Resistance Inducers Treatments against Downy and Powdery mildews of Cucumber under Commercial Plastic Houses Conditions

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Abstract: Evaluating the efficacy of different plant resistance inducers treatments against downy and powdery mildew foliar diseases incidence was carried out as spray treatments on growing cucumber plants under commercial plastic houses at Dokki and Tookh locations, Giza and Qualuwyia governorates. The evaluated foliar spray treatments were applied four times with fifteen days intervals starting at thirty days after transplanting. The obtained results revealed that plant spray with treatments, [Calcium chloride (20mM) + S. cerevisiae 10x10^{10} cfu/mL (10ml/L) + Chitosan (0.05mM)] and [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)] resulted in the highest reduction in foliar Downy and Powdery mildew diseases incidence, severity and increase the obtained yield of Cucumber plants grown under plastic houses conditions. Successful development of such compounds as antifungal would not only provide a potent tool for control of vegetables foliar diseases, but also could promise success in multipurpose biorational alternatives to conventional fungicides for the management of other plant diseases.

Key words: Cucumber, downy mildew, foliar spray, induce resistance, powdery mildew.

INTRODUCTION

Growing cucumber under protected cultivation is an important practice in Egypt (Anonymous, 2009). Powdery and Downy mildews are the most serious foliar diseases attacked cucumber plants grown in plastic houses. Powdery mildew disease is one of the most serious plant diseases, causing large yield losses in a number of crops (Kiss, 2003). In order to overcome such hazardous control strategies, scientists, researchers from all over the world paid more attention towards the development of alternative methods which are, by definition, safe in the environment, non-toxic to humans and animals and are rapidly biodegradable. A successful disease-control program could involve just a single practice, but the long term reduction of disease losses generally requires the application of several control measures. The best way to ensure success of a disease-management program is to use integrated disease-control measures (Dik et al., 2002). Generally, IPM is regarded as the use of environmentally safe practices to reduce the disease incidence and development or use of multiple control tactics integrated into a single pest control strategy (Zinkernagel et al., 2002). For example, different natural products, i.e., biocontrol agents, plant extracts and natural compounds were used as an IPM program to control powdery mildew of greenhouse crops (Dik et al., 2003; Napier and Oosthuysen, 2000). Since economic thresholds have not been established for most plant pathogens, an IPM takes a somewhat different approach in plant disease control. Salts have been previously studied as foliar applied control agents for powdery mildews on various horticultural crops. A recent review (Belanger et al., 1997) discussed the use of different foliar applications including compost or plant extracts, surfactants, and inorganic salts. In Israel, research has demonstrated that the severity of powdery mildew on cucumber, grape, nectarine, mango, and rose can be reduced through foliar applications of phosphate and potassium salts (Reuveni et al., 1994; Reuveni et al., 1996). Also, it was found that KHCO₃ applications were effective in reducing the severity of powdery mildew on E. japonica and pumpkin (Ziv and Zitter, 1992; Ziv, and Hagiladi, 1993). In pot experiment, under artificial infestation with pathogenic fungus, application of sodium bicarbonate or calcium chloride significantly reduced the early blight incidence and severity (El-Mougy and Abdel-Kader, 2009). They added that Calcium chloride proved higher efficacy for reducing both disease incidence and severity than that of sodium bicarbonate when applied either alone or combined with Saccharomyces cerevisiae.

Calcium administered to the plant through the nutrient feed has been reported to be important for resistance to bacterial wilt resistance in tomato (Yamazaki and Hoshima, 1995). These findings encouraged us to evaluate the potential use and the efficacy of foliar sprays of single or integrates of natural compounds as biological control (S. cerevisiae), mineral salt (CaCl₂, K₂HPO₄, CHCO₃), antioxidant (ascorbic acid), resistance chemical inducers (Chitosan, Saccharin) and essential oil (Thyme) on grown vegetables to provide acceptable control level of powdery and downy mildews under greenhouse conditions. Therefore, the main objective of the present study was foliar diseases control with eco-friendly environment by investigating the efficacy of foliar spray with some plant resistance inducers treatments under commercial plastic houses conditions.

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MATERIALS AND METHODS

Evaluation of plant resistance inducers under natural infestation with cucumber foliar diseases causal organisms against downy and powdery mildews infection was performed under protected cultivation system conditions in commercial plastic houses of Ministry of Agriculture and Soil Reclamation, A.R.E. at Dokki and Tookh locations, Giza and Qaluybia governorates.

Evaluating the efficacy of different plant resistance inducers treatments against downy and powdery mildews infection were applied as foliar sprays treatment as follows:

(A) **At Dokki Plastic Houses Location:**
1. Calcium chloride (20mM) + *Saccharomyces cerevisiae* 10x10^10 cfu/mL (10ml/L) + Chitosan (0.05mM)
2. Potassium bicarbonate (20mM) + Thyme oil (5ml/L)
3. Chitosan (0.05mM) + Thyme oil (5ml/L)
4. Potassium monohydrogen phosphate (20mM)
5. Control (received only the recommended fungicide TAZOLEN 72% [mancozeb 64% + metalaxyl 8%])

(B) **At Tookh Plastic Houses Location:**
1. Calcium chloride (20mM) + *Saccharomyces cerevisiae* 10x10^10 cfu/mL (10ml/L) + Chitosan (0.05mM)
2. Potassium bicarbonate (20mM) + Thyme oil (5ml/L)
3. Saccharin (3mM) + Chitosan (20mM)
4. Ascorbic acid (20mM)
5. Control (received only the recommended fungicide TAZOLEN 72% [mancozeb 64% + metalaxyl 8%])

The experimental plastic house consists of 5 rows, each (0.9 x 60m, width x long) divided into 3 parts 20m long of each, and every part considered as one replicate. Three replicates were used for each particular treatment in complete randomized block design.

The growing vegetables were sprayed with proposed treatments 3 times with 15 days intervals after transplanting (Aleandri *et al*., 2010).

At Dokki and Tookh locations, the growing vegetables in the experimental plastic houses received the recommended pesticides against harmful insects, *i.e.* aphids, trips, white fly, etc. as needed. Meanwhile, the untreated check control received traditional programs for controlling diseases and pests which recommended by following up committee of Protected Cultivation Administration Office, Ministry of Agriculture and Soil Reclamation. The growing cucumber in plastic house received traditional agricultural practices, *i.e.* irrigation, fertilization, etc.

Monitoring and scouting of foliar diseases incidence of downy and powdery mildews of cucumber were recorded. Percentages of disease incidence and severity were recorded at 60, 90 and 120 days of transplanted date.

**Disease Assessment:**

- **Disease Incidence:**

  Percentage of each foliar disease incidence was recorded as the number of diseased plants relative to the number of growing plants for each treatment, then the average of disease incidence in each treatment was calculated.

- **Disease Severity:**

  Percentage of each foliar disease severity was recorded as following equation:

  \[
  \text{D.S.} \% = \frac{\Sigma (n \times c)}{N} \times 100
  \]

  Where:  
  \( \text{D.S.} \) = Disease severity %
  \( n \) = Number of infected leaves per category
  \( c \) = Category number
  \( N \) = Total examined leaves

  Disease severity scale from 0 to 4 according to Cohen *et al.*, (1991) was followed, whereas: 0 = No leaf lesions; 1 = 25% or less; 2 = 26-50 %; 3 = 51-75 %; and 4 = 76-100% infected area of plant leaf.

  At the end of growing season the accumulated yield was calculated for each particular treatment.
Statistical Analysis:

All experiments were set up in a complete randomized design. One-way ANOVA was used to analyze differences between applied treatments. A general linear model option of the analysis system SAS (SAS Institute Inc. 1996) was used to perform the ANOVA. Duncan’s multiple range test at \( P < 0.05 \) level was used for means separation (Winer 1971).

RESULTS AND DISCUSSION

The obtained results in Table (1) and illustrated by Fig. (1) showed the downy and powdery mildews incidence of cucumber plants grown in plastic house at Dokki location. Presented data revealed that all applied treatments have positive effect on foliar diseases incidence comparing with control. Percentage of both downy and powdery mildews incidence increased as the plants grow up to reach their maximum at 120 day of growth.

Announced highly significant effect of treatments, [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)] and [Calcium chloride (20mM) + \( S.\ cer\text{evisiae} \ 10\times10^{10}\text{cfu/mL} \ (10\text{ml/L}) + \text{Chitosan} \ (0.05\text{mM}) \]], followed by treatments, [Potassium monohydrogen phosphate (20mM)] and [Chitosan (0.05mM) + Thyme oil (5ml/L)], respectively. Moreover, the applied treatments, [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)]; [Chitosan (0.05mM) + Thyme oil (5ml/L)] and [Calcium chloride (20mM) + \( S.\ cer\text{evisiae} \ 10\times10^{10}\text{cfu/mL} \ (10\text{ml/L}) + \text{Chitosan} (0.05\text{mM}) \] could suppress both downy and powdery mildews incidence more than 60 days of growing cucumber plants under natural infestation comparing with untreated control which recorded diseases incidence as 14.6 and 11.4%, respectively.

The illustrated data in Fig (1) showed that the highest reduction in disease incidence calculated as 100, 83.7, 79.2% and 100, 86.1, 82.3% for downy and powdery mildews at the treatment, [Calcium chloride (20mM) + \( S.\ cer\text{evisiae} \ 10\times10^{10}\text{cfu/mL} \ (10\text{ml/L}) + \text{Chitosan} \ (0.05\text{mM}) \], followed by treatment, [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)] which caused reduction in downy and powdery mildews calculated as 100, 81.0, 80.6% and 100, 89.0, 80.2% at growth periods of 60, 90 and 120 day, respectively.

The other applied treatments, [Calcium chloride (20mM) + \( S.\ cer\text{evisiae} \ 10\times10^{10}\text{cfu/mL} \ (10\text{ml/L}) + \text{Chitosan} \ (0.05\text{mM}) \] followed by [Potassium monohydrogen phosphate (20mM)] showed similar effect on the diseases incidence throughout the growth period in a lesser effect that at 120 days of plant growth they recorded the lowest reduction in diseases incidence calculated as (55.1, 51.3%); (53.9, 56.0%) for downy and powdery mildews, in respective order.

Table 1: Percentage of Downy and powdery mildew diseases incidence in response to application of different formula against foliar diseases of Cucumber grown in plastic houses under protected cultivation system (Dokki location)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Foliar diseases incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Downy mildew</td>
</tr>
<tr>
<td></td>
<td>Days of transplanting</td>
</tr>
<tr>
<td>Calcium chloride + ( S.\ cer\text{evisiae} ) + Chitosan</td>
<td>0.0 c</td>
</tr>
<tr>
<td>Potassium bicarbonate + Thyme oil</td>
<td>0.0 c</td>
</tr>
<tr>
<td>Chitosan + Thyme oil</td>
<td>0.0 c</td>
</tr>
<tr>
<td>Potassium monohydrogen phosphate</td>
<td>3.8 b</td>
</tr>
<tr>
<td>Control</td>
<td>14.6 a</td>
</tr>
</tbody>
</table>

Mean values within columns followed by the same letter are not significantly different (\( P \leq 0.05 \)).

Furthermore, the applied treatments showed significant suppressive effect on the Downy and Powdery mildews of cucumber comparing with untreated check control (Table 2 and Fig. 2). Presented data revealed an drastic suppressive effect against Downy and Powdery mildews disease development recorded as 0.0, 0.2, 0.4% ; 0.0, 0.3, 0.4% disease severity (DS) when the treatment [Calcium chloride (20mM) + \( S.\ cer\text{evisiae} \ 10\times10^{10}\text{cfu/mL} \ (10\text{ml/L}) + \text{Chitosan} \ (0.05\text{mM}) \] was applied as well as 0.0, 0.2, 0.4% ; 0.0, 0.2, 0.5% (DS) for the applied treatment [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)], in respective order. These applied treatments suppress diseases severity (Fig. 2) by 100, 90.9, 83.0% ; 100, 90.0, 83.3% for Downy mildew and 100, 85.0, 81.8%; 100, 90.0, 77.2% for Powdery mildew than that in control at growth periods of 60, 90 and 120 day, in respective order. The other applied treatments followed the same trend in lesser extent.
Fig. 1: Reduction (%) in Downy and powdery diseases incidence in response to application of different formula against foliar diseases of Cucumber grown in plastic houses under protected cultivation system (Dokki location)

Table 2: Percentage of Downy and powdery mildew diseases severity in response to application of different formula against foliar diseases of Cucumber grown in plastic houses under protected cultivation system (Dokki location)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Foliar diseases incidence (%)</th>
<th>Powdery mildew</th>
<th>Days of transplanting</th>
<th>Days of transplanting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Downy mildew</td>
<td>Powdery mildew</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium chloride + S. cerevisiae + Chitosan</td>
<td>0.0 c 0.2 c 0.4 c 0.0 b 0.3 c 0.4 bc</td>
<td></td>
<td>60 90 120 60 90 120</td>
<td></td>
</tr>
<tr>
<td>Potassium bicarbonate + Thyme oil</td>
<td>0.0 c 0.2 c 0.4 c 0.0 b 0.2 c 0.5 bc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chitosan + Thyme oil</td>
<td>0.0 c 0.3 c 0.8 bc 0.0 b 0.3 c 0.6 b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium monohydrogen phosphate</td>
<td>0.5 b 0.9 b 1.2 b 0.0 b 0.6 b 0.7 b</td>
<td></td>
<td>0.5 a 2.0 a 2.4 a 0.5 a 2.0 a 2.2 a</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.8 a 2.0 a 2.4 a 0.5 a 2.0 a 2.2 a</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean values within columns followed by the same letter are not significantly different (P ≤ 0.05).

Fig. 2: Reduction (%) in Downy and powdery diseases severity in response to application of different formula against foliar diseases of Cucumber grown in plastic houses under protected cultivation system (Dokki location)
Application of different formula of chemical plant resistance inducers as foliar spray to Cucumber plants grown in plastic house at Tookh location resulted a reduction in Downy and Powdery mildew diseases incidence and severity comparing with control plants (Figs 3).

Data in Table (3) showed that at 60 day of plant growth complete reduction in Downy and Powdery mildew diseases incidence was observed in sprayed plants with [Calcium chloride (20mM) + S. cerevisiae 10x10^10 cfu/mL (10ml/L) + Chitosan (0.05mM)] and [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)] comparing with 8.8 and 10.6% diseases incidence recorded at control plants, respectively.

The same treatments also showed superior significant effect on both diseases incidence throughout the growing season up to 120 day (11.2 – 12.2% for both diseases) of plant growth comparing with the other applied treatments. Also data (Table 3) showed that at 120 day of plant growth the recorded percentages of downy and powdery mildews were 19.4, 22.2% and 18.2, 22.6% of sprayed plants with [Saccharin (3mM) + Chitosan (20mM)] and [Ascorbic acid (20mM)] comparing with 48.6 and 45.4% in untreated control plants, respectively.

Table 3: Percentage of Downy and powdery mildew diseases incidence in response to application of different formula against foliar diseases of Cucumber grown in plastic houses under protected cultivation system (Tookh location)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Downy mildew</th>
<th>Powdery mildew</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Days of transplanting</td>
<td>Days of transplanting</td>
</tr>
<tr>
<td>Calcium chloride + S. cerevisiae + Chitosan</td>
<td>0.0 d</td>
<td>90</td>
</tr>
<tr>
<td>Potassium bicarbonate + Thyme oil</td>
<td>0.0 c</td>
<td>6.8 d</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>2.1 b</td>
<td>9.8 b</td>
</tr>
<tr>
<td>Saccharin + Chitosan</td>
<td>1.4 c</td>
<td>7.2 c</td>
</tr>
<tr>
<td>Control</td>
<td>8.8 a</td>
<td>18.6 a</td>
</tr>
</tbody>
</table>

Mean values within columns followed by the same letter are not significantly different (P ≤ 0.05).

Fig. 3: Reduction (%) in Downy and powdery diseases incidence in response to application of different formula against foliar diseases of Cucumber grown in plastic houses under protected cultivation system (Tookh location)

Illustrated data by Fig (3) showed that the highest reduction in downy and powdery mildew diseases incidence was observed at applied treatments of [Calcium chloride (20mM) + S. cerevisiae 10x10^10 cfu/mL (10ml/L) + Chitosan (0.05mM)] and [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)]. They recorded 100, 70.9, 76.5%; 100, 63.4, 54.3% and 100, 73.0, 74.0%; 100, 70.6, 73.1%, in respective order. These records followed in descending order by [Saccharin (3mM) + Chitosan (20mM)] and [Ascorbic acid (20mM)], respectively. They recorded disease reduction as 84.0, 61.2, 60%; 84.0, 61.2, 60.0% for downy and 83.0, 66.3, 59.0%; 81.1, 58.6, 50.2% for powdery mildews, respectively at 60, 90 and 120 days of cucumber plant growth.

The applied chemical plant resistance inducers as foliar spray against Downy and Powdery mildews of Cucumber plants grown in plastic house at Tookh location not only could reduced diseases incidence but also had suppressive effect on disease development. In this regard, the obtained data (Table 4) revealed that the
applied treatment, [Calcium chloride (20mM) + \textit{S. cerevisiae} \(10\times10^{10}\) cfu/mL (10ml/L) + Chitosan (0.05mM)] and [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)] recorded Downy and Powdery mildew disease severity as 0.0, 0.5, 0.8; 0.0, 0.4, 0.6% and 0.0, 0.5, 0.8; 0.0, 0.4, 0.6% (Table 4). This reduction in diseases severity calculated as 100, 77.2, 78.9% and 100, 81.8, 84.2% for Downy mildew 100, 82.1, 82.6% and 100, 85.7, 86.9% for Powdery mildew (Fig 4), respectively. Furthermore, at 120 day of plant growth, data presented in Table (4) and illustrated by Fig (4) showed that the applied treatments, [Saccharin (3mM) + Chitosan (20mM)] and [Ascorbic acid (20mM)] also had suppressive effect on disease development that resulted in reduction in disease severity recorded as 1.2, 1.4% and 1.2, 1.7% for Downy and Powdery mildews comparing with 3.8 and 4.6% in control, respectively.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Downy mildew incidence (%)</th>
<th>Powdery mildew incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium chloride + \textit{S. cerevisiae} + Chitosan</td>
<td>0.0 c 0.5 bc 0.8 cd</td>
<td>0.0 c 0.5 cd 0.8 cd</td>
</tr>
<tr>
<td>Potassium bicarbonate + Thyme oil</td>
<td>0.0 c 0.4 bc 0.6 cd</td>
<td>0.0 c 0.4 cd 0.6 cd</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>0.3 b 0.9 b 1.4 b</td>
<td>0.8 b 1.2 b 1.7 b</td>
</tr>
<tr>
<td>Saccharin + Chitosan</td>
<td>0.5 b 0.7 b 1.2 b</td>
<td>0.6 b 0.8 c 1.2 bc</td>
</tr>
<tr>
<td>Control</td>
<td>0.9 a 2.2 a 3.8 a</td>
<td>1.2 a 2.8 a 4.6 a</td>
</tr>
</tbody>
</table>

Mean values within columns followed by the same letter are not significantly different (P ≤ 0.05).

Fig. 4: Reduction (%) in Downy and powdery diseases severity in response to application of different formula against foliar diseases of Cucumber grown in plastic houses under protected cultivation system (Tookh location)

Application of different formula of chemical plant resistance inducers as foliar spray resulted in reduction of foliar diseases incidence and severity which reflected positively in plant stand and its healthy growth as well as its yield. The obtained yield of Cucumber plants in response to foliar application with different formula in plastic houses under protected cultivation system (Dokki location) was presented in Table (5). Presented data revealed that the highest recorded accumulated yield 1.417 Ton/ plastic house was obtained from plants sprayed with [Calcium chloride (20mM) + \textit{S. cerevisiae} \(10\times10^{10}\) cfu/mL (10ml/L) + Chitosan (0.05mM)] followed by 1.378, 1.328 and 1, 308 Ton/ plastic house for plants sprayed with the treatments, [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)], [Chitosan (0.05mM) + Thyme oil (5ml/L)] and [Potassium monohydrogen phosphate (20mM)], respectively. Meanwhile, the yield of control plants was recorded as 1,063 Ton/ plastic house. Illustrated data in Fig. (5) showed that the highest calculated increase in cucumber yield was recorded as 33.3 and 29.5% at the applied treatments [Calcium chloride (20mM) + \textit{S. cerevisiae} \(10\times10^{10}\) cfu/mL (10ml/L) + Chitosan (0.05mM)] and [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)], respectively. Meanwhile, 24.8 and 23.0% yield increase was recorded at the applied treatments, [Chitosan (0.05mM) + Thyme oil (5ml/L)] and [Potassium monohydrogen phosphate (20mM)], respectively. At Dokki location, the accumulated Cucumber yield (Fig 5) increased over control plants by 33.3, 29.5, 24.8 and 23.0% at applied treatments, [Calcium
chloride (20mM) + *S. cerevisiae* 10x10^10 cfu/mL (10ml/L) + Chitosan (0.05mM), [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)], [Chitosan (0.05mM) + Thyme oil (5ml/L)] and [Potassium monohydrogen phosphate (20mM)], respectively.

**Table 5:** The obtained yield of Cucumber in response to foliar application of different formula in plastic houses under protected cultivation system (Dokki location)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average Yield Kg/row</th>
<th>Yield Ton/plastic house</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium chloride + <em>S. cerevisiae</em> + Chitosan</td>
<td>283.4 d</td>
<td>1.417</td>
</tr>
<tr>
<td>Potassium bicarbonate + Thyme oil</td>
<td>275.3 c</td>
<td>1.378</td>
</tr>
<tr>
<td>Chitosan + Thyme oil</td>
<td>265.5 bc</td>
<td>1.328</td>
</tr>
<tr>
<td>Potassium monohydrogen phosphate</td>
<td>261.5 b</td>
<td>1.308</td>
</tr>
<tr>
<td>Control</td>
<td>212.6 a</td>
<td>1.063</td>
</tr>
</tbody>
</table>

Mean values within columns followed by the same letter are not significantly different (P ≤ 0.05).

**Fig. 5:** Increase (%) in the obtained yield of Cucumber in response to foliar application with different formula in plastic houses under protected cultivation system at Dokki location

At Toohk location, (Table 6) Cucumber plants sprayed with [Calcium chloride (20mM) + *S. cerevisiae* 10x10^10 cfu/mL (10ml/L) + Chitosan (0.05mM)] produced the highest significant accumulated yield recorded as 1, 498 Ton/ plastic house followed by 1,401 Ton/ plastic house which produced from plants sprayed with [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)]. Meanwhile, Cucumber plants sprayed with [Saccharin (3mM) + Chitosan (20mM)] and [Ascorbic acid (20mM)] produced significantly accumulated yield calculated as 1,362 and 1,351 Ton/ plastic house comparing with 1,016 Ton/ plastic house for control plants.

On the other hand, Cucumber plants grown in plastic house at Toohk location and received foliar spray with [Calcium chloride (20mM) + *S. cerevisiae* 10x10^10 cfu/mL (10ml/L) + Chitosan (0.05mM)] treatment resulted in an increase of the accumulated yield calculated as 47.2% followed by 37.8 which obtained by [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)] treatment. Meanwhile, 34.0 and 32.9% increase in yield was recorded at treatments, [Saccharin (3mM) + Chitosan (20mM)] and [Ascorbic acid (20mM)], respectively over control plants (Fig 6).

**Table 6:** The obtained yield of Cucumber in response to foliar application of different formula in plastic houses under protected cultivation system (Tookh location)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average Yield Kg/row</th>
<th>Yield Ton/plastic house</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium chloride + <em>S. cerevisiae</em> + Chitosan</td>
<td>299.6 d</td>
<td>1,498</td>
</tr>
<tr>
<td>Potassium bicarbonate + Thyme oil</td>
<td>280.2 c</td>
<td>1,401</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>270.2 bc</td>
<td>1,351</td>
</tr>
<tr>
<td>Saccharin + Chitosan</td>
<td>272.4 bc</td>
<td>1,362</td>
</tr>
<tr>
<td>Control</td>
<td>203.2 a</td>
<td>1,016</td>
</tr>
</tbody>
</table>

Mean values within columns followed by the same letter are not significantly different (P ≤ 0.05).
The obtained results in the present study showed high efficacy of application plant resistance inducers Calcium chloride, Potassium bicarbonate, Potassium monohydrogen phosphate, Thyme oil, Chitosan, S. cerevisiae as foliar spray treatment during the growing growth season against downy and powdery mildews of cucumber plants. Sprayed treatments, [Calcium chloride (20mM) + S. cerevisiae 10x10^{10}cfu/mL (10ml/L) + Chitosan (0.05mM)], [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)] and [Chitosan (0.05mM) + Thyme oil (5ml/L)] could suppress both incidence and severity of downy and powdery mildews of cucumber plants grown at Dokki location (Table 1 & 2). Also, the highest reduction of both diseases was also recorded at treatment of [Calcium chloride (20mM) + S. cerevisiae 10x10^{10}cfu/mL (10ml/L) + Chitosan (0.05mM)] followed by [Potassium bicarbonate (20mM) + Thyme oil (5ml/L)], [Saccharin (3mM) + Chitosan (20mM)] and [Ascorbic acid (20mM)] on disease development of cucumber plants growing at Toohk location. These results are confirmed with those obtained by several investigators. The obtained reduction in invaded vegetable plants with downy and powdery mildews pathogens may be attributed to the role of sprayed chemical induce resistance which act as elicitors of plant defense reactions against pathogenic fungi. Similar explanation was reported by various workers. In this concern, some chemicals were reported as resistance inducers against plant diseases. For example, the content of ascorbic acid in plant tissues has been associated with resistance to some diseases (Zacheo et al., 1977). Also, Ascorbic acid was reported for inducing resistance in many plants against fungal diseases (Koltunov et al., 1984; Khan et al., 2001). Also, these results are confirmed with those reported by Abd-El-Kareem (2002). He stated that chitosan application as seed dressing followed by foliar spray caused more than 83 % reduction on root-rot incidence of pea plants. Moreover, several investigators reported that chitosan has antifungal effect and plays a role as inductors for plant resistance. This effect due to chitinase inducing, a defense enzyme and to elicit phytoalexin formation (Brishammar and Meyerson, 1991). On the other hand chitosan was reported to induce resistance in tomato plants against root rot diseases when applied as root dipping, foliar spraying, seed dressing and soil amendment (Benhamou et al., 1994 and Lafontaine & Benhamou,1996). Furthermore, treatment of potato plants with chitosan induced resistance against late blight disease and reduced infection by 70% (Brichammar and Meyerson, 1991 and Perekhod et al., 1997). Moreover, Abd-El-Kareem et al. (2001 and 2002) reported that, treated potato plants with either chitosan or ASA induced resistance against the foliar diseases, late and early blight diseases and increased tuber yield under field conditions. On the other hand chemical plant resistance inducers were reported to inhibit plant disease incidence and severity. This result further supports the results of Wisniewski et al. (1995), who found that calcium chloride might reduce fungal infection through direct inhibition of spore germination and growth. Maouni et al. (2007) reported that in vitro, calcium chloride significantly reduced pear fruit decay caused by A. alternata and Penicillium expansum when used at 4 and 6%. Furthermore, calcium chloride was reported to suppress growth of the citrus mould pathogen Penicillium digitatum (Droby et al., 1997). It is also known that addition of calcium chloride can also improve the activity of biocontrol agents (Droby et al. 1997; McLaughlin et al., 1990). Furthermore, there was a considerable interest in the use of sodium bicarbonate (NaHCO₃) and potassium bicarbonate (KHCO₃) for controlling various fungal diseases in plants.
Smilanick et al., 2006). Bicarbonates are widely used in the food industry (Lindsay, 1985) and were found to suppress several fungal diseases of cucumber plants (Ziv and Zitter 1992). Spraying plants with NaHCO₃ solution provided good control of several plant diseases (Horst et al., 1992; Janisiewicz and Peterson, 2005). Also, spraying with KHCO₃ solution provided the most effective protection against plant diseases (Smilanick et al., 1999, 2006). Sodium or potassium bicarbonate combined with oils was effective in controlling plant diseases (Horst et al., 1992; Ziv and Zitter, 1992). Furthermore, the antimicrobial activity of sodium carbonate and sodium bicarbonate has been described in vitro (Corral et al., 1988; Curran et al., 1990; Smilanick et al., 1999).

In the present study, sprayed cucumber plants with all plant resistance inducers treatments reflected on announced increase of the yield obtained ranged between 23.0-33.3% for grown plants at Dokki location and 32.9-47.4% at for grown plants at Tookh location. The highest increase over control recorded as 47.4 and 33.3% was obtained by treatments, [Calcium chloride (20mM) + S. cerevisiae 10x10¹⁰cfu/mL (10ml/L) + Chitosan (0.05mM)] and [Potassium bicarbonate + Thyme oil], respectively. In this concern, several investigators reported that application of plant resistance inducers had positive effect on both plant stand and yield production. Abd-El-Kareem, et al., (2001) reported that, treated potato plants with chitosan induced resistance against late and early blight diseases and increased tuber yield under field conditions. Also, El-Gamal et al., (2007) stated that Calcium chloride showed an increase of potato yield which was between 36.4 to 50.0 % over control at two cultivation seasons, respectively. Moreover, Potato tuber harvested yield, in certain essential oils applied as foliar spray treatments, was significantly higher than control. Highly effective treatment induced the obvious increase of tuber yield being for 1% of thyme oil (22.1 and 40.0%) in 2006 and 2007 cultivation seasons, respectively (El-Mougy, 2009).

Hence, the objective of this study was to determine if plant resistance inducers and essential oils could provide enhancement effect against downy and powdery mildews. Considering their attribute and broad-spectrum activities, successful development of such compounds as antifungal would not only provide a potent tool for control of vegetables foliar diseases, but also could promise success in multipurpose biorational alternatives to conventional fungicides for the management of other plant diseases.

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REFERENCES


