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Study of the relationship between the severity of downy mildew infection in cucumber and its content of phenols and alkaloids under protected cultivation conditions

Aqeel A Khudhair & Neran S Aljarah*

Department of Plant Protection Department, University of Baghdad, Baghdad 10001, Iraq

*Email: neran.aljarah@coagri.uobaghdad.edu.iq

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Abstract

The study was carried out to investigate the distribution pattern and intensity of downy mildew disease in three different parts of cucumber plants (upper, middle and lower). Additionally, the study aimed to examine the correlation between the disease severity and the concentration of phenolic and alkaloid compounds in the plants. Under controlled greenhouse conditions, the results demonstrated that the cucumber plants had the most significant disease severity at the middle level, followed by the lower level near the ground. Conversely, no signs of infection were detected at the higher level of the plant. Furthermore, the most severe downy mildew symptoms were noticed in the greenhouses central region, compared to the areas near the front and back entrances. These differences were shown to be statistically significant. Before the onset of downy mildew infection, cucumber plants indicated minimal phenols and alkaloids. From the first day of infection, the concentration of phenols increased and peaked on the twelfth day following infection. Subsequently, it declined on the 15th day. The level of alkaloids peaked on the sixth day of disease infection and then gradually decreased. The cucumber plants exhibited the highest concentrations of phenols and alkaloids around the ground level, followed by the middle and upper levels These variations were statistically significant. The highest correlation coefficient was reported between the disease severity and the cucumbers content of alkaloids and phenols at the middle and the lower level of the two hybrids: Jamila and Mustaqbal. In the Fares hybrid, the highest correlation coefficient between the percentage of disease severity and phenols was 0.905 at the middle level, but it was 0.434 with the alkaloid contents. At the lower level of the plants, the correlation coefficient between disease severity with the alkaloids and phenols was 0.724 and 0.725, respectively.

Keywords

cucumber; phenols; plant protection; *Pseudoperonospora cubensis*

Introduction

The cucumber (*Cucumbis sativus* L.), which belongs to the Cucurbitaceae, is a significant vegetable that is grown in open, protected areas all over the world (1,2). Initially, the cucumber was first cultivated in northern India and then transported to the lands surrounding the Mediterranean Sea (3,4). Cucumber has various nutritional benefits; it contains several nutritional substances including vitamins A, B and C, as well as minerals such as manganese and copper. Also, it is composed of potash, boron, iron, calcium and 96% water, in addition to magnesium and phosphorus (5,6).

The quantity and quality of cucumber cultivated in the open fields and/or greenhouse in various regions were impacted by a range of harmful microbes,

including bacteria, viruses and fungi. and eventually, producing an uneconomic crop if it was not well maintained. The downy mildew (*P. cubensis*) is a pathogenic fungus that infects cucumbers at different ages (7,8). The fungal infection affects only the vegetative group of plants; however, the reduction in the efficiency of photosynthesis at the early stages of plants growth leads to a weakness of the plants and a reduction of crop production, especially in cucumber, in addition to falling off the leaves, which makes the fruits vulnerable to sunlight and sometimes, effects on flowers formation and their falling. After the infection, the diseases' sporangia emerge on the lower side of the leaves, which gives a dark brown colour to the infection area (9). The sporangia are transmitted to the healthy leaves through the wind and workers, an increasing rate infections transmission when the appropriate humidity is available. Downy mildew is one of the essential infections, that quickly spreads when high humidity and low temperatures (from 10°C to 28°C) are provided. Under high temperatures and dryness (as in the summer in Iraq) conditions, the progress of the disease suppers, but to a lesser extent in the spring season). The germination of sporangia and initiation of infection requires relative humidity ranging from 90 to 100% for 6 hours. The severity of the infection increases when the temperature decreases (10,11).

Phenols are secondary metabolic products of the Shikimic acid and the Malonic acid pathway. There are five subgroups within this large group of chemicals: coumarins, flavonoids, lignin, phenolic acids and tannins (12). These significant subgroups of phenols are essential for the physiological processes of plants' growth and the development of their interactions with the environment. Lignin is one of the fundamental substances that supports the structural shape of plants (13). It is deposited in the plant vessels and has a powerful antioxidant and a defensive potential against environmental stresses or pathogenic and insect infections (14-16). Tannins and lignin are the most essential secondary metabolic groups and defensive agents. The herbivores, birds and insects avoid feeding on the parts of the plants that contain high levels of tannins. It has been found that phenolic compounds extracted from olive leaves are used in controlling fever and malaria, in addition to their effectiveness against bacteria, mycoplasma and yeast (17).

Alkaloids are one of the essential groups of basic natural products in plants but with a lower percentage in animals and microorganisms (18). They have a distinguished complex chemical structure, a nitrogenous organic compound with alkaline features due to their structural contents of amino nitrogen, carbon, hydrogen and oxygen. In addition to their toxicity, alkaloids in the plants are related to bitter taste, which is a repellent to animals. Alkaloids are among the most significant predominant compounds in the plant kingdom, especially in the Solanaceae and Leguminosae (19,20). Many theories explain the possible role (the beneficial)and the reasons for alkaloids' presence. The following are the most critical theories. Most alkaloids are toxic substances and their presence serves as a defensive factor for plants to protect them from the harmful effects of insects or animals. Some alkaloids act as growth-regulating substances in plants, playing a role in the physiological processes of living plant tissues. Alkaloids are a reserve stock of elements; the most important is nitrogen, which plants require during the various stages of their growth or when these substances are lacking in the soil. Some scientists consider alkaloids to be the final products of cellular metabolism and the toxic compounds produced from these reactions, which are stored in alkaloids, form inside the cellular vacuoles (21).

The downy mildew infection of cucumber could appear at the different stages of crop growing. Therefore, this study investigated the distribution pattern of downy mildew infections at three levels of cucumber plants: upper, middle and lower levels (near the ground).

Materials and Methods

Disease severity of downy mildew

The study was conducted in a greenhouse in the Dujail region, north of Baghdad, during the spring season of 2022. The greenhouse has two entrances, front and back. It was divided into three blocks, each containing five double lines. The seedlings had been previously grown into special trays; each hybrid was grown separately. 40 seedlings (one-month-old) of each hybrid were planted, irrigated and fertilized according to the program used for growing cucumbers. The plants were left for natural infection and the greenhouse was monitored daily to report the first appearance of the infection during the season (Mar 21 to May 18, 2022). A complete randomized block design was employed to do statistical analysis. The downy mildew disease severity was reported in ten plants, from each line of each block/ hybrid, at the three levels of the cucumber plants (upper, middle and lower level (near the ground)) and three locations of the greenhouse (the front and back of the greenhouse, near the tow entrance and in the middle). The following disease scale was adopted: 0 = healthy leaves, 1 = 1-10% of the leaf is diseased, 2 = More than 10% to 25% of the leaf is diseased, 3 = >25–50% of the leaf is contaminated, 4= more than 50% to 75% of leaf areas are diseased, five more than75% - 100% of the leaf is infected. The disease severity was calculated as per the equation 1 (21).

$$\text{Disease severity} = \frac{(\text{plant of 0 scale x 0}) + \ldots + (\text{plant of 5 scale x})}{\text{total plants x 5}} \times 100 \quad \text{(Eqn.1)}$$

The density of trichomes in the cucumber leaves was determined with minor modifications (22). Estimating phenols content in the cucumber leaves was based on the standard methods (23-25). The number of alkaloids was measured using a UV spectrophotometer set according to the standard methods (26).

Results and Discussion

Generally, the results in Table 1. showed that the highest observed rate of disease severity was noticed at the middle level of the cucumber plant. Moreover, the highest rate of downy mildew severity was identified at the central region of the greenhouse, in comparison to the two entrances (front and back doors) of the greenhouse, with statistically significant differences. The highest rate of disease severity was reported at the middle level of the Jamila and Mustaqbal hybrid. In the front

Table 1. The rate of downy mildew disease severity in the three cucumber hybrids, at the three plant levels under greenhouse conditions

Region of greenhouse	Cucumber hybrid	The rate of disease severity at plants level			Greenhouse region × hybrid
		Upper	Middle	Lower	
	Mustaqbal	0.00	32.67	17.33	16.67
Front	Jamila	0.00	36.67	8.67	15.11
	Faris	0.00	20.00	8.67	9.56
	Mustaqbal	0.00	34.67	28.50	21.06
Central	Jamila	0.00	30.33	10.00	13.44
	Faris	0.00	26.33	14.67	13.67
	Mustaqbal	0.00	28.67	17.67	15.45
Back	Jamila	0.00	24.67	13.33	12.67
	Faris	0.00	14.67	11.80	8.82
L.S.D. 5%			4.73*		2.73*
Region of greenhouse		Region of greenhouse × Plants level			Average of Greenhouse region
Front		0.000	29.780	11.557	13.779
Central		0.000	30.443	17.723	16.056
Back		0.000	22.670	14.267	12.312
lsd5%			2.733**		1.578**
Hybrid		Hybrid × Plants level			Average of Hybrid
Mustaqbal		0.000	32.003	21.167	17.723
Jamila		0.000	30.557	10.667	13.741
Faris		0.000	20.333	11.713	10.682
L.S.D. 5%			2.733**		1.578**
Average of Plants level		0.000	27.631	14.516	
L.S.D. 5%			1.578**		

Number of replicates = 3, number of hybrids = 3, number of total plants = 40 for each replicate, number of plants whose data was reported = 10 for each replicate, number of readings = 5 for each cucumber hybrid.

of the greenhouse, the disease severity for Jamila was 36.67%. For the Mustaqbal hybrid, the disease severity at the greenhouses' front and middle area was recorded at 34.67% and 32.67%, respectively, with no significant differences. While at the lower level (near the ground) of the plants, a low percentage of disease severity was observed, as follows: 8.67% and 8.67% of Jamila and Fares hybrid, at the front area of the greenhouse, 10% of Jamila at the central region of the greenhouse and 11.80% of Fares at the end back of the greenhouse, with no significant differences. At the upper level of the plants, no infections were shown in the three cucumber hybrids and at all regions of the greenhouse.

This studys' findings revealed that the number of trichomes calculated under the microscopic field at 10X magnification was between 5-17 trichomes/ microscopic field on the upper surface and 25-44 trichomes/ microscopic field on the lower surface of the apical leaves. At the middle level of the plants, between two and five trichomes / microscopic fields were seen at the upper surface and on the lower surface of the leaves were 9 to 16 trichomes/ microscopic fields. In addition, the number of trichomes on the leaves' lower and upper surfaces taken from the plants' lower level (near the ground) was between 4-10 and 2-3 trichomes/ microscopic field, respectively, using 10X.

These results may explain the high disease severity at the middle level of cucumber leaves. It could be related to the number of trichomes at the upper surface of leaves at the middle levels of the plant compared to the upper surface of the apical leaves, besides the leaves' substantial surface area. Therefore, the water droplets reached the leafs' surface, where the sporangia were germinated and the germination tube reached the stomata opening, with the availability of appropriate conditions for the fungal infection at the upper surface of the leaf. That would facilitate the penetration of the downy mildew pathogen into the cucumber leaves. Density is a natural barrier that prevents pathogens from penetrating the leaf. In contrast, the high disease severity in the central area of the greenhouse could be attributed to the far distance from the front and back doors, which provides appropriate conditions for the occurrence and development of the pathogen infection, such as the high humidity level.

These results were close to the mentioned in which the inverse relationship between the number of trichomes in pumpkin (*Cucurbita pepo*) leaves and the diameter of necrosis spots resulting from inoculation of the leaf with *Didymella bryoniae*, the pathogenic agents of leaf gummy blight (27). Trichomes of the plant leaves have several vital functions, such as reducing heat stress, increasing the ability to freeze tolerance, protecting plants from UV rays and repelling insects (28). The density and length of the Trichomes in the leaves have also been linked to the resistance of the beans to rust infection (29).

Table 2 shows plants' phenols contents (concentrations) before and after infection. The lowest contents were noticed before disease infection and then increased after infection. Before infection, the highest concentration of the phenols was reported at the lower level in Mustaqbal and Jamila hybrids (48.50 and 45.0 mg/g fresh weight of leaves, respectively), with no significant differences. However, the phenols concentration significantly differed from the Fares hybrid, reaching 40.50 mg/g fresh weight of leaves. At the middle level of the plant, the average phenols concentration of the Mustaqbal hybrid was 41.50 mg/g fresh weight of leaves, with a significant difference from the phenols concentration in the two hybrids, Jamila and Fares, which were 36.50 and 33.0 mg/g, respectively. Regarding the upper level of the plants, the lowest concentrations of phenols were reported: 31.50, 30.0 and 28 mg/g in the three hybrids, respectively, with no significant differences. The highest phenols concentration was mentioned in the tested hybrid: Jamila 96.79 mg/g, then Mustaqbal 92.95 mg/g and Fares 91.17 mg/g, with statistically significant differences. Regarding the levels of the plant, the highest phenols concentration rate was observed at the lower level (near the ground) (121.19 mg/g), then

Table 2. The Average phenols concentration (mg/g) in the leaves of three cucumber hybrids during the different stages of downy mildew infection under greenhouse conditions in the Dujail region for the spring session, 2022

Hybrid	Level	Phenols concentration (mg/g) in cucumber after infection (days)							Hybrid × Level
		0	1	2	6	9	12	15	
	Upper	31.50	30.50	40.00	42.00	60.50	77.50	67.50	49.93
Mustaqbal	Middle	41.50	68.00	99.50	132.00	114.00	155.00	141.50	107.36
	Lower	48.50	72.50	116.50	145.00	127.50	179.00	162.00	121.57
	Upper	30.00	37.50	60.00	46.50	56.00	72.50	57.00	51.36
Jamila	Middle	36.50	65.00	96.50	140.00	106.00	170.50	158.00	110.36
	Lower	45.00	70.50	107.50	153.00	144.00	199.00	181.50	128.64
	Upper	28.00	34.00	52.00	45.50	64.00	66.50	58.50	49.79
Fares	Middle	33.00	87.00	80.50	111.00	148.50	137.00	175.50	110.36
	Lower	40.50	45.50	80.50	126.00	167.00	151.00	183.00	113.36
Hybrid					Hybrid × Time				Median of Hybrid
Mustaqbal		40.50	57.00	85.33	106.33	100.67	137.17	123.67	92.95
Jamila		37.17	57.67	88.00	113.17	102.00	147.33	132.17	96.79
Fares		33.83	55.50	71.00	94.17	126.50	118.17	139.00	91.17
Level					Level × Time				Median of Level
Upper		29.83	34.00	50.67	44.67	60.17	72.17	61.00	50.36
Middle		37.00	73.33	92.17	127.67	122.83	154.17	158.33	109.36
Lower		44.67	62.83	101.50	141.33	146.17	176.33	175.50	121.19
Median of Time		37.17	56.72	81.44	104.56	109.72	134.22	131.61	
Factors		Hybrid	Level	Time	Hybrid × Level		Hybrid × Time	Level × Time	Triple interaction
L.S.D. 5%		0.83**	0.83**	1.27**	1.45**		2.21**	2.21**	3.82**

Number of replicates = 3, number of hybrids = 3, number of total plants = 40 for each replicate, number of plants whose data were reported = 10 for each replicate and number of readings = 5 for each cucumber hybrid.

at the middle (109.36 mg/g) and finally at the upper level of the plants (50.30 mg/g).

After infection, at the middle level of the plant, the highest phenols concentration was 175.50 mg/g identified in the Fares hybrid on the 15th day of infection, followed by Jamila and Mustaqbal, in which the highest phenols concentration was 170.50 and 155.0 mg/g, respectively. Moreover, at the upper level of the plants, the highest phenols concentration was mentioned at Mustaqbal 77.50 mg/g, Jamila 72.50 mg/g and Fares 66.50 mg/g fresh weight. The results showed that the phenols concentration started increasing from the 1st day of infection until the 12th day, except for the Fares class, in which a continued increase of the phenols concentration at the middle and lower level (near the ground) levels of the plants, reaching 175.5 and 183.0 mg/g fresh weight of leaves, respectively, at the 15th day. In general, the highest phenols concentration was diagnosed 15 days after infection at the lower level (near the ground) level of the plants for Jamila hybrid (128.64 mg/g fresh weight), followed by the Mustaqbal (121.57 mg/g) and then the Fares (113.36 mg/g), with the statistically significant differences. The lowest phenols concentrations were noticed at the upper level of the cucumber hybrids: Fares 49.79 mg/g, Mustaqbal 49.93 mg/g and Jamila 51.36 mg/g. The highest average phenol concentration was observed in Jamila (96.76 mg/g), then Mustaqbal and Fares hybrid (92.95 and 91.17 mg/g, respectively).

In addition, the highest concentration of phenols was identified at the lower level (near the ground) (121.19 mg/g), then at the middle (109.36 mg/g), followed by the upper (50.36 mg/g) level of the plant, with statistically significant differences. It was noticed that the lowest phenol concentration was 37.17 mg/g, as determined before the fungal infection. It started increasing 1 day after the infection, when it was 56.72 mg/g and continued to grow until it reached 134.22 mg/g after 12 days of infection. On the 15th day, the concentration was decreased to 131.61 mg/g. Although few studies were published in this regard, the reason for phenolic concentrations elevation after plant infection could be attributed to its effective role in the plant defence mechanisms, whether directly against microbial pathogens or indirectly when combined with other compounds, such as phytoalexins, to tolerate pathogenic infection (30). This study noted that the leaves at the lower level (near the ground) of the plant had the highest contents of) phenols, which, in turn, were previously infected when they were at the middle level (31,32).

The results of this study were similar to the data reported by researchers, which referred to the importance of plants' phenols, such as lignin, in supporting the plant structure (33, 34). Lignin is deposited in the plant vessels and it is a powerful defence and antioxidant agent that increases plant resistance to environmental stresses, pathogenic infection and insects. Increasing phenols concentration at the upper of the plant after infection, even though the upper level was not infected, is evidence of plants' possession of an integrated defence system through the plants' response at the upper when the downy mildew infection occurred at the middle and lower level (near the ground) of the three cucumber hybrids. These findings were similar to the study result of (35), which indicated the critical role of phenolic compounds in enhancing the defence mechanism of plants.

Table 3 shows that the highest alkaloid concentration before infection was measured as follows: at the middle level of the Fares (148.50 mg/g), followed by Jamila hybrid (136.0 mg/g), with significant differences. Regarding the Mustaqbal, the highest alkaloid concentration was noticed at the plants' lower level (near the ground) (134.50 mg/g). The weakest concentrations before the infection were observed in the Mustaqbal, Jamila and Fares hybrid, as follows: 95.0, 105.0 and 124.0 mg/g, respectively, with statistically significant differences.

After the infection, the highest alkaloid concentration was reported at the plants' lower level (near the ground). On the 6th day of the infection for Jamila and Mustaqbal hybrid, it reached 302.50 and 291.50 mg/g fresh weight, respectively. For the Fares hybrid, the highest concentration of alkaloids was

Table 3. The Average alkaloid concentration (mg/g) of three cucumber hybrids during the different levels of downy mildew infection in greenhouse conditions at the Dujail region for the spring session, 2022

Hybrid	Level	Alkaloids concentration (mg/g) in cucumber after infection (days)							Hybrid × Level
		0	1	2	6	9	12	15	
	Upper	95.00	78.50	95.50	121.00	108.50	77.50	51.00	89.57
Mustaqbal	Middle	124.50	164.00	191.00	249.00	215.50	175.00	140.50	179.93
	Lower	134.50	164.00	214.00	291.50	241.50	181.50	153.50	197.21
	Upper	105.00	92.00	123.50	146.00	129.50	110.00	86.50	113.21
Jamila	Middle	136.00	172.50	204.50	260.50	238.50	179.00	154.50	192.21
	Lower	128.50	189.00	245.50	302.50	272.00	196.00	208.00	220.21
	Upper	124.00	107.00	133.50	147.00	124.50	91.00	65.00	113.14
Fares	Middle	148.50	180.00	214.00	243.50	200.50	166.00	126.50	182.71
	Lower	142.00	164.50	197.50	234.00	192.50	153.50	168.50	178.93
Hybrid	Hybrid × Time								Median of Hybrid
Mustaqbal	118.00		135.50	166.83	220.50	188.50	144.67	115.00	155.57
Jamila	123.17		151.17	191.17	236.33	213.33	161.67	149.67	175.21
Fares	138.17		150.50	181.67	208.17	172.50	136.83	120.00	158.26
Level	Level × Time								Median of Level
Upper	108.00		92.50	117.50	138.00	120.83	92.83	67.50	105.31
Middle	136.33		172.17	203.17	251.00	218.17	173.33	140.50	184.95
Lower	135.00		172.50	219.00	276.00	235.33	177.00	176.67	198.79
Median of Time	126.44		145.72	179.89	221.67	191.44	147.72	128.22	
Factors	Hybrid		Level	Time	Hybrid × Level		Hybrid × Time	Level × Time	Triple interaction
L.S.D. 5%	1.26**		1.26**	1.93**	2.19**		3.34**	3.34**	5.78**

Number of replicates = 3, number of hybrids = 3, number of total plants = 40 for each replicate, number of plants whose data were reported = 10 for each replicate, number of readings = 5 for each cucumber hybrid

243.00 mg/g, which was noticed at the middle level of the plant. After 6 days of infection, the highest concentrations of alkaloids were reported in the hybrid; Mustaqbal, Jamila and Fares reached 220.50, 236.30 and 208.17 mg/g, respectively. The highest alkaloid concentration was reported in the two hybrids, Jamila and Fares and then the Mustaqbal hybrid, reaching 175.21, 158.26 and 155.57 mg/g, respectively. Regarding the plants ' levels, the highest alkaloid concentration estimated on the 6th day of infection was at the lower level (near the ground), middle and then at the upper of the plant; it reached 276.0 and 251. 0 and 138.0 mg/g, respectively. In general, the highest alkaloid concentration was at the lower level (near the ground) of the plants (198.79 mg/g), followed by the middle (184.95 mg/g) and then the upper level (105.31 mg/g).

The high alkaloid concentration stored in the lower leaves of plants may be attributed to their role in the physiological processes of plant growth as defensive materials and repellents of pathogens during the growth stages. The presence of alkaloids in the plants' leaves represents cellular metabolisms' final products and what results from these reactions, including the toxic compounds stored as alkaloids in the cellular vacuoles. Most of the secondary metabolites are toxic to insects and fungi directly or indirectly, as intermediate compounds lead to the formation of other poisonous or pest-repellent compounds. It was mentioned that when various species of plants are exposed to damage, they release chemical substances as a defence mechanism, close the wound and prevent bacterial and fungal infections.

One of the most apparent examples is what the pine trees produce as a physical barrier against infectious organisms. When the plants' bark is damaged, it secretes rubber as a natural defence secretion (36,37). Furthermore, alkaloids regulate the plants' growth by inhibiting the action of enzymes, especially those that generate free radicals, such as oxidase and lipoxygenase enzymes. Conversely, phenolic compounds can suppress free radicals and thus act as antioxidants (38).

The correlation coefficient between the severity of downy mildew at the levels of the cucumber plant and their content of phenols and alkaloids. Based on the results of this study illustrated in Table 4, there was a high correlation of disease severity at the middle and lower level (near the ground) of the Mustaqbal hybrid with alkaloids content, which were 0.835 and 0.881 and with phenols contents reached 0.960 and 0.984, respectively. The correlation coefficients for the Jamila hybrid were determined to be 0.766 and 0.709 for the disease severity at the middle level of the plants and its alkaloid and phenol content, respectively. A higher correlation coefficient of 0.907 was observed for the lower level of the plants between disease severity and phenol content. In contrast, a correlation coefficient of 0.876 was found between disease severity and alkaloid content. In the Fares hybrid, a high correlation of 0.905 was observed in the middle of the plant with phenols content, while it was 0.724 and 0.725 at the lower level between the disease severity and the plants content of alkaloids and phenols, respectively.

The variation in correlation coefficient values may be attributed to the disparity in the genetic capacity of the tested hybrid to produce secondary metabolic substances and their effectiveness as defence agents against pathogenic microbes. This is particularly evident at the middle and lower levels of the plant, where the highest disease severity is observed compared to the leaves at the upper levels. The results of this investigation closely aligned with the data from a previous study, which indicated that herbivorous animals tend to avoid consuming plants that have a high concentration of phenols, particularly tannins in plants are composed of polyhydroxyphenols, which act as a deterrent to herbivores, thus explaining their defensive importance (39). Furthermore, the research conducted on subjects examined the significance of phenols and alkaloids as defensive agents in plants (40,41). The authors conducted a qualitative chemical study to identify the biologically active constituents of the medicinal plants employed in traditional medicine. The study encompassed 85 plant species in Jeddah, in

Table 4: Correlation coefficient between the downy mildew disease severity at the cucumber plants' three levels and their phenols and alkaloids content in greenhouse conditions

Hybrid	Plants Level	Alkaloids	Phenols
Mustaqbal	Upper	0.0	0.0
	Middle	0.835	0.881
	Lower	0.960	0.984
Jamila	Upper	0.000	0.000
	Middle	0.766	0.709
	Lower	0.876	0.907
Fares	Upper	0.000	0.000
	Middle	0.434	0.905
	Lower	0.724	0.725

The rate of three replicates was recorded for each number.

the Kingdom of Saudi Arabia. The researchers determined that tannins, alkaloids, glycosides, saponins and flavonoids were the predominant chemical components found in the therapeutic plants. The results align with the data presented in a prior work (42,43), which showed the suppressive impacts of the hot alcoholic extract obtained from *Cladophora glomerata* (Lin.) Kützing algae on the proliferation of plant-pathogenic fungi, *Pythium altimum* and *Rhizoctonia solani*. The observed efficacy of the extract can be related to the presence of phenols, alkaloids, flavonoids and tannins in the algal extract.

Conclusion

The severity of downy mildew was higher at the middle level of the plants, but it decreased at the lower level (near the ground). While at the upper level of the plants, the infection was absent. The highest average number of trichomes was noticed on the upper leaf surface at the plants' upper level, followed by the middle and then at the lower level (near the ground) of the plants. The number of trichomes was inversely proportional to the disease severity. The concentration of phenols and alkaloids was correlated with the distribution of downy mildew disease patterns at various levels of cucumber plants. The concentration of phenols and alkaloids increases gradually after the onset of infection. The highest concentrations of phenols and alkaloids were identified at the plants' middle and lower level (near the ground), as they are more exposed to infections than the upper levels of the plants, which were not infected throughout the crop growing season.

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Authors' contributions

AAK carried out the work schedule research field experiment measuring the plant researchers' concentration of alkaloids and phenols. NSA carried out the correlation, capillaries, results and discussion.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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