Pak. J. Biotechnol. Vol 15 (4) 979-984 (2018) ISSN Print: 1812-1837
www.pjbt.org ISSN Online: 2312-779

USE OF SOME *STREPTOMYCES* ISOLATES AND THEIR MIXTURES AS BIOLOGICAL CONTROL AGENTS AGAINST POWDERY MILDEW OF FLAX CULTIVAR MARYLIN R3 IN AN OUTDOOR POT EXPERIMENT

Sonya Hamouda Mohamed[1] and Mansour M.T.M[2]

[1]Agricultural Microbiology Department, Soil & Water and Environment Research Institute, Agricultural Research Center (ARC), 9 Gamaa st., 12619, Giza, Egypt. [2]Plant Pathology Research Institute, ARC, 9 Gamaa st., 12619, Giza, Egypt.

Article received 20.10.2018, Revised 30.11.2018, Accepted 9.12.2018

ABSTRACT

In this study, the effect of some isolates of *Streptomyces* and their mixtures was evaluated as a biological control agent against powdery mildew (PM) of flax cv. Marlin R3, its effect on disease incidence (DI), disease severity (DS), seed yield (SY) and straw yield (StY) R3 in an outdoor pot experiments of two seasons (2016 and 2017). Four *Streptomyces* isolates (SI) of SI-3, SI-5 and StI-11 with its mixture and 15 treatments. The individual isolates (SI-1), SI-3, and SI-5 were the most effective in the resistance of mildew disease with efficiency of 86.96, 69.57 and 86.96%, respectively. In contrast, individual isolates (SI-11) had no effect on the disease. On the other hand, there was a difference in the effect of the isolate's mixture in the resistance of the PM, as demonstrated by the efficiency of the three mixtures (SI-1, SI-3, SI-5, SI-11) and SI-1 (SI-3) and SI-3, SI-5, SI-11), 86.96, 73.33 and 56.67%, respectively. The rest of the mixtures did not have any effect on the resistance of the PM disease. Linear correlation analysis showed a significant positive correlation between DI and disease intensity at a significant level ($r = 0.985$, $p \leq 0.1$) in 2016 and 2017 ($r = 0.960$, $p \leq 0.1$). In 2016 there was a significant negative correlation between DI, DS, SY and StY. While in 2017 there was a negative correlation between the severity of the disease and the occurrence of the disease and SY only. Cluster analysis was only partially successful in the separation of the potent and ineffective strains of *Streptomyces* in the resistance to PM disease.

Key words: *Streptomyces*, Biological control, Powdery mildew, Flax, Disease incidence, Disease severity.

INTRODUCTION

The powdery mildew (PM) diseases are major foliar diseases have an important economic impact on a variety of plant species (Aly et al. 1994, Mansour and Mohamed 2007, Micali et al. 2008, Hegazi and El-Kot 2010). Chemical application is still the main strategy to decrease the risk of most crop diseases caused by fungi and other pathogens (Zaid *et al*. 2002, Saeed *et al*. 2016). One of the most important factors that have led to the control of plant pathogens is the use of bio-control agents (BCAs) which can minimize the use of chemical pesticides and its harmful side effects to human health (Bardin *et al*. 2015, Saeed *et al*. 2017).

Locci and Sharples (1984) showed that actinomycetes are an important bacterial group differs from other rods and cocci microorganisms, found in habitats such as soils, composts, freshwater, seawater and cold and warm-blooded animals (Williams and Wellington 1982). Genus *Streptomyces* spp. is the most dominant genera of order Actinomycetales, because of their dominance, ease of isolation and antibiotics production (Goodfellow and Williams 1983). At the level of their activities as BCAs, they were effective against many plant pathogens, in particular, fungi as shown by Lee *et al*. (2005) and El-Tarabily *et al*. (2009). This was due to producing a number of bioactive metabolites that can be employed to manage plant pathogens and improves crop productivity ((El-Tarabily and Sivasithamparam 2006, Mansour *et al*. 2010, Verma *et al*. 2011, Baltz 2016).

Several investigators (Singh *et al*. 2000, Abd El-Moneim 2001, Mosa 2002, El-Gamal 2003, Kamel 2003, Saber *et al*. 2003, McGrath 2004, Hussein *et al*., 2007, El-Tarabily *et al*. 2009, Mansour *et al*. 2010, AbuQamar *et al*. 2017) reported that bio-control, could be considered as an effective alternatives for limiting or spurring the populations of plant pathogens under greenhouses and/or field trials.

Microorganisms as BCAs typically have a relatively narrow spectrum of activity compared with synthetic pesticides (Baker 1991, Janisiewicz 1996), and soil actinomycetes particularly Strepto*myces* spp. has antagonistic activity against wide range of plant pathogens (Zarandi *et al.* 2009). Therefore, this study aimed to determine the effect of some *Streptomyces* isolates (SIs) and their mixtures as BCAs on disease intensity variables of PM of flax cultivar Marylin R3 in an outdoor pot experiment over two seasons.

MATERIALS AND METHODS

Materials source: Four SIs coded SI-1, SI-3, SI-5, and SI-11having antifungal activities were kindly provided by Department of Agricultural Micro-biology, Soil and Water and Environment

Resea-rch Institute; Agricultural Research Center (ARC), Giza, Egypt. Seeds of flax cultivar Marylin R3 and bunch fungicide, which used as a positive control compared to the *Streptomyces* spray, were obtained from Plant Pathology Research Institute, ARC, Giza, Egypt.

Antagonistic activities: The antibiosis activity of the four SIs against the fungus causing the PM of flax was determined according to the method described by Mansour and Mohamed (2007). The *Streptomyces* inocula (individual or mixtures) were prepared as mentioned by Mansour *et al*. (2010).

The outdoor pot experiment: The four SIs as well as their mixtures were used against the PM of flax cultivar Marylin R3 in an outdoor experiment was carried out over the two seasons of 2016 and 2017. A number of 15 treatments were designed as follows: four *Streptomyces* individual treatm-ents (SI-1, SI-3, SI-5, SI-11), 11 *Streptomyces* mixture treatments (SI-1, SI-3), (SI-1, SI-5), (SI-3, SI-5), (SI-1, SI-3, SI-5), (SI-1, SI-11), (SI-3, SI-11), (SI-1, SI-3, SI-11), (SI-5, SI-11), (SI-1, SI-5, SI-11), (SI-3, SI-5, SI-11), (SI-1, SI-3, SI-5, SI-11) as previously described by Mansour and Mohamed (2007) in a final concen-tration of 1 mL/50 mL water for each spraying treatment. At the concentration level three mL/ 100 mL water of Bunch fungicide was used (Trea-tment 16). As a negative control, the plants were sprayed with only water (Treatment 17). For each treatment, there were three replicates (pots) with a diameter of 25 cm containing sterilized soil and planted with flax seeds in the first week of December. On germination of flax seeds, the only plants were left in each pot. The flax plants were sprayed twice: the first spray was carried out in mid-March and the second one was carried out 15 days after the initial spray.

Disease variables: Four parameters of intensity variables, *i.e.*, disease incidence (DI, % of plants infected with powdery mildew for each pot), disease severity (DS, number of infected leaves in each plant), seed yield (SY, weight of produced seeds/plant) and straw yield (StY, weight of produced straw/plant) were determined. Both of DI and DS were assessed 15 days post the second spray with either *Streptomyces* or Bunch fungicide compared with control. SY and StY were measured at the beginning of May.

Statistical analyses: Data were subjected to anal-ysis of variance (ANOVA), and Duncan's multiple range test was used to compare treatment means. Linear correlation coefficient (r) was calculated to evaluate the degree of association between disease intensity variables and yield. ANOVA and corre-lation analyses were performed with MSTATC statistical package. *Streptomyces* isolates were also clustered as phenogram by unweighted pair group method with arithmetic mean (UPGMA) (Sokal and Michener 1958). Cluster analysis was performed with the software package Statistical Package for the Social Sciences (Spss) 6.0.

RESULTS AND DISCUSSION

Four *Streptomyces* isolates coded SI-1, SI-3, SI-5 and SI-11 and their mixtures containing fift-een treatments as shown in Table (1) were used to evaluate the effect of *Streptomyces* isolates (Indi-vidual or mixtures) on powdery mildew of flax cultivar Marylin R3 intensity variables (disease incidence, (DI) and disease severity (DS)), seed and straw yields in two growing seasons 2016 and 2017 in outdoor experiment. LSD was used to compare the means of individual streptomycete treatments in 2016 (Table 1). Data show that *Stre-ptomyces* treatment isolates 1(SI-1), 4(SI-5) and 15(SI-1, SI-3, SI-5, SI-11) significantly decreased DI compared to control. The efficiency of the tre-atment isolates was 86.96% for these three treat-ments. Similarly, treatments 2(SI-3), 3(SI-1, SI-3) and 14 (SI-3, SI-5, SI-11) were significantly dec-reased DI by 69.51, 65.21 and 43.49%, respect-ively.

Treatments 1(SI-1), 15(SI-1, SI-3, SI-5, SI-11), 2(SI-3), 3(SI-1, SI-3), 4(SI-5) and 14(SI-3, SI-5, SI-11) significantly decreased DI with eff-iciency 70.37, 70.37, 62.97, 59.26, 59.26%, res-pectively, while, one treatment 2(SI-3) signifi-cantly increased seed yield. None of *Streptomyces* treatments (Individually or mixture) significantly affected on straw yield. Referring to the results in Table 2 treatments 1(SI-1), 15(SI-1, SI-3, SI-5 and SI-11), 2(SI-3), 3(SI-1, SI-3) and 4(SI-5) signifi-cantly decreased DI with efficiency 70.37, 70.37, 62.97, 59.26 and 59.26% respectively. Treatments 1(SI-1), 2(SI-3), 3(SI-1, SI-3), 4(SI-5), 15(SI-1, SI -3, SI-5, SI-11) and 5(SI-1, SI-5) were signi-ficantly decreased DS with efficiency 96.07, 95.37, 94.55, 94.55, 83.90 and 80.11%, respecti-vely. In 2017 none of the *Streptomyces* treatments significantly affected both seed and straw yields.

Table 1: Effect of *Streptomyces* isolates (individual or mixture) on disease intensity variables (DI and DS), SY/plant and StYstraw yield/plant of flax cultivar Marylin R3 in outdoor experiment in 2016.

Treatments	*Streptomyces* isolates	Intensity variables							
		DI		DS		SY		StY	
T1	SI-1	10.00	E*	04.40	F	0.17	B	0.40	AB
T2	SI-3	23.33	D	13.90	E	0.27	A	0.50	A
T3	SI-1, SI-3	26.67	D	16.23	D	0.15	B	0.40	AB
T4	SI-5	10.00	E	12.63	E	0.13	B	0.40	AB
T5	SI-1, SI-5	76.67	AB	72.80	ABc	0.12	B	0.40	AB
T6	SI-3, SI-5	76.67	AB	64.00	Bc	0.16	B	0.40	AB
T7	SI-1, SI-3, SI-5	73.33	B	61.07	c	0.09	B	0.40	AB
T8	SI-11	76.67	AB	67.77	Bc	0.09	B	0.30	AB
T9	SI-1, SI-11	86.67	A	66.73	Bc	0.11	B	0.20	AB
T10	SI-3, SI-11	80.00	AB	73.27	ABc	0.12	B	0.30	AB
T11	SI-1, SI-3, SI-11	80.00	AB	81.73	A	0.15	B	0.30	AB
T12	SI-5, SI-11	73.33	B	72.33	ABc	0.12	B	0.30	AB
T13	SI-1, SI-5, SI-11	86.67	A	76.13	AB	0.12	B	0.30	AB
T14	SI-3, SI-5, SI-11	43.33	C	36.70	D	0.14	B	0.30	AB
T15	SI-1, SI-3, SI-5, SI-11	10.00	E	03.97	F	0.12	B	0.30	AB
T16	Bunch	00.00	F	00.00	G	0.16	B	0.40	AB
T17	Control	76.67	AB	71.7	Bc	0.10	B	0.30	AB

DI: Disease incidence (Percentage of infected plants/pot). DS: Disease severity (Percentage of infected leaves/plant). SY: Seed yield (g/plant). StY: Straw yield (g/plant). *: Means followed by the same letter(s) are not significantly different (P<0.05) according to Duncan's multiple range test.

Table 2: Effect of *Streptomyces* isolates (individual or mixture) on disease intensity variables (DI and DS), SY/plant and StYstraw yield/plant of flax cultivar Marylin R3 in outdoor experiment in 2017.

Treatments	*Streptomyces* isolates	Intensity variables							
		DI		DS		SY		StY	
T1	SI-1	26.67	E*	3.37[b]	GH	0.153	A	0.557	AB
T2	SI-3	33.33	DE	3.97	GH	0.083	Bc	0.393	BcD
T3	SI-1, SI-3	36.67	DE	4.67	GH	0.093	Bc	0.377	cD
T4	SI-5	36.67	DE	4.67	GH	0.073	Bc	0.333	D
T5	SI-1, SI-5	53.33	cD	16.53	F	0.083	Bc	0.437	ABcD
T6	SI-3, SI-5	70.00	BC	45.30	E	0.060	c	0.280	D
T7	SI-1, SI-3, SI-5	83.33	AB	76.83	D	0.063	Bc	0.353	Cd
T8	SI-11	83.33	AB	79.10	cD	0.060	Bc	0.327	D
T9	SI-1, SI-11	83.33	AB	86.47	BcD	0.083	Bc	0.397	BcD
T10	SI-3, SI-11	90.00	A	88.80	ABc	0.037	c	0.253	D
T11	SI-1, SI-3, SI-11	86.67	A	93.50	AB	0.063	Bc	0.297	D
T12	SI-5, SI-11	90.00	A	90.27	AB	0.053	c	0.330	D
T13	SI-1, SI-5, SI-11	93.33	A	91.47	AB	0.060	Bc	0.283	D
T14	SI-3, SI-5, SI-11	93.33	A	95.47	A	0.050	c	0.273	D
T15	SI-1, SI-3, SI-5, SI-11	26.67	E	13.80	FG	0.067	Bc	0.330	D
T16	Bunch	06.67	F	2.30	H	0.173	A	0.603	A
T17	Control	90.00	AB	85.70	BcD	0.120	ABc	0.520	ABc

T: Treatment. DI: Disease incidence (Percentage of infected plant/pot). DS: Disease severity (Percentage of infected leaves/plant). SY: Seed yield (g/plant). StY: Straw yield (g/plant). *: Means followed by the same letter(s) are not significantly different (P<0.05) according to Duncan's multiple range test.

Mansour and Mohamed (2007) mentioned that when percentages of disease incidence and disease severity increased, the seed yield and straw yield decreased. In other word, a negative relationship of powdery mildew of flax disease incidence, disease severity, seed yield and straw yield was noted. Results in Table 3 showed linear correlation coefficients shown that a highly positive correlation coefficients ($p< 0.01$) between DI and DS in both of two years, 2016 and 2017. In 2016 the relationship between DI and straw yield showed negative correlation ($p<0.05$) also DS shown negative correlation coefficient on both of seed yield and straw yield. These results are in agreements with that found by Mansour (1998), who found that it was evident that powdery mildew intensity variables (DI and DS) reached maximum levels on young plants (late sawing dates) and decline considerable on adult plants (early sowing dates). The intensity of disease on young plants was significantly reflect on deteriorate of seed and straw production.

Table 3: Correlation among disease intensity variables (DI and DS), SY and StY for evaluating effect of individual and mixture of some *Streptomyces* isolates on control of powdery mildew on flax in two seasons (2016 & 2017) under outdoor conditions.

Years	Variables		Variables							
			1st Year (2016)				2nd Year (2017)			
			1	2	3	4	5	6	7	8
1st	1	DI	1.000							
	2	DS	0.985[a]**	1.000						
	3	SY	-0.416*	-0.488*	1.000					
	4	StY	-0.540*	-0.534*	0.601*	1.000				
2nd	5	DI	0.886**	0.883**	-0.494*	0.633**	1.000			
	6	DS	0.812**	0.815**	-0.515*	-0.767**	0.960**	1.000		
	7	SY	-0.557**	-0.546*	0.211	0.347	-0.644**	-0.536*	1.000	
	8	StY	0.141	-0.107	-0.023	0.158	0.112	-0.038	-0.966**	1.000

[a]: Linear correlation coefficient (rs) is significant at P < 0.05 (*) or P < 0.01 (**).

On the other hand, relationship between seed yield and straw yield shown positive correlation (r = p<0.05). In 2017, highly positive correlation coefficient (r = p<0.01) between DI in both two years which means that the infection stable by DI, and this agree with that reported by Mansour (1998) and Aly *et al*. (1994). Results represented in Fig. 1 showed that the tested isolates were placed in three subclusters, the first one included three groups. The first subgroup (Distance = 0.0) included very highly susceptible treatments (T8, T13, T10, TI7, T12, T11, T9). However, the susceptible treatment (T6) (Distance 5.0) made up a separate group (subcluster) unrelated to the other susceptible treatments. The third subgroup included (T14, T15) made up a separate subcluster unrelated to the other treatments in the susceptibility which treatment (T15) considered very highly resistance to the disease (Tables 1 and 2). Treatment (T5) separated in subcluster (distance =2.5) although it belongs to the susceptible subgroup.

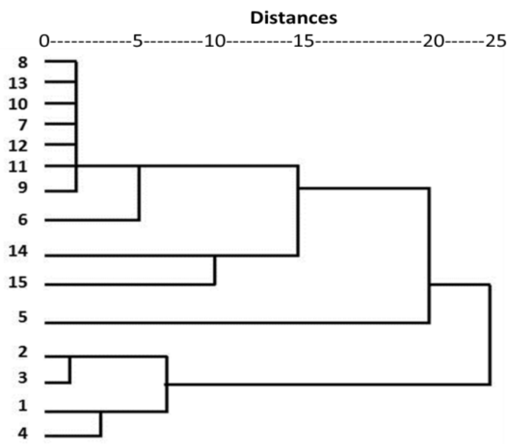

Figure 1: Phenogram based on average linkage cluster analysis of *Streptomyces* isolates (individual or mixtures) on disease intensity variables (disease incidence and disease severity) of flax powdery mildew, seed yield and straw yield. The isolates individual and mixture of *Streptomyces* were T1(SI-1), T2(SI-2), T3(SI-1, SI-3),T4(SI-5), T5(SI-1, SI-5), T6(SI-3, SI-5), T7(SI-1, SI-3, SI-5), T8(SI-11), T9(SI-1, SI-11), T10(SI-3, SI-11), T11(SI-1, SI-3, SI-11), T12(SI-5, SI-11), T13(SI-1, SI-5, SI-11), T14(SI-3, SI-5, SI-11), and T15(SI-1, SI-3, SI-5, SI-11).

The third subcluster included four treatments T2, T3 (Distance = 0.0) and treatments T1, T4 (Distance = 2.5) which exhibit highly resistance treatments. In general, the dendrogram has failed in differentiate between the resistance and susceptible treatments. This study suggested that antagonist treatments are more effective in biological control of powdery mildew of flax when used individually. Results showed that individual treatments were very effective (Tables 1 and 2). Dandurand and Kundsen (1993), Hubbard *et al*. (1983) reported that of combinations of biological control agents did not improved on suppression of disease compared with separate antagonists. Only one mixture treatment gave an effective result in controlling powdery mildew in this study 15 (SI-1, SI-3, SI-5, SI-11). Schisler *et al*. (1997) mentioned that the still very limited number of compatible and effective mixtures of BCAs is due to several factors. The majorities of mixtures have no benefit or are determinate to biocontrol activity. Further, a mixture that improves activity less than one set of conditions or on a different host. From an economical point of view, a biocontrol product composed of a mixture of strains has a potential draw back, because producing and registering such a product will likely be more-costly than a product composed of a single or individual strain.

REFERENCES

Abd El-Moneim, Maisa, L., Evaluation of some non-chemical methods to control some soil borne fungi and foliage diseases of cucumber. Ph.D. Thesis, Fac. Agric., Zagazig Univ. Egypt, pp. 143 (2001).

AbuQamar S.F., Moustafa K., Tran L.S., Mechanisms and strategies of plant defense against *Botrytis cinerea*. Crit. Rev. Biotechnol. 37: 263–275 (2017).

Aly A.A., Ashour A.Z.A. El-Kady E.A.F., Mostafa M.A., Effectiveness of fungicides for control of powdery mildew of falx and effect of disease on yield and yield components. J. Agric. Sci. Mansoura Univ. 19: 4383-4393 (1994).

Bardin M., Ajouz S., Comby M., Lopez-Feber M., Graillot B., Siegwart M., Nicot P., Is the efficacy of biological control against plant diseases likely to be more durable than that of chemical pesticides?. Frontiers in Plant Science 6: 1-14 (2015).

Bakr R., Diversity in biological control. Crop Prot. 10: 85-94 (1991).

Baltz R.H., Genetic manipulation of secondary metabolite biosynthesis for improved production in *Streptomyces* and other actinomycetes. J. Ind. Microbiol. Biotechnol. 43: 343–370 (2016).

Bressan W., Biological control of maize seed pathogenic fungi by use of actinomycetes. Biocontrol. 48: 233–240 (2003).

Dandurand L.M. and Kundsen G.R., Influence of Pseudomonas fluorescens on hyphal growth and biological activity of *Trichoderma harzionum* in the spermoshere and rhizosphere of pea. Phytopathology 83: 265-270 (1993).

Doumbou C.L., Salove M.K., Crawford D.L., Beaulieu C., Actinomycetes, promising tools to control plant diseases and to promote plant growth. Phytoprotection 82: 85–102 (2001).

El-Gamal, Nadia, G., Usage of some biotic and abiotic agents for induction of resistance to cucumber powdery mildew under plastic house conditions. Egypt. J. Phytopathol. 31(1-2): 129-140 (2003).

El-Tarabily K.A., Nassar A.H., Hardy G.E.S.J., Sivasithamparam K., Plant growth promotion and biological control of *Pythium aphanidermatum*, a pathogen of cucumber, by endophytic actinomycetes. J. Appl. Microbiol. 106: 13–26 (2009).

El-Tarabily K.A., Sivasithamparam K. Non-streptomycete actinomycetes as biocontrol agents of soil-borne fungal plant pathogens and as plant growth promoters. Soil Biol. Biochem. 38: 1505–1520 (2006).

Freeman S., Minz D., Kolesnik I., Barbul O., Zveibil A, Maymon M., et al., *Trichoderma* biocontrol of *Colletotrichum acutatum* and *Botrytis cinerea* and survival in strawberry. Eur. J. Plant Pathol. 110:361-370 (2004).

Goodfellow M., Williams S.T., Ecology of actionmycetes. Annu. Rev. Microbiol. 37: 189-216 (1983).

Hegazi M.A., El-Kot G.A., Biological control of powdery mildew on zinnia (*Zinnia elegans*, L.) using some biocontrol agents and plant extracts. Journal of Agricultural Science 2: 220-230 (2010).

Hubbard J.P., Harman G.E., Hadar Y., Effect of soilborne Pseudomonas spp. on the biological control agent, *Trichoderma hamatum*, on pea seeds. Phytppathology 73: 655-659 (1983).

Hussein M.A.M., Hassan M.H.A., Allam A.D.A., Abo-El-Yous K.A.M., Management of stemphylium blight of onion by using biological agents and resistance inducers. Egypt. J. Phytopathol. 35(1):49-60 (2007).

Janisiewicz W.J., Ecology diversity, niche overlap, and coexistence of antagonists used in developing mixtures for biocontrol of postharvest diseases of apples. Phytopathology 86: 473-479 (1996).

Kamel, S.M.H., Antagonistic effects of some microbial inhabitants on phylloplane of squash plants towards *Sphaerotheca fuliginea*. Ms. C. Thesis Fac. of Agric. Kafr El-Sheikh, Tanta Univ., pp. 94 (2003).

Lee H.B., Kim Y., Kim J.C., Choi G.J., Park S.H., Kim C.J., Jung H.S., Activity of some aminoglycoside antibiotics against true fungi, *Phytophthora* and *Pythium* species. J. Appl. Microbiol. 99: 836-43 (2005).

Locci R., Sharples G.P., Morphology, in The Biology of the Actinomycetes, eds Goodfellow M., Mordarski M., Williams S.T., editors, London: Academic Press Pp. 165–199 (1994).

Mansour M.T.M. (1998). Pathological studies on powdery mildew of flax in A.R.E. Ph.D. Thesis, fac. Agric., Zagazig Univ., Moshtohor, pp. 148 (1998).

Mansour M.T.M., Sonya H. Mohamed, Suppression of powdery mildew of flax by the foliar application of *Streptomyces*. 12th Conference of Microbiology, Cairo, Egypt, 18-20 March, 2007, Session (2), Biological Control, pp. 1 (2007).

Mansour, M.T.M., Mohamed Sonya H., Zayed S.M.E., Ashour A.Z.A., Field evaluation of some Streptomyces isolates to suppress powdery mildew of flax (Sakha 1 cultivar). Pak. J. Biotechnol.7(1-2): 101-107 (2010)

McGrath, M.T., Protectant fungicides for managing powdery mildew in cucurbits: How do they stack up?. Vegetable MD on Line. Dept. of Plant Pathology, Ithaca, Ny 14833. Magaret Tuttle McGrath, Associate Professor. Dept. of Plant Pathology, Long Island Horticulture Research and Extension Center/ Cornell University 3059 sound Avenue, River heals Ny1190, May Zaeir (2004).

Micali C., Göllner K., Humphry M., Consonni C., Panstruga R. (2008). The powdery mildew disease of Arabidopsis: A paradigm for the interaction between plants and biotrophic fungi. The Arabidopsis Book 6: e0115. (2008). American Society of Plant Biologists. https://doi.org/10.1199/tab.0115.

Mosa, A.A., Induced resistance in rice against blast disease using a biotic- and biotic agents. Ann. Agric. Sci., Ain Shams Univ., Cairo, 47(3): 993-1008 (2002).

Otto-Hanson L.K., Grabau Z., Rosen C., Salomon E., Kinkel L.L., Pathogen variation and urea influence selection and success of *Streptomyces* mixtures in biological control. Phytopathology 103:34-42 (2013).

Paulitz T.C. and Belanger R.R., Biological control in greenhouse systems. Annu. Rev. Phytopathol. 39:103-133 (2001).

Saber M.M., Abdou Y.A., El-Gantiry S.M., Ahmed S.S., Biocontrol of anthracnose disease of soybean caused by *Colletotricum dematium*. Egypt. J. Phytopathol. 31(1-2): 17-29 (2003).

Saeed E., Sham A., El-Tarabily K.A., Abu Elsamen F., Iratni R., AbuQamar S.F., Chemical control of black scorch disease on date palm caused by the fungal pathogen, *Thielaviopsis punctulata*, in United Arab Emirates. Plant Dis. 100: 2370-2376 (2016).

Saeed E., Sham A., Salmin Z., Abdelmowla Y., Iratni R., El-Tarabily K., AbuQamar S., *Streptomyces globosus* UAE1, a potential effective biocontrol agent for black scorch disease in date palm plantations. Front Microbiol. 8: 1455 (2017).

Schisler D.A., Sliniger P.J. and Bothast R.J., Effects of antagonist cell concentration and two strain mixtures on biological control of *Fusarium* dray rot of potatoes. Phytopathology 87: 177-183 (1997).

Shahidi B.G.H., Fooladi M.H., Mahdavi M.J., Shahghasi A., Broad spectrum, a novel antibacterial from *Streptomyces* sp. Biotechnology 3: 126–130 (2004).

Singh U.P., Prithiviraj B., Singh K.P., Sarma B.K., Control of powdery mildew (*Erysiphe pisi*) of pea (*Pisum sativum*) by combined application of plant growth promoting. Zeitschrit-planzenkrankheiten undplanzenschutz, 107:59-66 (2000).

Sokal R., Michener C., A statistical method for evaluating systematic relationships. University of Kansas Science Bulletin 38: 1409-1438 (1958).

Verma V.C., Singh S.K., Prakash S., Bio-control and plant growth promotion potential of siderophore producing endophytic *Streptomyces* from *Azadirachta indica* A. Juss. J Basic Microbiol. 51: 550-556 (2011).

Williams S.T., Wellington E.M.H., Actinomycetes, in Methods of Soil Analysis, part 2 Chemical and Microbiological Properties, *2nd* Edn, eds Page A.L., Miller R.H., Keency O.R., editors, Madison, WI: American Society of Agronomy/Soil Science Society of America Pp. 969–987 (1982).

Xu X.M., Jeffries P., Pautasso M., Jeger M.J., Combined use of biocontrol agents to manage plant diseases in theory and practice. Phytopathology 101:1024-1031 (2011).

Zaid A., de Wet P.F., Djerbi M., Oihabi A., Chapter XII: diseases and pests of date palm, in Date Palm Cultivation, FAO, Plant Production and Protection Paper No. 156, ed. Zaid A., editor. Rome, FAO (2002).

Zarandi Ebrahimi M., Shahidi Bonjar G.H., Padasht Dehkaei F., S.A. Ayatollahi Moosavi, Rashid Farokhi P., Aghighi S., Biological Control of Rice Blast (*Magnaporthe oryzae*) by use of *Streptomyces sindeneusis* isolate 263 in Greenhouse. American Journal of Applied Sciences 6(1): 194-199 (2009).