Egyptian Journal of Phytopathology, Vol. 49, No. 2, pp 10 – 28 (2021)
DOI 10.21608/ejp.2021.79498.1036

ORIGNAL PAPER

Performance of Soil Type, Cyanobacterium *Spirulina platensis* and Biofertilizers on Controlling Damping-off, Root Rot and Wilt Diseases of Moringa (*Moringa oleifera* Lam.) in Egypt

Imara, D.A.; Zaky, W.H. and Ghebrial, E.W.R.*

Received: 07 June 2021 / **Accepted**: 12 July 2021 / **Published online**: 17 July 2021.

ABSTRACT

The present study was carried out under pot experiments during 2019 and 2020. Four fungi were isolated from naturally infected moringa roots. *Sclerotium rolfsii* was the most frequently isolated fungus, followed by *Fusarium oxysporum*, while *Fusarium solani* and *Rhizoctonia solani* were the least frequent ones. *S. rolfsii* followed by *F. oxysporum* were the most virulent isolated fungi that caused the highest percentages of pre- and post-emergence damping-off, root rot and/or wilt. While, *F. solani* showed the lowest effect in this respect. Sandy soil followed by mixture of sandy + clay soil (2:1 w/w) were the best for decreasing pre- and post-emergence damping-off as well as root rot and/or wilt diseases and increasing percent of survived plants compared to clay soil. Cyanobacterium, *Spirulina platensis* and the mixture of biofertilizers, *i.e.*, nitrobein, phosphorein and potasiomag, as well as Topsin-M fungicide were effective to control the tested pathogens. All the tested treatments were capable to cause significant reduction of damping-off, root rot and/or wilt diseases and increase the percent of survived plants when used as soil treatments. Also, they significantly increased herb fresh weight/plant (g) and fresh weight of tuber (g) as well as no. of new plants, herb fresh weight of new plant (g), fresh weight of new tuber (g) and nutrients content in moringa leaves compared with control treatment. The biofertilizers proved to be the most effective treatment in this regard.

Keywords: *Moringa oleifera*, damping-off, root rot, wilt, soil types, *Spirulina platensis* and biofertilizers.

***Correspondence: Ghebrial, E.W.R.**
dr.emanwageeh@yahoo.com
Doaa A. Imara
https://orcid.org/0000-0003-1439-2722
Wafaa H. Zaky
Eman W.R. Ghebrial
https://orcid.org/0000-0001-8837-0994
Plant Pathology Research Institute, Agricultural Research Center, 12619, Giza, Egypt.

INTRODUCTION

Moringa (*Moringa oleifera* Lam.) belonging to the family Moringaceae is an economically significant typical multipurpose tree, owing to the wide variety of high-quality nutritional products it produces, as well as its exceptional medicinal properties and use in animal and human nutrition, which can be derived from its leaves and fruits (Dalla Rosa, 1993; Amaglo, 2006; Pérez *et al*., 2010 and Martín *et al*., 2013). Moringa is an outstanding source for nutritional component necessity. Its leaves contain calcium 17 times that of milk, vitamin-C 7 times that of oranges, potassium 15 times that of bananas, iron 25 times that of spinach, vitamin-A 10 times that of carrots and protein 9 times that of yoghurt. Hence, it is considered as a powerhouse of nutritional value, which makes it effective remedy for malnutrition (Rockwood *et al.*, 2013).

Moringa is attacked by root rot and wilt diseases caused by *Fusarium oxysporum*, *Fusarium solani*, *Rhizoctonia solani*, *Sclerotium rolfsii* and *Macrophomina phaseolina*, which are considered the most serious pathogens affecting moringa in Egypt and worldwide (El-Mohamedy *et al.*, 2014; Lezcano *et al.*, 2014 and Ziedan *et al.*, 2016) leading to significant losses every year. Epidemics of soil-borne diseases depend on interactions between the disease development and soil environment (Otten and Gilligan, 2006). Soils possess different electric conductivity (EC), pH (alkaline and acid character), organic manure, soil texture (ratio of sand, silt and clay particles) and inhibitory volatile fungistatic compounds which consequently alters the activity of soil borne plant pathogens (Ma *et al.*, 2001). Successful control of such diseases has been obtained by using a wide array of fungicides, but the application of chemical fungicides is extensive, harmful to human, living organisms and the environment, development of fungicidal resistance populations of the pathogen (Pimentel *et al.*, 1992 and Chen *et al.*, 2007). A promising strategy for the replacement of chemical fungicides has been implemented in biological control. The plant growth promoting

rhizobacteria (PGPR), viz. *Azotobacter* sp., *Azospirillum* sp., *Bacillus megaterium* and *B. mucilaginosus* produce biologically active compounds (antibiotics and toxic substances) that have antifungal activity (El-Mohamedy and Ahmad, 2009; Almeida *et al.*, 2011; Ismail *et al.*, 2011; Abdel-Monaim *et al.*, 2012 and Amin *et al*., 2017). However, biofertilizers became a positive alternative to chemical fertilizers. Because they are the most important for plant production and soil health in general as they play an important and complex role in plant growth, improving fruit quality and yield components of crops by way of various biochemical activities in the soil such as increases the soil fertility naturally, add nutrients through the natural processes, biological N fixation, solubilizing phosphorus, the availability of nutrients by their biological activity and uptake of nutrients (Sharma *et al.*, 2009; Baset *et al.*, 2010; El-Khawaga and Maklad, 2013). Cyanobacteria are considered one of the main biological agents that have been studied for the control of plant pathogens, particularly soil borne fungi. This is mainly due to producing various biologically active compounds such as antibiotics, antifungal and toxins, where these could operate in biological control of plant pathogens (Carmichael, 1992; Kulik, 1995; Skulberg, 2000; Noaman *et al.*, 2004 and Abedin and Taha, 2008) and increasing crop parameters of the plants (Jufri *et al.*, 2016). *Spirulina platensis* (*Arthrospira platensis*), a microscopic and filamentous cyanobacterium, has been recently recommended as a sustainable, highly nutritional and ecofriendly microalga (Eleiwa *et al.*, 2018). Spirulina contains potent antioxidants, free-radical scavengers and is able to inhibit the growth of some Gram-negative, Gram-positive bacteria and yeast such as *Candida albicans* (Marangoni *et al*., 2017). Polysaccharides extracted from Spirulina have antitumor, antioxidation, antiaging and antivirus properties (Choi *et al*., 2019). Nevertheless, little information about antifungal properties, especially against mycotoxigenic and phytopathogenic fungi, of *Spirulina platensis* is available in the literature and its potential toxic effects have not been largely investigated.

The objective of the present study was to evaluate soil type, *Spirulina platensis* and biofertilizers on controlling damping-off, root-rot and/or wilt diseases as well as growth parameters and chemical constituents of moringa plants.

MATERIALS AND METHODS

The present study was carried out at Medicinal, Aromatic and Ornamental Plant Dis. Dept., Plant Pathol. Res. Ins., Agric. Res. Center, Giza, Egypt, during 2019 and 2020 to evaluate soil type, *Spirulina platensis* and biofertilizers on controlling damping-off, root-rot and/or wilt diseases as well as growth parameters and chemical constituents of moringa plants. The seeds of moringa were obtained from twenty-year-old trees, grown in the tropical garden of Kom-Ombo, Aswan, Egypt.

Isolation, purification, and identification of the causal pathogens:

Samples of moringa seedlings and plants exhibited root rot and wilt symptoms were collected from different locations in Giza, Egypt. Roots were washed thoroughly with running tap water to remove any adhering soil particles. The entire stem and the main root were cut into small pieces, surface disinfested with 2% sodium hypochlorite solution for 2 min, rinsed three times in sterilized water and dried between sterilized filter papers. The surface sterilized pieces were then transferred onto Potato Dextrose Agar (PDA) medium in Petri dishes (9 cm in diam.) and incubated at 25±2°C in the dark for 7 days with daily observation for the occurrence of fungal growth. The developed fungal colonies were picked up and purified using the single spore or hyphal tip techniques and identified at the Mycol. and Plant Dis. Survey Dept., Plant Pathol. Res. Inst., Agric. Res. Center., Giza, Egypt according to their morphological characters using light microscope as described by Gilman (1957), Booth (1971) and Singh (1982). The frequency of the isolated fungi was calculated according to the following formula (Ahmed *et al.*, 2017).

$$\textbf{Frequency \%} = \frac{\text{No of fungal colonies of each isolated fungus}}{\text{Total Number of fungal colonies of all isolated fungi}} \times 100$$

Pathogenicity test of the isolated fungi:

The pathogenic potentialities of each purified isolated fungus, *i.e., F. solani*, *F. oxysporum*, *R. solani* and *S. rolfsii* were tested using moringa plants in pot experiment**.** Inocula of the four tested fungi were grown on sterilized sand corn medium (SCM) according to Ziedan (2003) for 15 days at 25±2°C. Clay pots (25 cm in diameter) were soaked in 5% formalin solution for 10 min and left to dry in open air for two weeks. While clay soil was sterilized by adding 5% formalin solution and covered with

polyethylene sheets for 7 days, then left uncovered for 10 days in order to be free from formaldehyde. Formalin-sterilized pots were filled with the formalin-sterilized soil at the rate of 3 kg soil/pot. The inoculum of the desired tested fungus at the rate of 3% (w/w) was mixed with the soil to ensure the distribution of the tested pathogens then watered daily for one week. Sterilized uninoculated sand corn medium was added to the disinfested soil at the same rate for healthy control treatment. Apparently healthy seeds of moringa were superficially sterilized with 1% sodium hypochlorite for 2 min. and washed several times with sterilized water, then left to dry for 6 hours, and then planted in the infested soil (4 seeds /pot). The experimental pots were arranged as randomized complete block design with 3 replicates for each isolate with a negative control (uninoculated). Re-isolation from the roots of the plants was carried out to fulfill the steps of etiology studying as Koch's postulates.

Effect of the Soil Type:

The highly virulent three fungi, *i.e., F. oxysporum, R. solani* and *S. rolfsii* were selected and separately used in this experiment. Soil infestation was carried out as mentioned under Pathogenicity test. The seeds were sown in sterilized clay pots (25 cm in diameter) filled with clay or sand individually and/or mixture of clay + sand (2:1w/w) soil at the rate of 4 seeds/pot. The pots were irrigated regularly as necessary, throughout the present study to maintain constant growth. Other agricultural procedures were performed according to normal practice**.** The experiment was set in a randomized complete blocks design with two factors, under natural conditions of day length and light intensity with three replications for each treatment. The first factor assigned to the tested soil type and the second one to the three tested fungal isolates.

Control Studies:

Cyanobacterium *Spirulina platensis* and the tested biofertilizers were used as biocontrol agents for controlling damping-off, root-rot and/or wilt diseases under artificially infested soil with each of the three tested fungal isolates as mentioned before in comparison with Topsin-M fungicide. The cyanobacterium (*Spirulina platensis*) was kindly obtained from Dept. of Microbiol., Soil, Water & Environ. Res. Inst., ARC, Giza, Egypt. *S. platensis* (previously grown in Zarrouk medium for 1 month (Zarrouk, 1966) was applied at the rate of 40 ml/pot. On the other hand, the three biofertilizers used namely, nitrobein (*Azotobacter* sp. and *Azospirillum* sp. at 10^7 CFU/g) as a nitrogen fixers, phosphorein (*Bacillus megaterium* var. *phosphaticum* at 10^8 CFU/g) as a phosphate dissolving bacteria and potasiomag (*Bacillus circulance* at 10^7 CFU/g) were obtained from the Biofertilization Unit, Agric. Res. Center., Giza as a microorganisms in peatmoss carrier substrate and used as mixture of them (at ratio 2:2:1, respectively) at the rate of 5 g/pot. The fungicide, Topsin M-70% WP (Thiophanate-methyl) was used at the rate of 2 g/l. water as soil treatment. Untreated infested pots were used as control. All tested treatments were applied to the soil before sowing. Soil infestation was carried out similar to the method of Pathogenicity test as previously mentioned, and the three tested pathogenic fungi were separately used. The seeds were sown at 4 seeds /pot in sterilized clay pots (25 cm in diameter) filled with sterilized mixture of clay and sand soil. All agricultural procedures and design of the experiments were used as previously mentioned under soil type test. Pot experiments were carried out during 2019 and repeated in 2020. The effects of all treatments on growth parameters and chemical constituents of moringa plants were recorded.

Disease Assessment:

According to Atwa (2018) the percentages of pre- and post-emergence damping-off were recorded 15 and 30 days after sowing, respectively. While disease incidence and severity of root rot and wilt diseases were determined after 90 and 120 days, respectively and estimated as follow:

Percentages of pre-, post-emergence damping-off and disease incidence of root rot and/or wilt diseases were estimated as (number of diseased plants in each phase / Total number of planted seeds) × 100.

Root rot severity was estimated based on the progress of yellowing and root rotting using the rating scale (0-5 scale) according to Dewidar *et al*. (2019).

Where:0=0, l=> 0-10, 2=>10-25, 3=>25-50, 4=>50-75 and 5=>75-100%. While wilt severity was assessed using a scale rating from (0-5 scale) according to Liu *et al.* (1995) based on the leaf wilt symptoms,

Where:

0 = no symptoms; 1 = plants up to 25% of leaves with drooping and yellowing symptoms; 2 = plants with >25-50% of leaves with drooping and yellowing symptoms; 3 = plants with >50-75% of leaves with drooping and

yellowing symptoms; 4 = plants with >75-100% of leaves with drooping and yellowing symptoms and 5 = plants with complete death.

Disease severity % = [Σ (n x c)]/ (N x C) x 100

Where: n = Number of infected plants, **c** = Category number, **N** = Total number of examined plants and **C** = the highest category number of infections.

Growth parameters of the plants *i.e.*, herb fresh weight/plant (g), fresh weight of tuber/plant (g), No. of new plants, herb fresh weight/new plant (g) and fresh weight of new tuber/plant (g) were also recorded 120 days after sowing. Nutrient's content *i.e.*, protein, phosphorous (P), potassium (K), calcium (Ca), iron (Fe) and manganese (Mn) contents in leaves of moringa plants were analyzed according to the method described by Chapman and Pratt (1961) and recorded.

Statistical Analysis:

Data were statistically analyzed for computing L.S.D. test at 5% probability according to the procedure outlined by Snedecor and Cochran (1989).

RESULTS

I- Isolation, Purification and Identification of the Causal Pathogens:

The isolated fungi were purified and identified as: *Fusarium solani* (Mart.) Appel & Wollenw, *F. oxysporum* Schlecht., *Rhizoctonia solani* Kühn and *Sclerotium rolfsii* Sacc. A total of 122 colonies of different isolated fungi were resulted from the diseased moringa plants collected from different localities in Giza governorate (Table, 1). It is clear that *S. rolfsii* was the most frequent fungus, being 48 colonies with 39.3 % frequency followed by *F. oxysporum* (44 colonies with 36.1 % frequency). However, *F. solani* and *R. solani* recorded the lowest frequencies (15 colonies with 12.3 % frequency for each fungus).

Table (1): Frequency (%) of fungi isolated from moringa diseased seedlings and plants, collected from Giza governorate.

Fungi	No. of isolates	Frequency (%)
Sclerotium rolfsii	48	39.3
Fusarium oxysporum	44	36.1
Fusarium solani	15	12.3
Rhizoctonia solani	15	12.3
Total	122	---

II- Pathogenicity Test of the Isolated Fungi:

Data elucidated in Table (2) show that all the four isolated fungi were pathogenic to moringa plants with different degrees. It was found that the tested isolates caused pre- and post-emergence damping-off. The highest percentages of pre- and post-emergence damping-off were recorded by *S. rolfsii* (33.33 & 41.67 %, respectively) followed by *F. oxysporum* (16.67 & 25.00 %, respectively) then *R. solani* (16.67 and 8.33 %, respectively) and *F. solani* (8.33 and 16.67%, respectively) with significant differences among them.

Meanwhile, percentages of disease incidence and severity of root rot and/or wilt diseases that were recorded by *F. oxysporum* and *R. solani* reached 16.67% of disease incidence and 8.33 &13.33 % of disease severity, respectively. While, the lowest infection was occurred by *F. solani* and *S. rolfsii*, (8.33% of disease incidence and 6.67 & 10.00% disease severity, respectively).

In general, *S. rolfsii* was the most virulent one, where it resulted in the lowest survived plants (16.67%) followed by *F. oxysporum* (41.66 %) then *R. solani* (58.33 %) and *F. solani* (66.67 %).

The most three virulent fungi *i.e.*, *S. rolfsii*, *F. oxysporum* and *R. solani* that caused the highest root rot and/or wilt diseases in Pathogenicity test were selected and used in the following control experiments during 2019 and 2020.

III- Control Experiments:

The two following control experiments were conducted during 2019 and 2020 under artificially infested soil with the three tested virulent fungi.

1-Effect of Soil Type:

1a- Effect on Damping-Off, Root Rot and Wilt Diseases:

Results shown in Tables (3, 4 and 5) reveal significant differences between soil types and causal pathogens. In the first experiment (2019), it was observed that sandy soil followed by mixture of sandy + clay soil showed statistically significant decrease in the percent of pre- and post- emergence damping-off as well as disease incidence and severity of root rot and wilt (mean values of 4.17 % for pre- emergence and 6.25 & 8.33% for post- emergence, 14.59 and 10.42 % for disease incidence and 3.75 and 2.92% for severity of root rot and/or wilt, respectively) and increasing percent of survived plants (75.00 & 77.09%) as compared to clay soil that resulted the maximum pre-, post- emergence damping-

off and disease incidence, disease severity as well as the minimum survived plants. The same trend was shown in the second experiment (2020).

Table (2): Pathogenicity test of the fungi isolated from moringa plants 15, 30, 90 and 120 days after sowing in artificially infested soil with the tested fungi.

Fungi	Disease assessment				
	% Damping-off		Root-rot and/or wilt		% Apparently Survived healthy plants
	Pre-emergence	Post-emergence	% Disease Incidence	% Disease Severity	
S. rolfsii[*]	33.33	41.67	8.33	10.00	16.67
F. oxysporum[**]	16.67	25.00	16.67	8.33	41.66
F. solani[*]	8.33	16.67	8.33	6.67	66.67
R. solani[*]	16.67	8.33	16.67	13.33	58.33
Control	00.00	00.00	00.00	00.00	100.00
L.S.D.at 5%:	0.71	1.22	2.41	0.67	1.51

[*] *F. solani*, *R. solani* and *S. rolfsii* caused root rot; [**]*F. oxysporum* caused wilt.

Table (3) Effect of soil type on damping-off, %disease incidence of root-rot and/or wilt as well as survived plants of moringa plants grown in soil artificially infested with the three pathogenic fungi 15, 30, 90 and 120 days after sowing, respectively during 2019.

Soil type	% Damping-off									
	Pre-emergence					Post- emergence				
	F. oxysporum	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)
Clay	16.67	33.33	16.67	0.00	16.67	25.00	33.33	33.33	0.00	22.92
Sand	0.00	16.67	0.00	0.00	4.17	8.33	8.33	8.33	0.00	6.25
Clay + sand	0.00	8.33	8.33	0.00	4.17	8.33	8.33	16.67	0.00	8.33
Mean (B)	5.56	19.44	8.33	0.00	---	13.89	16.66	19.44	0.00	---
L.S.D. at 5%	A = 0.97; B = 0.36; A × B = 0.62					A = 0.42; B = 0.38; A × B = 0.66				
	% Disease incidence of root-rot and/or wilt					% Apparently Survived healthy plants				
Clay	33.33	16.67	8.33	0.00	14.58	25.00	16.67	41.67	100.0	45.84
Sand	16.67	16.67	25.00	0.00	14.59	75.00	58.33	66.67	100.0	75.00
Clay + sand	25.00	0.00	16.67	0.00	10.42	66.67	83.34	58.33	100.0	77.09
Mean (B)	25.00	11.11	16.67	0.00	---	55.56	52.78	55.56	100.0	---
L.S.D. at 5%	A = 0.35; B = 0.27; A × B = 0.48					A = 0.35; B = 0.49; A × B = 0.84				

A = soil type; B = isolated fungi.

Table (4) Effect of soil type on damping-off, %disease incidence of root-rot and/or wilt as well as survived plants of moringa plants grown in soil artificially infested with the three pathogenic fungi 15, 30, 90 and 120 days after sowing, respectively during 2020.

Soil type	% Damping-off									
	Pre-emergence					Post- emergence				
	F. oxysporum	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)
Clay	16.67	41.67	16.67	0.00	18.75	33.33	16.67	41.67	0.00	22.92
Sand	0.00	8.33	8.33	0.00	4.17	8.33	8.33	8.33	0.00	6.25
Clay + sand	0.00	16.67	8.33	0.00	6.25	0.00	0.00	25.00	0.00	6.25
Mean (B)	5.56	22.22	11.11	0.00	---	13.89	8.33	25.00	0.00	---
L.S.D. at 5%	A = 0.41; B = 0.51; A × B = 0.88					A = 0.32; B = 0.24; A × B = 0.41				
	% Disease incidence of root-rot and/or wilt					% Apparently Survived healthy plants				
Clay	33.33	33.33	25.00	0.00	22.92	16.67	16.66	16.66	100.0	37.50
Sand	25.00	25.00	25.00	0.00	18.75	66.67	58.34	58.34	100.0	70.84
Clay + sand	8.33	16.67	25.00	0.00	12.50	91.67	66.66	41.67	100.0	75.00
Mean (B)	22.22	25.00	25.00	0.00	---	58.34	47.22	38.89	100.0	---
L.S.D. at 5%	A = 0.35; B = 0.55; A × B = 0.95					A = 0.67; B = 0.40; A × B = 0.70				

A = soil type; B = isolated fungi.

Table (5) Effect of soil type on % disease severity of root-rot and/or wilt of moringa plants grown in soil artificially infested with the three pathogenic fungi 120 days after sowing during 2019 and 2020.

Soil type	% Disease severity of root-rot and/or wilt									
	First experiment (2019)					Second experiment (2020)				
	F. oxysporum	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)
Clay	6.67	6.67	5.00	0.00	4.59	8.33	6.67	6.67	0.00	5.42
Sand	10.00	1.67	3.33	0.00	3.75	8.33	6.67	1.67	0.00	4.17
Clay + sand	5.00	0.00	6.67	0.00	2.92	6.67	3.33	6.67	0.00	4.17
Mean (B)	7.22	2.78	5.00	0.00	---	7.78	5.56	5.00	0.00	---
L.S.D. at 5%	A = 0.16; B = 0.15; A × B = 0.26					A = 0.22; B = 0.23; A × B = 0.40				

A = soil type; B = isolated fungi.

1b- Effect on Some Plant Growth Parameters:

Data presented in Table (6) show that the tested soil types significantly affected on herb fresh weight/plants (g) and fresh weight of tubers (g) in both experiments (2019 and 2020). The highest significant effects on fresh weight/plant and tuber fresh weight values were obtained from plants cultivated in sand soil followed by those grown in clay + sand soil with significant

differences between them, being 6.25, 13.47 g and 8.27, 10.73 g, respectively in the first experiment (2019) and 6.04, 13.61 g and 8.31, 10.86 g, respectively in the second experiment (2020). However, the lowest values were obtained from plants grown in clay soil in both experiments (4.98, 7.54 g and 4.83, 7.41 g, respectively). Regarding to the effect of the tested isolates on growth parameters of moringa plants, data showed that all the tested fungi significantly reduced the herb fresh weight/plant and tuber fresh weight compared to plants grown in uninfested soil which gave the highest herb fresh weight/plant, 10.42 and 9.45 g and the highest fresh weight of tuber, being 15.88 and 15.09 g in the two experiments (2019 and 2020), respectively. *R. solani* gave the lowest values, being 4.52, 5.00 g/plant and 7.08, 6.97 g in the first and second experiment, respectively followed by *S. rolfisii* and *F. oxysporum*. The interaction between tested isolates and soil type was significant in the two experiments. In the first experiment, the highest values of herb fresh weight of plant (7.52 g) and tuber fresh weight (13.51 g) were obtained from plants grown in sand soil artificially infested with *F. oxysporum*. Meanwhile, the lowest herb fresh weight (2.95 g) was obtained from plants grown in sand soil artificially infested with *R. solani*. Plants grown in clay soil artificially infested with *R. solani* gave the lowest tuber fresh weight (5.61 g).

Table (6): Effect of soil type on some growth characteristics of moringa plants grown in soil artificially infested with the three pathogenic fungi, each alone, during 2019 and 2020.

Soil type	Herb fresh weight of plant (g)					Fresh weight of tuber (g)				
	F. oxysporum	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean(A)
	First experiment (2019)									
Clay	4.01	4.43	3.48	8.00	4.98	5.97	5.61	5.97	12.61	7.54
Sand	7.52	2.95	6.05	8.47	6.25	13.51	7.32	13.27	19.76	13.47
Clay + Sand	5.72	6.17	6.40	14.79	8.27	7.95	8.32	11.37	15.28	10.73
Mean (B)	5.75	4.52	5.31	10.42	---	9.14	7.08	10.20	15.88	---
L.S.D. at 5 %	A = 0.64; B = 1.09; A × B = 1.88					A = 3.64; B = 1.99; A × B = 3.45				
	Second experiment (2020)									
Clay	3.86	4.67	3.07	7.71	4.83	5.88	5.57	5.55	12.62	7.41
Sand	7.33	2.69	6.19	7.96	6.04	13.74	6.61	13.81	20.26	13.61
Clay + Sand	5.84	7.64	7.06	12.68	8.31	7.71	8.73	11.61	15.39	10.86
Mean (B)	5.68	5.00	5.44	9.45	---	9.11	6.97	10.32	15.09	---
L.S.D. at 5 %	A = 0.94; B = 1.32; A × B = 2.29					A = 2.29; B = 2.27; A × B = 3.93				

A = soil type; B = isolated fungi.

2-Effect of cyanobacterium *Spirulina platensis*, Biofertilizers and Topsin-M 70%:

2a- Effect on Damping-Off, Root Rot and Wilt Diseases:

Data presented in Tables, (7, 8 and 9) demonstrate that all the tested treatments reduced percentages of pre-, post-emergence damping-off and delayed the progress of root rot/wilt diseases, as well as increased the percentage of survived plants compared with the untreated control during the two experiments (2019 and 2020). Among all treatments, the fungicide Topsin-M 70% was the most efficient in this regard which recorded the lowest pre- and post-emergence damping-off, being 4.17

and 6.25 %, respectively and significantly reduced the percent of disease incidence as well as delayed the progress of root rot/wilt to 12.50 and 1.67%, respectively and increased the survived plants to 77.09 % followed by biofertilizers treatment (mixture of nitrobein, phosphorein and potasiomag) and *Spirulina platensis* treatment in the first experiment (2019). The same trend was observed in the second experiment (2020). In general, the effectiveness of the tested treatments significantly varied according to the isolates tested. *F. oxysporum* was the highest sensitive fungus to the tested treatments which recorded the lowest percent of pre-, post-emergence damping-off, wilt severity and the highest percent of survived plants followed by *R. solani*, meanwhile *S. rolfsii* was the least sensitive in this regard.

Table (7): Effect of *S. platensis*, biofertilizers and Topsin-M 70% on damping-off, %disease incidence of root-rot/wilt and % survived plants of moringa plants grown in soil artificially infested with the three pathogenic fungi after 15, 30, 90 and 120 days from sowing, respectively during 2019.

Treatments	% Damping-off									
	Pre-emergence					Post- emergence				
	F. oxysporum	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)
S. platensis	8.33	16.67	8.33	0.00	8.33	16.67	8.33	25.00	8.33	14.58
*Biofertilizers	0.00	8.33	8.33	0.00	4.17	8.33	16.67	16.67	8.33	12.50
Topsin-M 70%	8.33	0.00	8.33	0.00	4.17	0.00	0.00	25.00	0.00	6.25
Infected control (untreated)	8.33	25.00	16.67	0.00	12.50	8.33	25.00	33.33	0.00	16.67
Mean (B)	6.25	12.50	10.42	0.00	---	8.33	12.50	25.00	4.17	---
L.S.D. at 5%	A = 0.45; B = 0.35; A × B = 0.71					A = 0.25; B = 0.22; A × B = 0.45				
	% Disease incidence of root-rot and/or wilt					% Apparently Survived healthy plants				
S. platensis	8.33	16.66	16.66	0.00	10.41	66.67	58.34	50.01	91.67	66.67
*Biofertilizers	16.66	8.33	8.33	0.00	8.33	75.01	66.67	66.67	91.67	75.01
Topsin-M 70%	16.66	8.33	25.00	0.00	12.50	75.01	91.67	41.67	100.0	77.09
Infected control (untreated)	25.00	33.33	33.33	0.00	22.92	58.34	16.67	16.67	100.0	47.92
Mean (B)	16.66	16.66	20.83	0.00	---	68.76	58.34	43.76	95.84	---
L.S.D. at 5%	A = 0.31; B = 0.47; A × B = 0.94					A = 0.46; B = 0.24; A × B = 0.48				

A = treatments; B = isolated fungi.
*Biofertilizers treatment = (mixture of nitrobein, phosphorein and potasiomag).

Table (8): Effect of *S. platensis*, biofertilizers and Topsin-M 70% on damping-off, %disease incidence of root-rot/wilt and % survived plants of moringa plants grown in soil artificially infested with the three pathogenic fungi after 15, 30, 90 and 120 days from sowing, respectively during 2020.

Treatments	% Damping-off									
	Pre-emergence					Post- emergence				
	F. oxysporum	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)
S. platensis	8.33	16.67	16.67	8.33	12.50	8.33	8.33	16.67	0.00	8.33
*Biofertilizers	8.33	8.33	8.33	0.00	6.25	0.00	16.67	8.33	0.00	6.25
Topsin-M 70%	8.33	8.33	0.00	0.00	4.17	8.33	8.33	16.67	8.33	10.42
Infected control (untreated)	16.67	25.00	16.67	8.33	16.67	8.33	33.33	33.33	0.00	18.75
Mean (B)	10.42	14.58	10.42	4.17	---	6.25	16.67	18.75	2.08	---
L.S.D. at 5%	A = 0.18; B = 0.22; A × B = 0.45					A = 0.40; B = 0.24; A × B = 0.47				
	% Disease incidence of root-rot and/or wilt					% Apparently Survived healthy plants				
S. platensis	8.33	16.66	25.00	0.00	12.50	75.01	58.34	41.66	91.67	66.67
*Biofertilizers	8.33	8.33	8.33	00.0	6.25	83.34	66.67	75.01	100.0	81.26
Topsin-M 70%	16.66	8.33	25.00	0.00	12.50	66.68	75.01	58.33	91.67	72.92
Infected control (untreated)	33.33	25.00	33.33	0.00	22.92	41.67	16.67	16.67	91.67	41.67
Mean (B)	16.66	14.58	22.92	0.00	---	66.68	54.17	47.92	93.75	---
L.S.D. at 5%	A = 0.36; B = 0.27; A × B = 0.54					A = 0.43; B = 0.25; A × B = 0.50				

A = treatments; B = isolated fungi.
*Biofertilizers treatment = (mixture of nitrobein, phosphorein and potasiomag).

Table (9): Effect of *S. platensis*, biofertilizers and Topsin-M 70% on % disease severity of root-rot and/or wilt of moringa plants grown in soil artificially infested with the three pathogenic fungi after 120 days from sowing, respectively during 2019 and 2020 years.

Treatments	% Disease severity of root-rot and/or wilt									
	First experiment (2019)					Second experiment (2020)				
	F. oxysporum	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)
S. platensis	6.67	1.67	3.33	0.00	2.92	3.33	5.00	3.33	0.00	2.92
*Biofertilizers	3.33	1.67	1.67	0.00	1.67	0.00	1.67	3.33	0.00	1.25
Topsin-M 70%	1.67	3.33	1.67	0.00	1.67	1.67	0.00	0.00	0.00	0.42
Infected control (untreated)	8.33	6.67	10.00	0.00	6.25	11.67	10.00	11.67	0.00	8.34
Mean (B)	5.00	3.34	4.17	0.00	---	4.17	4.17	4.58	0.00	---
L.S.D. at 5%	A = 0.20; B = 0.14; A × B = 0.29					A = 0.31; B = 0.16; A × B = 0.31				

A = treatments; B = isolated fungi.
*Biofertilizers treatment = (mixture of nitrobein, phosphorein and potasiomag).

2b- Effect on Some Plant Growth Parameters:

In general, all tested treatments promoted the growth of moringa plants with significant increase of herb fresh weight/plant (g) and fresh weight of tuber (g) as well as no. of new plants, herb fresh weight of new plant (g) and fresh weight of new tuber (g) in both years compared to the untreated plants (Tables, 10 and 11).The highest values were recorded with biofertilizer treatments, being 23.36 g, 33.50 g, 0.75, 2.83 g and 3.56 g, respectively. *S. platensis* treatment came next with significant differences except with no. of new plants parameter which gave 18.56 g, 18.70 g, 0.75, 1.59 g and 2.68 g, respectively during the first experiment (2019). The same trend was noticed in the second experiment (2020). Overall, improvement in growth parameters was significantly varied regarding the tested fungi. The interaction between treatments and the tested fungi had significant effect on herb fresh weight/plant and fresh weight of tuber as well as no. of new plants, herb fresh weight of new plant and fresh weight of new tuber. In 2019 experiment, the maximum values of herb fresh weight/plant (20.45 g) and fresh weight of tuber (37.93 g) were obtained from plants grown in soil infested with *R. solani* and treated with biofertilizers, where the maximum values of no. of new plant, herb fresh weight of new plant and fresh weight of new tuber were obtained from plants resulted from *S. platensis* treatment and grown in soil infested with *F. oxysporum* followed by plants received biofertilizers and infected with *S. rolfsii* without significant differences between them. The same trend was also true for the second experiment (2020).

Table (10): Effect of *S. platensis*, biofertilizers and Topsin-M 70% on some growth characteristics of moringa plants grown in soil artificially infested with the three pathogenic fungi during 2019 and 2020.

Treatments	Herb fresh weight of plant (g)					Fresh weight of tuber (g)				
	F. oxysporum	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)
	First experiment (2019)									
S. platensis	19.70	12.80	17.29	24.46	18.56	20.23	16.38	15.29	22.89	18.70
*Biofertilizers	20.28	20.45	17.25	35.46	23.36	24.06	37.93	23.68	48.31	33.50
Topsin-M 70%	6.53	9.18	12.86	17.16	11.43	8.61	4.47	10.90	13.63	9.40
Infected control (untreated)	4.99	4.81	9.42	11.87	7.77	5.93	3.49	7.50	8.29	6.30
Mean (B)	12.88	11.81	14.21	22.24	---	14.71	15.57	14.34	23.28	---
L.S.D. at 5%	A = 5.69; B = 3.39; A × B = 6.78					A = 2.19; B = 5.06; A × B = 10.12				
	Second experiment (2020)									
S. platensis	19.22	12.39	13.93	23.03	17.14	18.93	15.42	14.78	19.62	17.19
*Biofertilizers	19.27	17.67	17.19	24.13	19.57	18.85	36.06	23.20	42.30	30.10
Topsin-M 70%	6.21	7.77	15.71	16.93	11.66	9.12	4.15	9.61	11.12	8.50
Infected control (untreated)	4.92	4.59	9.35	10.38	7.31	5.47	3.19	7.08	7.79	5.88
Mean (B)	12.41	11.36	14.05	18.62	---	13.09	14.71	13.67	20.21	---
L.S.D. at 5%	A = 4.39; B = 3.13; A × B = 6.26					A= 3.96; B = 2.45; A × B = 4.90				

A = treatments; B = isolated fungi.

*Biofertilizers treatment = (mixture of nitrobein, phosphorein and potasiomag).

Table (11): Effect of *S. platensis*, biofertilizers and Topsin-M 70% on some new growth characteristics of Moringa plants grown in soil infested with the three pathogenic fungi during 2019 and 2020.

Treatments	No. of new plants					Herb fresh weight of new plant (g)					Herb fresh weight of new tuber (g)				
	F. oxysporum	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)	*F. oxysporum*	*R. solani*	*S. rolfsii*	Control (uninfested)	Mean (A)
	First experiment (2019)														
S. platensis	1.00	0.67	0.67	0.67	0.75	3.13	1.14	0.46	1.64	1.59	5.78	2.07	1.04	1.84	2.68
*Biofertilizers	1.00	0.00	1.00	1.00	0.75	2.77	0.00	3.17	5.36	2.83	3.48	0.00	5.17	5.60	3.56
Topsin-M 70%	1.00	0.00	0.00	0.00	0.25	1.83	0.00	0.00	0.00	0.46	1.60	0.00	0.00	0.00	0.40
Infected control (untreated)	1.00	0.00	0.00	0.00	0.25	0.41	0.00	0.00	0.00	0.10	1.72	0.00	0.00	0.00	0.43
Mean (B)	1.00	0.17	0.42	0.42	---	2.04	0.29	0.91	1.75	---	3.15	0.52	1.55	1.86	---
L.S.D. at 5%	A = 0.41; B = 0.52; A × B = 1.03					A = 1.01; B = 1.63; A × B = 3.25					A = 0.83; B = 2.34; A × B = 4.68				
	Second experiment (2020)														
S. platensis	1.33	0.66	1.33	1.00	1.08	3.44	1.58	1.78	3.68	2.62	5.55	1.99	1.74	2.48	2.94
*Biofertilizers	1.00	0.33	1.00	1.00	0.83	2.54	0.70	3.45	4.53	4.38	3.30	1.36	4.94	5.34	3.74
Topsin-M 70%	1.00	0.00	0.00	0.00	0.25	1.14	0.00	0.00	0.00	0.29	1.80	0.00	0.00	0.00	0.45
Infected control (untreated)	0.33	0.00	0.00	0.33	0.17	0.33	0.00	0.00	1.14	0.37	0.77	0.00	0.00	0.93	0.43
Mean (B)	0.92	0.25	0.58	0.58	---	1.86	0.57	1.31	2.34	---	2.86	0.84	1.67	2.19	---
L.S.D. at 5%	A = 0.53; B = 0.40; A × B = 0.81					A = 1.01; B = 1.31; A × B = 2.61					A = 2.61; B = 1.71; A × B = 3.42				

A = treatments; B = isolated fungi.

*Biofertilizers treatment = (mixture of nitrobein, phosphorein and potasiomag)**.**

3- Effect of Treating Soil with *S. platensis*, Biofertilizers and Fungicide on Main Contents in Leaves of Moringa Plants Grown in Soil Infested with *Sclerotium rolfsii*.

Data recorded in Tables (12 and 13) reveal that some components of protein contents, phosphorus, potassium, calcium, iron and manganese in leaves of moringa plants were significantly affected by the tested treatments during the two successive experiments, 2019 and 2020. Biofertilizers treatment increased plant content of these components more than *S. platensis* treatment, being 19.38, 0.42, 2.38, & 1.11 % for Protein, P, K & Ca, respectively and for Fe and Mn, 1597.5 and 52.25 ppm, respectively in the first experiment, 2019. The same trend was found in the second experiment, 2020.

Coefficients of correlation between severity % of root rot incited by *S. rolfsii*, fresh weight of herb and main contents in leaves of moringa plants during 2019 and 2020.

There was a strong correlation with both root rot severity percent and herb fresh weight assessed on main contents in leaves of moringa plants for the first and second experiment in Table (14). Data reveal that the high correlation coefficient of the disease severity (%) with herb fresh weight for the first and the second experiment was [(r = -0.929, p = 0.000) and (r = -0.977, p = 0.000)], respectively. Disease severity on the root was inversely proportional with herb fresh weight for the two experiments. On the other hand, a significant positive correlation was noticed between herb fresh weight and main contents in leaves of moringa plants in both the two experiments, except in case of the percent of Mn in the first experiment, 2019. As well as a significant positive correlation was found between % protein, % P, % K, Fe ppm. and Mn ppm in the first experiment, being [(r=0.871, p= 0.000), (r=0.996), p (0.000), r= (0.989), p= (0.000) and r= (0.854), p= (0.000)], receptivity.

Table (12): Effect of treating soil with *S. platensis*, biofertilizers and Topsin-M 70% on protein, phosphorus (P) and potassium (K) contents in leaves of moringa plants grown in soil infested with *S. rolfsii* during 2019 and 2020.

Treatments	% Protein			% P			% K		
	S. rolfsii	Control (uninfested)	Mean(A)	*S. rolfsii*	Control (uninfested)	Mean(A)	*S. rolfsii*	Control (uninfested)	Mean(A)
	First experiment (2019)								
S. platensis	16.25	18.75	17.50	0.36	0.41	0.39	2.40	2.28	2.34
*Biofertilizers	18.75	20.00	19.38	0.38	0.45	0.42	2.44	2.32	2.38
Topsin-M 70%	18.75	14.37	16.56	0.37	0.35	0.36	2.16	2.24	2.20
Infected control (untreated)	13.00	16.20	14.60	0.32	0.41	0.37	2.08	2.16	2.12
Mean(B)	16.69	17.42	---	0.36	0.41	---	2.27	2.25	---
L.S.D. at 5%	A = 0.66; B = 0.46; A × B = 0.93			A = 0.02; B = 0.01; A × B = 0.03			A = 0.03; B = 0.02; A × B = 0.04		
	Second experiment (2020)								
S. platensis	18.75	16.25	17.50	0.36	0.41	0.39	2.40	2.28	2.34
*Biofertilizers	19.37	20.75	20.06	0.38	0.45	0.42	2.44	2.32	2.38
Topsin-M 70%	14.75	16.00	15.38	0.37	0.35	0.36	2.19	2.24	2.22
Infected control (untreated)	10.00	15.25	12.63	0.32	0.41	0.37	2.08	2.16	2.12
Mean (B)	15.72	17.06	---	0.36	0.41	---	2.28	2.25	---
L.S.D. at 5%	A = 0.86; B = 0.61; A × B = 1.22			A = 0.02; B = 0.01; A × B = 0.02			A = 0.03; B = 0.02; A × B = 0.04		

A = treatments; B = isolated fungi.

*Biofertilizers treatment = (mixture of nitrobein, phosphorein and potasiomag).

Table (13): Effect of treating soil with *S. platensis*, biofertilizers and Topsin-M 70% on calcium (Ca), iron (Fe) and manganese (Mn) contents in leaves of moringa plants grown in soil infested with *S. rolfsii* during 2019 and 2020.

Treatments	Ca %			Fe ppm			Mn ppm		
	S. rolfsii	Control (uninfested)	Mean(A)	*S. rolfsii*	Control (uninfested)	Mean(A)	*S. rolfsii*	Control (uninfested)	Mean(A)
	First experiment (2019)								
S. platensis	0.96	1.06	1.01	1570	900	1235.0	28.5	54.0	41.25
*Biofertilizers	1.05	1.17	1.11	1810	1385	1597.5	49.5	55.0	52.25
Topsin-M 70%	0.65	0.74	0.70	755	515	635.0	65.0	9.0	37.00
Infected control (untreated)	0.48	0.63	0.56	430	610	520.0	35.5	13.0	24.25
Mean(B)	0.79	0.90	---	1141.3	852.5	---	44.63	32.75	---
L.S.D. at 5%	A = 0.03; B = 0.02; A × B = 0.04			A = 46.2; B = 32.7; A × B = 65.3			A = 2.31; B = 1.63; A × B = 3.26		
	Second experiment (2020)								
S. platensis	0.76	1.03	0.90	1570	910	1240.0	30.5	54.0	42.25
*Biofertilizers	1.05	1.17	1.11	1810	1385	1597.5	49.5	55.0	52.25
Topsin-M 70%	0.75	0.74	0.75	795	515	655.0	65.0	11.0	38.00
Infected control (untreated)	0.44	0.63	0.54	430	610	520	35.5	13.0	24.25
Mean(B)	0.75	0.89	---	1151.3	855.0	---	45.13	33.25	---
L.S.D. at 5%	A = 0.03; B = 0.02; A × B = 0.04			A = 44.8; B = 31.7; A × B = 63.3			A = 2.09; B = 1.48; A × B = 2.95		

A = treatments; B = isolated fungi.
*Biofertilizers treatment = (mixture of nitrobein, phosphorein and potasiomag).

Table (14): Coefficients of correlation between disease severity on root %, fresh weight of herb and main contents in leaves of moringa plants grown in soil infested with *S. rolfsii*.

Variables	+D.S.	++H.F.W.	Protein %	P %	K%	Ca%	Fe ppm.	Mn ppm.
				First experiment (2019)				
+D.S.	1	-0.929**[a] 0.000[b]	-0.638*[a] 0.26[b]	-0.932**[a] 0.000[b]	-0.649*[a] 0.022[b]	-0.711**[a] 0.010[b]	-0.669*[a] 0.017[b]	-0.220[a] 0.493[b]
++H.F.W.		1	0.412[a] 0.184[b]	0.795**[a] 0.002[b]	0.451[a] 0.141[b]	0.537[a] 0.072[b]	0.491[a] 0.105[b]	-0.101[a] 0.755[b]
Protein %			1	0.871**a 0.000[b]	0.996**[a] 0.000[b]	0.250[a] 0.434[b]	0.989**a 0.000[b]	0.854**[a] 0.000[b]
P %				1	0.881**[a] 0.000[b]	0.536[a] 0.072[b]	0.893**[a] 0.000[b]	0.523[a] 0.081[b]
K%					1	0.203[a] 0.528[b]	0.998**[a] 0.000[b]	0.815**[a] 0.001[b]
Ca%						1	0.190[a] 0.554[b]	0.110[a] 0.733[b]
Fe ppm.							1	0.779**[a] 0.003[b]
Mn ppm.								1
				Second experiment (2020)				
+D.S.	1	-0.977**[a] 0.000b	-0.894**a 0.000b	-0.987**[a] 0.000[b]	-0.855**[a] 0.000[b]	-0.695*[a] 0.012[b]	-0.747**[a] 0.005[b]	-0.410[a] 0.186[b]
++H.F.W.		1	0.778**[a] 0.003[b]	0.996**[a] 0.000[b]	0.945**[a] 0.000[b]	0.565[a] 0.055[b]	0.861**[a] 0.000[b]	0.592*[a] 0.042[b]
Protein %			1	0.819**[a] 0.001[b]	0.532[a] 0.075[b]	0.884**[a] 0.000[b]	0.382[a] 0.221[b]	-0.022[a] 0.947[b]
P %				1	0.915**[a] 0.000[b]	0.636*[a] 0.026[b]	0.813**[a] 0.001[b]	0.549[a] 0.65[b]
K%					1	0.283[a] 0.373[b]	0.973**[a] 0.000[b]	0.794**[a] 0.002[b]
Ca%						1	0.068[a] 0.832[b]	-0.104[a] 0.748[b]
Fe ppm.							1	0.828**[a] 0.001[b]
Mn ppm.								1

**Coefficient (r) is [a] linear correlation significant at the 0.01 level, *Coefficient (r) is [a] linear correlation significant at the 0.05 level, [b] probability level.
+Disease severity (%) on root = D.S., ++Herb fresh weight (g) = H.F.W.

DISCUSSION

Several soil-borne fungi can attack moringa plants during its various growth stages, from seedling till maturity causing damping-off, root rot and/or wilt diseases. The present results indicated that damping-off, root rot and/or wilt diseases were incited by the soil borne fungi, *F. solani*, *F. oxysporum*, *R. solani* and *S. rolfsii*. *S. rolfsii* was the most frequently isolated pathogen, followed by *F. oxysporum* while *F. solani* and *R. solani* came next. These results are in agreement with the obtained results by Lezcano *et al.* (2014); El–Mohamedy *et al.* (2014) and Ziedan *et al*. (2016). Generally, all fungal isolates had the potentiality to infect

moringa plants causing damping-off, root rot and/or wilt diseases. El–Mohamedy *et al.* (2014) reported that moringa emergence and initial seedling growth rate are influenced mainly by soil and seed borne pathogenic fungi, which cause seed rots and seedlings death after emergence.

Soil plays a crucial role for growth, plant survival, multiplication and dissemination of soil borne microorganisms because it provides a habitat for their growth and development (Chuankun *et al*., 2004 and Ozer *et al.*, 2009). Our results showed that percent of pre-and post-emergence damping-off as well as root rot and/or wilt diseases were more severe in a clay soil than in sandy or clay + sandy soils. Ghorbani *et al*. (2008) reported that soil texture and structure influence root growth and plant diseases through their effects on water holding capacity, nutrient status, and gas exchange. Otten *et al.* (1999) showed that small colonies with high biomass densities are formed when the spread of the fungus is restricted by blockage of pores with water. There are many factors that can influence fungal growth, such as resource availability (oxygen, nutrients and habitat space) and microbivory (Frey *et al.*, 1999). Regulation of microbial dynamics by this means occurs through the fragmentation in habitat space, water and substrate distribution and the spatial arrangement of pore pathways (Young and Ritz, 2000).

In the present study, it is worthy to note that soil treatments with *S. platensis* or biofertilizers significantly reduced percent of pre- and post-emergence damping-off and severity of root-rot and wilt diseases and increased the percent of survived plants compared to untreated control. Biofertilizers treatment showed the highest efficacy in this concern. The obtained results are in agreement with those obtained by EL-Barougy *et al* (2009) who found that *Azotobacter chroococcum* has high antagonistic ability against root rot pathogens under greenhouse and field conditions and increased some plant growth parameters. Moreover, the enhancing effect of phosphorein as a biofertilizer on disease incidence might attributed to many factors; (a) its ability to release plant promoting substance, mainly indole acetic acid, gibberellic acid and cytokinin like substances, which might be stimulate plant growth (Saber *et al*., 1998); (b) synthesis of some vitamins, *e.g.* B_{12} (Sobh *et al*., 2000); (c) increasing amino acids content (Saber *et al*., 1998); (d) increasing water and minerals uptake from soil surface area (Sobh *et al*., 2000 and El-Agrodi *et al*., 2003), root hairs and root elongation (Hanafy *et al*., 1997) and (e) enhancing the production of biologically active fungistatic substances, which may change the microflora in the rhizosphere and affect the balance between harmful and beneficial organisms (Stephen, 2012). The antifungal activity of the algal culture filtrates has been attributed to the presence of bioactive compounds, *i.e.,* total phenolic compounds, total saponins, and alkaloids in the algal culture filtrates. The inhibition mechanisms are related to the disruption of the cell membrane integrity in spores and newly formed germ tubes (Hussien *et al.,* 2009).

The reduction in disease severity was reflected on plant growth. Plants grown in soil treated with biocontrol agents produced herb and tuber fresh weight as well as No. of new plants, herb fresh weight of new plant and fresh weight of new tuber greater than untreated ones. Our results are in line with the reports of Akgül and Mirik (2008); Abdel-Monaim, *et al.* (2012) and Mahrous *et al.* (2015). Growth enhancement by *Bacillus* spp. may be associated to their ability to produce hormone, especially indole acetic acid (Sheng and Huang, 2001), and siderophore (Hu and Boyer 1996). It is also known that availability of phosphate in soils is important for the uptake of nitrogen from soils and its utilization in plant (Kim *et al.,* 2003). Co-inoculation of *Bacillus megaterium* var. *phosphaticum* and *Bacillus mucilaginosus* strains synergistically solubilized rock P and K, which were added into the soil and make them much more available for uptake by plant roots (Han and Lee, 2006). Higher availability of phosphate and other nutrients due to the solubilization with inoculation by *B. megaterium* var. *phosphaticum* might cause an enhancement of nitrogen uptake, resistance to stress, stabilize soil aggregates and improve soil structure and organic matter content (Al-Taweil *et al.,* 2009). Also, Khalid *et al.* (2004) reported that root colonizing with plant growth promoting bacteria referred to affect plant growth by increasing nutrient cycling, suppressing pathogens and producing biologically active compounds. El-Haddad *et al.,* (1993) and Mahmoud and Mahmoud (1999) noticed that Azotobacter as a biofertilizer has a capability to fix atmosphere nitrogen and convert it to inorganic from mineralization of nitrogen and promoting some growth substances, organic acid and enhanced nutrient

uptake. There have been many reports on the beneficial effects of *A. chroococcum* on growth and yield of various economic crops, It benefits plants in many ways, including the producion of ammonia, vitamins and growth substances that enhance seed germination, production of indole acetic acid and other auxins such as gibberllins and cytokinins, nutrient absorption, inhibition of phytopathogenic fungi through antifungal substances and production of siderophores, which solubilize Fe^{3+} and suppress plant pathogens through iron deprivation (Mrkovacki and Milic 2001 and Vaddar, 2007). *S. platensis* contains protein, 62 % amino acid, minerals, carotene and xanthophyll phytopigments, which are considered as a rich natural source of vitamin B-12, phytohormones and antioxidants (Kemka *et al.*, 2007). Chemical analysis of *S. platensis* as bio-stimulator revealed that it contains 6.7% N, 2.47% P and 2.14% K as well as adequate amounts of micro elements needed for plant nutrition (Aly and Esawy, 2008).

Our study showed a strong correlation between disease severity percent on root and herb fresh weight assessed on main contents in leaves of moringa plants during the two experiments. These results are in line with those reported by Huber and Haneklaus (2007); Scurich (2012); Gupta *et al.* (2017) and Zarpelon *et al.* (2019). Mineral nutrients are the components of plants and regulate metabolic activity associated with resistance of a plant and virulence of a pathogen. Plants contain preformed anti-microbial compounds and have active response mechanisms, where inhibitory phytoalexins, phenols, flavonoids, and other defense compounds accumulate around infection sites of resistant plants if the nutrients required for the synthesis or induction of those compounds are adequate (Huber and Haneklaus, 2007).

CONCLUSION

The present study indicated that soil types significantly influence disease development on moringa. Sandy soils followed by sandy + clay soil significantly decreased the percent of pre- and post-emergence damping-off as well as root rot and/or wilt severity and increased percent of survived plants as compared to clay soil. Cyanobacterium (*S. platensis*) and biofertilizers containing nitrogen fixers (nitrobein), phosphate dissolving bacteria (phosphorein) and potasiomag showed a good potential to control damping-off, root rot and/or wilt diseases of moringa and improved growth parameters. Therefore, it is recommended to use soil treatment with biofertilizers at the rate of 2:2:1 as safe biocontrol agents for controlling damping-off, root rot and/or wilt diseases of moringa and increasing its productivity.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

REFERENCES

Abdel-Monaim, M.F.; Abdel-Gaid, M.A. and El-Morsi, M.E.A. 2012. Efficacy of rhizobacteria and humic acid for controlling Fusarium wilt disease and improvement of plant growth, quantitative and qualitative parameter in tomato. International Journal of Phytopathology, 1(1): 39-48.

Abedin, R.M.A. and Taha, H.M. 2008. Antibacterial and antifungal activity of cyanobacteria and green microalgae. Evaluation of medium components by Placket-Burman design for antimicrobial activity of *Spirulina platensis*. Global J. Biotechnol. and Biochem., 3(1): 22 -31.

Ahmed, H.Z.; Armanious, H.A.; Abdel-Moneim, M.L. and Galal, A. 2017. Control of root rots and wilt diseases of Marjoram by using some mineral compounds and antioxidants. Minia J. Agric. Res. and Develop., 37(2): 141-156.

Akgül, D.S. and Mirik, M. 2008. Biocontrol of *Phytophthora capsici* on pepper plants by *Bacillus megaterium* strains. J. Pl. Patholo., 90(1): 29-34.

Almeida, A.M.; Gomes, V.M. and Souza, R.M. 2011. Greenhouse and field assessment of rhizobacteria to control guava decline. Bragantia, 70: 837-842.

Al-Taweil, H.I.; Osman, M.B.; Hamid, A.A. and Yussof, W.W.M. 2009. Development of microbial inoculants and the impact of soil application on rice seedlings growth. Am. J. Agric. Biol. Sci., 4: 79-82.

Aly, M.S. and Esawy, M.A. 2008. Evaluation of *Spirulina platensis* as bio stimulator for organic farming systems. J. Gen. Eng. Biotechnol., 6:1-7.

Amaglo, N. 2006. How to Produce Moringa Leaves Efficiently? Kwame Nkrumah University of Science and Technology, Ghana, 16-18 pp.

Amin, M.M.; Fawaz, S.B.M. and Abd-El-Motal, H.M. 2017. Using *Bacillus megaterium* var.

phosphaticum and calcium super phosphate for management sesame wilt disease. Menoufia J. Plant Prot., 2: 25-37.

Atwa, M.A.M. 2018. Combination of biocontrol agents for controlling soybean damping-off caused by *Rhizoctonia solani*. Egypt. J. Phytopathol., 46(2): 15-38.

Baset, M.M.A.; Shamsuddin, Z.H.; Wahab, Z. and Marziah, M. 2010. Effect of plant growth promoting rhizobacteria inoculation on growth and nitrogen incorporation of tissue-cultured Musa plantlets under nitrogen free hydroponics condition. Aust. J. Crop Sci., 4(2): 85-90.

Booth, C. 1971. The genus *Fusarium*. Commonwealth Mycological Institute, Kew, Surrey, England, 237.

Carmichael, W.W. 1992. Cyanobacteria secondary metabolites- the cyanotoxines. J. Appl. Bact., 72: 445-459.

Chapman, H.D. and Pratt, P.P. 1961. Methods of analysis for soils, plants and water. Univ. California, Berkeley, CA, USA, 309 pp.

Chen, W.J.; Delmotte, S.; Richard-Cervera, S.; Douence, L.; Greif, C. and Corio-Costet, M.F. 2007. At least two origins of fungicide resistance in grapevine downy mildew populations. Appl. Environ. Microbiol., 73(16): 5162-5172.

Choi, W.Y.; Sim, J.H.; Lee, J.Y.; Kang, D.H. and Lee, H.Y. 2019. Increased anti-inflammatory effects on LPS-induced microglia cells by *Spirulina maxima* extract from ultrasonic process. Appl. Sci., 9: 2144.

Chuankun, X.; Minghe, M.; Leming, Z. and Keqin, Z. 2004. Soil volatile fungistasis and volatile fungistatic compounds. Soil Biol. Biochem., 36: 1997-2004.

Dalla, R.K.R. 1993. *Moringa oleifera*: A perfect Tree for Home Gardens. Agroforestry Species Highlights. A Publication of the Agroforestry Information Service, USA, 1-5 pp.

Dewidar, A.A.; Kenawy, A.G.M. and Ghebrial, E.W.R. 2019. Influence of different garlic treatments on controlling basal stem rot, root rot and infection by broomrape in geranium plants. Egypt. J. Phytopathol., 47(1): 347 - 366.

El-Agrodi, M.W.; El-Fadaly, H.; Shams, A.; El-Din, H.A. and El-Shehawy, A.M. 2003. Effect of phosphorus fertilization and grains inoculation with phosphate dissolving bacteria on microbiology of rhizosphere bacteria, wheat yield and yield components. J. Agric. Sci., Mansoura Univ., 28(8): 6353-6369.

EL-Barougy, E.; Awad, N.M.; Turky, A.S. and Hamed, H.A. 2009. Antagonistic activity of selected strains of rhizobacteria against *Macrophomina phaseolina* of soybean plants. Am. Eur. J. Agric. and Environ. Sci., 5: 337-347.

Eleiwa, N.Z.; Galal, A.A.A.; Abd El-Aziz, R.M.; Hussin, E.M. 2018. Antioxidant activity of *Spirulina platensis* alleviates doxorubicin induced oxidative stress and reprotoxicity in male rats. Orient Pharm. Exp. Med., 18: 87-95.

El-Haddad, M.E.; Ishac, Y.Z. and Mostafa, M.I. 1993. The role of biofertilizers in reducing agricultural costs, decreasing environmental pollution and raising crop yield. Arab Univ. J. Agric. Sci., 1: 147-195.

El-Khawaga, A.S. and Maklad, M.F. 2013. Effect of combination between bio and chemical fertilization on vegetative growth, yield and quality of Valencia orange fruits. Hort. J. Suez Canal Univ., 1: 269-279.

El-Mohamedy, R.S.R. and Ahmad, M.A. 2009. Effect of biofertilizers and humic acid on control of dry root rot disease and improvement yield qualitative of mandarin. Res. J. Agric. Biological Sci., **5**: 127-137.

El-Mohamedy, R.S.R.; Abdalla, A.M. and Adam, S.M. 2014. Preliminary studies on response of *Moringa oleifera* plants to infection with some soil borne plant pathogenic fungi. Int. J. Curr. Microbiol. App. Sci., 3(12): 389-397.

Frey, S.D.; Elliott, E.T. and Paustian, K. 1999. Bacterial and fungal abundance and biomass in conventional and no-tillage agroecosystems along two climatic gradients. Soil Biol. Biochem., 31: 573-585.

Ghorbani, R.; Wilcockson, S.; Koocheki, A. and Leifert, C. 2008. Soil management for sustainable crop disease control: A review. Environ. Chemist. Lett., 6: 149-162.

Gilman, J.C. 1957. A Manual of Soil Fungi. 2nd Ed., The Iowa State Coll. Press, Ames, Iowa, USA, 450 pp.

Gupta, N.; Debnath, S.; Sharma, S.; Sharma, P. and Purohit, J. 2017. Role of nutrients in controlling the plant diseases in sustainable agriculture. Springer Nature Singapore Pte Ltd., India, 217-262.

Ismail, O.M.; Dakhly, O.F. and Ismail, M.N. 2011. Influence of some bacteria strains and algae as biofertilizers on growth of bitter

orange seedlings. Aust. J. Basic and Appl. Sci., 5: 1285-1289.

Han, H.S. and Lee, K.D.S. 2006. Effect of co-inoculation with phosphate and potassium solubilizing bacteria on mineral uptake and growth of pepper and cucumber. Pl. Soil Environ., 52(3): 130-136.

Hanafy, A.A.H.; Kheir, N.F. and Talaat, N.B. 1997. Physiological studies on reducing the accumulation of nitrate in Jew's mallow (*Corchorus olitorius*) and radish (*Raphanus sativus* L.) plants. Bull. Fac. Agric., Cairo Univ., 48(10): 25-64.

Hu, X. and Boyer, G.L. 1996. Siderophore-mediated aluminum uptake by *Bacillus megaterium* ATCC 19213. Appl. Environ. Microbiol., 62: 4044-4048.

Huber, D.M. and Haneklaus, S. 2007. Managing nutrition to control plant disease. LandbauforschungVölkenrode, (57): 313-322.

Hussien, M.Y.; Abd-El-All, A.A.M. and Mostafa, S.S. 2009. Bioactivity of algal extracellular byproducts on Cercospora leaf spot disease, growth performance and quality of sugar beet. In Proceeding of the 4th Conf. on Recent Technol. in Agric., Cairo, Giza, Pages 1-13.

Jufri, A.F.; Sudradjat and Sulistyono, E. 2016. Effects of dry *Spirulina platensis* and antitranspirant on growth and yield of chili pepper (*Capsicum annuum* L.). J. Agron. Indonesia, 44(2): 170-175.

Kemka, H.O.; Rebecca, A.A. and Gideon, O.A. 2007. Influence of temperature and pH bioresource and protein biosynthesis in putative *Spirulina* sp. Bioresource Technol., 98: 2207-2211.

Khalid, A.; Arshad, M. and Zahir, Z.A. 2004. Screening plant growth-promoting rhizobacteria for improving growth and yield of wheat. Journal of Applied Microbiology, 96: 473-480.

Kim, T.; Jung, W.; Lee, B.; Yoneyama, T.; Kim, H. and Kim, K. 2003. Effects on N uptake and remobilization during regrowth of Italian ryegrass (*Lolium mutiflorum*). Environ. Exp. Bot., 50: 233-242.

Kulik, M.M. 1995. The potential for using cyanobacteria (blue- green algae) and algae in the biological control of plant pathogenic bacteria and fungi. Eur. J. Plant Pathol., 101(6): 585-599.

Lezcano, J.C.; Alonso, O.; Marialys, T. and Martínez, E. 2014. Fungal agents associated to disease symptoms in seedlings of *Moringa oleifera.* Lamarck Pastos y Forrajes., 37(2): 228-232.

Liu, L.; Kloepper, J.W. and Tuzun, S. 1995. Induction of systemic resistance in cucumber against Fusarium wilt by plant growth promoting rhizobacteria. Phytopathology, 85: 695-698.

Ma, Q.; Gan, J.; Becker, J.O.; Papiernik, S.K. and Yates, S.R. 2001. Evaluation of propargyl bromide for control of barnyardgrass and *Fusarium oxysporum* in three soils. Pest Manag. Sci., 57: 781-786.

Mahmoud, H.M. and Mahmoud, A.F. 1999. Studies on effect of some biofertilizers on growth of peach seedlings and root rot disease incidence. Egypt. J. Hort., 26: 7-18.

Mahrous, N.M.; Abu-Hagaza, N.M.; Abotaleb, H.H. and Fakhry, S.M.K. 2015. Enhancement of growth and yield productivity of sesame plants by application of some biological treatments. Am. Eur. J. Agric. and Environ. Sci., 15(5): 903-912.

Marangoni, A.; Foschi, C.; Micucci, M.; Palomino, R.A.N.; Toschi, T.G.; Vitali, B.; Camarada, L.; Mandrioli, M.; De Georgio, M.; Aldini, R.; Corazza, I.; Chiarini, A.; Cevenini, R. and Budriesi, R. 2017. *In vitro* activity of *Spirulina platensis* water extract against different *Candida* species isolated from vulvo-vaginal candidiasis cases. PLoS ONE, 12: e0188567.

Martín, C.; Martín, G.; García, A.; Fernández, T.; Hernández, E. and Puls, J. 2013. Potencialidades y aplicaciones de *Moringa oleifera.* Una revisióncrítica. Pastos y Forrajes, 36(2): 137-149.

Mrkovacki, N. and Milic, V. 2001. Use of *Azotobacter chroococcum* as potentially useful in agricultural application. Ann. Microbiol., 51: 145-158.

Noaman, N.H.; Khaleafa, A.F.M. and Zaky, S.H. 2004. Factors affecting antimicrobial activity of *Synechococcus leopoliensis*. Microbiol. Res., 159: 395-402.

Otten, W.; Gilligan, C.A.; Watts, C.W.; Dexter, A.R. and Hall, D. 1999. Continuity of air-filled pores and invasion thresholds for soilborne fungal plant pathogen *Rhizoctonia solani*. Soil Biol. Biochem., 31: 1803-1810.

Otten, W. and Gilligan, C.A. 2006. Soil structure and soilborne diseases: Using epidemiological concepts to scale from fungal spread to plant epidemics. Eur. J. Soil Sci., 57: 26-37.

Ozer, N.; Koç, M. and Der, B. 2009. The sensitivity of *Aspergillus niger* and *Fusarium*

oxysporum f. sp. *cepae* to fungistasis in onion growing soils. J. Plant Pathol., 91: 401-410.

Pérez, A.; Sánchez, T.; Nayda, A. and Reyes, F. 2010. Características y potencialidades de *Moringa oleifera*, Lamarck. Una alternativa para la alimentación animal. Pastos y Forrajes, 33(4): 349-362.

Pimentel, D.; Acquay, H.; Biltonen, M.; Rice, P.; Silva, M.; Nelson, J.; Lipner, V.; Giordano, S.; Horowitz, A. and D'Amore, M. 1992. Environmental and economic costs of pesticide use. BioScience, 42(10):750-760.

Rockwood, J.L.; Anderson, B.G. and Casamatta, D.A. 2013. Potential uses of *Moringa oleifera* and an examination of antibiotic efficacy conferred by *M. oleifera* seed and leaf extracts using crude extraction techniques available to under-served indigenous populations. Int. J. Phytothearpy Res., 3: 61-71.

Saber, M.S.M.; Ahmed, M.K.A. and Kabesh, M.O. 1998. Utilization of biofertilizers in field crop production of barley. Proc. 8th Conf. Agron., Suez Canal Univ., Ismailia, Egypt, 11: 28-29.

Scurich, J.J. 2012. Strawberry growth, yield, fruit nutrition, and control of Verticillium wilt with pre-plant soil fumigants, ozone, and biological control. M.Sc. Thesis, Faculty of California Polytechnic State University, San Luis Obispo, 109 pp.

Sharma, A.; Kher, R.; Wall, V.X. and Baksm, P. 2009. Effect of biofertilizers and organic manures on physic-chemical characteristics and soil nutrient composition of Guava (*Psidium guajava* L.) cv. Sard. J. Res., SKUAST-J, 8:150-156.

Sheng, X.F. and Huang, W.Y. 2001. Physiological characteristics of strain NBT of silicate bacterium. Acta Pedol. Sci., 38: 569-574.

Singh, R.S. 1982. Plant Pathogens "The Fungi". Oxford and IBH Publishing Co. New Delhi, Bombay, Calcuta, 443.

Skulberg, O.M. 2000. Microalgae as a source of bioactive molecules-experience from cyanophyte research. J. Appl. Phycol., 12: 341-348.

Snedecor, G.W. and Cochran, W.G. 1989. "Statistical Methods". 8th. ed. Iowa State Univ. Press, Ames, Iowa, USA, 251 pp.

Sobh, M.M.; Genaidy, S. and Hegazy, M. 2000. Comparative studies on mineral and biofertilization for main field crops in northern delta soils. Zagazig J. Agric. Res., 27(1): 171-179.

Stephen, V. 2012. Alternative plant disease management practices for the home garden. University of Arkansas, United States Department of Agriculture, and County Governments Cooperating, pp. 1-6.

Vaddar, U.B. 2007. Studies on grape rhizosphere microorganisms. M.Sc. Thesis. Univ. of Agric. Sci. Dharwad. 91 pp.

Young, I.M. and Ritz, K. 2000. Tillage, habitat space and function of soil microbes. Soil Till. Res., 53: 201-213.

Zarpelon, T.G.; da Silva, A.C.; Santos, A.F.; Freitas, C.S.; Coutinho, M.M.; de Barros, N.F.; de Freitas, R.G. and Alfenas, A.C. 2019. Phosphorus, nitrogen and potassium nutrition on Calonectria leaf blight in eucalypt plants. Forest Pathol., 49: e12561

Zarrouk, C. 1966. Contribution à l'étude d'une cyanophycée: influence de divers facteurs physiques et chimiques sur la croissance et la photosynthèse de *Spirulina maxima* (Setch et Gardner) Geitler**.** Ph.D. Thesis, University of Paris, France, Pages 11-83.

Ziedan, E.H. 2003. Root-rot disease of grapevine in Egypt. J. Agric. Sci., Mansoura Univ., 28(2): 1473-1481.

Ziedan, E.H.; Farrag, E.S. and Mahmoud, S.Y. 2016. First Report: Pathological potential of fungi on *Moringa oleifera* Lam in Egypt. Int. J. Pharm. Tech. Res.**,** 9(8): 36-40.