Zagazig J. Agric. Res., Vol. 44 No. (6A) 2017 2021-2041

Plant Pathology

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANGEMENT FUSARIUM EAR ROT OF MAIZE AND ITS RELATION TO DAMPING-OFF

Reham R. El-Demerdash*, Entsar E.A. Abbas, H.M. El-Said and M.M. Atia

Plant Pathol. Dept., Fac. Agric., Zagazig Univ., Egypt

Received: 12/07/2017; Accepted: 29/08/2017

ABSTRACT: Maize (*Zea mays* L.) is the 2nd most important cereal crop worldwide. Maize ear rot caused by *Fusarium verticillioides* (Sacc.) Nirenberg (synonym *F. moniliforme* J. Sheld.) was reported as the most important soil-borne fungal pathogen infecting maize grains. Three isolates of *F. verticillioides* were isolated and identified from infected fields and storage maize grain samples collected from different Districts at El-Sharkia Governorate (Zagazig, Fakous and Hehia) during 2011 and 2012 growing seasons. Pathogenicity tests revealed that Zagazig isolate was the highest pathogenic one causing post emergence damping-off and root rot followed by Fakous isolate, whereas Hehia isolate was the least effective one. These isolates were varied in their pathogenic potentiality causing maize grain rot. Maize grains in non-sterilized and none wounded shelled ear, were highly infected, followed by grains in non-sterilized and wounded covered ears, whereas covered and sterilized grains in maize ear were the least infected one. Infection with *F. verticillioides* reduced germination percentage, coleoptile height, radical growth and vigor index. Seven maize hybrid were significantly varied in their reaction against infection with *F. verticillioides* under greenhouse conditions. Tri-Hybrid 323 revealed the highest percentage of survival healthy plants, followed by Tri-Hybrid 310 while, Tri-Hybrid 352 (Giza 352) was the lowest one. Fertilization with $N_3P_2K_3$ (0.96-0.60-0.22) levels reduced pre-emergence damping-off, however, $N_2P_2K_3$ (0.77-0.60-0.22) and $N_2P_3K_2$ (0.77-0.75-0.15) reduced post-emergence damping-off, $N_1P_3K_1$ (0.58-0.75-0.075) reduced root rot and $N_1P_2K_3$ (0.58-0.60-0.22) showed the highest percentage of healthy plants. Different levels of some organic and bio-fertilizers including vegetarian and animal compost as well as biofertilizer Halex were evaluated to suppress damping-off and root/rot of maize cultirvar Giza 352. The results of using different levels of NPK, some organic and bio-fertilizers significantly improved the vegetative growth parameters of plant growth (stalk height, number of leaves /plant, stalk weight, root weight and root length).

Key words: Maize ear rot, *Fusarium verticillioides*, fertilizer, organic, pathogenicity tests**,** cultivars reaction.

INTRODUCTION

Maize is one of the most important cereal crops grown in worldwide. *F. verticillioides* is one of the most common reported soil-borne fungal pathogen infecting maize (Bacon *et al*., 2001; Tsehaye *et al*., 2017). Tsehaye *et al*. (2017) found that, from different *Fusarium* species associated with maize kernels grown in different major maize growing areas, *F. verticillioides* was the most abundant one, representing 42% of the total number of *Fusarium* isolates. *F. verticillioides* not only causes severe reductions in yields and quality, but also produces secondary metabolites such as fumonisins (FB), especially fumonisin B1 (FB1), which accumulate in the kernels and be toxic for human and animals when used for food or feed (Munkvold and Desjardins, 1997). *F. verticillioides* can be found in maize fields at

*** Corresponding author: Tel. :** +201066427788
E-mail address: reemreda623@gmail.com

different stages of maize ear development (Kedera *et al*., 1992).

Selection of resistant hybrids as host resistance are the most efficient Fusarium ear rot management strategy (Ivic *et al.,* 2008). In addition, recent breeding and heritability studies suggest that selection against visible Fusarium ear rot symptoms should be an effective way in reducing susceptibility to fumonisin contamination (Robertson *et al.,* 2006). Grains of maize cultivars varied in their inoculation with *F. verticillioides* isolate (Sallem *et al*., 2006; Orhan and Nuray, 2010; Olumayowa *et al.,* 2015).

Suppressive composts have been commonly used to control plant diseases caused by soil-borne pathogens, such as *Pythium* spp., *Fusarium* spp. and *Phytophthora* spp. (Ros *et al.,* 2005). The disease suppression capacity of the compost is attributed to the activities of antagonistic microorganisms related to the stage of composting process (Hadar and Papadopoulou, 2012). So, soils received heavy organic compost were found to have markedly higher soil microbial activity than those received heavy nitrogen applications (Tian *et al.,* 2015). In soil culture, various composts are used as fertilizers or to improve the physicochemical properties of the soil. Compost-amended soil has also been found to be effective against plant diseases caused by nematodes, bacteria or fungi in various cropping systems (Eisa *et al.,* 2013).

Compost have been used as soil amendments to enhance soil fertility but they can also improve organic matter level, biological and physical properties of the amended soil. Widespread availability use of compost in sustainable agriculture as environmentally safe bio-fertilizers and soil conditions is increasing all over the world. Composts are known to influence plant diseases caused by soil-borne pathogens (Millner *et al.,* 2004) The effects of composts on diseases in the field have been generally more variable than in greenhouse or growth room experiments (Noble and Coventry, 2005). The degree of stabilization of compost has a positive effect on disease suppressing (Garcia *et al.,* 2004). Several studies under controlled conditions have demonstrated a suppressive effect of composts on soil borne diseases such as damping-off, root rots, and wilts (Hoitink and Boehm, 1999; Eisa *et al.,* 2013). Disease suppression with compost-amended substrates and parameters affecting their efficacy has been extensively studied by Darby *et al.* (2006). They showed that composted and fresh dairy manure solids can reduce cucumber damping-off and root rots of snap bean and sweet corn.

Amending agricultural soils and soilless growing media with organic matter supplies plant nutrients, increases natural suppressiveness of the soil against soil-borne pathogens and improves physicochemical and biological characteristics (Veeken *et al*., 2005 ; Janvier *et al*., 2007). On the other hand, Yamulki (2006) reported that organic matter inputs can lead to negative effects such as temporary oxygen depletion and denitrification, nitrogen immobilization and plant pathogen stimulation. Thus, knowing the type and optimum rate of organic amendment that results in positive effects on disease suppression and plant growth is of most importance to the farmers.

In addition, compost-amended soil can modify the microbial community. Thereby, it enhances the competition and/or antagonism among microorganisms, which in turn leads to a decrease in the incidence of soil-borne diseases (Hoitink and Boehm, 1999).

In particular, nutrients could affect the disease tolerance or resistance of plants to pathogens. There is a difference in the response of obligate parasites to N supply, where high N level increased severity of the infection. In contrast, in facultative parasites at high N supply caused decrease in the severity of the infection. Potassium level decreased the susceptibility of host plants up to the optimal level for growth. In contrast phosphorous variable and seemingly inconsistent. Dordas (2005) reported that, soil nutrient of P could be considered as a key factor to control the microbial biomass and diversity in subtropical red soils. Zhong and Cai (2007), He *et al*. (2008) and Bocianowski *et al*. (2016) noted, the largest percentage of plants affected by Fusarium diseases on the control plot, while the smallest percentage appeared with NPK fertilizers combination. The occurrence of diseases decreased with the increase of potassium and lower susceptibility to pathogen was observed. Potassium plays a significant role in plants. The presence of potassium (K) resulted in an enhanced resistance of maize plants to *Fusarium* spp. In addition, applying of mineral NPK monthly during the growing seasons, improved the vegetative growth and flowering parameters (plant height, number of leaves, leaf area, leaf dry weight, number of flowers/plant, flower dry weight and leaf chemical composition parameters (El-Naggar *et al.*, 2016).

Thus, this work was designed to isolate maize ear rot pathogen that caused damping-off disease and also its pathogenicity test, varietal reactions of isolated pathogens, and the effect of organic manure and mineral fertilizers on disease incidence and vegetative growth.

MATERIALS AND METHODS

Sample Collection

Naturally infected maize ear samples (thirty ears, ten for each district) exhibit typical symptoms doubted to be due to ear rot disease were collected from different District at El-Sharkia Governorate (Zagazig, Fakous and Hehia). Samples were transferred to Plant Pathology Lab. Plant Pathology Dept., Fac. Agric. Zagazig Univ., Egypt using ice box.

Isolation and Purification of the Pathogenic Fungi

Collected samples were subjected for isolation study. The infected maize grains were surface sterilized in 1% sodium hypochlorite solution for 2 minutes, rinsed twice in sterilized distilled water, dried between two sterilized filter papers and transferred into water agar (WA) medium. Ten kernels per Petri dish were used (Parsons and Munkvold, 2012) and incubated at 27±1ºC for 7 days.

The developed fungi were recorded as percentage of frequency for all of the isolates. All the developed fungi were purified using the hyphal tip and/or single spore techniques (Dhingra and Sinclair, 1995). The purified fungi were transferred to slant of potato dextrose agar (PDA) medium and kept at 5˚C for identification and further studies.

Detection of the Isolated Fungi

The isolated fungi from maize grains were microscopically identified according to the morphological features of mycelia and asexual spores using the description of Nelson *et al.* (1983) and Barentt and Hunter (2003). The selected three isolates (ZA, FB and HA) were identified by the Fungal Taxonomy Department, Plant Pathology Research Institute, Agricultural Research Centre, Giza and confirmed using the website, http://www. doctorfungus. org/ thefungi/ Description_index.php.

Pathogenicity Tests

Pathogenicity tests of three identified isolates of *F. verticillioides*, were carried out under the greenhouse conditions at Fac. Agric., Zagazig Univ.

Inoculum preparation

Inoculum of *F. verticillioides* was prepared using autoclaved maize meal (100 g of corn grains, 80 ml tap water per flask) and incubated at 27±1ºC for three weeks.

Pots and soil disinfestation

Sterilized plastic pots (25 cm in diameter) were filled with 3kg sterilized autoclaved soil. Chemical and physical analyses of the investigated clay soil were don as shown in Table 1.

Soil infestation

Soil infestation was carried out by adding the fungal inoculum (5 g/kg soil) to the sterilized autoclaved soil. The infested soil was watered as usual and left for 10–15 days before sowing to stimulate the fungal growth and ensure its distribution in the soil. Control pots were treated in the same way using pathogen free autoclaved maize meal as described by Abd El-Rahman (2002).

Hybrid maize grains and ears were obtained from Crops Research Institute, Agricultural Research Centre, Giza, Grains were sterilized as previously mentioned and sown at the rate of 10 seeds /pot. Three replicates were used for each particular treatment.

Disease incidence was recorded as percentage of pre, post-emergence damping-off and healthy survivals at 15, 30 and 45 days after sowing, respectively. Inoculated fungi were tentatively re-isolated from the infected plants.

Table 1. Chemical and physical analyses of the investigated clay soil

Physical analysis	
Clay	36.80%
Silt	16.70%
Sand	36.90
Textural class clay caco$_3$ 0.41	
Chemical analysis	
pH	6.8
ECdsm^{-1}	200
Na	15.4
K	0.90
Ca	5.90
Mg	1.30
Co$_3$	0.91
HCo$_3$	1.40
Cl	6.80
So$_4$	16.3
Organic matter	1.62%
Avilable contents (mg/kg soil)	
N	198
P	164
K	237

Pathogenicity Tests on Maize Ears

Pathogenicity test of *F. verticillioides* on maize ears was carried out under laboratory conditions. Maize ears (hybrid Giza 352) were cut into pieces 13- to 15-cm long and air-dried at room temperature then three pieces were placed in 30 × 20-cm mesh bags, and arranged in groups as follows: A = shelled corn ear, surface sterilized and wounded with sterile syringe, B = shelled corn ear, non-sterilized and wounded, C = sterilized non -wounded shelled corn ear, D = shelled corn ear, non-sterilized non-wounded, E = sterilized corn ear with the cover. Inoculation was carried as follows, a spore suspension (10^4 spores per ml) of *F. verticillioides* was prepared from 7 days old cultures in sterile distilled water. Bagged corn ears were inoculated with *F. verticillioides* by soaking them in a spore suspension for 18 to 20 hr., then maize ears were incubated for 4 to 5 days in plastic bags at 15 to 18°C to allow colonization of corn ears tissue by the tested fungi. Corn ears were then allowed to air-dry under laboratory condition for 48 hr. Similar control treatments were done without the fungus. Three replicates were used for each particular treatment. Disease incidence was recorded as the percentage of infected grains to the healthy ones.

Infected maize grains resulted from pathogenicity tests on corn ears were sterilized as previously mentioned and sown at the rate of 10 seeds/pot. Three replicates were used for each treatment. For control, three replicates were used at the rate of 10 uninfected grains/ pot.

Disease incidence was recorded as percentage of seed rot, pre, post-emergence damping-off and healthy survivals at 15, 30 and 45 days after sowing, respectively. Inoculated fungi were tentatively re-isolated from the infected plants. Length and weight of both stalks and roots were determined as growth parameter.

Seed Germination and Seedling Growth

Infected grains of maize were surface sterilized as previously mentioned. Twenty maize grains were transferred into sterilized Petri dishs (15 cm diameters) containing two layers of Whatman No. 1 filter papers impregnated with 8 ml sterilized distilled water. Three replicates were used for each particular treatment as well as fungal free control. All Petri dishs were incubated for 4 to 5 days at 15 to 25°C to allow colonization of maize seeds tissue by the fungus. The number of germinated seeds and seedling lengths were measured after 15 days (Hanana *et al.,* 2017). The seedling vigor index (SVI) was calculated according to the formula of Abdul-Baki and Anderson (1973). As follows:

SVI = Seedling length (cm) × germination percentage (%).

Disease incidence was recorded as the percentage of germinated grains to non-germinated ones, germination (%), and radical and coleoptile length of maize seedling.

Maize Cultivars Reaction to *Fusarium verticillioides*

The susceptibility of seven maize hybrids (Tri-Hybrid321, Odd hybrid10, Odd hybrid 167, Tri-Hybrid 314, Tri-Hybrid 352, Tri-Hybrid 310 and Tri-Hybrid 323) kindly obtained from Crop Research Institute, Agricultural Research Centre, Giza, Egypt were evaluated for damping-off and/or root rot disease incidence under greenhouse conditions. Grains of tested maize cultivars were sterilized by sodium hypochloride as previously mentioned. Ten grains of each tested cultivar were sown in sterilized pots (25 cm diameter) containing *F. verticillioides* infested soil as mentioned before in pathogenicity tests. Three replicates were used for each treatment and three pots of the same hybrid were sown in un-infested soil to serve as control. Pots were arranged in completely randomized design. Disease assessment was recorded after 15, 30 and 45 days from sowing as mentioned before. The length and weight of both stalks and roots were determined as well as number of leaves per plant.

Control Studies

These experiments were conducted under greenhouse conditions to investigate the effect of organic fertilizers, biofertilizer (Halex) and mineral fertilizers on percentage of seedling damping-off and root rot diseases of maize caused by *F. verticillioides*.

Effect of Mineral Fertilizers on Maize Damping-off

Effect of three different levels of investigated NPK fertilizers (Table 2) were used to investigate their effect on the percentage of damping-off and root/rot diseases as well as survived maize plant of Giza 352 hybrid, under greenhouse conditions. The amounts of nitrogen and potassium were divided into three equal parts and added before planting as well as 20 and 34 days after planting. However, the phosphorus fertilizer was divided into two halves; the first half was added to the soil before planting and the second one was added 20 days after planting. Ten surface sterilized grains of Tri-Hybrid Giza 352 were sown in each pot (25 cm in diameter) with infested soil. Soil infestation was carried out by adding *F. verticillioides* inoculum to the sterilized autoclaved soil 3-5 g/kg soil and pots normally fertilized using recommended dose $N_2P_2K_2$ (0.77, 0.6 and 0.15g/kg soil) served as control. This experiment was carried out in a complete randomized plot design using three replicates for each treatment. Disease incidence was recorded as percentage of pre, post-emergence damping-off and healthy survivals at 15, 30 and 45 days after sowing as well as, growth parameters were recorded.

Effect of Biofertilizer (Halex) and Organic Fertilizers on Maize Damping-Off

Four organic amendments, *i.e.* animal compost, mixed compost (animal + vegetarian), vegetarian compost, and organic (Animal manure

Table 2. Amounts of NPK fertilizers used under greenhouse conditions

Mineral fertilizer		Amount (g/kg soil)
Urea	N_1	0.580
	N_2	0.77
	N_3	0.967
Calcium superphosphate	P_1	0.45
	P_2	0.60
	P_3	0.75
Potassium sulfate	K_1	0.075
	K_2	0.15
	K_3	0.225

residues). Also effect of Halex as biofertilizer (Contains bacteria stabilized for atmospheric nitrogen) was investigated. Animal compost, mixed compost, vegetarian compost were obtained from Service Center of Compost Production Unit, Moshtohor, Fac. Agric. Benha Univ. Egypt. The organic amendment (Animal manure residues) was obtained from special farm at Zagazig, El-Sharkia Governorate. Halex was kindly obtained from Al-Sonna Fertilizer and Fertilizer Company 10 Darwish St., El-Bitash, Alexandria and was used to evaluate its effect on percentage of damping-off, root/rot diseases of Tri-Hybrid Giza 352 maize cultivar, under greenhouse conditions. Each amendment was added to infested and non-infested soil. Non amended soil was used as control. The amounts of organic fertilizers were added to the soil before sowing at 20% and 40% of soil weight (*V/W*). Ten surface sterilized maize grains of Giza 352 cultivar were sown in each pot (25 cm in diameter) in soil infested with *F. verticillioides*. This experiment was carried out in a complete randomized plot design using three replicates for each particular treatment. Disease incidence was recorded as mentioned before.

Statistical Analysis

Statistical analysis of the obtained data was carried out according to the methods described by Snedecor and Cochran (1980) using computer SPSS program for ANOVA and LSD analysis.

RESULTS AND DISCUSSION

Sample Collection

Fusarium ear rot symptoms in the infected maize are generally detected on the ear tips or dispersed throughout the ear on a single kernel or clusters of kernels with white to light pinkish or salmon-colored mold (Munkvold, 2003). This symptom develops with white streaks radiating out from the stylar canal (Duncan and Howard, 2010). As the disease develops, the infected kernels will gradually obtain tan or brown color, or white streaks. This disease does not usually affect the entire ear. Nevertheless, the pathogens are able to colonize the entire corn starting from seed to kernels without the plant showing visible symptoms (Parsons and Munkvold, 2012). Mohd Zainudin *et al.* (2017) confirmed that, seeds infected with *F. verticillioides* are a source of rot and stalk infection. In addition, the fungus can be transmitted from the planted seed to the developing kernels through the mature plant. The disease caused by *F. verticillioides* include seedling blight, stalk rot, root rot, kernel rot, ear rot, and seed rot. Infection by *F. verticillioides* decreased grain yields, and quality (Ju *et al.*, 2017).

Isolation, Identification and Frequency of Fungi Associated with Infected Maize Grains

Different fungal isolates of the collected maize samples from El-Sharkia Governorate were purified. To identify the isolated fungi, morphological characterization was used as it has been previously utilized in various other studies (Leslie, 2004; Watanabe, 2010; Tsehaye *et al*., 2017).

The obtained results, diagnosed fungal isolates associated with ear and grains of maize, as *Fusarium verticillioides* (Mart.) Sacc., *Alternaria* spp., *Rhizopus* spp. and *Aspergillus* spp.

Results presented in Table 3 show that, *F. verticillioides* and *Aspergillus* spp. were the most frequent isolated fungi of all the collected diseased samples with an average 51.74 and 29.79. *Rhizopus* spp. and *Alternaria* spp. were also isolated (11.33 and 7.11), respectively.

The frequency percentage of *F. verticillioides* was the highest at Fakous province (55.55) followed by Zagazig (52.63). The frequency of *Aspergillus* spp. was the highest at Hehia (35.29) followed by Fakous (27.77), respectively. *Alternaria* spp. was the least frequent one at all the investigated localities. *F. verticillioides* was the most abundant one representing 42% of the total number of fusarial isolates (Tsehaye *et al*., 2017).

Though, the explanation for this might be due to the ability of *Fusarium* sp. to produce micro-conidia in colossal amounts, which are known to transmit through air to large distances, finally infecting yellow corn plant parts (Leslie and Summerell, 2006). However, enormous presence of this fungus may be correlated with countrified growth conditions of high temperature and a low moisture (Rheeder *et al*., 2002). The obtained results especially of both *F. verticillioides* and *Aspergillus* spp. might be due to the climatic differences of the investigated localities, irrigation water, relative humidity, the underground water level, soil type and the usual agricultural practices that might appropriate the needs of one organism rather than the others.

Results obtained in these study also support the facts enlightened by previous studies that *F. verticillioides* is an influential fungus, associated enormously with maize plants in Egypt (Sallem *et al*., 2006) as well as in other countries (Miller, 2001; Al-Juboory and Juber, 2013).

Pathogenicity Tests

Results obtained from pathogenicity tests as shown in Table 4 and illustrated by Fig. 1 carried out under greenhouse conditions reveal that, the isolated fungi varied in their pathogenic potentiality causing damping-off and root rot diseases of maize. *F. verticillioides* (Zagazig isolate) was highly pathogenic causing pre-and post-emergence damping-off, whereas Faqous isolate revealed the highest root rot percentage (11.11) and healthy survival percentage (88.9). Similar results were obtained by Tsehaye *et al*. (2017).

Several epidemiological studies reported that the amount of airborne spores of *F. verticillioides* as a potential inoculum are available for the main way of infection through the silks at flowering (Rossi *et al*., 2009; Duncan and Howard, 2010) and are significantly related to environmental and cultural practices (temperature, humidity, rainfall, crop rotation, *etc.*), level of total mycoflora and the genetic variability of *Fusarium* strains occurring in the field (Munkvold, 2003; Dorn *et al.,* 2009; Rossi *et al.,* 2009). In this respect, Bush *et al.* (2004) and Fandohan *et al.* (2005) reported an increase of disease levels associated to the moisture available and rainfall during the period from flowering to maturity that appeared to have key role in kernel infection.

Typical symptoms of damping-off and root rot diseases were observed on infected plants with severe necrosis for roots and hypocotyl, stunting of plants, yellowing of foliage, death of lower leaves, deteriorating and eventually death of plants Fig. 1. Re-isolation trials proved that, these pathogens were re-isolated from such plants showing typical damping-off and root rot disease symptoms.

Pathogenicity tests of maize ears

Obtained results of pathogenicity tests as shown in Table 5 reveal that *F. verticillioides* varied in their pathogenic potentiality causing grain rot. The shelled inoculated maize ear, non-sterilized and none wounded was highly infected 97.43% followed by shelled maize ear, non-sterilized and wounded (96.15). Whereas, treated shelled maize ear and sterilized was the least infected (9.19%). The wounds play an important

Table 3. Frequency of the isolated fungi associated with maize grains from three provinces at El Sharkia Governorate

Isolated fungi	District			Mean
	Hehia	Zagazig	Fakous	
Alternaria spp.	00.00	15.78	5.55	7.11
Rhizopus spp.	17.65	5.26	11.13	11.36
Aspergillus spp.	35.29	26.31	27.77	29.79
Fusarium verticillioides	47.06	52.65	55.55	51.74
Total	100	100	100	100
LSD at 0.05	Fungi (A)	Localities (B)	AB	
	2.40	2.77	4.80	

Table 4. Pathogenicity tests of three investigated fungi isolated from infected maize grains under greenhouse conditions

Isolates of	Disease parameter				Growth parameter		
	Pre (%)	Post (%)	Root rot (%)	Healthy (%)	Stalk weight (g)	Root weight (g)	Plant height (cm)
Zagazig	3.33	4.44	6.66	85.57	3.70	0.91	56.66
Faqous	1.11	2.22	11.11	85.56	8.96	0.68	78.00
Hehia	2.22	1.11	7.77	88.9	3.53	0.56	51.33
Control	00.00	00.00	00.00	100.00	3.08	1.47	86.33
Average	1.66	1.94	6.38	90.00	4.81	0.90	68.08
LSD at 0.5	0.50	0.17	0.42	0.08	0.31	0.60	0.13

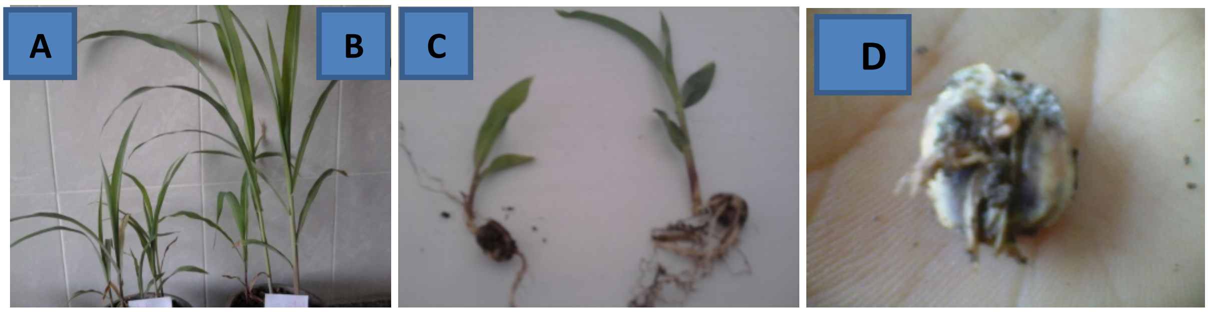

Fig. 1. Pathogenicity test under greenhouse condition of investigated fungal isolates isolated from infected maize grains. A=infected plants, B=control, C=Infected seedling and D= Infected grain

Table 5. Pathogenicity test of the isolated *Fusarium verticillioides* on maize ears

Treatment	Average number of healthy grains	Average number of infected grains	Total grains	Infection (%)
Sterilized and wounded maize ear	16.66	221.33	238	92.84
Control	273.33	23.33	296.66	7.89
Non-sterilized and wounded shelled maize ear	11.66	288.33	300	96.15
Control	295	48.33	333.33	14.07
Sterilized and non-wounded shelled maize ear	16.33	231	248	93.88
Control	292	6.00	298	2.03
Non-sterilized and non-wounded shelled maize ear	13.33	256.66	270	97.43
Control	260.33	36.33	296.66	12.65
Maize ear with the cover and sterilized	630.33	56.66	683.66	9.19
Control	292	00.00	292	00.00
Average	210.1	116.8	325.63	42.61
LSD at 0.05	0.83	10.989	0.204	6.768

role in the infection, making the fungus easier to enter the grains (Sallem *et al*., 2006). They found significant difference among maize genotypes to *Fusarium moniliform* in addition to positive correlation between ear rot for both of shank length and husk looseness degree, therefore. selection for complete cover length and short shank length lead to increasing ear rot resistance.

Obtained results in Table 6 reveal that pre-emergence damping-off (6.66%) grain rot (22.21%) and post -emergence damping-off (7.77%), root rot (39.53%) symptoms appear as elongated water-soaked areas on roots one to three weeks after planting. The cortex of severely infected plants will rub off, leaving the white stele. The pathogen extensively prunes roots, reduce overall plant growth, and can destroy much of the main root system. The water-soaked region may extend several inches above the soil line, with little, if any, visible evidence of the fungus. The water-soaked area eventually dries out, becomes somewhat sunken, and tan to brown in color. Above ground, symptoms include stunting and yellowing; eventually plants wilt and die. Slow germination and poor drainage typically result in damping-off and seedling blight. Plant parameters are also affected by pathogen. Displaying low values where stalk weight (2.58 g) root weight (2.93 g), stalk length (33.16 cm) and root length (31.03 cm) comparing with the control treatments.

Seed Germination and Seedling Growth

Fusarium verticillioides infected grains of maize were used to evaluate their reaction on damping-off (Table 7 and Fig. 2). Infection with *F. verticillioides* reduced germination percentage (51.66%) of maize seed compared to control (96.66%). Decreased coleoptile length and radical length compared to control (1.65 and 2.91 cm) and (3.26 and 8.2 cm), respectively. As well as, decreased maize vigor index were (258.81 and 1073.89), respectively.

The levels of infested soil and root colonization was correlated with reduced seedling growth, which was more pronounced at the early growth stages, while infected grains did not suppress plant growth and may even have enhanced plant development. Enhanced growth of *Fusarium*-infected plants has been previously reported and was attributed to the endophytic nature of the fungus (Yates *et al.*, 1997; Leslie *et al.*, 1990; Oren *et al*., 2003).

Table 6. Effect of *Fusarium verticillioides* infected maize seeds on disease and plant growth parameters, under greenhouse conditions

Treatment	Disease parameter					Growth parameters			
	Seed rot	Pre emergence	Post emergence	Root rot	Healthy	Stalk weight (g)	Root weight (g)	Stalk height (cm)	Root length (cm)
Infected (maize seed infected with *F. verticillioides*)	22.21	6.66	7.77	39.53	46.04	2.58	2.93	33.16	31.03
Control (non-infected)	5.44	00.00	00.00	6.78	93.22	21.93	7.03	65.65	48.79
LSD at 0.05	1.290	0.5	0.33	0.66		0.33	0.28	0.16	0.119

Table 7. Effect of *Fusarium verticillioides* on maize seed germination (%), coleoptile length, radical length and vigor index, under laboratory conditions

Treatment	Average germinated grains	Average non germinated grains	Germination (%)	Coleoptile length (cm)	Radical length	Vigor index
Corn seed inculated with *Fusarium*	10.33	9.66	51.66	1.65	3.36	258.81
Control healthy, corn seed	19.33	0.66	96.66	2.91	8.20	1073.89
LSD at 0.05	0.64	0.64	0.64	0.46	0.42	

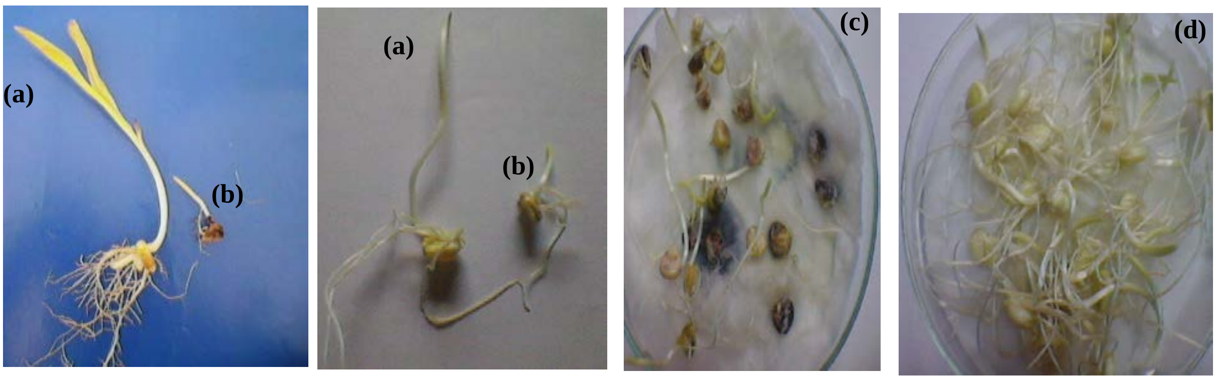

Fig. 2. Effect of *Fusarium verticillioides* on germination, radical and coleoptile length of maize, under laboratory conditions (a: healthy seedling; b : infected seedling; c: infected seeds; d: control seeds)

Maize Hybrids Reaction to *Fusarium. verticillioides*

Results presented in Table 8 indicate that, Tri-Hybrid 323 cultivar gave the highest percentage of healthy survived plants (71.11), followed by Tri-Hybrid 310 (68.89), Odd hybrid10 (63.33), Odd hybrid 167 (58.88), Tri-Hybrid 314 (54.34) and Tri-Hybrid 314 (53.39), while Tri-Hybrid 352 was the lest one (34.00). Differences Tri-Hybrid 310 (68.89), Odd hybrid10 (63.33), Odd hybrid 167 (58.88), Tri-Hybrid 314 (54.34) and Tri-Hybrid 314 (53.39), while Tri-Hybrid 352 was the least one (34.00). Differences between maize tested hybrids were significant. Results presented in Table 7 indicate that, Tri-Hybrid 321 cv. gave the highest stalk weight (1.66g) while Odd hybrid 10 gave the lowest stalk weight (0.60 g). Root weight (0.28 g), root length (8.38 cm) and stalk length (18.78 cm). Tri-Hybrid 323 cv. gave the highest root weight (0.66g), the highest root length (17.92 cm) and the highest stalk height (25.49 cm). Similar results were obtained by Sallem *et al.* (2006), they found significant difference among maize genotypes to *F. moniliform.* In addition, positive correlation between ear rot and both of shank length and husk looseness degree, therefore selection for complete cover length and short shank length lead to increasing ear rot resistance.

Differences between maize tested hybrids in their susceptibility to *F. verticillioides* might be due to different reaction by the host as a result of infection. In addition, due to their genome structure that master of various biological behaviors, chemical components of tested cultivars and their root exudates may play a part in their susceptibility. As well as, the differences in genetic make-up between maize tested cultivar and environmental conditions which might affect host pathogen relationship might play a role in their susceptibility (Abdel El-Rahman, 2002).

Table 8. Reaction of different investigated maize hybrids to *Fusarium verticillioides* infection

Maize hybrid	Disease parameter (%)				Growth parameter				
	Pre	Post	Root rot	Healthy	Stalk weight (g)	Root weight (g)	Root length (cm)	Stalk height (cm)	Germination (%)
Tri-Hybrid321	33.33	16.65	7.77	53.39	1.18	0.43	17.57	23.73	100
Control	00.00	00.00	00.00	100	1.66	0.73	24.4	27.3	100
Odd hybrid10	26.66	5.55	4.44	63.33	0.60	0.28	8.38	18.78	100
Control	00.00	00.00	00.00	100	0.818	0.465	16.28	18.989	100
Odd hybrid 167	32.22	5.50	3.33	58.88	0.62	0.579	9.285	23.42	93.33
Control	00.00	00.00	00.00	100	1.213	0.45	16.55	26.62	93.33
Tri-Hybrid 314	36.66	2.22	6.66	54.34	1.096	0.401	10.94	29.92	96.66
Control	00.00	00.00	00.00	100	1.59	0.82	24.97	34.41	96.66
Tri-Hybrid 352 (Giza 352)	53.33	4.44	7.77	34.00	0.69	0.43	8.466	20.48	100
Control	00.00	00.00	00.00	100	1.39	0.53	22.00	30.82	100
Tri-Hybrid 310	3.33	18.88	8.88	68.89	1.06	0.53	11.90	23.38	96.66
Control	00.00	00.00	00.00	100	1.29	0.865	21.62	33.76	96.66
Tri-Hybrid 323	19.99	1.11	7.77	71.11	1.171	0.66	17.92	25.49	96.66
Control	00.00	00.00	00.00	100	1.34	0.85	26.20	26.42	96.66
Average	14.68	3.88	3.33	78.85	1.12	0.57	76.15	25.96	97.61
LSD %5	13.987	3.513	0.866	36.68	3.59	2.24	13.96	2.25	00.00

Control Studies

Effect of Mineral Fertilizers on Maize Damping-off

Fertilization with $N_3P_2K_3$, $N_2P_2K_3$ and $N_2P_3K_2$ levels completely reduced pre- emergence damping-off, $N_1P_1K_1$, $N_1P_3K_1$ and $N_1P_3K_3$ level reduced post- emergence damping-off. On the other hand, fertilization using $N_1P_3K_1$, $N_2P_3K_1$ and $N_2P_3K_2$ levels reduced root rot (Tables 9 and 10). The highest percentage of healthy plants was detected in plants fertilized by the levels of $N_1P_2K_3$, $N_1P_3K_2$ and $N_2P_3K_1$ (healthy survival%) were 93.33, 91.11 and 91.10, respectively. Such results consequently followed by significant high parameters of plant growth (Table 10) especially stalk height, number of leaves/ plant, stalk weight, root weight and root length. Mineral fertilizers, *i.e.*, nitrogen, phosphorus and potassium are considered among the most important factors affected plant disease control (Abdel El-Rahman, 2002; Bocianowski *et al.*, 2016). Combination levels of $N_1P_2K_3$ gave the best disease control where low level of N make plant less succulent, P_2 increases cell rigidity and K_3 elevate cell thickness. All of these factors induce host more resistance to infection. Potassium and phosphorous fertilizers application decreased disease incidence and this might be due to reduction in activities of protopectianse, polygalacturonase, transaminase, pectin trans-eliminate and celluloses after inoculated with, thereby inhibiting disease development and increased host resistance to pathogens. Also, their effect might be attributed to contribution in thickening of plant cell wall and this might retard the penetration of fungal pathogen (Atia, 2000; Dordas, 2005; Bocianowski *et al.*, 2016). Thus, these fertilizers might be play an important role in enhancing crop productivity through application of potassium and phosphorous fertilizers and led to control at least causing a reduction of various plant diseases. Several researchers concluded that high rates of nitrogen fertilizer application increased *Fusarium* infection level in grains (Lemmens *et al*., 2004; Van der Burgt *et al*., 2011). Lemmens *et al*. (2004) explained that increasing N input changes the plant canopy density, which in turn influences microclimatic conditions in plant-soil environment and delays the flowering period, therefore creating favorable conditions for infection. Probably the low or high rate of nitrogen leads the plant to be stresses that makes them more susceptible to *Fusarium* spp. and other pathogenic micro-fungi (Blandino *et al.*, 2008).

The highest pre and post emergence in the rate of N_3 was probably due to the stress caused by nutrient deficiency; also, the plant height was lower than in other treatments. It may be caused by the fact that the macro-conidia from *Fusarium* spp. can splash disperse as high as 40, 60 cm vertically from the source (Jenkinson and Parry, 1994; Lemmens *et al.*, 2004), Dordas (2005) discusses the effect of N on contamination of pathogen depending on the type of fungi. He says that although high N application increases the severity of infestation by obligate parasitic fungi (such as *Puccinia* spp. and other diseases), it also decreased the infestation by facultative fungi (such as *Alternaria* spp., *Fusarium* spp.). In addition to interactions, repression and competitions are held between the different microorganisms, where the host plant responds with a complex of biochemical reactions, thereby becoming more susceptible or resistant to the pathogens (Dordas, 2005). The characteristic of plant density can also influence a distribution of *Fusarium* and other fungi whereas in tight plant spacing humid conditions could remain for longer than in a sparser intercrop.

Effect of Biofertilizers (Halex) and Organic fertilizers on Maize Damping-off

Results in Table 11 reveal that, fertilization with vegetarian compost (20%), mixed compost (animal + vegetarian) (40%) and organic (40%) reduced pre-emergence damping-off. Halex reduced post-emergence damping-off followed by animal compost 40%, vegetarian compost (20% and 40%), and organic (40%). Animal compost (20%) and mixed (animal + vegetarian) 40% reduced root rot. The highest percentage of healthy plants was detected in plants fertilized by Halex (96.44), followed by mixed compost (animal + vegetarian40%) (94.44), vegetarian compost 40% being (92.22) and organic 40% (92.21). Such results consequently followed by significant higher plant growth parameters (Table 8) especially stalk height, number of leaves/ plant, stalk weight, root weight and root

Table 9. Effect of NPK fertilizers on *Fusarium verticillioides* damping off disease incidence root rot and healthy plants of Tri-Hybrid Giza 352 maize cultivar, under greenhouse conditions

Inorganic fertilizers (NPK)	Disease parameter							
	Pre-emergence damping-off (%)		Post emergence damping-off (%)		Root rot (%)		Healthy survival (%)	
	Infected	Control	Infected	Control	Infected	Control	Infected	Control
$N_0P_0K_0$	7.77	4.44	10.00	00.00	19.99	2.22	62.23	93.33
$N_1P_1K_1$	8.88	00.00	00.00	00.00	7.77	1.11	83.34	98.88
$N_1P_1K_2$	5.55	00.00	3.33	00.00	6.66	00.00	84.45	100.00
$N_1P_1K_3$	4.44	00.00	5.55	00.00	4.44	00.00	85.56	98.88
$N_1P_2K_1$	17.77	00.00	6.66	00.00	8.88	1.11	76.67	98.88
$N_1P_2K_2$	17.77	00.00	4.44	00.00	8.88	00.00	78.91	100.00
$N_1P_2K_3$	12.22	00.00	2.22	00.00	4.44	1.11	93.33	98.88
$N_1P_3K_1$	18.88	00.00	00.00	00.00	3.33	2.22	87.77	97.77
$N_1P_3K_2$	13.33	00.00	2.22	00.00	3.33	00.00	91.11	100.00
$N_1P_3K_3$	1.11	00.00	00.00	00.00	8.88	00.00	89.99	100.00
$N_2P_1K_1$	4.44	00.00	13.33	00.00	6.55	00.00	76.67	100.00
$N_2P_1K_2$	4.44	00.00	7.77	00.00	6.66	1.11	81.11	98.88
$N_2P_1K_3$	3.33	00.00	6.66	00.00	31.11	1.11	58.89	98.88
$N_2P_2K_1$	3.33	00.00	8.88	00.00	16.66	00.00	71.166	100.00
$N_2P_2K_2$	2.22	00.00	7.77	00.00	7.77	00.00	83.35	100.00
$N_2P_2K_3$	00.00	00.00	6.66	00.00	14.44	00.00	78.99	100.00
$N_2P_3K_1$	4.44	00.00	1.11	00.00	3.33	00.00	91.10	100.00
$N_2P_3K_2$	00.00	00.00	7.77	00.00	3.33	00.00	88.89	100.00
$N_2P_3K_3$	4.44	00.00	5.55	00.00	6.66	00.00	82.22	100.00
$N_3P_1K_1$	2.22	00.00	1.11	00.00	15.55	3.33	81.11	96.66
$N_3P_1K_2$	5.55	00.00	3.33	00.00	36.67	1.11	72.21	98.88
$N_3P_1K_3$	1.11	00.00	3.33	00.00	17.77	00.00	77.78	100.00
$N_3P_2K_1$	2.22	00.00	1.11	00.00	15.55	00.00	81.01	100.00
$N_3P_2K_2$	3.33	00.00	2.22	00.00	32.22	1.11	63.33	98.88
$N_3P_2K_3$	1.11	00.00	17.77	00.00	11.11	00.00	71.11	100.00
$N_3P_3K_1$	5.55	00.00	13.33	00.00	12.22	00.00	68.90	100.00
$N_3P_3K_2$	2.22	00.00	2.22	00.00	22.22	1.11	73.34	98.88
$N_3P_3K_3$	1.11	00.00	1.11	00.00	17.77	00.00	80.00	100.00
Average	5.67	0.158	5.19	00.00	12.64	0.59	79.09	99.20
LSD at 0.05	27.95		37.23		48.28		13.7	

Table 10. Effect of NPK fertilizers and inoculation with *Fusarium verticillioides* on plant growth parameters of Tri-Hybrid 352 maize cultivar under, greenhouse condition

Inorganic fertilizers (NPK)	Growth parameter									
	Stalk weight (g)		Root weight (g)		Stalk height (cm)		Root length (cm)		Number of leaves/plant	
	Infected	Control	Infected	Control	Infected	Control	Infected	Control	Infected	Control
$N_0P_0K_0$	13.68	14.6	2.91	6.04	35.06	34.8	69.2	76.84	6.3	9
$N_1P_1K_1$	17.43	15.44	2.71	4.33	66.33	67.47	36.45	44.79	7.66	10.00
$N_1P_1K_2$	12.27	14.61	2.55	2.26	71.61	74.64	35.56	33.22	8.00	10.00
$N_1P_1K_3$	12.33	15.85	2.17	2.82	66.69	78.91	33.81	37.46	5.66	8.00
$N_1P_2K_1$	14.73	18.90	2.13	2.66	75.34	82.07	37.74	38.42	8.00	9.66
$N_1P_2K_2$	14.63	26.05	1.26	2.73	81.83	91.89	30.77	33.96	6.66	9.33
$N_1P_2K_3$	11.41	27.81	1.54	2.43	67.31	92.41	27.36	48.03	8.00	9.33
$N_1P_3K_1$	18.01	22.79	1.91	5.35	58.72	36.95	31.5	45.14	6.66	9.33
$N_1P_3K_2$	12.30	16.66	3.10	3.23	40.74	75.56	24.38	33.46	8.00	9.00
$N_1P_3K_3$	6.10	12.66	1.69	3.82	55.38	66.49	38.17	40.62	5.33	7.00
$N_2P_1K_1$	17.04	20.67	4.03	8.02	63.75	73.88	73.57	30.54	7.00	6.33
$N_2P_1K_2$	16.85	20.56	2.17	2.46	76.17	74.76	38.33	35.87	5.00	6.33
$N_2P_1K_3$	36.93	22.51	2.72	4.99	68.63	76.06	47.22	49.31	5.30	9.80
$N_2P_2K_1$	26.13	17.37	2.58	5.15	68.70	75.52	46.69	48.78	5.30	6.60
$N_2P_2K_2$	17.41	18.47	3.746	1.236	71.69	81.15	36.65	39.68	5.30	6.30
$N_2P_2K_3$	13.70	14.97	2.26	3.56	62.50	65.33	34.98	93.74	5.60	6.60
$N_2P_3K_1$	13.04	11.62	2.37	1.50	70.42	61.10	41.57	21.21	5.30	4.60
$N_2P_3K_2$	10.58	10.41	1.08	1.39	66.00	70.89	26.67	40.79	4.60	4.60
$N_2P_3K_3$	10.94	20.93	2.40	6.75	71.80	80.01	31.29	40.16	6.30	7.00
$N_3P_1K_1$	3.35	5.44	0.75	2.32	48.96	50.64	34.58	40.75	4.00	4.00
$N_3P_1K_2$	8.26	10.77	1.516	3.10	55.25	64.57	56.50	51.52	4.00	7.30
$N_3P_1K_3$	8.34	10.78	0.48	2.23	44.17	63.28	25.60	34.34	4.66	6.33
$N_3P_2K_1$	7.85	11.31	2.69	3.58	50.49	67.38	35.18	38.69	6.33	6.33
$N_3P_2K_2$	6.17	18.86	1.53	3.95	52.76	68.10	32.96	41.621	5.66	7.33
$N_3P_2K_3$	4.71	8.27	1.40	2.26	41.76	47.16	32.46	33.02	5.33	5.66
$N_3P_3K_1$	6.56	9.66	0.88	1.52	55.90	56.07	14.50	34.30	5.60	7.00
$N_3P_3K_2$	14.82	16.26	3.67	3.51	60.550	71.35	39.65	46.77	6.33	5.66
$N_3P_3K_3$	6.61	19.34	1.426	3.86	52.00	69.66	35.55	61.18	5.66	8.66
Average	12.93	16.19	2.13	3.46	60.73	68.50	37.46	43.36	5.98	7.39

LSD at 0.05	3.91	13.92	5.10	2.72	12.48

Table 11. Effect of organic and biofertilizers on percentage of damping off disease incidence of Tri-Hybrid Giza 352 maize cultivar and plant growth parameters, under greenhouse conditions

	Disease parameter				**Growth parameter**				
Treatment	**Pre (%)**	**Post (%)**	**Root rot (%)**	**Healthy (%)**	**Stalk weight (g)**	**Root weight (g)**	**Stalk height (cm)**	**Root length (cm)**	**Number of leaves/ plant**
Halex	1.11	00.00	2.22	96.64	206.40	10.22	104.60	54.33	9.00
Halex control	00.00	00.00	00.00	100.00	230.25	21.13	100.33	71.00	9.33
Animal 20	2.22	5.55	1.11	91.11	188.68	13.49	105.33	53.33	8.33
Control	00.00	00.00	00.00	100.00	184.73	11.01	93.33	54.00	9.66
Animal 40	1.11	1.11	6.66	91.11	169.59	8.88	91.66	52.66	8.66
Control	00.00	00.00	00.00	100.00	174.29	7.77	85.00	85.00	9.00
vegetarian 20	00.00	1.11	6.66	85.38	166.19	11.02	95.66	61.66	9.00
Control	00.00	00.00	00.00	100.00	208.19	9.02	107.33	72.00	8.66
Vegetarian 40	4.44	1.11	2.22	92.22	136.80	9.43	90.00	72.33	8.00
Control	00.00	00.00	1.11	98.88	244.41	21.44	103.00	82.33	9.33
Mixed 20	1.11	12.22	2.22	84.44	245.88	13.86	104.66	74.66	8.33
Control	00.00	00.00	00.00	100.00	198.40	13.81	98.33	80.00	10.00
Mixed 40	00.00	4.44	1.11	94.44	117.16	8.68	71.66	64.33	8.33
Control	00.00	00.00	00.00	100.00	252.16	17.23	99.66	89.66	9.00
Organic 20	00.00	12.22	2.22	85.55	190.41	10.33	79.00	81.00	8.33
Control	00.00	00.00	00.00	100.00	134.70	9.08	95.66	78.16	9.33
Organic 40	1.11	1.11	5.55	92.21	127.71	10.11	84.66	69.33	8.33
Control	00.00	00.00	10.11	98.88	144.52	8.49	89.33	66.33	8.66
Average	0.158	2.53	2.71	95.86	166.43	11.10	88.32	75.54	8.85
LSD at 0.05	1.15	2.34	1.48	9.91	.99	1.076	1.55	1.54	3.13

length. The suppressive effects of composted farmyard manure was attributed to high substrate availability with high N content (high total Organic Carbon TOC content, high available N content, and a low C/N ratio), and high microbial activity (Islam and Toyota, 2004).Other researchers also showed that the disease suppressiveness or enhancement were affected by the compost used and depending on their chemical and biological composition (Litterrick *et al.,* 2004), as well as on the pathogen involved (Termorshuizen *et al.,* 2006).

High level of disease control resulted from compost application that might be due to the role of compost on improving soil physical properties (Abd El-Mouty *et al.,* 2001).

Moreover, compost contains higher levels of relatively available nutrient elements, which are essentially required to plant growth especially nitrogen and micronutrient elements (Awad, 2002; Hafez and Mahmoud, 2004; El-Etr *et al.*, 2004). Moreover (El-Etr *et al.*, 2004; El-Desuki *et al.*, 2010) reported that the vegetative growth of pea plant (plant length, number of leaves and branches as well as fresh and dry weight of leaves and branches), green pods yield and pod quality (pod length, weight and seed weight per pods) were significantly increased by increasing the applied compost (type of compost and concentration used).

The effects of organic amendments, suggests that both chemical and biological components of compost-amended soils can contribute to disease suppression (Zhang *et al*., 1998; Abbasi *et al*., 2002; Bulluck *et al.*, 2002). However, a further characterization and understanding of the different mechanisms by which organic amendments reduce plant diseases incidence improve the disease control effect and reduce variability (Hoitink and Boehm, 1999). It also increase the spectrum of soils that can be treated.

Frequent application of organic materials such as manure or compost eventually resulted in higher substrate availability for competitors, reducing the growth of pathogens in the rhizosphere and reducing their infection rate (Hoitink and Boehm, 1999). Also, it is well known that incorporation of cow dung manure (Nishiyama *et al.*, 1999) household compost (Schönfeld *et al.*, 2003), and pig slurry have been found to reduce bacterial wilt incidence and severity. According to these facts Islam and Toyota (2004) reported that suppression of bacterial wilt of tomato (BWT) was observed in soils amended with poultry manure and farmyard manure. Suppression of bacterial wilt by pig slurry was also associated with a microbial community shift.

In general, different types of composts (garden wastes and cow manure) produced a higher number of tomato and cucumber leaves and stalks, high dry weight of leaves and stalks and a significantly better growth of seedlings (Jahromi *et al.*, 2012).

Microbial communities of compost are directly implied in the suppressive effect against plant pathogens. Therefore, differences detected on compost microbial composition could provoke an important impact on the suppressive capacity of this kind of bio-products (Hoitink and Boehm, 1999). Compost is the result of a microbial degradation and thus, the optimization of its quality is directly linked to the variable composition and the succession of the different microbial communities during the composting process (Beffa *et al*., 1996; Amir *et al.*, 2008). The microbial characterization in the final compost could be indicative of the stability and/or maturity degree of the obtained organic materials. The initial decomposers are mesophilic organisms (bacteria and fungi). In the next stage, thermophilic actinomycetes appear, and the fungal populations decrease. The final phase of composting is characterized by the development of a new mesophilic community; the actinomycetes remain and the fungi reappear along with cellulose- decomposing bacteria (Herrmann and Shann, 1997; Amir *et al*., 2008). The suppressive effects of several composts from different origin towards soil-borne fungal plant pathogens have been described (Szczech, 1999; Kavroulakis *et al*., 2005; Termorshuizen *et al*., 2006; Suárez-Estrella *et al.*, 2007; Joshi *et al*., 2009).

REFERENCES

Abbasi, P.A., J. Al-Dahmani, F. Sahin, H.A.J. Hoitink and S.A. Miller (2002). Effect of compost amendments on disease severity and yield of tomato in conventional and organic production systems. Plant Dis., 86: 156-161.

Abd El-Mouty, M.M.A., H. Ali and F.A. Rizk (2001). Potato yield as affected by the interaction between bio and organic fertilizers. Egypt. J. Appl. Sci., 16 (6): 267-286.

Abd El-Rahman, Hanaa (2002). Studies on some soil borne fungi infesting cowpea plants. M.Sc. Thesis, Fac. Agric., Zagazig Univ., 103.

Abdul-Baki, A.A. and J.D. Anderson (1973). Vigor determination in soybean seed by multiple criteria. Crop Sci., 13: 630 - 641.

Al-Juboory, H.H. and K.S. Juber (2013). Efficiency of some inoculation methods of *Fusarium proliferatum* and *F.verticilloides* on the systemic infection and seed transmission on maize under field conditions. Agric. Biol. J. N. Ame., 4 (6): 583-589.

Amir, S., G. Merlina, E. Pinelli, P. Winterton, J.C. Revel and M. Hafidi (2008). Microbial community dynamics during composting of sewage sludge and straw studied through phospholipid and neutral lipid analysis. J. Hazardous Materials, 159: 593-601.

Atia, M.M.M. (2000). Studies on tomato late blight caused by *Phytophtora infestans*. Ph.D. Thesis., Fac. Agric., Zagazig Univ., Egypt, 206

Awad, E.M. (2002). Effect of compost and some bio-fertilizers on growth, yield and quality of potato crops (*Solanum tubersum*, L.). J. Agric. Sci, Mansoura Univ., 27 (8): 5525-5537.

Bacon, C.W., I.E. Yates, D.M. Hinton and F. Meredith (2001). Biological control of *Fusarium moniliforme* in maize, Environ. Health Persp., 109 (2): 325–332.

Barnett, H.L. and B.B. Hunter (2003). Illustrated Genera of Imperfect fungi. 4th Ed. Burgess Publishing Company Minneapolis 15, Minn.

Beffa, T., M. Blanc, P.F. Lyon, G. Vogt, M. Marchiani, J.L. Fischer and M. Aragno (1996). Isolation of *Thermus* strains from hot composts (60 to 80ºC). Appl. Environ. Microbiol., 62: 1723-1727.

Blandino, M., A. Reyneri and F. Vanara (2008). Influence of nitrogen fertilization on mycotoxin contamination of maize kernels. Crop Prot., 27: 222- 230.

Bocianowski, J., P. Szulc, A. Tratwal, K. Nowosad and D. Piesik (2016). The influence of potassium to mineral fertilizers on the maize health. J. Integrative Agric., 15 (6): 1286–1292

Bulluck, L.R., M. Brosius, G.K. Evanylo and J.B. Ristaino (2002). Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. Appl. Soil Ecol., 19: 147-160.

Bush, B.J., M.L. Carson, M.A. Cubeta, W.M. Hagler and G.A. Payne (2004). Infection and fumonisin production by *Fusarium verticillioides* in developing maize kernels. Phytopathology, 94: 88–93.

Darby, H.M., A.G. Stone and R.P. Dick (2006). Compost and manure mediated impacts on soil-borne pathogens and soil quality. Soil Sci. Soc. Ame. J., 70: 347-358.

Dhingra, O.D. and J.B. Sinclair (1995). Basic Plant Pathology Methods, Second Edition, Boca Raton, Florida: CRC Press. Inc., 434.

Dordas, C. (2005). Role of nutrients in controlling plant diseases in sustainable agriculture. A review. Agron. Sust. Develop., 28:33 -46.

Dorn, B., H.R. Forrer, S. Shcurch and S. Vogelgsang (2009). *Fusarium* species complex on maize in Switzerland: occurrence, prevalence, impact and mycotoxins in commercial hybrids under natural infection. Eur. J. Plant. Pathol., 125: 51–61.

Duncan, K.E. and R.J. Howard (2010). Biology of maize kernel infection by *Fusarium verticillioides*. Mol. Plant Microbe Interact., 23 (1): 6–16.

Eisa, N.A., M.A. Hafez, M.M.A. Khalifa, Kh.E. Eid and H.A.M.M. Mahdy (2013). Effect of different types of compost in combination with some biological agents and folicur fungicide on onion white rot disease. J. Appl. Sci. Res., 9(4): 2803-2810.

El-Desuki, M., M.M. Hafez, A.R. Mahmoud and F.S. Abd El-Al (2010). Effect of organic and bio fertilizers on the plant growth, green pod yield, quality of pea. Int. J. Acad. Res., 2 (1): 87-92.

El-Etr, W.T., L.K.M. Ali and E.L. El-Khatib (2004). Comparative effects of bio-compost and compost on growth yield and nutrients content of pea and wheat plants grown on sandy soils. Egypt. J. Agric. Res., 82 (2): 73-94.

El-Naggar, A.H., M.N. Esmaiel and A.A. El-Naggar (2016). Effect of mineral and bio-fertilization on vegetative growth and flowering of *Anthurium andreanum* L. plants under greenhouse conditions. Alex. Sci. Exchange J., 37 (1): 1123-1140

Fandohan, P., B. Gnonlonfin, K. Hell, W.F. Marasas and M.J. Wingfield (2005). Natural occurrence of *Fusarium* and subsequent fumonisin contamination in pre-harvest and stored maize in Benin, West Afri. Int. J. Food Microbiol., 99:173–183.

Garcia, C., J.A. Pascual, E. Mena and T. Hernández (2004). Influence of the stabilization of organic materials on their bio pesticide effect in soils. Bio Res. Technol., 95 (2): 215-221.

Hadar, Y. and K.K. Papadopoulou (2012). Suppressive composts: microbial ecology links between abiotic environments and healthy plants. Ann. Rev. Phytopathol., 50: 133-153.

Hafez, M.M. and A.R. Mahmoud (2004). Response of snap bean (*Phaseolus vulgaris* L.) to nitrogen fertilizer source. Ann. Agric. Sci., Mashtohor, 42(1): 261-270.

Hanana, M., M.B. Mansour, M. Algabr, I. Amri, S. Gargouri, A. Romane, B. Jamoussi and L. Hamrouni (2017). Potential use of essential oils from four Tunisian species of *Lamiaceae*: Biological alternative for fungal and weed control. Rec. Nat. Prod., 11 (3): 258-269.

He, J.Z., Y. Zheng, C.R. Chen, Y.Q. He and L.M. Zhang (2008). Microbial composition and diversity of an upland red soil under long term fertilization treatments as revealed by culture dependent and culture independent approaches. J. Soils Sediments, 8:349–358.

Herrmann, R.F. and J.F. Shann (1997). Microbial community changes during the composting of municipal solid waste. Microb. Ecol., 33: 78-85.

Hoitink, H.A. and M.J. Boehm (1999). Bio-control within the context of soil microbial communities: A substrate dependent phenomenon. Ann. Rev. Phytopathol., 37: 427-446.

Islam, T.M.D. and K. Toyota (2004). Suppression of bacterial wilt of tomato by *Ralstonia solanacearum* by incorporation of composts in soil and possible mechanism. Microbes Environ., 19: 53-60.

Ivic, D., M. Cˇabric´, B. Palaveršic and B. Cvjetkovic´ (2008). No correlation between pericarp thickness and fusarium ear rot in Croatian maize hybrids and lines. May Di. Ck., 5: 297-301.

Jahromi, M.G., A. Aboutalebi and M.H. Farahi (2012). Influence of different levels of garden compost (garden wastes and cow manure) on growth and stand establishment of tomato and cucumber in greenhouse condition. Afri. J. Biotechnol., 11 (37): 9036-9039.

Janvier, C., F. Villeneuve, C. Alabouvette, Edel-V. Hermann, T. Mateille and C. Steinberg (2007). Soil health through soil disease suppression: Which strategy from descriptors to indicators. Soil Biol. and Biochem., 39 : 1-23.

Jenkinson, P. and D.W. Parry (1994). Splash dispersal of conidia of *Fusarium culmorum* and *Fusarium avenaceum*. Mycol. Res., 98:506- 510.

Joshi, D., K.S. Hooda, J.C. Bhatt, B.L. Mina and H.S. Gupta (2009). Suppressive effects of composts on soil-borne and foliar diseases of French bean in the field in the western Indian Himalayas. Crop Prot., 28: 608-615.

Ju, M., Z. Zhou, C. Mu, X. Zhang, J. Gao, Y. Liang and J. Wen (2017). Dissecting the genetic architecture of *Fusarium verticillioides* seed rot resistance in maize by combining QTL mapping and genome-wide association analysis. Scien. Rep., 7.

Kavroulakis, N., C. Ehaliotis, S. Ntougias, G.I. Zervakis and K.K.P. Apadopoulou (2005). Local and systemic resistance against fungal pathogens of tomato plants elicited by compost from agricultural residues. Physiol. and Molec. Pl. Pathology., 66 : 163-174.

Kedera, C.J., J.F. Leslie and L.E. Claflin (1992). Systemic infection of corn by *Fusarium verticillioides*. Phytopathology, 82: 118.

Lemmens, M., K. Haim, H. Lew and P. Ruckenbauer (2004). The effect of nitrogen fertilization on fusarium head blight development and deoxynivalenol contamination in wheat. J. Phytopathology, 152: 1 8.

Leslie, J.F. (2004). Interfertility of two mating populations in the *Gibberella fujikuroi* complex. Euro. J. Pl. Pathology, 110: 611-618.

Leslie, J.F. and B.A. Summerell (2006). The *Fusarium.* Laboratory Manual. Blackwell Publishing, IA, USA, 388.

Leslie, J.F., C. Pearson, P. Nelson and T. Toussoun (1990). *Fusarium* spp. from corn, sorghum, and soybean fields in the central and Eastern United States. Phytopathology, 80: 343–350.

Litterick, A.M., L. Harrier, P. Wallace, C.A. Watson and M. Wood (2004). The role of un composted materials, composts, manures and compost extracts in reducing pest and disease incidence and severity in sustainable temperate agricultural and horticultural crop production- A Review. Critical Rev. Pl. Sci., 23: 853-884.

Miller, S.D. (2001). Factors that affect the occurrence of fumonisin. Environ. Health. Persp., 109 (2): 321-324.

Millner, P.D., C.E. Ringer and J.L. Maas (2004). Suppression of strawberry root disease with animal manure composts. Compost Sci. Utiliz., 12: 298-307.

Mohd Zainudin, N.I., F.A. Hamzah, N.A. Kusai, N.S. Zameri and S. Salleh (2017). Characterization and pathogenicity of *Fusarium proliferatum* and *Fusarium verticillioides*, causal agents of Fusarium ear rot of corn Turk. J. Biol., 41: 220-230.

Munkvold, G.P (2003). Epidemiology of Fusarium diseases and their mycotoxins in maize ears. Eur. J. Plant Pathol., 109: 705-713.

Munkvold, G.P. and A.E. Desjardins (1997). Fumonisins in maize: can we reduce their occurrence. Pl. Dis., 81: 556–565.

Nelson, P.E., T.A. Tousoun and W.F. Marasas (1983). Fusarium species: An Illustrated Manual For Identification. The Pennsylvania State Univ. Press, 193.

Nishiyama, M., Y. Shiomi, S. Suzuki and T. Marumoto (1999). Suppression growth of *Ralstonia solanacearum*, tomato bacterial wilt agent, on/in tomato seedlings cultivated in a suppressive soil. Soil Sci. and Pl. Nut., 45: 79-87.

Noble, R. and E. Coventry (2005). Suppression of soil-borne plant diseases with composts: A review. Biocontrol Sci. Technol., 15: 3-20.

Olumayowa, O., O. Odunayo and O. Adegboyega (2015). Response of maize genotypes to *Fusarium verticillioides* strains from two agro ecological zones in Southwest Nigeria. Int. J. Pure Appl. Sci. Technol., 27 (2) : 77-86.

Oren, L., S. Ezrati, D. Cohen and A. Sharon (2003). Early events in the *Fusarium verticillioides*-maize interaction characterized by using green fluorescent protein expressing transgenic isolate. Appl. and Environ. Microbiol., 69: 1695-1701.

Orhan, B. and O. Nuray (2010). Reactions of local maize cultivars to *Fusarium verticillioides* based on disease severity and production of pectolytic enzymes and zearalenone toxin. J. Turk. Phytopath., 39 (1): 19-29.

Parsons, M.W. and G.P. Munkvold (2012). Effects of planting date and environmental factors on Fusarium ear rot symptoms and fumonisin B1 accumulation in maize grown in six North American locations. Plant Pathol., 61: 1130-1142.

Rheeder, J.P., W.F. Marasas and H.F. Vismer (2002). Production of fumonisin analogs by *Fusarium* species. Appl. Environ. Microbiol., 68: 2101-2105.

Robertson, L.A., C.E. Kleinschmidt, D.G. White, G.A. Payne, C.M. Maragos and J.B.

Holland (2006). Hertiabilities and correlations of Fusarium ear rot resistance and fumonisin contamination resistance in two maize populations. Crop Sci., 46: 353-361.

Ros, M., M.T. Hernlndez, C. Garca, A. Bernal and J.A. Pascual (2005). Bio pesticide effect of green compost against fusarium wilt on melon plants. J. Appl. Microbiol., 98: 845–854.

Rossi, V., A. Scandolara and P. Battilani (2009). Effect of environmental conditions on spore production by *Fusarium verticillioides*, the causal agent of maize ear rot. Eur. J. Plant Pathol., 123: 159–169.

Sallem, M.A., H.A. Awaad, M.M.M. Atia, M.I.S.D. El-Sherbiny and M.I.E. Abd El Hamid (2006) Inheritance of ear rot resistance and grain yield in maize. Egypt. J. Appl. Sci., 21(7):143-158.

Schönfeld, J.A., L.S. Gelsomino, A. Van Overbeek, K.S. Gorissen and J.D. Van Elsas (2003). Effects of compost addition and stimulated solarization on the fate of *Ralstonia solanacearum* biovar 2 and indigenous bacteria in soil. FMES Microbiol. Ecol., 43: 63-74.

Snedecor, G.W. and W.G. Cochran (1980). Statistical Methods. Oxford and J.P.J. Publishing Com. 7th Ed.

Suárez-Estrella, F., M.C. Vargas-García, M.J. López C. Capel and J. Moreno (2007). Antagonistic activity of bacteria and fungi from horticultural compost against F*usarium oxysporum* f.sp. *melonis*. Crop Prot., 26: 46-53.

Szczech, M.M. (1999). Suppressiveness of vermin compost against Fusarium wilt of tomato. J. Phytopathol., 147: 155-161.

Termorshuizen, A.J., E. Van Rijn; D.J. Van der Gaag. C. Alabouvettec. Y. Chen. J. Lagerlöf. A.A. Malandrakis. E.J. Paplomatas. B. Rämert. J. Ryckeboerg. C. Steinberg and S. Zmora-Nahum (2006). Suppressiveness of 18 composts against 7 pathosystems: Variability in pathogen response. Soil Biol. and Biochem., 38: 2461-2477.

Tian, W., L. Wang and Y. Li (2015). Responses of microbial activity, abundance, and community in wheat soil after three years of heavy fertilization with manure-based compost and inorganic nitrogen. Agric Ecosyst Environ., 213:219–227.

Tsehaye, H., M.B. Brurberg, L. Sundheim, D. Assefa, A. Tronsmo and A.M. Tronsmo (2017). Natural occurrence of *Fusarium* species and fumonisin on maize grains in Ethiopia. Eur J. Plant Pathol., 147:141–155

Van der Burgt, G.J., B.G. Timmermanns, J.M. Scholberg and A.M. Osman (2011). Fusarium head blight and deoxynivalenol contamination in wheat as affected by nitrogen fertilization. Wageningen J. Life Sci., 58:123 -129.

Veeken, A.H.M., W.J. Blok, F. Curci, G.C.M., Coenen, A.J. Termorshuizen and H.V.M. Hamelers (2005). Improving quality of composted biowaste to enhance disease suppressiveness of compost-amended, peat-based potting mixes. Soil Biol. and Biochem., 37: 2131-2140.

Watanabe, T. (2010). Pictorial Atlas of Soil and Seed Fungi: Morphologies of Cultured Fungi and Key to Species, 3rd Ed. CRC Pres.

Yamulki, S. (2006). Effect of straw addition on nitrous oxide and methane emissions from stored farmyard manures. Agric., Ecosystems and Environ., 112: 140-145.

Yates, I.E., C.W. Bacon and D.M. Hinton (1997). Effects of endophytic infection by *Fusarium moniliforme* on corn growth and cellular morphology. Plant Dis., 81: 723-728.

Zhang, W., D.Y. Han, W.A. Dick, K.R. Davis and H.A.J. Hoitink (1998). Compost and compost water extract-induced systemic acquired resistance in cucumber and Arabidopsis. Phytopathology, 88: 450-455.

Zhong, W.H. and Z.C. Cai (2007). Long-term effects of inorganic fertilizers on microbial biomass and community functional diversity in a paddy soil derived from quaternary red clay. Appl. Soil Ecol., 36: 84–91.

مكافحة عفـــن الكيزان الفيـوزاريومـــي فـــي الـــذرة الشــــامية وعلاقتـــه بمـــوت البـادرات

ريهام رضا الدمرداش - انتصار السيد عبد النبي عباس- هاني محمد السعيد- محمود محمد عطيه

قسم أمراض النبات – كلية الزراعة – جامعة الزقازيق - مصر

يعتبر محصول الذرة الشامية واحداً من أهم محاصيل الحبوب علي مستوي العالم حيث يحتل المرتبة الثانية بعد محصول القمح، ويعتبر مرض عفن الكيزان الوردي المتسبب عن الفطر فيوزاريم فيرتسيلويدس أحد أهم الفطريات القاطنة في التربة والتي تصيب الذرة، تم إجراء عزل وتعريف الفطر المسبب للمرض من كيزان الذرة المصابة والتي تم الحصول عليها من عدة مراكز بمحافظة الشرقيه (فاقوس - ههيا - الزقازيق) خلال الموسم الزراعي ٢٠١٢/٢٠١١، وقد كانت عزلة الزقازيق أكثر قدرة على إحداث المرض بينما عزلة ههيا كانت الأقل قدرة علي إحداث المرض، وقد وجد أن كيزان الذرة المعداه العارية وغير المعقمة وغير المجروحة الأكثر إصابة يليها كيزان الذرة المغطاة وغير المعقمة والمجروحة، بينما كانت الكيزان المغطاة والمعقمة هي الأقل إصابة، كما اختلفت أصناف الذرة المختبرة في حساسيتها للإصابة بموت البادرات تحت ظروف الصوبة، وقد كان الهجين الثلاثي ٣٢٣ الأقل إصابة حيث أظهر أعلى نسبة من النباتات السليمة تلاه الهجين الثلاثي ٣١٠، بينما كان الهجين الثلاثي ٣٥٢ هو الأكثر إصابة، وقد أدي التسميد بالمستوى $N_3P_2K_3$ إلى خفض نسبة موت البادرات قبل الظهور فوق سطح التربة والمستويات $N_2P_2K_3$ و$N_2P_3K_2$ قللت من موت البادرات بعد الظهور فوق سطح التربة، بينما قلل المستوي $N_1P_3K_1$ من عفن الجذور، أدت إضافة الكمبوست النباتي بنسبة ٢٠% والكمبوست المختلط بنسبة ٤٠% (حيواني + نباتي) والمخلفات الحيوانية العضوية بنسبة ٤٠% إلى تقليل موت البادرات قبل الظهور فوق سطح التربة، وقد أدي المخصب الحيوي الهاليكس إلى تقليل موت البادرات بعد الظهور فوق سطح التربة يليه الكمبوست الحيواني بنسبة ٤٠% والكمبوست النباتي بنسبة ٢٠% و٤٠% والمخلفات الحيوانية العضوية بنسبة ٤٠%، وعلى صعيد آخر قلل الكمبوست الحيواني بنسبة ٢٠%، الكمبوست المختلط بنسبة ٤٠% من نسبه عفن الجذور، بينما كانت أكبر نسبة للنباتات السليمة في المعاملة بالمخصب الحيوي هاليكس، يليه الكمبوست المختلط بنسبة ٤٠% والكمبوست النباتي بنسبة ٤٠% ثم المخلفات الحيوانية العضوية بنسبة ٤٠%.

المحكمـون:

١- أ.د. علـــى محمـــد كـريم أستاذ أمراض النبات المتفرغ – كلية التنمية والتكنولوجيا – جامعة الزقازيق.

٢- أ.د. دولت أنور عبدالقادر أستاذ أمراض النبات المتفرغ – كلية الزراعة – جامعة الزقازيق.