J. Plant Prot. and Path., Mansoura Univ., Vol.9 (12): 787 – 794, 2018

Effect of Integrated Control Program of Powdery Mildew Disease on Growth and Productivity of Apple

Radwan, M. A.[1] and D. R. Darwesh[2]
[1] Plant Pathol. Res. Inst., ARC, Giza, Egypt
[2] Hort. Res. Inst., ARC, Giza, Egypt.
Corresponding author: drmahmoudawwad67@yahoo.com & darwesh_ra@yahoo.com

ABSTRACT

Disease incidence % and disease severity % of the powdery mildew fungus (*Podosphaera leucotricha*) were assessed on Anna apple trees (*Malus domestica*, Borkh) budded on MM106 rootstock during 2016-2017 seasons in three different locations in Egypt. The disease occurrence was more prevailing in Qalyoubia governorate than the two orchard sites in Behaira (Kafr El Dawar and Noubaria). The efficacy of eleven foliar spray programs for management apple powdery mildew and on vegetative growth, fruiting parameters and fruit quality of Anna apple trees was evaluated in experimental farm at El-Qanater El-Khairia Horticultural Research Station in Qalyoubia, Agricultural Research Centre. All treatments reduced the disease severity % of powdery mildew with significant increase to all investigated vegetative growth measurements, fruiting parameters and fruit quality of Anna apple trees in relation to the control. The alternative fungicides in program 4 (Microvit, Punch and Topas) provided protection at an important level against powdery mildew infection and improved parameters and characters as compared with fungicide Microvit (P1), Punch (P2) or Topas (P3) each alone in the two seasons. In addition, alternation sprays among biofungicides in program 8 (Bio Zied , Bio Arc and AQ10) gave more efficiency, both growth and fruiting parameters and fruit characters as compared with those used in a single treatment in P5 (Bio Zied), P6 (Bio Arc) and P7 (AQ10). The effectiveness of Potassium Silicate in (P9) in inhibiting powdery mildew disease led to used it in alternation with Microvit and AQ10 in program10 as an integrated pest management (IPM) program. In general, the effectiveness of the alternative treatments with non-systemic fungicide Microvit, Potassium Silicate and AQ10 in (P10) was similar to that recorded of the systemic fungicides P2 (Punch) and P3 (Topas)) in both seasons. Results show that P10 can be used as alternative method for farmers to have eco-friendly management of powdery mildew with significant increase to the produced growth, productivity and fruit quality.

Keywords: Apple powdery mildew, integrated control program, fungicides, potassium silicate, biofungicides, vegetative growth, productivity and fruit quality.

INTRODUCTION

Apple (*Malus domestica*, Borkh) is considered one of the most common popular and favorite deciduous fruit trees cultivated in Egypt. Anna is one of the most important and favorite apple cultivars in Egypt. Anna apple variety is considered as a hybrid between Red Hadassiya and Golden Delicious. Powdery mildew, caused by the obligate biotrophic fungus *Podosphaera leucotricha*, is a major disease attacks all apple growing areas of the world Urbanietz and Dunemann (2005). The disease results in yield reduction and loss of fruit quality in the absence of control measures. In the beginning of spring the disease appeared on leaves which are the most susceptible organs. The disease appears on the upperside of infected leaf as powdery white lesions and eventually the infected part of leaf turn brown and infections on the underside of infected leaf result in chlorotic patches. Infected leaves become crinkle, curl and drop prematurely. Although blossom and fruit infections are less common, they are important because infected fruits are small and stunted if they do not drop. *P. leucotricha* survives the winter as mycelium in vegetative tissues or in infected flower buds. The primary infection starts when infected buds break dormancy and fungus resumes growth and colonizes developing shoots. Spores growing on infected shoots spread nearby and initiate secondary infections. Primary infections of flower buds cause severe yield losses Turechek *et al.,* (2004). The highest percentage in disease incidence and severity were recorded in Qalyoubia governorate. Intensive applications of fungicides in controlling diseases have resulted in the development of resistance in the fungus. The residual effects of fungicides on the crop, soil and water are hazardous and toxic to both people and domestic animals and causes environmental pollution Wightwick *et al.,* (2010). However, there is a need to pay more attention towards the development of effective alternative methods to suppress apple powdery mildew, to increase and improve both productivity and quality of apple fruits and to be safe in the environment, humans and animals. Potassium Silicate uses in agricultural production to supply plants with highly soluble potassium and silicon. Biofungicides are naturally bioproducts that contain fungus and bacteria which can affect fungal organisms and do not have negative impacts on the environment, humans, animals and non-target organisms McGrath, (2004). During the last few years, several reports have been published on using fungal and bacterial biofungicides and sodium and potassium silicate compounds for controlling powdery mildew on grape (*Uncinula nacator*) by the mycoparasite *Ampelomyces quisqualis* Falk *et al.*, (1995) and Mahrous, (2001) and by using Potassium Silicate (Blaich and Wind, 1989) and Reynolds *et al.*, (1996). Tarabih *et al.*, (2014) found that Potassium Silicate concentrations inhibited linear growth of *Penicillium expansum*. Complete inhibition of the linear growth appeared at 0.3% treatment. Dipping Anna apple fruits at 0.3% of Potassium Silicate recorded the lowest significant values of disease infection percentage of *P. expansum* and maintained the quality of the apples during storage and marketing. Yildirim *et al.,* (2002) reported that alternative methods to synthetic fungicides may be managed to utilize a scheme of inducible plant defenses which may provide protection against a broad spectrum of disease-causing organisms.

This study aims to assess the effectiveness of eleven foliar spray programs on infection of powdery mildew and their impact on vegetative growth measurements, fruit productivity and fruit quality of Anna apple trees.

MATERIALS AND METHODS

Survey of powdery mildew incidence and severity in apple orchards.

Survey was conducted after the first disease symptoms were observed during spring seasons of 2016 and 2017 on Anna apple trees (*Malus domestica*, Borkh), 10- year- old budded on MM106 rootstock, planted at

3.5×3.5 m in a loamy clay soil in two Egyptian governorates, i.e. Qalyoubia (experimental farm at El-Qanater El-Khairia Horticultural Research Station, Agricultural Research Centre) and two orchard sites at the Beheira (Kafr El Dawar and Noubaria). Trees were normal growth, uniform in vigor as possible, trained on open vase training system. Common agriculture practices were treated in both seasons. The trees were left to the natural infection by powdery mildew and fifteen trees were used as three replicates. Twenty leaves were selected randomly from each tree. Disease incidence % was assessed as the number of infected leaves relative to the total leaves. Disease severity % was assessed according to the modified scale (0-5) by Reuveni and Reuveni, (1995) where:

0 = No powdery mildew colonies observed.
1 = 1–10% of the leaf area infected.
2 = More than 10–25% of the leaf area infected.
3 = More than 25–50% of the leaf area infected.
4 = More than 50 –75% of the leaf area infected.
5 = More than 75–100% of the leaf area infected.

The following formula was used to estimate the disease severity:

$$\text{Disease severity \%} = \frac{\sum n \times v}{5N} \times 100$$

Where:

n = Number of the infected leaves in each category.
v = Numerical values of each category.
N = Total number of the examined leaves.

Efficacy of application programs.

Effect of foliar spray programs on the development of powdery mildew on apple under field conditions.

Field experiments were carried out during 2016 and 2017 growing seasons on 10- year- old apple trees Anna cv. grown in experimental farm at El-Qanater El-Khairia Horticultural Research Station, Agricultural Research Centre, Qalyoubia governorate to evaluate the effect of eleven programs i.e. three fungicides (Microvit, Punch and Topas) sprayed three times each alone as well as the alternation among them, three biofungicides (Bio Zied, Bio Arc and AQ10) sprayed three times each alone as well as the alternation among them, one fertilizer (Potassium Silicate) sprayed three times and an alternating treatment among (Microvit, Potassium Silicate and AQ10) compared with control treatment (distilled water) on development of the powdery mildew fungus, *Podosphaera leucotricha* as Table 1. The trees were left to the natural infection by powdery mildew and distributed according to a complete randomized design, with three replicates, using five trees as experimental unit. Three foliar sprays were applied at 15-day intervals during spring seasons. Infected leaves were examined at the end of the experiment to estimate disease severity. Twenty leaves were selected randomly from each tree five days after the last application and assessed for the presence or absence of mildew. Disease severity % was recorded using disease scale as previously mentioned.

Table 1. Application programs and test treatments.

Pro. No.	Types of treatment of three sprays	Application rate/100 L water
P1	Non-systemic fungicide Microvit (Sulfur)	250g
P2	Systemic fungicide Punch (flusilazole)	6mL
P3	Systemic fungicide Topas (penconazole)	25mL
P4	Alternation treatments among (Microvit , Punch , Topas)	250g, 6mL and 25mL
P5	Bio Zied (*Trichoderma album*)	250g
P6	Bio Arc (*Bacillus megaterium*)	250g
P7	AQ10 (*Ampelomyces quisqualis*)	5g
P8	Alternation treatments among (Bio Zied , Bio Arc , AQ10)	250g, 250g and 5g
P9	Potassium Silicate (K_2Sio_3)	300g
P10	Alternation treatments among (Microvit , Potassium Silicate , AQ10)	250g, 300g and 5g
P11	Untreated protectant program	-

The efficiency of each program was calculated as follow:

$$\text{Efficiency \%} = \frac{\text{Disease severity \% in the control} - \text{Disease severity \% in each program}}{\text{Disease severity \% in the control}} \times 100$$

Effect of foliar spray programs on growth and fruiting parameters.

This study was carried out during 2016 and 2017 growing seasons on 10- year- old apple trees Anna cv. to evaluate the effect of foliar sprays of previous eleven programs on vegetative growth measurements [shoot length (cm), number of leaves/shoot and leaf area (cm^2)], fruiting parameters [fruit set % and yield (kg/tree)], fruit characteristics [fruit weight (g), fruit volume (cm^3) and fruit firmness (Ib/$inch^2$)], fruit dimensions (fruit height and fruit diameter in cm) and fruit chemical characteristics [TSS (%) and Acidity (%)].

Effect on vegetative growth measurements.

To measure vegetative growth measurements [shoot length increase (cm), number of leaves per each shoot and leaf area (cm^2)], ten main branches were chosen randomly from four geographical directions of each tree of all eleven programs. Length of new shoots which emerged from these labeled branches was measured on the 1st week of April then

Shoot length increase (cm) = shoot length on the 4th week of August - shoot length on the 1st week of April

Whereas number of leaves per each labeled shoot were counted and recorded on the 4th week of August in both seasons. Moreover, samples of ten mature leaves were collected by picking the 3rd to 5th one from the base of the previously labeled shoots then, leaf area was measured by using the planimeter.

Effect on fruiting parameters:

a. Fruit set %:

In all eleven programs, number of flowers per each tree were counted and recorded at full bloom stage. Then, the initial number of flowers were counted and recorded per each tree at the end of blooming stage (set fruitlets) to estimate fruit set % according to Westwood (1978) as follow:

$$\text{Fruit set (\%)} = \frac{\text{No. of set fruitlets}}{\text{Total no. of flowers at full bloom}} \times 00$$

b. Productivity (yield):

Estimate yield (kg/tree) is considered the best study of a reflection of the tested programs on fruit productivity of apple trees. At the harvesting period fruits of each replicate tree for each program were separately harvested and were transported to the laboratory to estimate the average yield as kg/tree.

Fruit characteristics:

Samples of 20 mature fruits of all replicate trees for each program were randomly selected at the harvesting period to determine fruit characteristics.

a. Fruit physical characteristics:

Fruit weight (g), fruit volume (ml^3), fruit firmness ($Ib/inch^2$), fruit dimensions (fruit height and fruit diameter in cm) were determined by using pressure tester with 7/18-inch plunger according to Magness and Taylor (1982).

b. Fruit chemical characteristics:

Data on two fruit juice chemical properties were determined from 20 mature fruits from each program as follows:

Total Soluble Solids percentage (TSS %): was determined by using a Carl Zeiss hand refractometer according to A.O.A.C (2000).

Total titratable acidity percentage: malic acid (1g/100g fruit juice) was measured according to the method described by Vogel (1975) to estimate Fruit juice acidity %.

Statistical analysis:

Data that obtained during 2016 and 2017 growing seasons were subjected to analysis of variance method according to Snedecor and Cochran (1990) to assess the program effects. Duncan's Multiple Range tested (Duncan, 1955) were used to compare differences among means.

RESULTS

Survey of powdery mildew incidence and severity in apple orchards.

A survey results during 2016 and 2017 growing seasons in Table 2 show that the highest percentage in disease incidence and severity were recorded in Qalyoubia governorate (38.33, 28.00% and 35.00, 24.80%) in the two seasons, respectively, followed by Noubaria (Behaira governorate) (35.33, 24.27% and 33.66, 22.26%), respectively, while Kafr El Dawar (Behaira governorate) recorded the lowest disease occurrence.

Table 2. Disease incidence and severity % of powdery mildew in the three sites in the two governorates during 2016 and 2017 seasons.

Governorate		2016		2017	
		D.I%*	D.S%**	D.I%*	D.S%**
Beheira	Kafr El Dawar	33.66B	22.40B	32.33A	20.33B
	Noubaria	35.33B	24.27B	33.66A	22.26AB
Qalyoubia	El-Qanater	38.33A	28.00A	35.00A	24.80A
Mean	----------	35.77B	24.89B	33.66A	22.46AB

D.I%*= disease incidence
D.S% = disease severity**
Mean numbers within columns followed by different letters are significantly different *at P* < 0:05 according to Duncan's Multiple Range Test.

Efficacy of application programs.

Effect of foliar spray programs on the development of powdery mildew on apple under field conditions.

The efficacy of the tested eleven programs under natural conditions was determined in 2016 and 2017 seasons. Data presented in Table 3 show that all the tested programs reduced the severity of powdery mildew compared with control treatment. Systemic fungicides Punch in (P2) and Topas in (P3) were more effective than Microvit in (P1). The alternative fungicides in program 4 (Microvit, Punch and Topas) gave protection at an important level against powdery mildew infection which recorded the highest efficacies (89.28 and 90.88%), respectively as compared with fungicide Microvit, Punch or Topas each alone which recorded (77.39 and 79.55%, 86.21 and 88.18% and 84.07 and 85.20%), respectively in the two seasons. In addition, results of both seasons proved that alternation sprays among biofungicides in program 8 (Bio Zied , Bio Arc and AQ10) gave more efficiency in reducing the disease severity as compared with those used in a single treatment in P5 (Bio Zied), P6 (Bio Arc) and P7 (AQ10). Potassium Silicate in (P 9) showed effectiveness in reducing the severity of the disease which ranged from 67.86 to 68.83 in both seasons.

Table 3. Effect of foliar spray programs on controlling apple powdery mildew under field conditions in 2016 and 2017 seasons.

Pro. No.	Types of treatment	Season 2016		Season 2017	
		DS%*	Effi%**	DS%*	Effi%**
P1	Microvit	6.33CD	77.39	5.07CD	79.55
P2	Punch	3.86FG	86.21	2.93DE	88.18
P3	Topas	4.46E-G	84.07	3.67DE	85.20
P4	Microvit, Punch and Topaz	3.00G	89.28	2.26E	90.88
P5	Bio Zied	7.87BC	71.89	6.80BC	72.58
P6	Bio Arc	8.46B	69.79	7.60B	69.35
P7	AQ10	5.80DE	79.28	4.93CD	80.12
P8	Bio Zied , Bio Arc and AQ10	4.86D-F	82.64	4.13DE	83.34
P9	Potassium Silicate	9.00B	67.86	7.73B	68.83
P10	Microvit, Potassium Silicate and AQ10	4.20E-G	85.00	3.33DE	86.57
P11	Untreated Protectant Program	28.00A	--	24.80A	--

***DS%= disease severity** ****Effi%= Efficiency**
Mean numbers within columns followed by different letters are significantly different *at P* < 0:05 according to Duncan's Multiple Range Test.

In general, similar efficacies were found among the program 10 (Microvit, Potassium Silicate and AQ10) which showed (85.00 and 86.57%) efficacies and programs 2 (Punch) and program 3 (Topas) which recorded efficacies (86.21 and 88.18%) and (84.07 and 85.20%), respectively in both seasons. Symptoms of powdery mildew on apple trees were initially observed only on leaves of untreated control trees. The disease severity clearly indicated that spraying of Potassium Silicate in alternation with Microvit and AQ10 in program 10 significantly inhibited powdery mildew similar to the effect of commercial fungicide. These data clearly indicate that Potassium Silicate treatment when applied in alternation with the fungicides and biofungicides in IPM control programs to reduce using systemic fungicides has a role in retarding powdery mildew. It should be noted that better protection against the disease was obtained from the alternation treatments on the three alternative programs in p4 (Microvit, Punch and Topas), p8 (Bio Zied , Bio Arc and AQ10) and p10 (Microvit, Potassium Silicate and AQ10) than from each treatment alone.

Effect of foliar spray programs on some vegetative growth measurements, fruiting parameters and fruit characteristics.

Data represented in Table 4, 5, 6, 7 and 8 show the effect of eleven programs on vegetative growth measurements [shoot length (cm), number of leaves/shoot and leaf area (cm^2)], fruiting parameters [fruit set % and yield (kg/tree)], fruit characteristics [fruit weight (g), fruit volume (cm^3) and fruit firmness ($Ib/inch^2$)], fruit dimensions (fruit height and fruit diameter in cm) and fruit chemical characteristics [TSS (%) and Acidity (%)]. Data declared that all the application programs showed remarkable increase in all growth, yield and fruit quality of Anna Apple trees compared with the control trees which exhibited the least shoot length (cm), no. of leaf/shoot, leaf area (cm^2), fruit set%, yield (kg/tree), fruit weight (g), fruit volume (cm^3) F. firmness ($Ib/inch^2$), fruit height, fruit diameter in cm, TSS (%) and acidity (%)) during the two seasons of study. The alternatives fungicides in program 4 (Microvit, Punch and Topas) were superior and had more effect on all growth, yield and fruit quality as compared with the other investigated fungicides each alone, where the highest value of all growth, yield and fruit quality were resulted from them during both 2016 and 2017 seasons of study. Additionally, alternation sprays among biofungicides in program 8 (Bio Zied, Bio Arc and AQ10) increased all growth, yield and fruit quality as compared with those used in a single treatment in P5 (Bio Zied), P6 (Bio Arc) and P7 (AQ10). In addition, results of both seasons revealed that Potassium Silicate exhibited higher growth, yield and fruit quality than Bio Zied and Bio Arc. Generally, spraying of Potassium Silicate fertilizer in alternation with non-systemic fungicides (Microvit) and biofungicides (AQ10) in program 10 significantly exhibited growth, yield and fruit quality similar to that recorded in commercial systemic fungicide Punch in (P2) and Topas in (P3).

Table 4. Effect of foliar spray programs on shoot length (cm), number of leaf/shoot and leaf area (cm^2) of Anna apple trees during both 2016 and 2017 seasons.

Pro. No.	Types of treatment	Shoot length (cm) 2016	Shoot length (cm) 2017	No. of leaf/shoot 2016	No. of leaf/shoot 2017	Leaf area (cm^2) 2016	Leaf area (cm^2) 2017
P1	Microvit	39.36E	40.18F	29.69DE	31.01CD	34.17F	35.12E
P2	Punch	44.60B	45.97C	33.97AB	35.43AB	39.05C	39.97AB
P3	Topas	43.59C	44.97D	33.12BC	34.63B	38.16D	39.20BC
P4	Microvit ,Punch and Topaz	49.78A	49.87A	36.24A	38.15A	39.94A	41.75A
P5	Bio Zied	35.99G	37.12H	27.59EF	28.59D	31.51H	32.13F
P6	Bio Arc	35.48G	36.75H	27.00F	28.19D	31.06I	31.97F
P7	AQ10	41.27D	42.88F	31.59CD	33.02BC	36.39E	37.61CD
P8	Bio Zied , Bio Arc and AQ10	45.67B	46.26B	34.06AB	35.84AB	39.49B	40.65AB
P9	Potassium Silicate	38.01F	39.17G	29.29EF	30.20CD	33.28G	36.48DE
P10	Microvit, Potassium Silicate and AQ10	44.88B	46.08C	33.97AB	35.43AB	39.00C	40.03AB
P11	Untreated Protectant Program	30.98H	31.50I	28.67EF	29.71CD	26.62J	29.53G

Mean numbers within columns followed by different letters are significantly different *at P* < 0:05 according to Duncan's Multiple Range Test.

Table 5. Effect of foliar spray programs on fruit set (%), yield (kg/tree) of Anna apple trees during both 2016 and 2017 seasons.

Pro. No.	Types of treatment	Fruit set (%) 2016	Fruit set (%) 2017	Yield (kg/tree) 2016	Yield (kg/tree) 2017
P1	Microvit	11.24D	11.76D	33.13E	36.64F
P2	Punch	12.98B	13.16B	37.96BC	41.87C
P3	Topas	12.63B	13.26B	37.04C	40.92D
P4	Microvit ,Punch and Topaz	13.52A	14.01A	40.33A	42.82A
P5	Bio Zied	10.48E	10.85E	31.03F	33.78H
P6	Bio Arc	10.38E	10.69E	30.44F	33.31I
P7	AQ10	12.05C	12.53C	34.89D	39.01E
P8	Bio Zied , Bio Arc and AQ10	13.07AB	13.60AB	38.56B	42.35B
P9	Potassium Silicate	11.06D	11.34D	33.08E	35.68G
P10	Microvit, Potassium Silicate and AQ10	12.98B	13.47B	38.48B	41.87C
P11	Untreated Protectant Program	9.33F	9.80F	28.20G	28.55J

Mean numbers within columns followed by different letters are significantly different *at P* < 0:05 according to Duncan's Multiple Range Test.

Table 6. Effect of foliar spray programs on fruit weight (g), fruit volume (cm^3) and fruit firmness ($Ib/inch^2$) of Anna apple trees during both 2016 and 2017 seasons.

Pro. No.	Types of treatment	Fruit weight (g)		Fruit volume (cm^3)		F. firmness ($Ib/inch^2$)	
		2016	2017	2016	2017	2016	2017
P1	Microvit	123.41D	124.53F	115.69D	117.12F	10.41DE	10.80EF
P2	Punch	141.03AB	141.96C	132.22AB	133.98C	10.63CD	11.20DE
P3	Topas	137.83B	139.23D	129.65B	130.94D	10.93BC	11.63CD
P4	Microvit ,Punch and Topaz	144.24A	145.92A	135.51A	137.03A	12.17A	12.62A
P5	Bio Zied	114.02E	114.92H	106.50E	108.10H	9.60F	10.03G
P6	Bio Arc	112.19E	113.59H	104.70E	106.58I	9.47F	10.04G
P7	AQ10	131.64C	133.06E	122.24C	124.85E	11.09B	11.50CD
P8	Bio Zied , Bio Arc and AQ10	141.79A	144.42AB	133.04AB	135.51B	10.87BC	11.23DE
P9	Potassium Silicate	120.59D	121.70G	108.47E	114.19G	12.23A	12.37AB
P10	Microvit, Potassium Silicate and AQ10	141.05AB	142.80BC	131.44AB	133.98C	11.90A	12.01BC
P11	Untreated Protectant Program	107.33F	123.07FG	107.77E	108.57H	10.13E	10.53GF

Mean numbers within columns followed by different letters are significantly different *at P* < 0:05 according to Duncan's Multiple Range Test.

Table 7. Effect of foliar spray programs on fruit dimensions (fruit height and fruit diameter in cm) of Anna apple trees during both 2016 and 2017 seasons.

Pro. No.	Types of treatment	Fruit height (cm)		Fruit diameter (cm)	
		2016	2017	2016	2017
P1	Microvit	5.88C-E	5.89CD	5.90BC	5.94C
P2	Punch	6.58AB	6.71AB	6.54A	6.79A
P3	Topas	6.44A-C	6.89A	6.33AB	6.63AB
P4	Microvit, Punch and Topaz	6.76A	6.85A	6.52A	6.70A
P5	Bio Zied	5.32EF	5.69CD	5.54C-E	5.73CD
P6	Bio Arc	5.20F	5.61D	5.40DE	5.50DE
P7	AQ10	6.11B-D	6.57AB	6.32AB	6.38B
P8	Bio Zied , Bio Arc and AQ10	6.20A-C	6.21BC	6.65A	6.86A
P9	Potassium Silicate	5.62 D-F	6.01CD	5.78CD	5.86C
P10	Microvit, Potassium Silicate and AQ10	6.58 AB	6.88A	6.76A	6.79A
P11	Untreated Protectant Program	5.32 EF	5.50D	5.17E	5.32E

Mean numbers within columns followed by different letters are significantly different *at P* < 0:05 according to Duncan's Multiple Range Test.

Table 8. Effect of foliar spray programs on fruit chemical characteristics (TSS % and acidity %) of Anna apple trees during both 2016 and 2017 seasons.

Pro. No.	Types of treatment	TSS %		Acidity %	
		2016	2017	2016	2017
P1	Microvit	11.05D	11.18B	0.513D	0.526BC
P2	Punch	12.63A	12.80A	0.586AB	0.614A
P3	Topas	12.34B	12.73A	0.573B	0.595A
P4	Microvit, Punch and Topaz	12.30B	12.44A	0.599A	0.626A
P5	Bio Zied	10.19F	10.60BC	0.490E	0.491CD
P6	Bio Arc	10.05F	10.49C	0.466F	0.485D
P7	AQ10	11.77C	12.24A	0.546C	0.550B
P8	Bio Zied , Bio Arc and AQ10	12.56A	12.91A	0.593A	0.615A
P9	Potassium Silicate	10.77E	11.19B	0.500DE	0.516BCD
P10	Microvit, Potassium Silicate and AQ10	12.63A	12.91A	0.586AB	0.609A
P11	Untreated Protectant Program	10.17F	10.24C	0.400G	0.447E

Mean numbers within columns followed by different letters are significantly different *at P* < 0:05 according to Duncan's Multiple Range Test.

DISCUSSION

Apple (*Malus domestica*, Borkh) is considered one of the common popular favorite and consumed fruits in Egypt. Apple is widely grown throughout the temperate climate region in the Northern hemisphere (where Egypt lies) and Southern hemisphere Brown, (2012). Great efforts have been exerted for expanding apple into subtropical and tropical zones (Karakurt and Aslantas, 2010). *Podosphaera leucotricha* is the causal agent of powdery mildew disease, can attack all apple trees of the world (Urbanietz and Dunemann, 2005).The fungus spend winter in previous year infected terminal buds and twig tips as mycelium which in spring it can resume growth and can attack young leaf tissue (growing shoots) causing primary infections. Thousands of spores which give powdery white appearance on infected shoots are responsible for spreading the fungus later in the growing season (Xu, 1999). *P. leucotricha* infects mainly leaves causing chlorotic (yellow) patches or spots on the upperside of the leaf and eventually turn a darker brown. The infected leaves crinkle, curl upward and covered with a powdery coating of spores and drop in the summer. *P. leucotricha* can also infect fruits causing a netlike russetting (Koch *et al.*, 2015). Powdery mildew infections on blossoms and fruits are less common but when blossoms were infected lead to fail set fruit and when the fruit were infected they are unsuitable for marketing (Turechek *et al.*, 2004). Survey was conducted after the first disease symptoms were observed during spring season of 2016 and 2017 seasons on Anna apple trees. The highest percentage in disease incidence and severity were recorded in Qalyoubia governorate, followed by Noubaria (Behaira governorate), while Kafr El Dawar (Behaira governorate) recorded the lowest disease occurrence.

Efficiency of eleven programs i.e. three fungicides (Microvit, Punch and Topas) sprayed three times each alone as well as the alternation among them, three biofungicides (Bio Zied, Bio Arc and AQ10) sprayed three times each alone as well as the alternation among them, one fertilizer (Potassium Silicate) sprayed three times and an alternating treatment among (Microvit, Potassium Silicate and AQ10) were evaluated for reducing apple powdery mildew and increasing vegetative growth measurements [shoot length (cm), number of leaves/shoot and leaf area (cm^2)], fruiting parameters [fruit set % and yield (kg/tree)], fruit characteristics [fruit weight (g), fruit volume (cm^3) and fruit firmness ($Ib/inch^2$)], fruit dimensions (fruit height and fruit diameter in cm) and fruit chemical characteristics [TSS (%) and Acidity (%)]. under field conditions during 2016-2017 seasons. In this study, it has been found that systemic fungicides (Punch and Topas) were more effective in controlling powdery mildew on apple and gave more vegetative growth, fruiting parameters and fruit quality than Microvit, Potassium Silicate and biofungicides. The alternatives fungicides in program 4 (Microvit, Punch and Topas) gave protection at an important level against powdery mildew infection which recorded the highest efficacies and the highest values of vegetative growth, fruiting parameters and fruit quality as compared with fungicide Microvit, Punch or Topas each alone. In addition, alternation sprays among biofungicids in program 8 (Bio Zied , Bio Arc and AQ10) gave more efficiency and vegetative growth, fruiting parameters and fruit quality as compared with those used in a single treatment in P5 (Bio Zied), P6 (Bio Arc) and P7 (AQ10).The inhibitory effectiveness and the high values of vegetative growth, fruiting parameters and fruit quality of Potassium Silicate fertilizer and biofungicides makes them potential major components of an integrated pest management program (IPM). The disease severity and the values of vegetative growth, fruiting parameters and fruit quality clearly indicated that spraying of Potassium Silicate in alternation with Microvit and AQ10 in program 10 significantly inhibited powdery mildew and increased values of vegetative growth, fruiting parameters and fruit quality similar to the effect of commercial systemic fungicide (Punch and Topas). The necessary number of fungicide applications was reduced when they were alternated with Potassium Silicate and biofungicides sprays in program10. It should be noted that better protection against the disease and the best values of vegetative growth, fruiting parameters and fruit quality were obtained from the alternation treatments on the three alternative programs p4, p8 and p10 than from each treatment alone. This alternative treatment appeared similar protection to that obtained from the commercial application of systemic fungicides, and therefore it offers environmentally friendly possibilities for disease control, with reduction of fungicide use by at least 50%, whether expressed as the number of treatments or as the total dosage per season. Sulfur is cheaper than most other fungicides and is widely used for controlling powdery mildew diseases on all crops. Continues use of sulfur in spray programs is important to prevent the development of resistance to systemic fungicides and ensure optimum control of powdery mildew.

Silicon (Si) is the second richest and prevalent element in the earth's crust and it minimizes abiotic and biotic stresses when uptakes by plants. Si content of winter wheat cultivars tissues was 0.1-10% of their dry weight Liang et *al.,* (2008). Silicon has stimulating defense reaction mechanisms that made it uses as alternative to fungicides to control various fruit crops diseases beside to it has no toxic effect on plants (Ma and Yamaji 2006). The obtained reduction in apple powdery mildew disease and high values of vegetative growth, fruiting parameters and fruit quality on trees which sprayed with Potassium Silicate (K_2Sio_3) may be attributed to the role of Si in increasing plant resistance against pathogenic fungi (Abdel-Kader *et al*., 2012). Effect of Si content on plant tissues and disease severity have been reported for powdery mildew diseases of barley *(Erysiphe gruminis*) Jiang *et al.,* (1989), wheat *(E. graminis*) Leusch and Buchenauer, (1989), and cucumber *(Sphaerotheca fuliginea)* Menzies *et al.,* (1991a) and sheath blight *(Corticium sasakii* Shiriai) of rice Aleshin *et al.,* (1986). Menzies *et al*., (1992) showed that leaves of Cucumber, Muskmelon, and Zucchini Squash which received the Si-amended nutrient solution or foliar sprays of 17.0 mM Si 7 days before inoculation with *Sphaerotheca fuliginea* developed fewer powdery mildew colonies than those on control plants. Menzies *et al.,* (1991b) reported that light microscope and scanning electron microscope studies have indicated that Si applied in nutrient solutions may enhance the natural resistance of cucumber to *Sphaerotheca fuliginea* . Both Si and phenolic compounds have been observed to accumulate around sites of penetration by the powdery mildew fungus. Samuels *et al*., (1991) showed that Si accumulation in cucumber leaves play an important role for controlling *Sphaerotheca fuliginea*, the causal agent of powdery mildew disease. Fauteux *et al*., (2006) reported that treating *Arabidopsis thaliana* plants with Si increased the resistance of plants to *Erysiphe cichoracearum* , the causal fungus powdery mildew and reduced abiotic and biotic stresses. Reuveni *et al*., (1998) reported that apple trees alternating treatment with 1% solution of mono-potassium phosphate fertilizer and sterol inhibiting fungicides gave high efficiency for controlling powdery mildew fungus, *Podosphaera leucotricha*. This efficiency was similar to that recorded on trees that sprayed with commercial systemic fungicides. AQ10 *(Ampelomyces quisqualis)* is considered the first biofungicide developed, especially for controlling powdery mildew disease. *A. quisqualis* is a naturally occurring pycnidial hyperparasite of powdery mildew fungi. The mycoparasite is wholly internal within the mycelium, conidiophores and conidia of several important species of Erysiphaceae, including the powdery mildew of pear (Marboutie *et al.*, 1997) and on peaches (Marboutie *et* al., 1995) and on grapevine (Mahrous, 2001) and many vegetable and horticultural crops (Kiss *et al*., 2004).

Development of resistance in the pathogens, residual effects, and environmental pollution along of the cost of controlling diseases are problems associated with use of these chemicals make the use of synthetic chemicals to control plant diseases are more restricted Wightwick *et al.,* (2010). Recently, search for alternative substances for controlling diseases have been initiated. Integrated Pest Management (IPM) has been developed as a way to control pests without relying solely on pesticides. IPM is a systematic plan which brings together different pest control tactics into one program. With IPM, a farmer uses pesticides as one tool in an overall pest-control program. IPM is a way to keep pests below the levels where they can cause economic damage. It does not mean eradicating pests but it means finding tactics that are effective and economical, and that keep environmental damage to a minimum. Fungicides mostly are of high efficiency in management of plant diseases. (Reuveni and Reuveni, 1995) investigated the effect of foliar sprays with solutions of K_2HPO_4 and KH_2PO_4 + KOH (both plus Triton X-100) and commercial systemic fungicides i.e. diniconazole (Marit 12.5% WP), myclobutanil (Sisthane 12 E) and penconazole (Ophir) each alone and alternative treatment among them for controlling powdery mildew on nectarine, mango trees and grapevines. They found that the effect of alternative treatment among phosphate salt with each of the tested fungicides gave more efficiency than that recorded in the case of phosphate salt and the tested fungicides each alone. Alternative methods for controlling the diseases are favorite by the public due to the increasing concern that fungicides may negatively impact on the environment and human health (Gullino *et al.,* 1999).

In conclusion, it could be recommend that Potassium Silicate treatment when applied in alternation with the Microvit and AQ10 as (IPM) program to reduce using systemic fungicides has an important role in controlling apple powdery mildew disease and increased vegetative growth, fruiting parameters and fruit quality of Anna apple trees.

REFERENCES

Abdel-Kader M.M.; El-Mougy, Nehal S. and E.I. Embaby (2012). Resistance inducers treatment against downy and powdery mildew of cucumber under commercial plastic houses conditions. Australian Journal of Basic and Applied Sciences, 6(5):249-259.

Aleshin,N.E.; E.R. Avakyan; S.A. Dyakunchak; E.P. Aleshkin; V.P. Baryshok and M.G. Voronkov (1986). Role of silicon in resistance of rice to blast. Dokl. Akad. Nauk SSSR 291(2):499-502.

Association of Official Analytical Chemists (A.O.A.C.) (2000). Official methods of analysis, the A.O.A.C. 15th Ed., Published by A.O.A.C. Washington, DC 2004, U.S.A.

Blaich, R. and R. Wind (1989). Inducible silica incrusts in cell walls of *Vitis* leaves. Vitis 28:73-80.

Brown S. A. (2012). In: Badenes ML, Byrne DH, editors. Fruit Breeding, Handbook of Plant Breeding. Springer Science Business Media; Philadelphia, PA: pp. 329–367.

Duncan, D. B. (1955). Multiple range and multiple F. tests. Biometrics, 11: 1-42.

Falk, S. P.; D. M. Gadoury; R. C. Pearson; R. C. Seem (1995). Partial control of grape powdery mildew by the mycoparasite *Ampelomyces quisqualis*. Plant Disease. 79 (5): 483-490.

Fauteux, F.; F. Chain; F. Belzile; J. G. Menzies and R. R B. elanger (2006). The protective role of silicon in the *Arabidopsis*—powdery mildew pathosystem. Proceedings of the National Academy of Science USA. 103: 17554–17559.

Gullino M. L.; R. Albajes and J. C. vanLenteren (1999). Setting the stage: Characteristics of protected cultivation and tools for sustainable crop protection. In: Integrated Pest and Disease Management in Greenhouse Crops, pp. 1–13.

Jiang, D.; R.J. Zeyen and V. Russo (1989). Silicon enhances resistance of barley to powdery mildew. Phytopathology 79:1198.

Karakurt, H. and R. Aslantas (2010). Effects of some plant growth promoting rhizobacteria (PGPR) strains on plant growth and leaf nutrient content of apple. J Fruit Ornam Plant Res. 18:101–110.

Kiss L.; J. C. Russell; X. O. Szentivanyi and X. P. Jeffries (2004). Biology and biocontrol potential of *Ampelomyces mycoparsites* , natural antagonistis of powdery mildew fungus. Biocontrol Science and 793.

Koch, A.; F. Felsenstein and G. Stammler (2015). No Evidence of QoI Resistance in Apple Powdery Mildew (Podosphaera leucotricha). J. Phytopathol., 178-184.

Leusch, H.J. and H. Buchenauer (1989). Effect of soil treatments with silica; rich lime fertilizers and sodium trisilicate on the incidence of wheat by *Erysiphe graminis* and *Septoria nodorum* depending on the form of N-fertilizer. Z. Pflanzenkr. Pflanzensshutz 96(2):154-172.

Liang, Y.; J. Zhu; Z. Li; G. Chu; Y. Ding; J. Zhang and V. Sun (2008). Role of silicon in enhancing resistance to freezing stress in two contrasting winter wheat cultivars. Environ. Exp. Bot., 64: 286-294.

Ma, J.F. and N. Yamaji (2006). Silicon uptake and accumulation in higher plants. Trends Plant Sci., 11: 392-397.

Magness, J. R. and G. F. Taylor (1982). An improved type of pressure tester for the determination of fruit maturity. U.S. Dept. Agric. Circ., 50 (8): 350 -358.

Mahrous, H.A.H. (2001). Biological control of grape vine powdery mildew by *Ampelomyces quiqualis* Congr. Proc. Of 11*th* Congress of the Mediterranean Phytopathological Union, Evora, Portugal, 17-20 September.

Marboutie, G.; F. Combe; E. Boyer; A. Berne and P. Cravedi (1995). Work on *Ampelomyces quisqualis* (1993-1994). Proceedings of the Meeting on Integrated Plant Protection in Stone Fruit; Nimes France, 6-8 Sep., Bulletin, OILB, SROP. 18:2,75-78.

Marboutie G.; F. Combe; P. Cravedi; C. Hartfield and E. Mazzni (1997). Taxonomy of *Ampelomyces quisqualis on Sphaerotheca pannosa* on Var. Bailey and contribution to the study of its use in the control of powdery mildew of pear in mid-Rhane valley. Proceedings of the Meeting at Zaragoza, Spain, 24-26 Gotheran September. Bulletin, OILB.SROP, 20:6, 79-83.

McGrath, M.T. (2004). What are fungicides? The plant health instructor. APS Press, St. Paul, MN. 10 June 2006. <http://www.apsnet.org/education/ Intro/ Topics/ fungicides/default.htm>.

Menzies, J.G.; D.L. Ehret; A.D.M. Glass; T. Helmer; C. Koch and F. Seywerd (1991a). The effects of soluble silicon on the parasitic fitness of *Sphaerotheca fuliginea* on *Cucumis sativus.* Phytopathology 81:84-88.

Menzies, J.G.; D.L. Ehret; A.D.M. Glass and A.L. Samuels (1991b). The influence of silicon on the cytological interactions between *Sphaerotheca fuliginea* and *Cucumis sativus.* Physiol. & Mol. Plant Pathol. 39:403-414.

Menzies J.; P. Bowen and D. Ehret (1992). Foliar Applications of Potassium Silicate Reduce Severity of Powdery Mildew on Cucumber, Muskmelon, and Zucchini Squash. J. Amer. Soc. Hort. Sci. 117(6):902-905.

Reuveni M. and R. Reuveni (1995). Efficacy of foliar sprays of phosphates in controlling powdery mildew in field-grown nectarine, mango trees and grape vines. Crop Protection, 14:311-314.

Reuveni, M.; D. Oppenheim and R. Reuveni (1998). Integrated control of powdery mildew on apple trees by foliar sprays of mono-potassium phosphate fertilizer and sterol inhibiting fungicides. Crop Protection 17: 563-568.

Reynolds, A.G.; L.J. Veto; D.A. Sholberg; D.A. Wardle and P. Haag (1996). Use of potassium silicate for the control of powdery mildew [*Uncinula nacator* (Schw.) Burrill] in *Vitis vinifera* L. cultivar *Bacchus*. Am.J.Enol. Viticulture 47:421-428.

Samuels, A. L.; A. D. M. Glass; D. L. Ehret and J. G. Menzies (1991). Distribution of silicon in cucumber leaves during infection by powdery mildew fungus (*Sphaerotheca fuliginea*). *Canadian Journal of Botany* 69: 140–146.

Snedecor, G.W. and G.W. Cochran (1990). Statistical Methods. 8th Ed The Iowa State Univ., press Ames, Iowa. U.S.A. pp.503-507.

Tarabih, M.E.; E.E. EL-Eryan and M.A. EL-Metwally (2014). Physiological and pathological impacts of Potassium Silicate on storability of Anna apple fruits. American Journal of Plant Physiology 9 (2): 52-67

Turechek, W.W.; J.E. Carroll and D.A. Rosenberger (2004). Powdery mildew of apple. NY State Integrated Pest Management (www.nysipm.cornell.edu/factsheets/treefruit/diseases/pm/apple_pm.pdf).

Urbanietz, A. and F. Dunemann (2005). Isolation, identification and molecular characterization of physiological races of apple powdery mildew (*Podosphaera leucotricha*). Plant Pathology , 54: 125–133.

Vogel, A. (1975). A Text Book of Quantitative Inorganic Analysis. Longmans, New York, pp.1216.

Westwood, M. N. (1978). Temperate Zone Pomology W. H. Freeman and Company. San Francisco.

Wightwick, A.; R.Walters; G. Allinson; S. Reichman and N. Menzies (2010). Environmental Risks of Fungicides Used in Horticultural Production Systems, Fungicides. (Carisse, O., ed.), ISBN: 978-953-307-266-1, In Tech, Available from: http://www.intechopen.com/books/fungicides/environmental-risks-offungicides- used-in-horticultural-production-systems.

Xu, X. M. (1999). Modelling and forecasting epidemics of apple powdery mildew (*Podosphaera leucotricha*). Plant Pathology, 48:462-471.

Yildirim, I.; E. Onogur and M. Irshad (2002). Investigations on the efficacy of some natural chemicals against powdery mildew [*Uncinula necator* (Schw.) Burr.] of grape. J. Phytopathol., 150:697-702.

تأثير المكافحة المتكاملة لمرض البياض الدقيقي علي نمو وإنتاجية أشجار التفاح

محمود عواد رضوان[1] و درويش رجب درويش[2]

[1]معهد بحوث أمراض النباتات – مركز البحوث الزراعية – جيزة – مصر

[2]معهد بحوث البساتين – مركز البحوث الزراعية – جيزة – مصر

تم حساب نسبة الإصابة وشدة الإصابة بمرض البياض الدقيقي على أشجار التفاح صنف أنا المطعومة على أصل 106 في موسمي 2016- 2017 في ثلاث مناطق بمصر. وأثبتت النتائج أن المرض كان أكثر إنتشارا في محافظة القليوبية عن محافظة البحيرة (كفر الدوار والنوبارية). ولقد تم تقييم فعالية رش إحدى عشر برنامجا لمكافحة المرض في مزرعة التجارب البحثية بمحطة بحوث البساتين بالقناطر الخيرية- مركز البحوث الزراعية. ولقد أثبتت التجارب أن كل هذة البرامج قد أدت إلى خفض شدة الإصابة بالمرض مع زيادة ملحوظة في قياسات النمو الخضري وكذلك قياسات الإثمار وصفات جودة الثمار مقارنة بالكنترول. ولقد أدت المعاملة التبادلية بالمبيدات الفطرية في البرنامج الرابع (ميكروفيت- بانش- توباس) إلى الوقاية من المرض مع زيادة قياسات النمو الخضرى وكذلك قياسات الإثمار وصفات جودة الثمار لمستوى أعلى من إستخدام كل مبيد على حدة في كل من الموسمين . بالإضافة لذلك أعطت المعاملة التبادلية بالمبيدات الحيوية (بيوزيد – بيوأرك - ايه كيو10) كفاءة أكثر في مكافحة المرض مع زيادة قياسات النمو الخضري وكذلك قياسات الإثمار وصفات جودة الثمار من إستخدام كل مبيد على حدة في كل من الموسمين. ولقد أدت كفاءة سيليكات البوتاسيوم في البرنامج التاسع في خفض الإصابة بالمرض مع زيادة قياسات النمو الخضرى وكذلك قياسات الإثمار وصفات جودة الثمار إلى إمكانية إستخدامها في برنامج المكافحة المتكاملة. وعلى العموم، أثبتت النتائج أن كفاءة المعاملة التبادلية (بالمبيد الفطري الغير جهازي ميكروفيت، سيليكات البوتاسيوم، المبيد الحيوى ايه كيو10) في البرنامج العاشر في مكافحة المرض وزيادة قياسات النمو الخضرى وكذلك قياسات الإثمار وصفات جودة الثمارعلى أشجار التفاح كانت مشابهة تقريبا للمعاملة بالمبيدات الجهازية في البرنامج الثانى (بانش) والثالث (توباس) في كل من الموسمين. ومن الممكن أن نستنتج أنة يمكن إستخدام برنامج المكافحة المتكاملة العاشر في مكافحة مرض البياض الدقيقى على التفاح كطريقة بديلة للمبيدات الفطرية الجهازية نظرا لأن مكونات هذا البرنامج تؤدي إلى زيادة ملحوظة في قياسات النمو الخضري وقياسات الإثمار وصفات جودة الثمار على أشجار التفاح بالإضافة الى أن ليس لها تأثير علي صحة الإنسان والنبات والبيئة.