New fungi causing postharvest spoilage of cucumber fruits and their molecular characterization in Egypt

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Abstract

This work was carried out during two successive seasons (2016 and 2017) on cucumber fruits from a plastic greenhouse and from open field cultivation in El Gharbeia and El Giza Governorates, Egypt. Isolation trials from spoilage fruit samples of plastic greenhouse cultivation recorded high frequency of Alternaria tenuis, Fusarium spp. and Pleospora allii. The most common fungi of rotten cucumber fruits from an open field were Galactomyces spp. and Fusarium spp. Pathogenicity tests proved that, Fusarium solani from El-Gharbeia followed by A. tenuis from El-Giza were the most frequent isolates responsible for rot of cucumber fruits from plastic greenhouse cultivation. Moreover, the most frequent isolates causing postharvest disease of cucumber fruits of the open field were Galactomyces candidum from El-Giza followed by Geotrichum sp. and F. fujikuroi from El-Gharbeia Governorates, respectively. This is the first report of several fungi causing postharvest fruit rot disease of cucumber i.e., G. candidum, Geotrichum sp., A. tenuis, P. allii and Fusarium spp. (F. fujikuroi, F. verticillioides, F. solani, E. geraminearum and Fusarium incarnatum). Fungal isolates were identified according to cultural, morphological and molecular characterization based on sequencing of internal transcribed spacer1 (ITS1). All the ITS nucleotide sequences of fungi were applied and conserved in GenBank.

Keywords: cucumber, fruit rot, fungi, internal transcribed spacer (ITS), molecular characterization

Introduction

Cucumber (Cucumis sativus L.) is one of the most important economic vegetable crops all over the world. It is cultivated in open fields and protected houses in Egypt for both local consumption and export. The occurrence of fungal spoilage of fruits is recognized as a potential health hazard to man due to their production of mycotoxins (Effiuwvewwere 2000). Cucumber plants are subject to attack by several fungal diseases that affect the yield quantity and quality including Alternaria tenuis, A. alternata, Botrytis cinerea, Chaanephora cucurbitarum, Didymella bryoniae, Fusarium oxysporum, Geotrichum candidum, Penicillium oxalicium, Phytophthora capsici, Rhizopus nigricans and Sphaerotheca fuliginea (Blancard et al. 2005; Farrag et al. 2007; Sani et al. 2015; Ziedan and Saad 2016). Fruit rot pre- and postharvest caused by B. cinerea (An and Ma 2005–2006; Soliman et al. 2015), Geotrichum candidum was reported as a fruit rot causal pathogen on carrot, cucumber, tomato and pumpkin in South Korea (Kim et al. 2011), Monilinia spp. on peach, pear and apple fruits (Di Francesco et al. 2015) and Galactomyces reessii on tomato fruits (Suwannarach et al. 2016). Recently, G. candidum was reported on peach fruit (Alam et al. 2017). Molecular biology has offered a number of insights into the detection and enumeration of fungal pathogens and information on identifying unknown species from their DNA sequences. A rapid assay and accurate identification of fungal pathogens...
can be important for initiating treatment in the earliest stages of infection and for guiding antifungal therapy (Khot et al. 2009). The interest in ribosomal genes for species identification comes from the concerted fashion in which they evolve, showing a low intraspecific polymorphism and a high interspecific variability (Li 1997). Previous results have demonstrated that the internal transcribed spacer (ITS) of the complex regions (non-coding and variable) and the 5.8S rDNA gene (coding and conserved) are useful in measuring close fungus phylogenetic relationships, since they exhibit far greater interspecific differences than the 18S and 26S rDNA genes (Kurtzman 1992; Cai et al. 1996; James et al. 1996). The ITS has been used in numerous systematic studies at genus and species levels of a wide array of plant taxa (Sang et al. 1995; Alice and Campbell 1999). ITS-1 and ITS-2 are two internal spacers which are located between genes which encode the 18, 5.8 and 28S nuclear ribosomal RNA (nrRNA) subunits. In addition, the 5.8S nrRNA are referred to as nrDNA ITS region (Baldwin 1992). This investigation was aimed at surveying the incidence of postharvest diseases on cucumber fruits and identification of fungal isolates by molecular methods based on sequencing of ITS1 and 5.8S rDNA regions.

Materials and Methods

Disease survey

A survey of postharvest fruit rot diseases of cucumber in El-Giza and El-Gharbeia governorates, Egypt was performed during the winters of 2016 and 2017. Disease incidence and their severity were determined using the following formula:

\[
\text{Disease incidence} = \frac{\text{No. of infected plants}}{\text{Total no. of plants assessed}} \times 100\%.
\]

Disease severity was assessed as a percentage of rotten tissue of cucumber fruits using a linear scale from 0 to 4 according to Cohen et al. (1991) as follows:

- 0 = healthy fruits;
- 1 = 1−25% soft rot of fruit;
- 2 = 26−50% soft rot of fruit;
- 3 = 51−75% soft rot of fruit;
- 4 = 76−100% soft rot of fruit.

Isolation of fungi associated with postharvest fruit rot

Samples of rotten fruit tissue were washed thoroughly with tap water, then cut into small pieces and rinsed with 5% chlorox (sodium hypochlorite) for 3 min. They were then cultured on potato dextrose agar (PDA) medium. Five pieces of rotten tissue were placed in individual Petri dishes. Plates were incubated at 25 ± 2°C for 5 days and subsequently colonies were counted. Frequency occurrence of isolated fungi was recorded using the following formula:

\[
\text{Fungal frequency} = \frac{\text{No. of fungal genera of each location}}{\text{Total fungal colonies of each location}} \times 100\%.
\]

Fungal identification

Different fungal colonies were isolated and purified using single spore and hyphal tip methods and identified according to their cultural and morphological characteristics (Booth 1971; Ellis 1971; Nelson et al. 1983; Barnett and Hunter 1998).

Pathogenicity test

The pathogenicity of the isolated fungi was tested by artificially infecting sterilized cucumber fruits from an open field (cv. Beta alfa) and a greenhouse (cv. Golden) by sodium hypochlorite (1%) for 1 min then dried under sterilized conditions. Ten fruits were sprayed with spore suspensions 1 × 10^4 spore · ml⁻¹ of each fungal isolate tested. Cucumber fruits were incubated at 25 ± 2°C for 20 days. Percentage of diseased fruits and disease severity were determined 20 days after infestation by each fungal isolate as previously mentioned.

Molecular identification

DNA extraction

Genomic DNA was extracted from pure cultures of fungal strains isolated from rotten cucumber fruit samples from open field and plastic greenhouse cultivation grown on PDA using i-genomic BYF DNA extraction Mini Kit (iNtRON Biotechnology Inc., South Korea) following the manufacturer’s instructions (Sambrook et al. 1989).

PCR partial amplification and sequencing of 18S rDNA

Identification of the fungal isolates was based on molecular genetic analysis using the initials ITS. Partial sequences of the isolates18S rDNA were obtained using a strategy based on Boekhout et al. (1994). A divergent domain of the gene was amplified using three different primers:

- the first primer (ITS1) sequence: 5’-TCCGTAGGTGAACCTGCGG-3’;
- the second primer (ITS2) sequence: 5’-GGAAGTAAAAGTCGTAACAAGG-3’;
- the reverse primer (nrDNA ITS) sequence: 5’-GGTCCCGTTGGATTCTGATGATG-3’.

Frequency occurrence of isolated fungi was recorded using the following formula:

\[
\text{Fungal frequency} = \frac{\text{No. of fungal genera of each location}}{\text{Total fungal colonies of each location}} \times 100\%.
\]
- the second primer (ITS2) sequence: 5’-GCT GCGTTCTTCATCGATGC-3’;
- the third primer (ITS4) sequence: 5’-TCCTC CGCTTATTGATATGC-3’.

All primers were supplied by Operon Technologies Company, Netherlands. To each polymerase chain reaction (PCR) bead, 12 ng of the used primer and 40 ng of the purified DNA sample were added. The total volume of the amplification reaction was completed to 25 µl using sterile distilled water. The amplification protocol was carried out as follows: denaturation at 95°C for 5 min (each of the 35 cycles consisted of the following segments: denaturation at 95°C for 1 min; primer annealing at 55°C for 2 min and incubation at 72°C for 2 min for DNA polymerization). Finally, the PCR was kept at 4°C till analysis. The amplified DNA products were electrophoretically on 1.0% agarose gel and 1X TBE (Tris-borate-EDTA) buffer at a constant 100 V for about 2 h. The different band sizes were determined against 100 bp ladder (Vivantis # NL 1407-Malaysia) and the separated bands were stained with 0.5 µg · ml⁻¹ ethidium bromide and photographed using the Gel Documentation System with UV Transeliminator.

**Fungal DNA purification**

The PCR product was cleaned up using GeneJET™ PCR Purification Kit (Thermo K0701).

**Identification of isolates**

The DNA sequencing of the purified PCR products was done with ABI 3730xl DNA sequencer (GATC Company, Germany) by using forward primer.

**Phylogenetic analysis**

The DNA sequences of the fungal isolates were compared with the sequences available by the Basic Local Alignment Search Tool (BLAST) in the NCBI, GenBank database (http://www.ncbi.nlm.nih.gov). The sequences were aligned together with those of reference taxa retrieved from public databases. The evolutionary distances were generated based on parameter model (Jukes and Cantor 1969) and phylogenetic trees were constructed by using the neighbor-joining method (Saitou and Nei 1987).

**Data analysis**

The ITS nucleotide sequences for each isolate were then compared to those in the public domain databases NCBI (National Center for Biotechnology Information; www.ncbi.nih.gov) using the Basic Local Alignment Search Tool for Nucleotide Sequences (BLASTN). Alignment of ITS DNA sequences was done using Clustal W program [30]. A phylogenetic tree was created using CLC Sequence Viewer Version 6.3 based on UPGMA (unweighted pair-group method for arithmetic analysis). The confidence of the branching was estimated by bootstrap analysis.

**Statistical analysis**

The obtained data were statistically analyzed according to Snedecor and Cochran (1980). Means were compared by using the LSD test at 0.05 level.

**Results and Discussion**

**Incidence and severity of cucumber fruit rot**

Different colonies were observed at the end of the procedure necessary for the isolation and identification of fungi associated with cucumber fruit rot. The fungal colonies spoiled the cucumber fruits, causing their deterioration. Mixed colonies were obtained when the fungi were first isolated on PDA medium. Pure cultures of the spoilage fungi were observed afterwards when each colony of the fungi was subcultured on freshly prepared medium.

Data in Table 1 and Figure 1 indicated that postharvest fruit rot of cucumber was observed in open field and greenhouse cultivations during storage. The percentage of fruit rot of open field cultivation was less than fruits from greenhouse cultivation. Severity of fruit rot, represented as the percent of symptomatic cucumber fruits of the total fruit number, varied from 1.0 to 3.6%. Data also showed that a high percentage of cucumber fruits was recorded in El-Dokki followed by El-Gharbeia. Also, syndromes on cucumber fruits from an open field differed from greenhouse cultivation (Fig. 1).

<table>
<thead>
<tr>
<th>Cultivation</th>
<th>Location</th>
<th>Fruit rot incidence of cucumber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>Open field</td>
<td>El Gharbeia</td>
<td>5.0 c</td>
</tr>
<tr>
<td></td>
<td>El-Dokki</td>
<td>7.0 c</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>El Gharbeia</td>
<td>60.0 b</td>
</tr>
<tr>
<td></td>
<td>El-Dokki</td>
<td>100.0 a</td>
</tr>
</tbody>
</table>

Values followed by the same letter are not significantly different at p ≤ 0.05 according to Duncan’s multiple range
Pathogens associated with cucumber fruit rot

The frequency of occurrence of fungal isolates associated with the spoilage of cucumber fruits is shown in Table 2. A total of six fungal genera were obtained from spoiled cucumber fruits. The fungal genera were identified as *Fusarium*, *Galactomyces*, *Mucor*, *Aspergillus*, *Alternaria*, *Pleospora*, of which *Fusarium* spp. and *Galactomyces* spp. were the most common fungi associated with cucumber fruits from El-Gharbeia open field cultivation, 50 and 25%, respectively. This was followed by *Mucor* spp. and *Aspergillus niger* as saprophytic fungi. *Galactomyces* spp. (40%) and *Mucor* spp. (30%) were recorded in El-Giza Governorates. Data in Table 2 also showed that *Alternaria* had the highest frequency occurrence (65.0%) on cucumber fruits of greenhouse cultivation in El-Gharbeia Governorate, followed by *Pleospora allii* (20.0%), then *Fusarium* spp. (14.0%). *Alternaria* and *Fusarium* spp. (90.0 and 10.0%), respectively, were detected in El-Giza Governorate. These results are in agreement with Kim et al. (2011), Di Francesco et al. (2015), Sani et al. (2015), Ziedan and Saad (2016), Suwannarach et al. (2016), and Alam et al. (2017). It is worth mentioning that the two fungal isolates of *Galactomyces* spp. and *Pleospora allii* were isolated and recorded for the first time from spoiled cucumbers in Egypt.

Table 2. Frequency of isolation of different fungi associated with postharvest fruit rot of cucumber from different locations

<table>
<thead>
<tr>
<th>Cultivation</th>
<th>Location</th>
<th>Fungal name</th>
<th>Frequency [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open field</td>
<td>El Gharbeia</td>
<td><em>Fusarium</em> spp.</td>
<td>50.0 c</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Galactomyces</em> ssp.</td>
<td>25.0 f</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Aspergillus niger</em></td>
<td>12.5 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Mucor</em> ssp.</td>
<td>12.5 h</td>
</tr>
<tr>
<td></td>
<td>El-Giza</td>
<td><em>Galactomyces</em> ssp.</td>
<td>40.0 d</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Mucor</em> ssp.</td>
<td>30.0 e</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unknown</td>
<td>30.0 e</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>El Gharbeia</td>
<td><em>Alternaria</em> ssp.</td>
<td>65.0 b</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Pleospora allii</em></td>
<td>20.0 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Fusarium</em> ssp.</td>
<td>14.0 h</td>
</tr>
<tr>
<td></td>
<td>El-Giza</td>
<td><em>Alternaria</em> ssp.</td>
<td>90.0 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Fusarium</em> ssp.</td>
<td>10.0 i</td>
</tr>
</tbody>
</table>

Values followed by the same letter are not significantly different at p ≤ 0.05 according to Duncan’s multiple range
Pathological potential of isolated fungi

Differences were observed between the isolated fungi in their aggressiveness on cucumber fruits. Data in Table 3 and Figures 2 and 3 indicated that the common fungi, i.e., *G. candidium* from El-Giza and *G. candidium*, *Geotrichum* sp., *F. fujikuroi* and *F. verticiloides* from El-Gharbeia were highly pathogenic, causing cucumber fruit rot. *Galactomyces candidium* from El-Giza was highly pathogenic, followed by *Geotrichum* sp. and *F. fujikuroi* from El-Gharbeia. *Fusarium verticiloides* from El-Gharbeia Governorate caused the least fruit rot. In addition, fungi isolated from cucumber fruit, cultivated under a protective greenhouse, i.e., *Alternaria tenussium* (No. 2) *F. geraminearum*, and *P. allii*, *Fusarium solani* and *F. incarnatum* from El-Gharbeia were pathogenic to cucumber fruit (Cv. Golden) and *A. tenussium* (No. 1) was non-pathogenic. Symptoms in most of the inoculated fruits were characterized by yellowing of the tissue, followed by browning and fruit rot. The pathogenic fungi which induced symptoms in the inoculated fruits were re-isolated from symptomatic tissue. These results are in agreement with Blancard et al. 2005; Kim et al. 2011; Di Francesco et al. 2015; and Sani et al. 2015. Recently, in Pakistan, peach, fruit decay was caused by *Geotrichum candidum* (Alam et al. 2017). Also, Al-Sadi et al. (2011) reported that *Alternaria alternata*, *F. equiseti*, *F. solani*, *Cladosporium tenuissimum*, *Corynespora cassicola*, *Aspergillus* spp., *Curvularia* sp. and *Bipolaris* sp. were isolated from diseased cucumber fruits.

**Fig. 2.** Fruit rot incidence of cucumbers from open field cultivation 20 days after infestation. Control (A), *Galactomyces candidium* (B) and *Geotrichum* sp. (C)

**Fig. 3.** Fruit rot disease incidence of cucumbers from greenhouse cultivation 20 days after infestation. Control (A), *Alternaria tenussima* (B), *Fusarium geraminearum* (C) and *F. solani* (D)
Molecular identification of fungi associated with postharvest diseases

After the DNA isolation from the different fungal pathogenic strains and determination of the concentration by spectrophotometer, the ITS1 and ITS2 primers were used to amplify the region of the rDNA repeat unit that includes the ITS1 from the genomic DNA of the fungal pathogenic strains. After amplification, approximately 150 to 200 bp were obtained as shown in Figure 4. On the other hand, the ITS1 and ITS4 primers were used to amplify the region of the rDNA repeat unit that includes ITS1, 5.8S, ITS2 and 28S from the genomic DNA of the fungal pathogenic strains. After amplification, approximately 450 to 550 bp were obtained as shown in Figures 5 and 6. Only two strains (Z-Kh-F1 and Z-Kh-F2) did not produce any products after PCR amplification by ITS1 and ITS4 primers. After the DNA sequencing of the purified PCR products with ABI 3730xl DNA sequencer (GATC Company, Germany) by using forward primer, the 12 obtained DNA sequences (Seq1 to Seq12) with the identified fungal strains were applied and conserved in the GenBank under the following accession numbers:

- Seq1 [organism = *Galactomyces candidum*] Z-Kh-F1, ITS1, partial sequence (GenBank accession number MF373433),
- Seq2 [organism = *Fusarium verticillioides*] Z-Kh-F2, 5.8S ribosomal RNA gene, partial sequence; ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373434),

Table 3. Pathogenicity test of fungal isolates on postharvest disease of cucumber fruits 20 days after infestation

<table>
<thead>
<tr>
<th>Cultivation</th>
<th>Location</th>
<th>Fungal name</th>
<th>Fungal Fruit rot incidence</th>
<th>Fruit rot incidence (%)</th>
<th>Disease severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open field</td>
<td>El-Giza</td>
<td><em>Galactomyces candidium</em></td>
<td>100.0 a</td>
<td>100.0 d</td>
<td>2.0 b</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Fusarium verticillioides</em></td>
<td>00.0 d</td>
<td>0.0 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>F. fujikuroi</em></td>
<td>40.0 c</td>
<td>0.1 f</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>F. verticillioides</em></td>
<td>20.0 d</td>
<td>0.1 f</td>
<td></td>
</tr>
<tr>
<td></td>
<td>El-Gharbeia</td>
<td><em>G. candidium</em></td>
<td>20.0 d</td>
<td>0.8 d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Geotrichum sp.</em></td>
<td>60.0 b</td>
<td>1.2 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>00.0 d</td>
<td>0.0 g</td>
<td></td>
</tr>
<tr>
<td>Greenhouse</td>
<td>El-Giza</td>
<td><em>Alternaria tenuissima</em></td>
<td>00.0 d</td>
<td>0.0 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>A. tenuissima</em></td>
<td>100.0 a</td>
<td>1.0 c</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>F. geraminearium</em></td>
<td>60.0 b</td>
<td>0.8 d</td>
<td></td>
</tr>
<tr>
<td></td>
<td>El-Gharbeia</td>
<td><em>Pleospora allii</em></td>
<td>60.0 b</td>
<td>0.8 d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>F. solani</em></td>
<td>100.0 a</td>
<td>2.4 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>F. incarnatum</em></td>
<td>40.0 c</td>
<td>0.4 e</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>00.0 d</td>
<td>0.0 g</td>
<td></td>
</tr>
</tbody>
</table>

Values followed by the same letter are not significantly different at p ≤ 0.05 according to Duncan’s multiple range.
- **Seq3** \([\text{organism} = \text{Fusarium fujikuroi}]\) Z-Kh-F3, ITS1, partial sequence; 5.8S ribosomal RNA gene, and ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373436),
- **Seq4** \([\text{organism} = \text{Fusarium verticillioides}]\) Z-Kh-F4, ITS1, partial sequence; 5.8S ribosomal RNA gene, and ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373437),
- **Seq5** \([\text{organism} = \text{Geotrichum sp.}]\) Z-Kh-F5, ITS1, partial sequence; 5.8S ribosomal RNA gene, complete sequence; and ITS2, partial sequence (GenBank accession number MF373438),
- **Seq6** \([\text{organism} = \text{Alternaria tenuissima}]\) Z-Kh-F6, ITS1, partial sequence; 5.8S ribosomal RNA gene, complete sequence; and ITS2, partial sequence (GenBank accession number MF373439),
- **Seq7** \([\text{organism} = \text{Alternaria tenuissima}]\) Z-Kh-F7, 18S ribosomal RNA gene, partial sequence; ITS1, 5.8S ribosomal RNA gene, and ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373440),
- **Seq8** \([\text{organism} = \text{Alternaria tenuissima}]\) Z-Kh-F8, 18S ribosomal RNA gene, partial sequence; ITS1, 5.8S ribosomal RNA gene, and ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373441),
- **Seq9** \([\text{organism} = \text{Galactomyces candidum}]\) Z-Kh-F9, ITS1, partial sequence; 5.8S ribosomal RNA gene, and ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373435),
- **Seq10** \([\text{organism} = \text{Geotrichum sp.}]\) Z-Kh-F6, ITS1, partial sequence; 5.8S ribosomal RNA gene, and ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373434),
- **Seq11** \([\text{organism} = \text{Galactomyces candidum}]\) Z-Kh-F10, 18S ribosomal RNA gene, partial sequence; ITS1, 5.8S ribosomal RNA gene, and ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373442),
- **Seq12** \([\text{organism} = \text{Fusarium incarnatum}]\) Z-Kh-F11, ITS1, partial sequence; 5.8S ribosomal RNA gene, and ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373443),
- **Seq13** \([\text{organism} = \text{Fusarium solani}]\) Z-Kh-F12, ITS1, partial sequence; 5.8S ribosomal RNA gene, and ITS2, complete sequence; and 28S ribosomal RNA gene, partial sequence (GenBank accession number MF373444).

**Fig. 6.** Photograph of ITS-DNA amplified band for six fungal pathogenic strains (Z-Kh-F7, Z-Kh-F8, Z-Kh-F9, Z-Kh-F10, Z-Kh-F11 and Z-Kh-F12) isolated from cucumber fruit from open field cultivation (lanes: 2, 3, 4, 5, 6, 7) using ITS1 and ITS4 primers against 100 bp ladder DNA marker (lane M)

**Fig. 7.** Phylogenetic dendrogram showing the taxonomic positions of different fungal strains (Z-Kh-F1, Z-Kh-F2, Z-Kh-F3 and Z-Kh-F4) isolated from greenhouse cultivation, based on the ITS sequences and other closely related species available from NCBI
DNA sequencing of the ITS1, 5.8S, ITS2 and 28S regions was conducted for the differentiation of fungal pathogenic strains in comparison with the reference strains from GenBank. In the amplified sequences from fungal pathogenic strains with other sequences from GenBank no significant size variation could be detected between strains after alignment. Moreover, according to ITS sequences most of the fungi we isolated had 97–100% similarity with the related fungi recorded in the GenBank. Furthermore, the ITS regions of the fungal pathogenic strains have many nucleotide substitutions in comparison with the strains from GenBank. From phylogenetic analysis of the obtained sequences in comparison with the related sequences from the GenBank, the phylogenetic trees showed the taxonomic positions of six fungal strains isolated from greenhouse cultivation (Figs 7 and 8). Also, the phylogenetic trees of six fungal strains isolated from open field cultivation are presented in Figures 9 and 10.

The amplification gene and DNA sequencing have led to the detection of new pathogens as agents of disease and have enabled us to better classify microorganisms isolated from samples. DNA sequencing has greatly improved the ability to accurately and reproducibly identify plant pathogenic fungi. Fungal taxonomists have been using DNA sequences for many
years as a basis for the re-classification of all fungal taxa and have more recently moved to ITS sequencing as the “Gold Standard” (Hall et al. 2003). The obtained results are in harmony with those obtained by Barry et al. (2000); Maiko (2013); and Jeewon (2013). Alwakeel (2013) demonstrated that sequence analysis of the ITS regions of the nuclear encoded rDNA showed significant alignments for \( P. \) chrysogenum, \( P. \) adametzii and \( A. \) oryzae. Jeewon (2013) showed that the most commonly isolated fungi were related to \( A. \) s. flavus, \( A. \) oryzae and \( C. \) polymorpha. Phylogenetic analyses revealed that the recovered fungi belong to five different fungal lineages (Hypocreaceae, Trichocomaceae, Nectriaceae, Xylariaceae, and Botryosphaeriaceae). DNA data from the ITS regions were reliable in the classification of all recovered isolates up to the genus level, but identification to an exact species name was not possible at this stage.

Agwanande et al. (2016) isolated nine fungal strains which were identified through 18S rDNA sequencing. It was found that \( R. \) oryzae, \( A. \) flavus, \( A. \) oryzae and \( C. \) polymorpha were common in both maize and groundnuts. \( A. \) tamari, \( T. \) purpureogenus and \( P. \) citrinum were present only in maize, while \( A. \) parasiticus and \( R. \) stolonifer were identified only from groundnuts.

**Conclusions**

This was the first report of postharvest disease of cucumber fruits caused by several fungal genera i.e., \( G. \) candidium, \( G. \) sp., \( A. \) tenusinum, \( P. \) allii and \( F. \) spp. (\( F. \) fujikuroi, \( F. \) verticillodes, \( F. \) solani, \( F. \) geraminearium and \( F. \) incarnatum) in El Gharbeia and El Giza Governorates, Egypt. Fungal isolates were identified according to cultural and morphological characterization, PCR amplification and sequencing of ITS regions. Several new nucleotide sequences were conserved in GenBank. We can detect and classify the isolated fungal precisely and rapidly using the DNA-based technology. The usefulness of ITS sequencing has already been proved in phylogenetic analysis of the fungal pathogenic strains isolated from the surface of cucumber fruits according to the present study. Our results will be helpful for rapid detection and to further study the pathogenesis and molecular evolution of the fungal pathogenic strains.

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**References**


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