Effectiveness of organic compounds in controlling root rot/wilt diseases, growth and yield parameters of pepper

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Root rot and wilt caused by Fusarium solani and F. oxysporum, are the most important diseases of pepper in Egypt. The possibility to reduce disease severity using some organic compounds viz. Humic acid, Inicium, Bio-Health, Alga Grow-4 and Effective Microorganisms (EM1) was investigated on two pepper cultivars (Long Red Cayenne and California Wonder) under greenhouse and field experiments. Pepper transplanting treated with Humic acid followed by Inicium was the highest efficient in reducing area under disease progress curve (AUDPC) compared with to the other treatments under green house and field conditions. While, pepper transplanting treated with Alga Grow-4 and EM1 recorded the lowest reduction in area under disease progress curve (AUDPC) in this respect. On the other hand, all treatments significantly improved plant growth (plant height and number of branches plant\(^{-1}\)) and yield parameters (fruit height, fruit diameter, fruit weight plant\(^{-1}\), No. of fruits plant\(^{-1}\), pod weight and total yield feddan\(^{-1}\) (Kg) in both cultivars during growing seasons (2010-2011 and 2011-2012). Humic acid and Inicium were the most effective in improving plant growth and yield parameters. On the contrary pepper transplanting treated with Alga Grow-4 and EM1 gave the lowest increased of these parameters in both cultivars during growing seasons.

Key words: Pepper, root rot and wilt, organic compounds, effective microorganisms, growth parameters, yield parameters.

INTRODUCTION

Hot and sweet pepper (Capsicum annuum L.) is one of the most popular vegetable crops in many parts of the world. Green and red pods are used for fresh meal and food industries. Under Egyptian conditions, pepper plants are liable to be attacked by several diseases, among which damping-off, root rots and wilt are widespread and serious in many governorates both in open fields and protected cultivation, in young and relatively even aged plants (Abada, 1994; Abdel-Kader, 1999; Abdel-Monaim and Ismail, 2010; Ragab et al., 2012).

Root rot and wilt diseases caused by soil borne pathogenic fungi is one of the most serious diseases affected several cultivated plants worldwide. It results in poor production, poor quality, poor milling returns and reduced agriculture income (Abdel-Monaim and Ismail, 2010; Ragab et al., 2012).

Fungal disease control is achieved through the use of fungicides which is hazardous and toxic to both people and domestic animals and leads to environmental pollution. Therefore, a more balanced, cost effective and eco-friendly approach must be implemented and adopted by farmers (Atitia et al., 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. Such strategy is use of effective microorganisms to control fungal plant diseases (Dhahira and Qadri, 2010) as well as other fungicides alternatives, that is plant resistance inducers (Abdel-Monaim and Ismail, 1010; Abdel-Monaim et al., 2011) organic compounds (El-Morsi et al., 2009).

The present study aims to evaluate organic compounds
that is Humic acid, Inicium, Bio-Health, Alga Grow-4 and Effective Microorganisms (EM1) as resistance inducers on pepper plants against root rot and wilt diseases under greenhouse and field conditions. Also, its effect on growth parameters and yield parameters of tow pepper cultivars were studied in field.

MATERIAL AND METHODS

Host and Pathogens

Pepper seeds (Capsicum annuum L.), cvs. Long Red Cayenne and California Wonder used in the experiments were obtained from unit sale vegetable crops seeds, Horticulture Res. Institute, Agric. Res. Center, Giza, Egypt. Seeds were sown in trays containing sterilized peat vermiculite.

The plants were grown under greenhouse conditions for about 40 days. The highly pathogenic Fusarium solani and F. oxysporum were grown on potato dextrose agar (PDA) medium and spore suspension (10^4 spores/ml) was prepared.

Source of Organic Compounds and EM1

In this experiment, four organic compounds and effective microorganisms (EM1) (Table 1) were evaluated under greenhouse and field conditions to control root rot and wilt diseases on two pepper cultivars (Long Red Cayenne and California Wonder).

Effect of Organic Compounds and EM1 on Root Rot and Wilt Diseases of Pepper Under Greenhouse Conditions

The trials were carried out in the greenhouse of Plant Pathology Dep., New Valley Agric. Res. Station. Pot experiments were conducted in 2010-2011 season to investigate the influence of seedlings treated with each of organic compounds and EM1 listed in Table 1 against root rot and wilt diseases caused by F. solani and F. oxysporum. Surface sterilized seedlings of two pepper cultivars (40 days old) were used for all experiments. Pepper seedlings were treated by dipping the root at rate 100 seedlings per 100 ml of the following treatments, Inicium, Bio-Health, Elga Grow-4, Humic acid and EM1 at the recommended concentrations, for one hour. The treated pepper seedlings were then transferred to the pathogen infested pots. Four seedlings were transplanted in each pot and 4 replicates were planted for each treatment. In addition, untreated seedlings were transplanted in pots containing infested soil (infected control). Plants were irrigated when needed and fertilized as usual.

Disease Assessments.

Root rot and wilt severity was estimated at 10 days interval for 60 days after transplanting according to Abdou et al. (2001) using a rating scale of (0 – 5) based on leaf yellowing grading, viz., 0 = healthy, 1 = one leaf yellowing, 2 = more than one leaf yellowing, 3 = one wilted leaf, 4 = more than one leaf wilted, and 5 = completely dead plants. Disease severity index (DSI) described by (Liu et al., 1995) was adapted and calculated as follows:

\[ DSI = \frac{\sum d}{d_{max} \times n} \times 100 \]

Where: \( d \) is the disease rating of each plant, \( d_{max} \) the maximum disease rating and \( n \) the total number of plants/samples examined in each replicate.

The mean of area under disease progress curve (AUDPC) for each replicate was calculated as suggested by (Pandy et al., 1989).

\[ \text{AUDPC} = D \left[ \frac{1}{2} (Y_1 + Y_k) + \left( Y_2 + Y_3 + \ldots + Y_k \right) \right] \]

Where \( D \) = Time interval; \( Y_1 \) = First disease severity; \( Y_k \) = Last disease severity; \( Y_2, Y_3, \ldots, Y_{k-1} \) = Intermediate disease severity.

Field Experiments

Field experiments were carried out at New Valley Agric. Res. Station Farm, New Valley governorate, Egypt, during 2010-2011 and 2011-2012 growing seasons, to evaluate the efficiency of the tested organic compounds and EM1 for controlling root rot and wilt diseases of pepper plants (Long red Cain and California Wonder) as well as its effect on growth parameters and yield parameters. The chosen field test area was naturally infested with root rot and wilt pathogens. The experimental design was a complete randomized block with four replicates. The experimental unit area was 15 m² (5 × 3 m). Each unit included three rows; each row was 5 m in length and 1 m width. Pepper seedlings cv. Long red Cain and California Wonder were treated by dipping the roots for one hour at rate 100 seedlings per 100 ml of the following treatments: Inicium, Bio-Health, Elga Grow 4, Humic acid and EM1 at the recommended concentrations, for one hour. Seedlings transplanted into the field in 10 October in both seasons at rate 10 seedlings per row; one seedling/hill was sown with 50 cm apart between hills. Untreated seedlings were used as control. The NPK mineral fertilizers were applied at the recommended dose of Ministry of Agriculture and Land Reclamation. Disease severity was recorded every 30 days for 4 months. The mean of area under disease progress curve (AUDPC) for each replicate was calculated as above. Plant height, number of branches, fruit length (cm) and fruit diameters, number of fruits plant^{-1}, fruit weight plant^{-1} (kg), number of fruit Kg^{-1}, fruit yield feddan^{-1} (kg) were calculated at the end of the growing season.
Table 1. Trade name, common name, active ingredient (%) and recommended doses of the used organic compounds and EM1.

<table>
<thead>
<tr>
<th>Trade name</th>
<th>Common name</th>
<th>% Active ingredient</th>
<th>Recommended doses</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inicium</td>
<td>Amino acids and phosphorus pentoxide.</td>
<td>10%FS</td>
<td>5 mL/L</td>
<td>Grow Tech for Agricultural Development</td>
</tr>
<tr>
<td>Bio- Health</td>
<td>T. harzianum, B. subtilis, Amino acids, Trace elements, Humic acid, Fulvic acid, vitamins, Auxin and Cytokinin.</td>
<td>100% WSG</td>
<td>2.5 g/L</td>
<td>Grow Tech for Agricultural Development</td>
</tr>
<tr>
<td>Alga Grow-4</td>
<td>Algae extract, nitrogen, phosphorus pentoxide and potassium oxide.</td>
<td>16% FS</td>
<td>1 mL/L</td>
<td>Grow Tech for Agricultural Development</td>
</tr>
<tr>
<td>Humic acid</td>
<td>Potassium humate soluble granule</td>
<td>85% WSG</td>
<td>4 g/L</td>
<td>Broadtech Chemical International Co. Ltd., Inner Mongolia, China</td>
</tr>
<tr>
<td>Effective Microorganisms (EM1)</td>
<td>Photosynthetic bacteria (Rhodopseudomonas plastris and Rhodobacter sphacodes), lactobacilli (Lactobacillus plantarum, L. casei, and Streptococcus lactis), yeasts (Saccharomyces spp.), and actinomycetes (Strptomycetes spp.)</td>
<td>100% FS</td>
<td>5 mL/L</td>
<td>EMRO</td>
</tr>
</tbody>
</table>

Statistical Analysis

All experiments were performed twice. Analyses of variance were done using MSTAT-C program version 2.10, 1991. Least significant difference (LSD) was calculated at $P \leq 0.05$ according to (Gomez and Gomez, 1984).

RESULTS

Efficiency of Organic Compounds and EM1 on Area Under Disease Progress Curve Under Greenhouse Conditions

A pot experiment was carried out to examine the efficiency of organic compounds and EM1 against root rot and wilt diseases caused by *F. solani* and *F. oxysporum* in two pepper cultivars (Long Red Cayenne and California Wonder) under greenhouse conditions. Presented data in Figures (1 and 2) revealed that all the tested organic compounds and EM1 significantly reduced area under disease progress curve (AUDPC) comparing with un-treated check control. In this respect, pepper transplanting treated with Humic acid was the highest efficient in reducing AUDPC compared with the other treatments. In case of Long Red Cayenne cultivar, the AUDPC reduced from 1105.33 and 1042.33 to 258.69 and 141.29 AUDPC cased by *F. solani* and *F. oxysporum*, respectively. While, in case of the California Wonder cultivar AUDPC reduced from 1205.33 and 1042.33 to 321.69 and 152.48 in case of soil infested with *F. solani* and *F. oxysporum*, respectively.

On the other hand, pepper transplanting treated with Alga Grow-4 and EM1 recorded the lowest reduction in AUDPC caused by *F. solani* and *F. oxysporum* in both cultivars.

Efficiency of Organic Compounds and EM1 Under Field Conditions

On area under disease progress curve (AUDPC)

Data in Figure (3) revealed that the high infection percentage of pepper plants (cv. Long Red Cayenne) with the pathogen recorded with control whereas, low infection percentage was observed in the treated seedlings with Humic acid, where gave 121.36 and 135.24% AUDPC compared with 812.36 and 912.23 AUDPC during first and second growing seasons, respectively, followed by treatment Inicium. Conversely,
pepper transplanting treated with Alga Grow-4 and EM1 showed the lowest protection against root rot and wilt diseases. Also the same data obtained in case of pepper plants cv. California Wonder (Figure 4), were Humic acid recorded the lowest AUDPC followed by Inicium in both seasons. Conversely, pepper transplanting treated with Alga Grow-4 and EM1 gave the lowest protection in both growing seasons.

On growth parameters.

Data in Tables (2 and 3) indicate that all tested organic compounds and effective microorganisms (EM1) significantly increased growth parameters (plant height and number of branches plant$^{-1}$) in both cultivars during both growing seasons (2010-2011 and 2011-2012) compared with untreated transplanting. Humic acid recorded
the highest growth parameters in both cultivars, where increased plant height from 66.67 and 67.33 in control to 88.33 and 90.25 in case of cv. Long Red Cayenne in both seasons, respectively. While in case of cv. California Wonder, plant height increased from 63.33 and 62.15 cm in control to 85 and 89.39 cm in both growing seasons, respectively. Also, the obtained data show that Humic acid recorded the highest number of branches plant$^{-1}$ in both cultivars during both growing seasons where increased number of branches in cv. Long Red Cayenne from 3.44 and 3.49 to 7.56 and 8.26 and increased number of branches plant$^{-1}$ from 3.67 and 3.21 to 6.67 and 7.85 in case of cv. California Wonder in both seasons respectively.

On the other hand, pepper transplanting treated with Alga Grow-4 and EM1 gave the lowest increased of plant...
Table 2. Effect of organic compounds and effective microorganisms (EM1) on growth parameters of pepper (cv. Long Red Cayenne) during seasons (2010-2011 and 2011-2012).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Season 2010-2011</th>
<th>Season 2011-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant height (cm)</td>
<td>No. of branches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>plant(^1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plant height (cm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>plant(^1)</td>
</tr>
<tr>
<td>Inicium</td>
<td>83.33 ab</td>
<td>6.78 b</td>
</tr>
<tr>
<td>Bio-Health</td>
<td>80.00 bc</td>
<td>5.78 c</td>
</tr>
<tr>
<td>Alga Grow 4</td>
<td>78.33 bc</td>
<td>5.33 c</td>
</tr>
<tr>
<td>EM1</td>
<td>75.00 c</td>
<td>4.67 d</td>
</tr>
<tr>
<td>Humic acid</td>
<td>88.33 a</td>
<td>7.56 a</td>
</tr>
<tr>
<td>Control</td>
<td>66.67 d</td>
<td>3.44 e</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences between treatments according to L.S.D. test (\(P=0.05\)).

Table 3. Effect of organic compounds and effective microorganisms (EM1) on growth parameters of pepper (cv. California Wonder) during seasons (2010-2011 and 2011-2012).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Season 2010-2011</th>
<th>Season 2011-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant height (cm)</td>
<td>No. of branches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>plant(^1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plant height (cm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>plant(^1)</td>
</tr>
<tr>
<td>Inicium</td>
<td>80.00 ab</td>
<td>6.22 a</td>
</tr>
<tr>
<td>Bio-Health</td>
<td>78.33 bc</td>
<td>5.56 b</td>
</tr>
<tr>
<td>Alga Grow 4</td>
<td>73.67 cd</td>
<td>4.22 c</td>
</tr>
<tr>
<td>EM1</td>
<td>72.00 d</td>
<td>4.22 c</td>
</tr>
<tr>
<td>Humic acid</td>
<td>85.00 a</td>
<td>6.67 a</td>
</tr>
<tr>
<td>Control</td>
<td>63.33 e</td>
<td>3.67 d</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences between treatments according to L.S.D. test (\(P=0.05\)).

height and number of branches in both cultivars during growing seasons (2010-2011 and 2011-2012).

On yield parameters.

Data present in Tables (4 and 5) show that all treatments significantly increased yield parameters viz. fruit height (cm), fruit diameter (cm), pod weight \(^1\) (gm), Number of fruits \(^1\), pod weight (gm), total yield feddan \(^1\) (kg) in both cultivars during growing seasons 2010-2011 and 2011-2012 compare with untreated plants (control). Pepper transplanting (cv. Long Red Cayenne) treated with Humic acid recorded the highest increased of fruit height (9.19, 10.24 cm); fruit diameter (1.25, 1.29 cm); fruit weight \(^1\) (726.86, 802.14 gm); Number of fruits \(^1\) (115.37, 802.14); pod weight (6.30, 6.72 gm); total yield feddan \(^1\) (4088.74, 4120.36 kg) compared with 5.12 and 6.09 cm; 3.01 and 3.09 cm; 420.61 and 402.15 gm; 32.34 and 36.25; 13.01 and 11.09 gm; 2070.52 and 1998.25 kg in control during both seasons, respectively. Also the same trained in cultivar were recorded the highest fruit height (7.12, 7.32 cm); Fruit diameter (4.45, 4.50 cm); Fruit weight \(^1\) (745.24, 785.36 gm); Number of fruits \(^1\) (45.23, 46.36); Pod weight 16.48, 16.94 gm); total yield feddan \(^1\) (5433.40, 551236 kg) compared with 5.12 and 6.09 cm; 3.01 and 3.09 cm; 420.61 and 402.15 gm; 32.34 and 36.25; 13.01 and 11.09 gm; 2070.52 and 1998.25 kg in control during both seasons, respectively. On the other hand, pepper transplanting treated with Inicium and EM1 gave the lowest increased of all yield parameters in both cultivars during both growing seasons.

DISCUSSION

Pepper plants are subject to infection with many diseases (Dmitriev et al., 2003; Utkhede and Mathur, 2005; Abdel-Monaim and Ismail, 2010), among which the soil-borne diseases are the most important. Many fungi that is *Fusarium*, *Macrophomina*, *Rhizoctonia*, *Pythium*, *Verticilium* and *Sclerotinia* causing damping-off, root rot and wilt diseases are commonly encountered in the greenhouse, nurseries and fields (Soner et al., 2005; Goicoechea, 2006; Abdel-Monaim and Ismail, 2010). Because high disease pressure and high crop value require frequent applications of chemical pesticides, significant environmental pollution and selection of resistant pathogen strains are among the main problems
Table 4. Effect of organic compounds and effective microorganisms (EM1) on yield parameters of pepper (cv. Long Red Cayenne) during seasons (2010-2011 and 2011-2012).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Season 2010-2011</th>
<th>Season 2011-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fruit height (cm)</td>
<td>Fruit diameter (cm)</td>
</tr>
<tr>
<td>Inicium</td>
<td>9.19a</td>
<td>1.25a</td>
</tr>
<tr>
<td>Bio-Health</td>
<td>8.77a</td>
<td>1.21a</td>
</tr>
<tr>
<td>Alga Grow-4</td>
<td>8.61a</td>
<td>1.19a</td>
</tr>
<tr>
<td>EM1</td>
<td>8.37a</td>
<td>1.19a</td>
</tr>
<tr>
<td>Humic acid</td>
<td>9.48a</td>
<td>1.29a</td>
</tr>
<tr>
<td>Control</td>
<td>6.79b</td>
<td>1.09a</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences between treatments according to L.S.D. test ($P \leq 0.05$).

Table 5. Effect of organic compounds and effective microorganisms (EM1) on yield parameters of pepper (cv. California Wonder) during seasons (2010-2011 and 2011-2012).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Season 2010-2011</th>
<th>Season 2011-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fruit height (cm)</td>
<td>Fruit diameter (cm)</td>
</tr>
<tr>
<td>Inicium</td>
<td>6.05cd</td>
<td>3.48b</td>
</tr>
<tr>
<td>Bio-Health</td>
<td>6.56b</td>
<td>4.25a</td>
</tr>
<tr>
<td>Alga Grow-4</td>
<td>6.47bc</td>
<td>3.31bc</td>
</tr>
<tr>
<td>EM1</td>
<td>5.82d</td>
<td>3.59b</td>
</tr>
<tr>
<td>Humic acid</td>
<td>7.12a</td>
<td>4.45a</td>
</tr>
<tr>
<td>Control</td>
<td>5.12e</td>
<td>3.01c</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences between treatments according to L.S.D. test ($P \leq 0.05$).
encountered in fields. This situation has prompted the search for biological alternatives that could be efficient either for conventional disease management programs or for integration with other methods (Hibar et al., 2006). Various organic compounds were tested for biological control of root rot and wilt diseases in pepper plants. Data obtained in this study demonstrated that all organic compounds viz. Inicium, Bio-Health, Alga Grow-4, Humic acid, EM1 reduced significantly area under disease progress curve caused by F. solani and F. oxysporum under artificial infection in greenhouse and natural infection in field in both pepper cultivars (Long Red Cayenne and California Wonder). Pepper transplanting treated with Humic acid recorded the lowest AUDPC compared with the other organic compounds followed with Inicium. Conversely, pepper seedlings treated with Alga Grow-4 and EM1 showed the lowest protection against root rot and wilt diseases. On the other hand, all tested organic compounds improved growth and yield parameters of both pepper cultivars under field conditions compared with untreated plants (control). Humic acid followed by Inicium gave the highest plant height, number of branches plant⁻¹, fruit height (cm), fruit diameter (cm), fruit weight plant⁻¹ (gm), number of fruits plant⁻¹, pod weight (gm), total yield feddan⁻¹ (Kg). On the contrary, pepper plants treated with Alga Grow-4 and EM1 recorded the lowest increased of growth parameters and yield parameters in both cultivars. Similar studies have been conducted for other pathogens using the same organic compounds to try to demonstrate if these ones can reduced root rot and wilt severity and improved growth parameters and yield parameters (El-Morsi et al., 2009; Abdel-Monaim et al., 2011). The role of the tested organic compounds in reducing root rot/wilt diseases severity and stimulating plant growth may be due to enhanced natural resistance against plant diseases and pests, stimulated plant growth through increased cell division, as well as optimized uptake of nutrients, water and stimulated the soil microorganisms (Chakroune, 2008; El-Morsi et al., 2009; Okorski et al., 2010; Abdel-Monaim et al., 2011). Application of Humic acid enhances the activity of antioxidants such as α-tocopherol, α-carotene, superoxide dismutases and ascorbic acid concentrations in turf grass species. These antioxidants may play a role in the regulation of plant development, flowering and chilling of disease resistance (Demirci and Dolar, 2006).

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