combination on Attika Seedless grapevines over the course of two consecutive seasons (2022 & 2023). The vines are trellised using a Spanish Parron supporting system and planted 2 × 3 meters apart. The grapevines were pruned in the first week of January. As compared to the control, the results demonstrated that foliar application of chitosan and moringa leaf extract, either alone or in combination, had favourable effects on the berry quality as well as vegetative development characteristics for Attika Seedless grapevines. Using a 0.4% foliar spray of chitosan and moringa leaf extract together produced the greatest values for improving the vegetative growth characteristics, cluster, and berry quality for Attika Seedless grapevines. Additionally, at a rate of 0.4% treatment with chitosan and moringa leaf extract together ultimately had the best results for controlling powdery mildew. In conclusion, foliar treatment of chitosan and moringa leaf extract may be suggested for Attika Seedless grapevines in order to improve berry quality, increase yield, and control powdery mildew infections.

Key words: Chitosan, moringa leaf extract, Attika Seedless, powdery mildew.

1. Introduction

Finding natural methods to improve plant defense mechanisms and productivity that result in ecologically friendly agriculture is one of the most important goals of scientists. Methods for reaching this goal include applying chitosan and moringa leaf extract to grapevines, which would allow for a reduction in the usage of agrochemicals, heat stress tolerance, and increased yield both quantitatively and qualitatively, as well as manage fungal infections.

Chitosan is regarded as one biopolymer that contains various compounds, including vitamins, amino acids, polyamines, macro- and microelements, plant growth regulators, and antifungal activity, all of which have positive impacts on fruit quality, yield, vegetative growth, and nutritional status **(Shah *et al*., 2025)**. The beneficial effects of chitosan on vegetative development are because it contains oligosaccharides that boost photosynthesis, cell division, and metabolic pathways for better assimilation and greater uptake of nitrogen (**Rojas-Pirela *et al*., 2024).** Moreover, chitosan, which is abundant in auxins and cytokinins, may be responsible for the growth in shoot length and leaf area. Additionally, according to **Liu *et al*. (2023)**, IAA plays a critical function in the regulatory gene (VvCEB1), which regulates cell proliferation and strengthens the cell-wall network, both of which have a good impact on vegetative development characteristics. In addition to over-expressing genes involved in photosynthesis, chitosan treatment alters the control of protein metabolism by increasing the metabolism of hormones and other storage proteins, as discussed by **Bakry *et al*. (2024)**. Further, the chitosan treatments increased the production of pigments that are needed in photosynthesis. Moreover, **Behboudi *et al*. (2018)** say that increases might be because of more amino acids being released from chitosan or because cytokinin levels increased, which helped chlorophyll production. The positive effect of chitosan, according to **Ahmad *et al*. (2017)**, may result from an improvement in the transport of energy capacity regarding the antenna particles, located at the reaction site of photosystem II, which plays a vital role in heat stress tolerance. Recently, according to **Stasinska-Jakubas and Hawrylak-Nowak (2022)**, the chitosan molecule's positive ionic charges strengthen the plant's protection and immunity mechanism against diseases by creating physicaland chemical barriers. Importantly, **Bedrech and farroh (2021)** noted that the foliar spray of chitosan had had a known effect on promoting growth characteristics of Flame Seedless grapevine cultivar.

Moringa (*Moringa oleifera*) is a plant that has many health advantages and is a rich source of phytochemicals, macro- and micronutrients, antioxidants, phenolics, vitamins, carotene, and ascorbates, as described by **Leone *et al*. (2015)**. One of the most strongly effective bio stimulants is a moringa leaf extract, which farmers have utilized as a practical supplement to or alternative to synthetic fertilizers. Moreover, moringa leaf extract effectively reduces the negative effects of climatic fluctuations on plants because it provides an adequate supply of antioxidant chemicals (**Afzal *et al*., 2020)**. Therefore, moringa leaf extract plays a crucial role in helping plants survive heat stress. According to **Abusuwar and Abohassan (2017)**, moringa leaf extract had 15.9 ppm auxins, 16.8 ppm gibberellins, 10.5 ppm abscisic acid, and 27.5 ppm cytokinins (zeatin) on a dry weight basis. Because moringa leaf extract contains a lot of zeatin (cytokinin), which is useful in agricultural operations and plays an essential part in cell division and elongation, it encourages plant growth **(Mashamaite *et al*., 2022)**. In addition, the foliar spray of moringa leaf extract has been shown to support the growth and development of various horticultural crops because of the presence of the aforementioned compounds **(Nasir *et al*., 2020)**. Also, they found that, when treated with 0.3% moringa leaf extract along with K and Zn during the fruit set stage, Kinnow Mandarin trees demonstrated noticeably improved fruit quality and increased productivity.

Interestingly, according to **Jalil *et al*. (2017)**, the Superior Seedless table grapes' improved cane and rachis length may be the result of the presence of plant growth regulators (like zeatin), phenolics, and mineral elements that are abundant in moringa leaves. These elements are crucial for cell division and elongation, which promote plant growth and defense mechanisms against fungus, and have applications in the agricultural sector.

Powdery mildew had negative effects on the grapevines productivity and quality. The environment has suffered as a result of the several fungicides used to treat it. However, in recent years, the use of natural products like chitosan and moringa leaf extract has improved grapevine berry quality, vegetative growth characteristics and the control of powdery mildew, while also having a positive environmental impact.

This study objective was to study the effects of foliar applications of natural substances such as chitosan and moringa leaf extract on the cluster, vegetative growth characteristics, and powdery mildew of Attika Seedless grapevines.

2. Materials and Methods

This study was conducted on uniformly healthy six-year-old Attika Seedless grapevines in a vineyard in the Samalot area of the Minia Governorate during two seasons (2022& 2023). The area of study located in the Valley of the Nile, middle Egypt. It represents one of the largest dry agricultural zones in the Egyptian Western Desert. The area located at longitude of 30°34'00"E - 30°34'15"E and latitudes of 28°10'25"N - 28°10'45"N as presented in Figure (1).

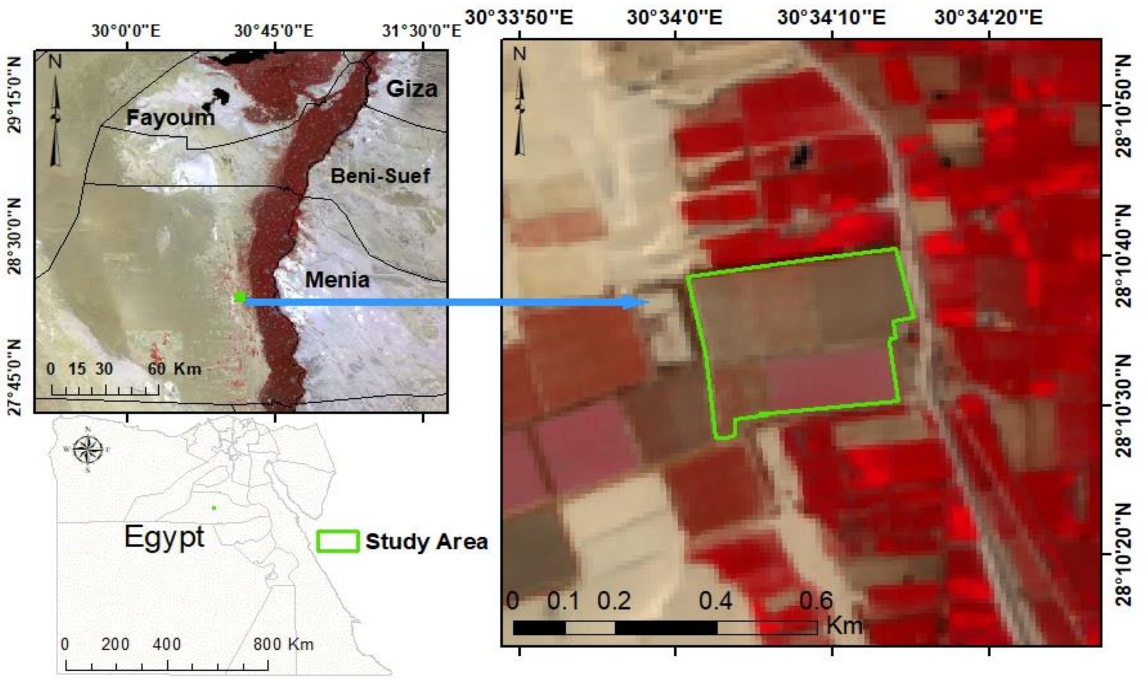

Figure (1). Location of the farm area, Samalut, Menia governorate

The region characterized by arid Mediterranean climate with lack of available water and very low annual rainfall, which are significant factors for grapevine cultivation under proper irrigation systems. The annual precipitation is about 2 mm and average temperature approximately 22.4 in 2022 and 23.5 in 2023 as showed in Table (1) And Figure (2).

Table (1). Temperature variation during the 2022 and 2023 growing seasons

Air Temperature	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Avg.	2022	9.7	12.5	14.8	23.8	26.5	30.5	30.8	31.6	29.7	24.1	18.7	15.8	22.4
Max.		22.6	25.7	31.8	41.9	41.7	44.7	40.4	42.5	42.2	41.6	28.7	27.4	44.7
Min.		-0.1	3.4	3.2	9.1	12.6	18.9	19.4	21.7	19.3	14.8	10.1	6.7	-0.1
Avg.	2023	13.5	12.6	18.9	22.9	26.8	31.2	32.5	32.1	30.2	25.4	20.1	16.0	23.5
Max.		27.4	31.2	36.0	38.7	40.4	44.2	44.2	44.9	45.1	35.5	32.9	26.5	45.1
Min.		5.0	2.7	6.9	7.9	13.4	20.7	22.0	21.9	20.9	16.3	9.3	7.5	2.7

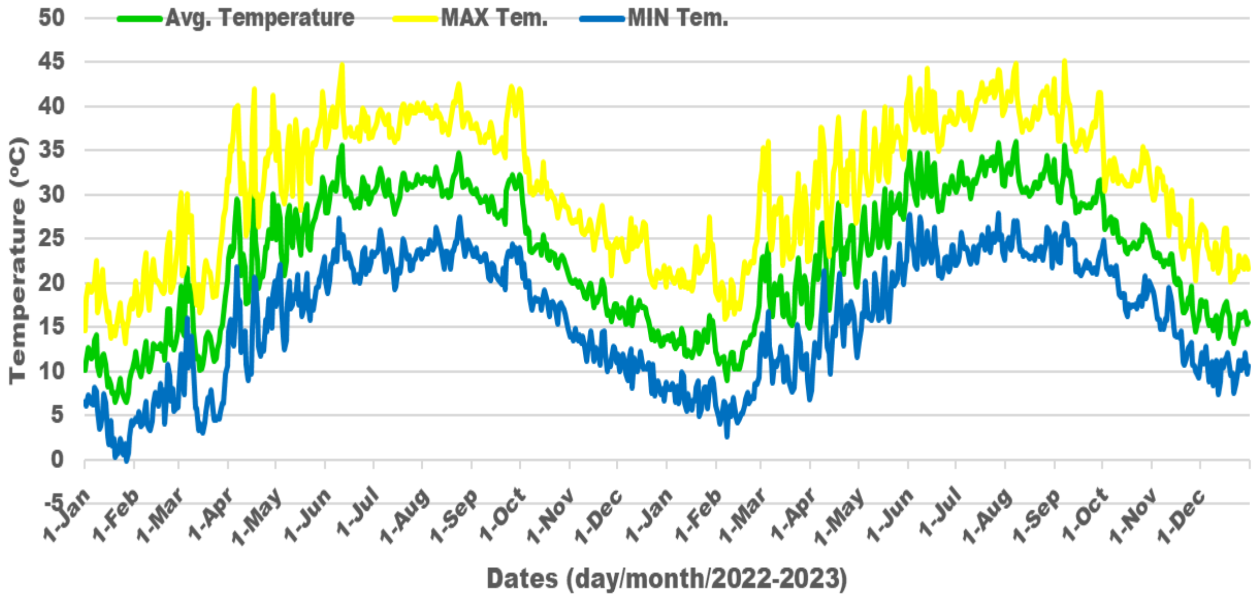

Figure (2). The temperature of the farm region during 2022 - 2023 growing seasons

The soils in this study are predominantly sandy-textured with good drainage. These conditions support healthy root development, reducing root health problems and minimizing disease risks. Spanish parron was the system that provided support. The chosen vines are irrigated using drip irrigation system at a distance of 2 × 3 meters.

Attika Seedless grapevines were pruned in the first week of January. We acquired two Landsat imagery for the 2022 and 2023 seasons. The Landsat data used to estimate Land Surface Temperature (LST) for March, April and June in both seasons. Radiometric calibration and the atmospheric correction were processed to ensure accurate LST retrieval.

The nine treatments used in this study as follow:

1. Control (spraying with water).
2. Chitosan at rate 0.2%.
3. Chitosan at rate 0.4%.
4. Moringa leaves extract at rate 0.2%
5. Moringa leaves extract at rate 0.4%.
6. Chitosan at rate 0.2% + moringa leaves extract at rate 0.2%.
7. Chitosan at rate 0.2% + moringa leaves extract at rate 0.4%.
8. Chitosan at rate 0.4% + moringa leaves extract at rate 0.2%.
9. Chitosan at rate 0.4% + moringa leaves extract at rate 0.4%.

Five replications of each treatment were made, with three vines in each replication. For every cultivar, every treatment was applied four different times during each season: one week prior to blooming, immediately following berry setting, one month following berry setting, as well as during the veraison stage. Triton B was added to each treatment at a rate of 0.05 percent as a wetting agent.

Preparation of moringa leaves extract

Fresh moringa leaves were collected from the field at Sids research station in BeniSuef Governorate, Egypt. They were cleaned, left to dry for seven days at room temperature in the shade, ground into a powder, weighed, and then placed in an airtight bottle for later use. In order to create moringa leaf extract (0.2 and 0.4%), 2 and 4 g/L of powdered moringa sample were mixed with tap water until a homogenized suspension was achieved. The mixture was then allowed to sit for 24 hours before being filtered through a muslin cloth. After being refiltered through No. 2 Whatman filter paper, the extracted material was diluted with one liter of tap water **(Yuniati *et al*., 2022)**. Table 2 shows Quantitative content of aqueous solution moringa leaf extracts as reported by **Nweze and Nwafor (2014)**.

Table (2). Chemical analysis of 100 grams of powdered moringa leaves

Components	Value	Components	Value
Moisture (%)	4.10	Copper (g)	0.01
Protein (g)	17.90	Iron (g)	0.03
Fat (g)	2.70	Sulphur (g)	0.80
Carbohydrate (g)	49.51	Nitrogen (g)	3.00
Fiber (g)	9.37	Iron (g)	0.03
Calcium (g)	2.10	Zinc (g)	0.01
Magnesium (g)	0.43	Phytochemical (g)	0.07
Phosphorus (g)	0.44	Ash (g)	7.90
Potassium (g)	1.60		

The following parameters were used to assess the treatments under test:

Vegetative growth characters

The following measurements were carried out on five vegetative shoots on the studied vines during the first week of June:

- Average length of the main shoots (cm).
- The average leaf area (cm^2) was calculated using a leaf area device (American style CI 203) after ten leaveswere randomly selected from each vine's apical vegetative shoots.
- Cane thickness (cm): Using a vernier caliper, five vegetative shoots per vine were chosen and labeled during the growing season, and the thickness was measured in the five basal internodes of five canes per vine during the first week of December.
- During the winter pruning season, the pruning weight/vine, expressed in kg, was calculated.

Chemical parameters of canes and leaves

The 5-7th apical leaves on the top of the vegetative shoots were harvested during the second week of June in order to measure the following parameters:

- Total leaf chlorophyll: Using the nondestructive Minolta chlorophyll meter model SPAD 502, total leaf chlorophyll was determined in accordance with **A.O.A.C. (1995)**.
- The percentages of nitrogen, phosphorus, and potassium in the leaf petioles were calculated using the **A.O.A.C. (1995)** method.
- Total carbohydrates were taken from vegetative canes by marked five vegetative shoots during season and measured at winter pruning (**A.O.A.C., 1995)**.

Yield and physical characteristics of clusters and berries

Five clusters were harvested from each vine at the ripening stage when the juice was TSS% reached approximately 16–17% at the untreated vines, Attika Seedless, in both seasons. This allowed for the estimation of the following criteria:

- Yield: It was estimated by number of clusters per vine was multiplied by the cluster weight, and the result was reported in weight (kg) as yield/vine.
- Average cluster length (cm), weight (g), and width (cm).
- The average number of vine clusters.
- Average berry weight (g).
- Determine the berry's average diameter and length (in centimeters) with the Vernier caliper.
- The average firmness of berries (g/cm^2) was calculated using an Italian Device Model FT011.

Chemical berries characteristics

- Juice's total soluble solids (TSS) percentage was measured with a hand refractometer.
- In accordance with **A.O.A.C. (1995)**, acidity was calculated as grams of 100 milliliters of juice to tartaric acid.
- TSS / acid ratio.
- **A.O.A.C. (1995)** method was used to calculate the total anthocyanin (mg/100g fresh weight) in berry skin.
- Antioxidant activity in the berry juice (DPPH %): The antioxidant properties were evaluated using (DPPH) radical scavenging **(Cheng *et al*., 2008)**.

Data of powdery mildew

- The severity of clusters of powdery mildew was assessed for the Attika Seedless grape cultivar. The infection rate per cluster and yield after loss (kg) for each cultivar were ascertained as follows:
- Clusters were collected at harvest, and the amount of infected berries in each cluster, the total number of berries per cluster, and the numbers of infected clusters per vine were counted. The infection per cluster percentage was calculated using the following formula:

$$\text{Cluster/vine infection \%} = \frac{\text{number of berries infected/cluster x number ofclustersinfected /vine}}{\text{total number of berries /cluster x total number of clusters/vine}} \text{x100}$$

- The actual yield that remained after utilizing the yield (kg) after loss was following formula to deduct the percentage of infection severity from the yield per vine:
- Yield per vine (kg) after loss = yield per vine – (yield per vine x cluster/vine infection %).

Statistical analysis and design of experiments

The randomized complete block design (RCBD) was used to set up the experiment. The current data was statistically analyzed in accordance with **Snedecor and Cochran (1980)**. The updated L.S.D. values at the 5% level were used to compare the averages **(Steeland Torrie, 1980)**.

3. Results

Parameters of vegetative growth

The data in Table 3 make it abundantly clear that, in comparison to the control treatment, individual or combination foliar treatments of chitosan and moringa leaf extract at significantly different rates improved vegetative characters like shoot length, leaf area, cane thickness, and pruning weight in Attika Seedless grape. In this case, chitosan and moringa leaf extract applied together performed better than either chemical used alone. Attika Seedless grapevines had the highest vegetative parameter values in both seasons when chitosan and moringa leaf extract were applied at a 0.4% concentration. In contrast, the first and second seasons yielded the lowest values in Attika Seedless grapevines obtainedfrom untreated vines.

Table (3). The effects of applying chitosan and moringa leaf extract on the vegetative growth characters of Attika Seedless grapevines during 2022 & 2023 seasons

Treatments	Main shoot length (cm)		Leaf area (cm^2)		Cane thickness (cm)		Pruning weight (kg)	
	2022	2023	2022	2023	2022	2023	2022	2023
T1	162.4	165.7	107.3	107.7	0.95	0.95	3.62	3.63
T2	173.8	178.1	119.7	120.5	0.99	1.01	3.94	3.98
T3	177.7	182.5	124.5	126.5	1.05	1.08	4.02	4.05
T4	174.3	178.3	122.8	124.2	1.01	1.03	3.99	4.03
T5	182.3	188.4	131.2	133.7	1.09	1.13	4.05	4.11
T6	188.7	193.6	133.6	135.5	1.12	1.15	4.22	4.26
T7	193.0	197.7	137.9	145.9	1.15	1.19	4.27	4.34
T8	208.0	214.1	140.1	144.0	1.17	1.20	4.37	4.43
T9	216.7	223.3	143.3	150.9	1.20	1.25	4.53	4.57
New L.S.D at 0.05	2.1	2.2	1.5	1.6	0.01	0.01	0.02	0.01

T1: Control, T2: chitosan (CS) at 0.2%, T3: CS at 0.4%, T4: moringa leaves extract (MLE) at 0.2, T5: MLE 0.4%, T6: CS at 0.2% +MLE at 0.2%, T7: CS at 0.2% + MLE at 0.4%, T8: CS at 0.4% + MLE at 0.2%, T9: CS at 0.4% + MLE at 0.4%.

Chemical constituents of leaves and canes

According to the data in Table 4 Attika Seedless grapevines treated with chitosan and moringa leaf extract at varying doses, either alone or in combination, showed notable differences in total carbohydrates, total chlorophyll, nitrogen, phosphorus, and potassium when compared to control treatment. Moreover, Attika Seedless grapevines improved response to the aforementioned characteristics when chitosan and moringa leaf extract were applied in both seasons as compared to when applied alone.

Using chitosan and moringa leaf extract at 0.4% for two seasons in cultivar Attika Seedless grapevines produced the greatest levels in total carbohydrates, total chlorophyll, nitrogen, phosphorus, and potassium. However, during the 2022 and 2023 growing seasons, there is a positive correlation between the K contents in the leaves of Attika Seedless grapevines and treatments with moringa leaf extract, either applied alone or in combination with chitosan. In this regard, foliar applications of chitosan at 0.4% and moringa leaf extract at 0.4% in over two seasons produced the best K values in the petioles of the leaves.

Table (4). The impact of foliar application of chitosan and moringa leaf extract on the chemical parameters of canes and leaves in Attika Seedless grapevines throughout the 2022 & 2023 seasons

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Total chlorophyll (SPAD)		Total carbohydrates (%)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T1	1.81	1.82	0.20	0.21	1.81	1.82	26.1	26.2	23.0	23.1
T2	1.95	2.00	0.21	0.22	1.88	1.90	31.9	32.4	24.8	25.3
T3	2.01	2.32	0.24	0.25	1.91	1.94	34.3	35.1	25.3	26.0
T4	1.98	2.04	0.22	0.23	1.83	1.84	32.5	33.1	25.0	25.6
T5	2.05	2.09	0.25	0.27	1.85	1.86	35.9	36.4	26.1	27.0
T6	2.10	2.13	0.27	0.29	1.92	1.95	36.3	36.9	27.3	27.5
T7	2.14	2.20	0.29	0.31	2.01	2.03	38.4	39.1	28.5	28.7
T8	2.17	2.28	0.30	0.32	1.95	1.98	39.2	40.6	29.9	31.2
T9	2.29	2.34	0.32	0.34	2.03	2.05	41.2	42.7	31.8	32.5
New L.S.D at 0.05	0.03	0.04	0.02	0.02	0.01	0.01	0.8	0.9	0.06	0.07

T1: Control, T2: chitosan (CS) at 0.2%, T3: CS at 0.4%, T4: moringa leaves extract (MLE) at 0.2, T5: MLE 0.4%, T6: CS at 0.2% +MLE at 0.2%, T7: CS at 0.2% + MLE at 0.4%, T8: CS at 0.4% + MLE at 0.2%, T9: CS at 0.4% + MLE at 0.4%.

Yield, cluster, and berry physical characters

Table 5 make it abundantly evident that, in comparison to Attika Seedless grapevines during the 2022 and 2023 seasons, the yield and physical characteristics of clusters, including weight, width, and length of the cluster, and the number of each vine's clusters, were significantly improved by single or combined foliar applications of chitosan and moringa leaf extract at varying rates. Additionally, the physical characteristics of berries (Table, 6), including berry weight, berry length, diameter, and firmness, were also improved. During the two seasons, the foliar application of chitosan at 0.4% + moringa leaf extract at 0.4% achieved the greatest values of the previously described characteristics, whereas the control treatment produced the lowest values in Attika Seedless grapevines.

Table (5). The impact of foliar application of chitosan and moringa leaf extract on yield, cluster and physical characteristics in Attika Seedless grapevines throughout the 2022 & 2023 seasons

Treatments	Yield/ vine (kg)		Cluster length (cm)		Cluster width (cm)		Cluster weight (g)		No. of clusters /vine	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T1	12.05	12.10	26.3	26.3	10.8	10.9	480.2	480.5	25.1	25.2
T2	15.37	14.85	28.3	28.5	11.4	11.7	569.5	571.2	27.0	26.0
T3	15.75	15.98	28.8	29.1	12.1	12.3	581.3	585.7	27.1	27.3
T4	14.69	15.21	28.4	28.7	11.6	11.9	571.7	576.3	25.7	26.4
T5	15.62	16.06	28.9	29.0	12.3	12.8	578.8	584.2	27.0	27.5
T6	15.29	16.50	29.0	29.3	12.7	13.1	583.9	589.4	26.2	28.0
T7	15.52	17.52	29.5	29.8	13.1	13.4	595.0	598.1	26.1	29.3
T8	15.69	18.92	29.9	30.1	13.6	13.8	601.3	606.5	26.1	31.2
T9	16.31	19.69	30.6	31.6	14.2	14.6	620.4	627.1	26.3	31.4
New L.S.D at 0.05	0.15	0.17	0.2	0.2	0.3	0.2	5.1	5.2	N.S.	0.1

T1: Control, T2: chitosan (CS) at 0.2%, T3: CS at 0.4%, T4: moringa leaves extract (MLE) at 0.2, T5: MLE 0.4%, T6: CS at 0.2% +MLE at 0.2%, T7: CS at 0.2% + MLE at 0.4%, T8: CS at 0.4% + MLE at 0.2%, T9: CS at 0.4% + MLE at 0.4%.

Table (6). The impact of foliar application of chitosan and moringa leaf extract on berry physical characteristics in Attika Seedless grapevines in the 2022 & 2023 seasons

Treatments	Berry weight (g)		Berry length (cm)		Berry diameter (cm)		Berry firmness (g/cm²)	
	2022	2023	2022	2023	2022	2023	2022	2023
T1	4.52	4.83	2.01	2.01	1.53	1.57	368.8	369.0
T2	5.47	5.79	2.10	2.14	1.71	1.77	507.2	510.0
T3	5.69	6.03	2.15	2.18	1.78	1.86	520.4	525.5
T4	5.58	5.90	2.13	2.14	1.73	1.79	499.1	504.0
T5	5.70	6.03	2.16	2.18	1.80	1.87	508.2	512.6
T6	5.72	6.05	2.24	2.27	1.84	1.90	526.3	530.1
T7	5.75	6.07	2.34	2.38	1.88	1.96	539.9	547.7
T8	5.81	6.22	2.40	2.43	1.92	1.98	535.2	542.9
T9	5.87	6.26	2.45	2.47	1.96	2.06	549.8	565.2
New L.S.D at 0.05	0.03	0.01	0.01	0.02	0.01	0.02	3.3	3.5

T1: Control, T2: chitosan (CS) at 0.2%, T3: CS at 0.4%, T4: moringa leaves extract (MLE) at 0.2, T5: MLE 0.4%, T6: CS at 0.2% +MLE at 0.2%, T7: CS at 0.2% + MLE at 0.4%, T8: CS at 0.4% + MLE at 0.2%, T9: CS at 0.4% + MLE at 0.4%.

Berry chemical characteristics

Table 7 clearly show that, in comparison to untreated vines, foliar applications of chitosan and moringa leaf extract, either alone or in combination, significantly improved TSS%, TSS/acidity ratio, as well as total acidity % in Attika grape during both seasons. Throughout the two seasons, the application of 0.4% chitosan and 0.4% moringa leaf extract improved the TSS% and TSS/acidity ratio, as well as decreased acidity %.

Antioxidants activity (DPPH)

According to the data in Table 7, foliar application of moringa leaf extract and chitosan, either separately or in combination, was highly successful in raising the percentage of antioxidant activity of grape berries when compared to the control. In this regard, the best findings for antioxidant activity in grape berries throughout the two seasons were obtained by treating them with chitosan at 0.4% + moringa leaf extract at 0.4%.

Anthocyanin

Results from both seasons in Table 7 indicate that foliar application of chitosan and moringa leaf extract improved the anthocyanin content of the berry skin of the Attika Seedless grape variety. In this case, the combined treatment was superior to treating each material separately. In comparison to the other treatments in the 2022 and 2023 seasons, the chitosan at 0.4% + moringa leaf extract at 0.4% produced the greatest values of anthocyanin content in the berry skin of the Attika Seedless grape cultivar.

Table (7). The impact of foliar application of chitosan and moringa leaf extract on berry chemical characteristics in Attika Seedless grapevines in the 2022 & 2023

Treatments	TSS (%)		Acidity (%)		TSS/ acid ratio		Total anthocyanin (%)		Antioxidants (DPPH %)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T1	16.04	16.05	0.83	0.82	19.32	19.57	25.2	26.2	45.2	44.3
T2	16.81	16.85	0.74	0.70	22.71	24.07	28.6	29.1	53.6	55.6
T3	16.87	16.93	0.71	0.66	23.76	25.65	29.3	29.8	55.2	57.4
T4	16.74	16.76	0.80	0.75	20.92	22.34	28.0	28.3	49.4	50.8
T5	16.77	16.79	0.77	0.73	21.77	23.00	28.3	28.6	52.2	54.2
T6	17.00	17.06	0.70	0.66	24.28	25.84	30.0	30.2	56.4	57.9
T7	17.18	17.22	0.63	0.59	27.26	29.18	30.6	30.9	58.2	60.0
T8	17.04	17.09	0.65	0.62	26.21	27.56	30.2	30.6	57.6	59.5
T9	17.40	17.51	0.60	0.52	29.00	33.67	31.3	32.0	61.7	64.1
New L.S.D at 0.05	0.03	0.02	0.02	0.03	0.82	0.91	0.2	0.2	0.6	0.5

T1: Control, T2: chitosan (CS) at 0.2%, T3: CS at 0.4%, T4: moringa leaves extract (MLE) at 0.2, T5: MLE 0.4%, T6: CS at 0.2% +MLE at 0.2%, T7: CS at 0.2% + MLE at 0.4%, T8: CS at 0.4% + MLE at 0.2%, T9: CS at 0.4% + MLE at 0.4%.

Analysis of Land Surface Temperature (LST)

The results of Land Surface Temperature (LST) presented in Figure 3. The data showed there is a significant variation in LST among 2022 and 2023 seasons. The variation was more notable during the spring months from March to May.

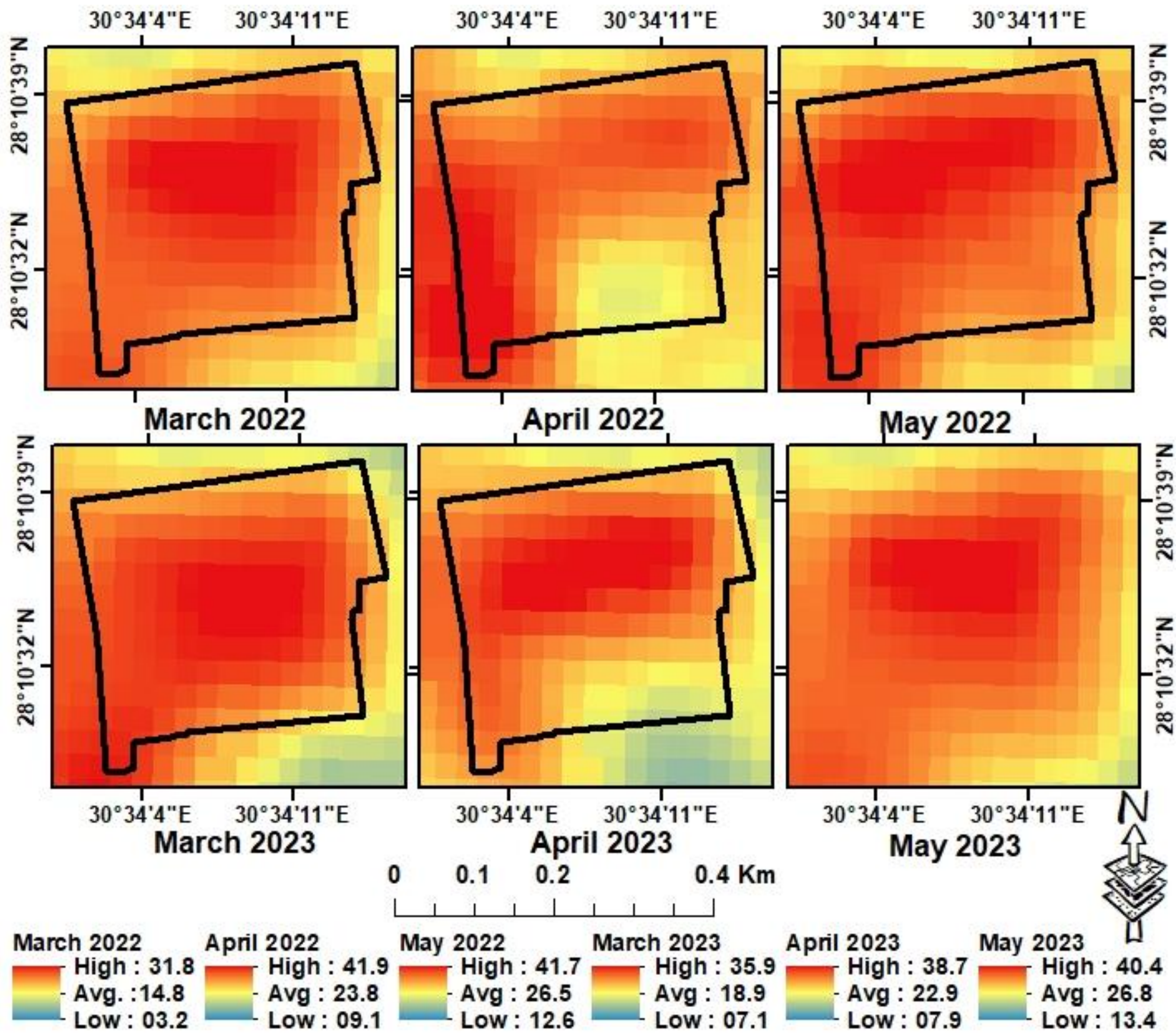

Figure (3). Land Surface Temperature of the farm area during March/May (2022 – 2023)

In March 2023, the average temperature was around 18.9°C. It raised with an average about 4.1°C comparing to the previous year in March 2022 14.8°C. Similarly, the minimum temperature rose from 3.2°C to 6.9°C. This indicating a trend toward warmer weather during early spring. The LST data showed a potential climatic fluctuation with a broader warming pattern. Hence, there are an increase in the average and minimum temperatures from 2022 season to 2023 particularly in May.

Powdery mildew progression

Comparing the foliar application of chitosan and moringa leaf extract to the control treatment, either separately or in combination significantly reduced the advancement of powdery mildew in clusters of Attika Seedless grapevines (Table 8). However, the control treatment had the highest values. For reducing the progression of powdery mildew in clusters of Attika Seedless grapevines over the course of two seasons, the greatest results of the aforementioned character were obtained using chitosan + moringa leaf extract at 0.4%.

Table (8). The impact of foliar application of chitosan and moringa leaf extract on the progression of powdery mildew in Attika Seedless grapevines in 2022 and 2023

Treatments	Number of berries/ cluster		Number of infected berries/ cluster		Number infected clusters/vine		Cluster/vine infection (%)		Yield/vine after loss (Kg)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T1	109.1	109.9	29.1	30.8	14.0	15.1	13.86	15.78	10.38	10.19
T2	113.1	113.1	13.6	13.2	6.4	5.8	2.85	2.60	14.93	14.46
T3	110.8	110.9	10.6	10.3	4.4	3.9	1.55	1.32	15.50	15.77
T4	111.2	111.8	18.2	17.5	7.4	7.2	4.71	4.26	14.00	14.56
T5	110.1	110.6	12.6	12.2	6.0	4.6	2.54	1.84	15.23	15.76
T6	110.6	111.2	9.6	9.9	5.4	5.1	1.78	1.62	15.02	16.23
T7	112.1	112.3	8.4	7.8	2.6	2.3	0.74	0.54	15.41	17.42
T8	112.1	110.9	8.7	8.2	3.4	3.1	1.01	0.73	15.53	18.78
T9	114.3	114.9	2.0	1.3	2.4	1.6	0.15	0.05	16.29	19.67
New L.S.D at 0.05	N.S	0.1	0.3	0.4	0.2	0.3	0.13	0.16	0.08	0.09

T1: Control, T2: chitosan (CS) at 0.2%, T3: CS at 0.4%, T4: moringa leaves extract (MLE) at 0.2, T5: MLE 0.4%, T6: CS at 0.2% +MLE at 0.2%, T7: CS at 0.2% + MLE at 0.4%, T8: CS at 0.4% + MLE at 0.2%, T9: CS at 0.4% + MLE at 0.4%.

4. Discussion

There is currently a global movement to find new ways to reduce agricultural product losses without the use of chemical treatments. Priority is given to methods that do not negatively impact the environment or human health. These techniques include the use of moringa leaf extract and chitosan, which have emerged as effective bio-stimulants and suitable treatments for improving fruit and vegetative growth. The improvement in fruit characteristics and vegetative growth parameters may be the result of improved photosynthesis and the metabolic activity of some key enzymes. Moreover, the growth and development of grapevines are greatly affected by high temperatures, which also seriously affect grape yield and quality and irreversibly damage plants (**Wu *et al*., 2024)**. They also discussed that high temperatures negatively affect plant cells' osmotic adjustment by increasing evapotranspiration, which in turn irreversibly affects the composition of solutes–a necessary component for heat stress tolerance. In addition, chitosan and moringa leaf extract, either separately or in combination, have different effects on the berry quality, vegetative growth, and heat stress tolerance of Attika Seedless grapevines, thus affecting their increased yield. Moreover, moringa leaf extract and chitosan, alone or in combination with others, successfully suppressed powdery mildew infection in Attika Seedless grapes, which affect yield and berry quality.

The beneficial effects of chitosan on vegetative growth have been attributed to its oligosaccharide content, which enhanced photosynthesis, cell division, and metabolic pathways to increase nitrogen uptake and assimilation (**Rojas-Pirela *et al*., 2024)**. Furthermore, adding chitosan to plants increased the amount of nitrogen. This increase could be explained by the release of nitrogen from chitosan (polysaccharides—NH2) due to the action of hydrolytic enzymes or by encouraging the growth of xylem vessels, which elevates nutritional status and nutrient uptake, particularly nitrogen, for the synthesis of amino acids (**El-Amerany *et al*., 2020)**. For this reason, the application of chitosan had a positive effect on vegetative growth parameters including a leaf area; shoot length, pruning weight, cane thickness for Attika Seedless grape cultivar. Moreover, chitosan alleviates oxidative stress, enhances photosynthesis, optimizes mineral nutrient uptake, and improves water-use efficiency, and this has a vital role in tolerating heat stress. So, the treatment with chitosan may be increasing the total cane carbohydrate content and mineral nutrient absorption, such as N, P, and K. The estimation of land surface temperature (LST) improved our understanding of vegetative characteristics for grapevines cultivars (**Parastatidis *et al*., 2017)**. The vegetation density and vigor contributed to moderating the surface temperature through the shading and the evapotranspiration processes. These findings agree with **Morin *et al*. (2020)** and **Zorer *et al*. (2011)**, who reported that LST largely influenced by canopy characteristics and seasonal variability and effectively represent the thermal conditions of vineyards. In addition, this may reflect improved plant physiological status under the foliar treatments of chitosan and moringa extract which is in line with **Irshad *et al*. (2025)**. The increase in total chlorophyll content after chitosan application for grape cultivar confirms that the chitosan treatment improves the process of photosynthesis by boosting photosynthetic pigments (**Dzung *et al*., 2011)**. Further, the impact of chitosan could be caused by an improvement in ability to transfer energy performance of the molecules in the antenna, which are found in the response of photosystem II site **(Ahmad *et al*., 2017)**.

The vital role of chitosan on the effect on physical berry parameters by increasing phytohormones in plant cells for Attika Seedless grape cultivar. Since **Batista-Silva *et al*. (2018)** reported that foliar application with chitosan increases phytohormones in the plant cells. The three main types of phytohormones, such as gibberellins, auxins, and cytokinins, generally promote fruit growth. Following the process of fertilization, the ovary produces these phytohormones to promote cell division and growth. It is tempting to hypothesize that a higher concentration of phytohormones, including IAA, may be the cause of the larger fruit. Also, firmness represents one of several important attributes that consumers value most; it has a significant economic impact on items as a whole. Because a chitosan film forms on the fruit's surface, spraying the foliage with chitosan before the harvest may help maintain the firmness of the fruit (**Sajid *et al*., 2020)**.

The important chitosan's effects grapevine yield as well as its constituents could be attributed regarding the cumulative impact of chitosan on biochemical mechanisms and the boosted translocation of mineral nutrients through useful leaves, which enhance vegetative development parameters (**Singh *et al*., 2022)**. In addition, chitosan may be able to prevent cell damage, as evidenced by the higher antioxidant levels in the fruits of chitosan-treated plants compared to the control (**Li *et al*., 2017)**. As a result of application with chitosan, antioxidants (DPPH) in the berry have an appositive relationship with increasing concentration. By increasing the activity of polyphenol oxidase, which is linked to the production of reactive oxygen species, chitosan application strengthens a plant's defenses against infections. According to **Riseh *et al*. (2022)**, chitosan may play a role within the signaling channel for the synthesis phenolics. Additionally, it promotes the production of chitosanase and chitinase, which may break down Some plant pathogens' cell walls and improve host plant defenses. The beneficial activity of chitosan on increasing the berries' total anthocyanins, TSS %, and TSS/acid ratio and decreasing total acidity by enhancing leaf pigments and the photosynthesis system, as mentioned above. These findings about chitosan's ability to improve cluster characteristics and vegetative growth parameters are consistent with those of **El-Kenawy (2017)**, **Bedrech and farroh (2021)**, and **Singh *et al*. (2022)** for different grapevine cultivars. The positive effects of moringa leaf extract on the vegetative growth have been attributed to its containing phytochemicals, macro- and micronutrients, antioxidants, phenolics, vitamins, carotene, and ascorbates **(Leone *et al*., 2015)**. In this research, the increase of N, P, and K in grape leaves in Attika Seedless grape cultivar may be the application of moringa leaf extract that includes macro elements and its direct action on increasing macro elements in grapevine leaves. According to **Mashamaite *et al*. (2022)**, the enhancements in shoot length, leaf area, and cane length exhibited by the grape cultivars under investigation may be the result of the presence of plant hormones like zeatin as well as contains both macro and micro mineral components that are abundant at moringa leaves. These elements are essential for division of cells and cell growth, which promote plant growth. Because cytokinin causes increases in sink capacity and photosynthesis that reflect on leaf chlorophyll enhancement and total carbohydrate content in canes in Attika Seedless grape cultivar. Therefore, **Tian *et al*. (2017)** reported that the presence of phytohormones such as glycine betaines in moringa leaf extract may increase the amount of chlorophyll in leaves and prevent its destruction. These phytohormones preserve the thylakoid membrane by improving ion homeostasis and controlling osmotic adjustment, and for this reason, they play a crucial role in helping plants survive heat stress. In addition, magnesium and nitrogen present in moringa leaf extract also play a vital role in chlorophyll synthesis, which may lead to increased chlorophyll content in the leaves and subsequently affect the accumulation of carbohydrate reserves in the cane in Attika Seedless grapevines. The function of minerals like K, Ca, and Zn in moringa leaf extract may also be linked to the enhancement of physical and chemical berry parameters. Although Zinc, a precursor to tryptophan, participates in the synthesis of IAA, that is necessary as fruit development, K controls the accumulation and synthesis of starch and sugar, as described by (**Nasir *et al*., 2016)**. As is well known, calcium has a binding role in complex proteins and polysaccharides and is involved in the formation of cell walls. Additionally, calcium contributes to cell wall integrity; for this reason, moringa leaf extract had a vital role in improving berry firmness for Attika Seedless grapevines. Importantly, based on how it affects potassium levels and the photosynthetic activity of leaf petioles of leaves, as affected by foliar application of moringa leaf extract, also increased the anthocyanin content of berry skin. This may be reflected in the increased anthocyanin content of the berry skin of the Attika Seedless grape cultivar. These results regarding the ability of moringa leaf extract to improve the parameters of vegetative growth and cluster features are consistent with those of **Nasir *et al*. (2016)**, **Khan *et al*. (2020)**, and **Abou-Zaid *et al*. (2025)** for several grapevine varieties. Eventually, the foliar application of chitosan and moringa leaf extract was discussed as a way to control fungal diseases, which include powdery mildew. According to **Stasinska-Jakubas and Hawrylak-Nowak (2024)**, the chitosan molecule's positive ionic charges strengthen the plant's immunity and defense mechanism against diseases such as powdery mildew by creating chemical and physical barriers. Moreover, the antifungal activity of moringa leaf extract perhaps due to the existence of phenolic substances **(Pinto *et al*., 2015)**. These phenolic components degrade enzymes that can inhibit amino acids involved in spore germination, and this has a positive effect in suppressing powdery mildew in Attika Seedless grape cultivar.

5. Conclusion

The findings of this study demonstrate the improvement of vegetative growth characteristics and berry quality, as well as the reduction of certain fungal disease infections such as powdery mildew of grape berries for Attika Seedless grapevines, that can be achieved through foliar application of chitosan and moringa leaf extract, either alone or in combination. LST was a good indicator of Attika Seedless grapevines microclimate and plant response. It strongly affected by the grapevines characteristics and the vine canopy. Importantly, chitosan and moringa leaf extract at a rate of 0.4% are recommended for improving vegetative characteristics and berry quality. Additionally, chitosan and moringa leaf extract at a rate of 0.4% achieved the best results in reducing powdery mildew for Attika Seedless grapevines.

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تأثير الرش الورقي بالشيتوزان ومستخلص المورينجا على النمو الخضري، العناقيد والبياض الدقيقي لكرمات العنب الاتيكا سيدليس

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الملخص

تناولت هذه الدراسة تأثير الرش الورقي بالشيتوزان ومستخلص أوراق المورينجا (0.2 أو 0.4%)، إما بمفردهما أو معًا على كرمات العنب أتيكا سيدليس خلال موسمين متتاليين (2022 و2023) وتم تدعيم الكرمات باستخدام نظام البارون الإسباني، بمسافة 2 × 3 متر بين كل كرمة وأخرى. تم تقليم كرمات العنب في الأسبوع الأول من شهر يناير. وبالمقارنة مع الكنترول، أظهرت النتائج أن الرش الورقي بالشيتوزان ومستخلص أوراق المورينجا، بمفردهما أو معًا ، كان لها تأثير إيجابي على جودة الثمار وخصائص النمو الخضري لكرمات العنب أتيكا سيدليس. وقد أدى استخدام الرش الورقي بتركيز 0.4% من الشيتوزان ومستخلص أوراق المورينجا معًا أفضل النتائج في تحسين خصائص النمو الخضري، والعناقيد، وجودة الثمار لكرمات العنب أتيكا سيدليس. بالإضافة إلى ذلك، أظهرت الرش الورقي بتركيز 0.4% باستخدام الشيتوزان ومستخلص أوراق المورينجا معًا أفضل النتائج في مكافحة البياض الدقيقي. وبناءا عليه، يُنصح بالرش الورقي بكلا من بالشيتوزان ومستخلص أوراق المورينجا لكرمات العنب اتيكا سيدليس لتحسين جودة الثمار، زيادة المحصول، ومكافحة الإصابة بمرض البياض الدقيقي.