# Commercial Algae Products as Biocide Treatments for Controlling Squash Powdery Mildew Disease

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## ABSTRACT

**Fungicides considered as most effective method of controlling powdery mildew diseases on cucurbits, but there remains more than one challenge facing this method, and one of major challenges is resistance in pathogen populations, as well as their harmful impact on the ecosystem.**

**Six commercial algae products besides green algae extract were applied to estimate their effectiveness against powdery mildew disease in squash plants under field condition during two successive seasons 2020-2021. In addition to studying the role of algal formulations used in increasing the resistance of squash plants against powdery mildew, this is through its effect on some biochemical changes within the plant, which in turn increases the plant's ability to resist disease. The results of this study showed that the correlation between the incidence of the disease and the content of the leaves of total soluble phenols is negative, and the value of this correlation reached 28%. The same result was obtained with the leaves content of total proteins, the correlation value reached 51%. PPO and acid invertase showed the same trend. In the end, we can say that the use of algal extracts and their formulations may provide an ideal choice to control powdery mildew disease on squash plants, whether by its direct effects on the disease or even through the indirect effect by increasing the level of phenolic substances and proteins as well as stimulating some enzymatic systems through which the plant can defend itself against disease.**


**Key words*:* Algae, powdery mildew, squash, plant defense**

## INTRODUCTION

Powdery mildew, arising due to *Sphaerotheca fuliginea* considered one of the most dangerous diseases facing squash plants in the world (*Nuñez-Palenius et al., 2006).* Infection of the plant with powdery mildew disease leads to the loss in the green area of the leaves, which reduces the rate of photosynthesis, thus leads to the early loss of plant leaves, reduces the growth rate and, consequently, the low yield. The greater the severity of the disease and the longer the plant is infected, the greater this loss (Mossler and Nesheim, 2001).

Use of fungicides is one of the most important tools for control powdery mildew disease, thus increasing production (Wolf and Verreet, 2008), But it may cause some harmful effects (Zhang *et al.,* 2016). Therefore, we must continue to search for safer and more environmentally friendly methods and fungicides. One of the new means that must be focused on to reduce the use of pesticides, especially fungicides, is marine algae because of its good properties, both in terms of enhancing the plant's ability to absorb nutrients, or even for its effectiveness against many pests and diseases (Mishra *et al.,* 2020). Marine algae, especially green, brown, and red algae, are good sources of biologically active compounds, especially against plant pathogenic fungi. Therefore, they are a good source of compounds which used for plant diseases control. As a result of the high safety of marine algae and its low impact on the environment, as well as its increased applicability, marine algae extracts have now become a good alternative to fungicides in controlling plant pathogens (Brimmer & Boland, 2003; Galal *et al.*, 2011 and Hamed *et al.,* 2018). Accordingly, we find that a good number of studies have shown the role of marine algae and its extracts in protecting plants from fungal pathogens (Cluzet *et al.*, 2004; Paulert *et al.*, 2009, 2010; Abdel-Kader and El-Mougy, 2013; Ahmed *et al.,* 2016 and El-Sheekh, *et al.,* 2020).

It is interesting and hopeful that the use of induced resistance has become an important and common strategy for plant disease control (Awad *et al.,* 2012 and Jayaraman *et al.,* 2008).

Despite this, we cannot deny that the use of fungicides is the main strategy in powdery mildew disease control and thus increase the yield (Keinath & DuBose, 2004 and Wolf & Verreet, 2008). We cannot also deny that the indiscriminate and unregulated use of fungicides led to bad effects, both on humans and the environment, and led to the emergence of resistant strains of fungi (McGrath, 1991; Garcia, 1993; Durmusoglu *et al.,*1997 and Fernandez- Aparicio *et al.*, 2009). Therefore, we must focus and pay attention to reducing our dependence on the use of chemical pesticides and searching for alternative methods of pest control (Sutton, 1996).

**DOI: 10.21608/asejaiqjsae.2022.278533**

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Received November 25, 2022, Accepted, December 28, 2022.

Hence, developing safe alternatives to chemical pesticides may be a good way to overcome their negative effects. Fortunately, one of the sources of these safe alternatives is marine algal compounds, where algae is a good source for compounds group that can be considered as promising biological compounds that help the plant in its ability to survive and protect itself from pathogen attach (Demirel *et al.*, 2009; Jiménez *et al.*, 2011and Islam *et al.*, 2020). Besides They are compounds that stimulate the growth of plants, especially in their low concentrations, because they contain auxins, gibberellins, and cytokines, which are substances that stimulate growth. This is in addition to containing some small nutrients that act as antioxidants through their role in increasing enzymes activity (Ibraheem *et al.*, 2020 and Shukla *et al.*, 2019).

A key objective of the present research is to find alternatives that are safe for humans and the environment, like algae that could provide another solution to control squash powdery mildew disease. Similarly, determining how they affect some biochemical parameters that are related to the induction of plant defenses against pathogens.

## MATERIALS AND METHODS

At the Faculty of Agricultural Research Experimental Station, Alexandria University at Abbis Abies, two field experiments were conducted during 2020-2021. The soil type was clay loam (clay 41%, silt 22.2% and sand 36.16%), to study the efficacy of algae treatments on Powdery mildew disease cause by Sphaerotheca fuliginea in squash (*Cucurbita pepo* L.). Squash was directed seeded; the experiment was carried out in randomized block designs with four replications of four rows and six meters long ($24m^2$). Number of plants in each plot was approximately thirty plants. Management of insect pests and weeds were applied as needed by supplying insecticide [Cypermethrin (Saprol 10% EC) and herbicide [Pendimethalin (stomp 50% EC, 1.7L/Fed.). Fertilization and irrigation were also applied as needed, when the plants reached two weeks old, fungal inoculation was natural. When first colony of the disease was appeared, treatments were applied. Treatments include water extract of green algae which collected from Abu-Qir of Alexandria and was identified as *Ulva lactuca* according to Abou-El Wafa (2005). Extraction was made as described by Flora & Rani (2012); Ahmed *et al. (*2016), and six commercial algae products (Engromax, *Ascophyllum nodosum* extract, Pharmaceutica for Chemicals, made in Egypt), (Goltamax, *Fhylum phaephyta* extract, Cairochem Egypt), (Algifol, *Ascophyllum nodosum*, Chema Industries products, Egypt), (Start-S, *Ascophyllum nodosum*, it is one of the products of spainsh Salquisa Company) and (Cytokan, *Ascophyllum nodosum* extract +*Fhylum phaephyta* extract, Salquisa agrociencias company, made in spain ), (Geno-s, *Ascophyllum nodosum* extract+ *Ulva lactuca* extract, Agrega global chemical industries, made in spain). All treatments were applied at the rate of 100 ml or g/100 L water

**Assessment of DSI (Disease severity Index) and FPP (foliage protection percentage).**

Leaf lesions were measured on a scale from 0 to 4 to calculate the powdery mildew disease severity index (DSI) by Cohen and Mosinger (1991), DSI = ∑ (((nxc)/Nxdf)*100). Where N is the total number of leaves, c is the number of categories, n is the total number of infected leaves for each category, and df is the degree of freedom. Calculation of the foliage protection percentage (FPP): FPP (%) = 100 (1- x/y), where the values of the disease severity index for the treated and control plants, respectively, are x and y, as also stated by Cohen (1994). Each DSI or FPP figure is the mean of four sprays conducted over the course of two growth seasons.

**Effect on some parameters related to plant defense against powdery mildew disease.**

Induction of plant defense against the pathogen may be enhanced by many biochemical parameters in the plants. Content of total soluble phenol and protein, activity of some enzyme like poly phenol oxidase and acid invertase are proven to have played a significant part in the plant's early defence against plant disease.

**Total Soluble Phenol Content:** According to Slinkard and Singleton (1997), the total soluble phenol content of squash leaves was extracted using 80% methanol and expressed as g tannic acid/gm fresh weight using the following formula. A= absorbance at 765 nm, K= the extension coefficient =0.0169 g-1, and tannic acid/g fresh weight = (((A/K)* (20/0.2)/1)).

**Total protein assay:** The amount of total protein was calculated using the method outlined by Bradford (1976), with some modifications suggested by Dixon (1985). Since mg protein/g fresh weight = ((O/K) * 100)/0.25, K (BSA protein) = 0.029 mg/ml, and O = The absorption at 595 nm, the total protein was calculated as mg protein/gm fresh weight.

**Polyphenol oxidase (PPO) activity:** According to Broesch (1954), polyphenol oxidase activity has been assessed. % Activity = ((A1/A2) * 100), A1, A2: Absorbance of the treatment and control samples at 575 nm

**Acid Invertase (AI) activity:** Acid invertase activity was determined using the procedures of Hwang and Heitefuss (1986). The invertase activity was expressed as mg reducing sugar per gram fresh weight per hour and % of activity (%**A**). Reducing sugar was determined by the method of Thomas and Dutcher (1924).

mg reducing sugar / gram fresh wt. /hour = ((A/K) *10), A: absorbance of reducing sugar (R.S.) at 540 nm, K: extension coefficient = 0.1068

**%A = (((mg R.S. of treat. – mg R.S. of cont.) / mg R.S. of cont.) * 100)**

### Statistical analysis

The Duncan's test was used to examine mean differences between groups of findings with a p-value of 0.05. All results were analysed using an analysis of variance (SPSS 14 software package) (Anonymous, 2005).

## RESULTS AND DISCUSSION

### Effect of algal extract and algal products on disease severity index (DSI) and foliage protection percentage (FPP) against squash powdery mildew

The effect of seven treatments including six commercial algae products and green algae extract besides control treatment on the disease of powdery mildew as squash plants' foliage protection percentage (FPP) and disease severity index (DSI) in two successive growing seasons 2020 and 2021 were shown in Tables (1 and 2). The results show that all the treatments, Angromax, Gultamax, Algifol, Start-S, Cytokan, Geno-S and Ulva extract treatments decreased the DSI of the powdery mildew disease either in the first season or the second one with no significant differences between treatments, but the values were highly significant in relation to the control, and the mean value of disease severity index (DSI) ranged between 3.46 and 4.92.for the first season and 0.94 to 4.52 for the second one, compared to the control treatment which was 7.67 and 19.06, respectively. It is also noticeable that Geno-S treatment was less significant DSI reduction with a value of 3.46 in the first season and 0.94 for the second one with general mean 2.20. Looking at the sprays, we discover that the sprays' impact and reduction persisted through the first spray and grew until the fourth spray. The first season foliage protection percentages ranged from 67.02 to 81.26%, while the second season ranged from 72.02 to 93.02%. We can also note that Geno-S and Cytocan gave an excellent control rate, especially in the second season, where the control rate ranged from 68.87 to 100% with an average of 93.02% for Geno-S and 92.5% for the second one.

It is clear from these results the effective role of algae extracts in combating fungal diseases affecting plants, and this has been proven by several previous studies. Patel *et al. (*2020) stated that the combination of the extract of *Ascophyllum nodosum* and chitosan owned a respectable inhibitory effect on powdery mildew of peas since it reduced disease severity to 35%, as compared to control (90.5%). Esserti *et al.* (2016) found that extracts of the brown algae *Cystoseira myriophylloides, Laminaria digitata,* and *Fucus spiralis* significantly reduced disease severity of *Verticillium dahliae* and *Agrobacterium tumefaciens in* tomato plants. Roberti *et al. (*2016) found that water extract of seaweed had antifungal activity against *Podosphaera xanthii* on zucchini squash. According to research by Ahmed *et al.* (2016) and Ambroziak *et al.* (2015), various commercial algae products and green algae extract reduced the severity of illness on potato plants in comparison to infection rates seen in the control treatment. Similarly, Jaulneau *et al.* (2011) and Moenne (2009) discovered that *the green alga Ulva armoricana reduced the severity of the disease caused by powdery* mildew in bean, grapevine, and cucumber by up to 90%. Jayaraman *et al.* (2008) found that *treated carrot plants with the seaweed Ascophyllum nodosum significantly reduced disease* severity of fungal pathogens *Alternaria radicina* and *Botrytis cinerea*. Aziz *et al.* (2003) and Klarzynski *et al.* (2000), found that brown algae (*Phaeophyta*) were very successful in protecting grapevine plants from the disease caused by the fungus *Plasmopara viticola.*

**Table 1. Effect of algal products and extract on disease severity index (DSI) of squash plants**

| Treatments | Disease Severity Index (DSI) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st season | | | | | 2nd season | | | | | General mean of 1st and 2nd seasons |
| | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | |
| Ulva Extract | 2.59 | 3.00 | 7.05 | 7.05 | 4.92 b | 1.88 | 2.95 | 3.64 | 5.81 | 3.57 b | 4.25 b |
| Angromax | 0.37 | 3.33 | 5.00 | 6.14 | 3.71 b | 1.05 | 2.44 | 6.06 | 6.24 | 3.95 b | 3.83 b |
| Gultamax | 2.00 | 2.19 | 5.99 | 9.18 | 4.84 b | 1.78 | 2.73 | 4.55 | 9.02 | 4.52 b | 4.68 b |
| Algifol | 1.33 | 2.99 | 7.12 | 7.27 | 4.68 b | 1.16 | 2.24 | 6.23 | 7.19 | 4.21 b | 4.44 b |
| Start-S | 1.96 | 4.00 | 4.00 | 6.00 | 3.99 b | 0.00 | 1.56 | 2.07 | 7.33 | 2.74 b | 3.37 b |
| Cytocan | 1.74 | 4.00 | 4.67 | 8.75 | 4.79 b | 0.00 | 0.67 | 1.85 | 2.50 | 1.25 b | 3.02 b |
| Geno-S | 1.03 | 1.33 | 5.50 | 6.00 | 3.46 b | 0.00 | 0.74 | 1.33 | 1.67 | 0.94 b | 2.20 b |
| Control | 6.00 | 15.11 | 29.53 | 33.25 | 20.97 a | 7.67 | 15.85 | 18.18 | 26.86 | 17.14 a | 19.06 a |

According to the least significant difference test (p=0.05), different letters indicate significant differences among treatments within the same column.

**Table 2. Efficacy of algae products and extract on foliage protection percentage (FPP) of squash plants**

| Treatments | foliage protection percentage (FPP) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st season | | | | | 2nd season | | | | | General mean of 1st and 2nd seasons |
| | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | |
| Ulva Extract | 56.84 | 58.37 | 75.89 | 76.97 | 67.02 a | 64.79 | 72.73 | 74.83 | 77.93 | 72.57 ab | 69.79 a |
| Angromax | 70.31 | 77.82 | 83.10 | 93.83 | 81.26 a | 64.79 | 70.00 | 74.26 | 86.15 | 73.80 ab | 77.53 a |
| Gultamax | 62.79 | 63.41 | 67.92 | 79.59 | 68.43 a | 60.52 | 75.24 | 75.62 | 78.41 | 72.45 ab | 70.44 a |
| Algifol | 51.49 | 75.41 | 77.06 | 93.49 | 74.36 a | 53.99 | 67.50 | 74.83 | 91.77 | 72.02 ab | 73.19 a |
| Start-S | 53.64 | 68.07 | 79.96 | 84.21 | 71.47 a | 54.17 | 71.11 | 77.30 | 100.00 | 75.64 ab | 73.56 a |
| Cytocan | 50.70 | 70.25 | 70.33 | 84.21 | 68.87 a | 85.42 | 91.74 | 92.86 | 100.00 | 92.50 a | 80.69 a |
| Geno-S | 43.56 | 80.77 | 81.34 | 94.74 | 75.10 a | 88.54 | 89.42 | 94.12 | 100.00 | 93.02 a | 84.06 a |
| Control | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

According to the least significant difference test (p=0.05), different letters indicate significant differences among treatments within the same column.

**Effect of algal products and extract on plant defense parameters**

**Effect of tested treatments on total soluble phenol content of squash leaves**

It is well known that plant phenols, particularly the free phenols – which are toxic substances - play a significant role in controlling pathogenic microorganisms attacking variety of plants. the plants inducted by either biotic or abiotic inducers contained higher levels of phenols. Many plants phenolic compounds are known to be antimicrobial, function as precursors to structural polymers such as lignin, or serve as signal molecules (Hammerschmidt, 2005). Significant increase in phenolic content was positively proportional to the degree of plant resistance against the pathogens (Abo-Elyousr *et al.*, 2009). It is clear that the application of algae treatments, whether commercial or extracted by spraying on the foliage of squash leaves, increased the content of polyphenolic compounds in the leaves compared to the control, and this increase was significant in the case of the treatment of Angromax 1346,65 micrograms of tannic acid per gram of fresh weight of leaves, as well as the treatment of Gultamax, which gave 1295.86 µg compared to the control, whose leaves contained 987.67 µg, (Table 3).

Our results agreed with Ahmed *et al.(*2016); Ashok Kumar *et al.(*2012) and Jayaraj *et al.* (2008) who showed that the use of marine algae treatments led to an increase and accumulation of phenols inside the plant, whether soluble or bound phenols. The increase in the content of phenols within the plant may be due to an increase and development of the plant's defense ability against diseases (Daayf *et al*., 1995, 1997 and Aly *et al.*, 2003).

**Effect of tested treatments on total soluble protein content of squash leaves**

Total soluble proteins are crucial for plant defense because they accumulate quickly as well as to their activity against microbes, and thus their ability to reduce and limit the development of symptoms (Wang *et al*., 2005). So, expression of genes encoding PRPs is one of the most important strategies proposed to obtain a broad and durable level of resistance against different phytopathogenic fungi (Veronese *et al*., 1999). Table (4) shows that all the treatments that were applied provided the protein content of squash leaves with a significant increase, whether in the first season or in the second one, and the first place in the increase treatment went to of Glutamax with a value of 173.10 and 175.29 mg protein per gram leaves for the first and second seasons, respectively, compared to the control which had a protein content 98.33 and 104.60 mg for the first season and second one, respectively. Our results were harmony with Ahmed et al. (2016), Ashok Kumar et al. (2012) who found that affirmative relation between algal treatments and total protein content. The results obtained in this research differed with the results obtained by El-Sheekh *et al.* (2020), where it was found the protein level of tomato plants was reduced by using algae extracts to control Fusarium wilt disease.

**Effect of tested treatments on activity of Polyphenol Oxidase of squash leaves**

Several studies confirm that the activity of the polyphenol oxidase enzyme may play an important role in plant resistance against disease through the oxidation of polyphenols to quinones and the latter are antimicrobial compounds as well as its role by conferring lignin on plant cells while the pathogen attacks the plant (She-ze *et al.*, 2008; Chérif *et al.*, 2007; Hassan *et al.*, 2007 and Melo *et al.*, 2006). Results from table (5) appeared that the treatments of algal products and its extract enhanced polyphenol oxidase activity (PPO) in the four sprays either in the first season or the second one treatment with a significant level, the activation rate was close to 60% for the treatment of Gultamax as a mean of the two seasons. The treatments can be arranged in descending order in terms of their increase in the activity of the enzyme polyphenol oxidase as follows: Gultamax, Ulva extract, Angromax, Cytocan, Algaefol, Geno-S and Start-S. The results obtained were similar with (Ahmed *et al.*, 2016 and Jayaraman *et al*., 2011, 2008), who confirmed that the extract of brown marine algae *Ascophyllum nodosum* activates the defense enzymes inside the plant, especially the enzymes of peroxidase and polyphenol oxidase. These results were also confirmed by El-Sheekh *et al. (*2020); Patel *et al. (*2020) and Esserti *et al. (*2016), who confirmed that the plants which treated with seaweed extracts had higher levels of activity of defense enzymes especially polyphenol oxidase and peroxidase compared to the untreated plants. Hence, it has been suggested that the protection provided by marine algae extracts to the plant is represented by induced resistance.

**Effect of tested treatments on acid invertase activity of squash leaves**

The activity of algal extract and algal products on acid invertase activity in squash leaves was measured after one week from the treatment. It was specified as mg reducing sugar per gram of fresh leaf weight, (Table 6). The activity of acid invertase was significantly increased by all the treatments either in the first season or in the second one. As an overall average for the two seasons, the Geno S treatment ranked first in this regard with a value of 22. 86 mg reducing sugar/g fresh weight compared to control 9.05 mg reducing sugar/g fresh weight.

**Table 3. Effect of algae products ad extract on content of total soluble phenol as µg tannic acid /g fresh weight of sqash leaves**

| Treatments | Polyphenol content | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st season | | | | | 2nd season | | | | | General mean of 1st and 2nd seasons |
| | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | |
| Ulva Extractt | 950.69 | 978.30 | 1045.36 | 1049.31 | 1005.92c | 1072.98 | 1065.09 | 1163.71 | 1159.76 | 1115.38b | 1060.65c |
| Angromax | 1238.66 | 1747.53 | 1076.92 | 1226.82 | 1322.49a | 1230.77 | 1656.80 | 1258.38 | 1337.28 | 1370.81a | 1346.65a |
| Gultamax | 1136.09 | 1806.71 | 1167.65 | 1104.54 | 1303.75a | 1120.32 | 1775.15 | 1171.60 | 1084.81 | 1287.97a | 1295.86a |
| Algifol | 1053.25 | 1562.13 | 1108.48 | 1104.54 | 1207.10b | 1065.09 | 1420.12 | 1053.25 | 773.18 | 1077.91 b | 1142.50b |
| Start-S | 623.27 | 986.19 | 1120.32 | 1072.98 | 950.69c | 796.84 | 1088.76 | 1092.70 | 1140.04 | 1029.59 b | 990.14 c |
| Cytocan | 863.91 | 990.14 | 820.51 | 1065.09 | 934.91 c | 1072.98 | 1108.48 | 1021.70 | 1104.54 | 1076.92 b | 1005.92 c |
| Geno-S | 1029.59 | 1151.87 | 923.08 | 1001.97 | 1026.63 c | 1124.26 | 1159.76 | 1029.59 | 1084.81 | 1099.61 b | 1063.12 c |
| Control | 1001.97 | 879.68 | 998.03 | 852.07 | 932.94 c | 1033.53 | 1065.09 | 1112.43 | 958.58 | 1042.41 b | 987.67 c |

According to the least significant difference test (p=0.05), different letters indicate significant differences among treatments within the same column

**Table 4. Effect of algae products and extract on total soluble protein content as mg protein/g fresh weight of squash leaves**

| Treatments | Total Soluble Protein | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st season | | | | | 2nd season | | | | | General mean of 1st and 2nd seasons |
| | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | |
| Ulva Extract | 137.93 | 154.02 | 255.17 | 114.94 | 165.52ab | 124.14 | 259.77 | 165.52 | 96.55 | 161.49bc | 163.51b |
| Angromax | 136.09 | 193.10 | 225.29 | 75.86 | 157.59b | 195.40 | 186.21 | 158.62 | 124.14 | 166.09ab | 161.84b |
| Gultamax | 147.59 | 206.90 | 229.89 | 108.05 | 173.10a | 163.22 | 213.79 | 220.69 | 103.45 | 175.29a | 174.20a |
| Algifol | 111.03 | 94.25 | 186.21 | 124.14 | 128.91c | 108.05 | 101.15 | 188.51 | 96.55 | 123.56e | 126.24e |
| Start-S | 76.32 | 167.82 | 160.92 | 110.34 | 128.85c | 96.55 | 195.40 | 220.69 | 72.41 | 146.26d | 137.56d |
| Cytocan | 82.07 | 82.76 | 124.14 | 91.95 | 95.23e | 78.16 | 137.93 | 131.03 | 110.34 | 114.37fe | 104.80f |
| Geno-S | 85.52 | 197.70 | 202.30 | 89.66 | 143.79c | 75.86 | 206.90 | 220.69 | 96.55 | 150.00dc | 146.90c |
| Control | 85.29 | 103.45 | 133.33 | 71.26 | 98.33e | 89.66 | 124.14 | 124.14 | 80.46 | 104.60e | 101.47f |

According to the least significant difference test (p=0.05), different letters indicate significant differences among treatments within the same column.

**Table 5. Effect of algal products and its extract on polyphenol oxidase activity of squash leaves**

| Treatments | Polyphenol oxidase activity as % of Control | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st season | | | | | 2nd season | | | | | General mean of 1st and 2nd seasons |
| | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | |
| Ulva Extract | 136.51 | 116.28 | 132.40 | 186.92 | 143.03b | 141.88 | 119.80 | 147.99 | 178.36 | 147.01b | 145.02b |
| Angromax | 121.04 | 121.52 | 141.54 | 181.67 | 141.44b | 128.59 | 122.40 | 161.60 | 180.00 | 148.15b | 144.80b |
| Gultamax | 158.69 | 141.45 | 152.21 | 197.53 | 162.47a | 153.41 | 134.37 | 163.96 | 183.19 | 158.73a | 160.60a |
| Algifol | 121.08 | 158.04 | 119.39 | 166.18 | 141.17b | 113.25 | 154.70 | 128.76 | 175.40 | 143.03bc | 142.10bc |
| Start-S | 114.27 | 114.54 | 110.46 | 158.60 | 124.47c | 123.64 | 112.50 | 114.40 | 173.49 | 131.01d | 127.74d |
| Cytocan | 128.14 | 179.94 | 115.23 | 143.65 | 141.74b | 121.42 | 163.53 | 117.37 | 170.30 | 143.16bc | 142.45bc |
| Geno-S | 124.80 | 117.09 | 130.80 | 179.27 | 137.99b | 120.31 | 112.98 | 132.94 | 177.60 | 135.96cd | 136.98c |
| Control | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

According to the least significant difference test (p=0.05), different letters indicate significant differences among treatments within the same colum

**Table 6. Effect of algal products and its extract on acid invertase activity of squash leaves**

| Treatments | Acid Invertase as mg reducing sugar | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st season | | | | | 2nd season | | | | | General mean o 1st and 2nd seasons |
| | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | 1st spray | 2nd spray | 3rd spray | 4th spray | Mean | |
| Ulva Extract | 12.17 | 15.92 | 16.85 | 11.86 | 14.20ab | 12.48 | 12.17 | 17.79 | 11.55 | 13.50 c | 13.85ab |
| Angromax | 13.11 | 11.24 | 17.17 | 12.17 | 13.42ab | 12.48 | 11.86 | 18.41 | 12.80 | 13.89 bc | 13.65b |
| Gultamax | 15.29 | 17.17 | 17.79 | 13.11 | 15.84ab | 15.92 | 15.92 | 17.79 | 12.48 | 15.53 ab | 15.68 ab |
| Algifol | 15.92 | 16.85 | 16.85 | 13.11 | 15.68ab | 16.85 | 17.17 | 17.79 | 12.48 | 16.07a | 15.88 ab |
| Start-S | 16.85 | 16.85 | 14.98 | 14.98 | 15.92ab | 16.23 | 17.79 | 17.79 | 12.80 | 16.15a | 16.03 ab |
| Cytocan | 15.61 | 15.92 | 17.17 | 13.42 | 15.53ab | 15.92 | 15.92 | 17.79 | 13.11 | 15.68 ab | 15.61 ab |
| Geno-S | 15.92 | 73.35 | 17.79 | 12.17 | 29.81a | 16.85 | 17.79 | 16.85 | 12.17 | 15.92 a | 22.86a |
| Control | 11.24 | 8.43 | 8.43 | 7.18 | 8.82b | 10.30 | 10.92 | 8.74 | 7.18 | 9.29 d | 9.05b |

According to the least significant difference test (p=0.05), different letters indicate significant differences among treatments within the same column.

**Table 7. correlation factors of disease severity and the tested physiological parameters**

| Parameters | Correlation factor | | |
|---|---|---|---|
| | 1st season | 2nd season | Mean |
| Total Phenol | -0.37 | -0.17 | -0.28 |
| Protein content | -0.53 | -0.48 | -0.51 |
| PPO | -0.79 | -0.78 | -0.80 |
| Acid invertase | -0.54 | -0.91 | -0.74 |

Same trend was found by Ertani *et al.* (2018) found that different responses of glucose content were shown as a result of applying marine algae extracts to maize plants. Precisely, some extracts of *Ascophyllum nodosum* significantly increased the level of glucose content.

Examining the link between the disease severity index and the physiological traits of squash plants that were recorded over the course of two seasons as a result of the application of seven treatments and four sprays during each season (Table 7). Correlation factor (r) confirmed that the total amount of soluble polyphenols had a negative connection with the severity of the disease which reached to 37% in the first season, and it was 17% in the second one. The same relation was also found in the case of total protein with a value of 51% as a general mean of the two seasons. PPO took the same trend either in in the first season or in the second one. Concerning acid invertase, the value of correlation factor was greater in second season than the first one with value of 91% and 54%, respectively. In the end, we can conclude that overcoming plant pathogens and protecting plants by increasing the activity of some enzymatic systems responsible for plant defense as well as increasing the level of phenolic substances as well as proteins inside the plant became possible using algae formulations and extracts.

## CONCLUSION

Marine algae can be categorized as a resistance inducer because it has been demonstrated to primarily function by priming defense responses. Additionally, marine algae are generally regarded as promising multifunctional bioinoculants and environmentally friendly farming tools in current organic farming trends.

**Conflict of interests:**

There are no conflicts of interest, according to the authors.

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DOI10.1021/acs.jafc.5b05624.

## الملخص العربي

# منتجات الطحالب التجارية كمبيدات حيوية لمكافحة مرض البياض الدقيقي فى الكوسة

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تعتبر مبيدات الفطريات هى أكثر الطرق فعالية لمكافحة أمراض البياض الدقيقي على القرعيات، ولكن لا يزال هناك أكثر من تحدٍ يواجه هذه الطريقة، وأحد هذه التحديات الرئيسية هو مقاومة الكائنات الممرضة لها، فضلاً عن تأثيرها الضار على النظام البيئي .فى هذا العمل تم استخدام ستة منتجات تجارية من الطحالب إلى جانب مستخلص الطحالب الخضراء لتقدير فعاليتها ضد مرض البياض الدقيقي في نباتات الكوسة تحت الظروف الحقلية خلال موسمين متتاليين ٢٠٢٠ و ٢٠٢١ .هذا بالإضافة إلى دراسة دور مستحضرات الطحالب المستخدمة في زيادة مقاومة نباتات الكوسة ضد البياض الدقيقي وذلك من خلال تأثيرها على بعض التغيرات الكيميائية داخل النبات والتي بدورها تزيد من قدرة النبات على مقاومة الأمراض .وقد أظهرت نتائج هذه الدراسة أن الارتباط بين الإصابة بالمرض ومحتوى أوراق الفينولات الكلية الذائبة سلبي، وبلغت قيمة هذا الارتباط ٢٨٪ .تم الحصول على نفس النتيجة مع محتوى الأوراق من البروتينات الكلية ، وبلغت قيمة الارتباط ٥١٪ . كذلك نشاط انزيمى البولى فينول اوكسيديز وانزيم الأنفرتيز قد اخذوا نفس الأتجاه. في النهاية يمكننا القول أن استخدام مستخلصات الطحالب وتجهيزاتها قد توفر خيارًا مثاليًا للسيطرة على مرض البياض الدقيقي على نباتات الكوسة سواء بتأثيراتها المباشرة على المرض أو حتى من خلال التأثير غير المباشر عن طريق زيادة مستوى الفينولات والبروتينات وكذلك تحفيز بعض النظم الأنزيمية التي يمكن للنبات من خلالها الدفاع عن نفسه ضد الأمراض.