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ORIGINAL PAPER

Effect of Temperature, Relative Humidity and Some Systemic Fungicides on Cucumber Downy Mildew and Certain Crop Parameters

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ABSTRACT

Downy mildew caused by *Pseudoperonospora cubensis* (Berk. and Curt) Rostow is a major disease of cucumber (*Cucumis sativus* L.) in Egypt. The current study was carried out in Fayoum, Ismailia and Kafr Elsheikh Governorates in summer and fall during of 2018 and 2019 seasons. The effect of some whither parameters on downy mildew was studied. Temperature, relative humidity, disease severity and their relationships were determined. Five fungicides Previcur N 72.2 SL, Veulet 80 WP, Previcur Energy 840 SL, Infinito 68.75 SC and Profiler 71.1 WG, were used for the disease control. Final disease severity (FDS), area under disease progressive curve (AUDPC) and fungicides efficacy were measured and analyzed. Scanning electron microscope was used for histopathological studies. Fresh, dry weight and the average number of fruits/plant and fruit yield/feddan (ton) were recorded. Kafr Elsheikh recorded the lowest average temperature, being 23.8°C during the two growing seasons followed by Ismailia and Fayoum, being 25.2°C and 26.9°C, respectively. Kafr Elsheikh, also recorded the highest average of relative humidity, being 53.3% during the two growing seasons followed by Fayoum and Ismailia, being 52.9% and 51.9%, respectively. The same trend was observed for disease severity that recorded the highest average in Kafr Elsheikh, Ismailia and Fayoum 36.2, 31.45 and 30.9%, respectively during the two growing seasons. On the other hand, the lowest average temperature and the highest average of relative humidity were recorded in 2018 and 2019 seasons, respectively, while the highest averages of disease severity were recorded in 2018 and 2019 seasons, being 34.3 and 31.4, respectively. Fungicide, Infinito recorded the lowest FDS%, AUDPC and the highest efficacy%, being 6.6, 142.3 and, 7.0% and 171.8 in 2018 and 2019 seasons, respectively, followed by Profiler, Previcur Energy, Previcur N and Veulet. compared with control. Twisting, loss turgor, collapsing of sporangiophores and sporangium explosion were observed after application. Increasing and improvement of yield parameters were recorded.
Keywords: cucumber, downy mildew, disease severity, environmental factors, and fungicides.

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INTRODUCTION

Cucurbit downy mildew caused by the oomycete *Pseudoperonospora cubensis* (Berk. & M.A. Curtis) Rostovzev is a major disease of cucumber (*Cucumis sativus* L.) (Palti and Cohen, 1980). Chemical control of downy mildew is necessary to achieve high yields in the absence of adequate host plant resistance. Most of the currently grown cultivars have some resistance to downy mildew. The disease causes greater yield losses under low temperature and high relative humidity (Sharma *et al*., 2003 and Granke *et al*., 2014). Optimum temperature for germination and sporulation of *P. cubensis* is 20±2°C and production of sporangia started during the nighttime (Lebeda and Cohen, 2011). Significant sporulation reduction of *P. cubensis* was observed during April-May period due to hot dry climate during that period. Temperature and leaf wetness greatly influenced the infection of cucurbits downy mildew (Hembram *et al*., 2014). Parameters like night leaf wetness duration, average night temperature, night relative humidity and number of night hours having RH>95% from sowing time were key weather parameters for predicting disease initiation (Ghosh *et al*., 2015). Correlation Co-efficient of R2 value (0.63) represented that 63% influence on the intensity of downy mildew by two independent variables temperature and evaporation (Daunde *et al*., 2017). Temperature and leaf wetness were positively associated disease occurrence while solar radiation was negatively associated disease occurrence in the study for at least one site-year. Previous studies explored whether or not fungicide applications might be reduced or avoided during low leaf wetness period and high solar radiation accompanied by sporangia concentrations. Airborne sporangia concentrations were one of the most important factors identified that caused increase in downy mildew (Granke *et al*., 2014).

Resistant cultivars were recently introduced into Egypt, but yield losses were high if no fungicides were used (Metwally and Rakha, 2015). Propamocarb is a systemic carbamate fungicide with protective action against (*Pythium* spp., *Phytophthora* spp.) (Sahoo *et al.,* 2014). It exhibits a high level of controlling activity against a range of economically significant plant pathogens of oomycetes for example, grape downy mildew caused by *Plasmopara viticola* and potato and tomato late blight caused by *P. infestans* (Bardsley *et al*., 2006 and Gouot, 2006). Furthermore, fluopicolide has a novel biochemical mode of action and does not show cross-resistance with other fungicide groups (Latorse *et al*., 2006 and Toquin *et al*., 2006). Fluopicolide in combination with propamocarb hydrochloride superior to metalaxyl and mancozeb in controlling potato late blight (Cooke and Little 2006). Profiler (fluopicolide + fosetyl-Al) and the standard fungicide Mikal Flash (fosetyl-Al + folpet) showed high effective when were tested for controlling *Plasmopara viticola* in grapevine in field trials in 2006 and 2007. There were no significant differences in the efficacies of Profiler (96.1-99.7%) and Mikal Flash (94.9-99.2%). The investigated fungicide mixture fluopicolide + fosetyl-Al was highly effective even when it was applied at long intervals and under high disease pressure (Rekanović *et al.,* 2008). Disease might not be reduced greatly with improved fungicide programs, the effect in yield was great when propamocarb HCL + chlorothalonil alternated with famoxadone + cymoxanil + mancozeb treatment yielded significant higher effect than mancozeb in all cultigens. The newly added program, fluopicolide + chlorothalonil alternated with cyazofamid + mancozeb, generally outperformed all other treatments for both disease and yield (Ojiambo *et al*., 2010 Adam and Todd, 2013). Famoxadone + cymoxanil was the most effective treatment against downy mildew when significantly reduced the disease severity of cucumber downy mildew relative to control treatment. Systemic fungicides were highly effective even at low concentration levels (Mohamed *et al.,* 2016). Minimum disease severity was recorded by spraying metalaxyl + mancozeb (9.59%), metalaxyl M + mancozeb (11.02%), azoxystrobin (13.37%), CurzateM-8 (cymoxanil + mancozeb) (18.99 %), dimethomorph) (20.66 %), mancozeb (24.85 %), fluopicolide + propamocarb (24.88 %), Mandipropamid (26.21 %), propineb) (26.48 %), metiram (28.05 %), copper hydroxide (29.86 %) (Bhat *et al*., 2018).

Increasing of fruit weight/plant and reduction of disease severity were observed by using Amistar fungicide followed by potassium silicate and died spores (Ahmed, 2016). Amistar fungicide gave the best performance followed by both *P. fluorescens* I and II with slight differences with respect to disease severity, area under disease progress curve (AUDPC), efficacy (%) and plant growth parameters during the two successive seasons (Essa *et al.,*2017 and Rani *et al.*,2017). Fruit yield was significantly higher in treated plots with fungicides Ridomil MZ, and Ridomil Gold as compared to other fungicides and untreated control (Bhat *et al*., 2018).

Current study was carried out to investigate the effect of environmental factors; temperature (T) and relative humidity (RH) on cucumber downy mildew disease caused by *P. cubensis* and the efficacy of fungicide combinations as active ingredients in controlling cucumber downy mildew. Also, their effects on some growth and yield parameters were evaluated.

MATERIALS AND METHODS

1- Survey of downy mildew.

Survey of cucumber downy mildew (CDM) was carried out in the summer (1st Marsh) and in the fall (1st September) during 2018 and 2019 seasons, at Fayoum, Ismailia and Kafr Elsheikh Governorates. The experiments were carried out in open field at the Experimental Station of Agric., Kasasin Research Station and Sakha Research Station, (ARC), at Fayoum, Ismailia and Kafr Elsheikh, respectively. Seeds of cucumber cv. Hail (Suiz Canal Co.) were sown in trays 84cell filled with peat moss for 28 days, Cucumber seedlings were transplanted to the open field in summer and fall during 2018 and 2019 seasons. The experimental unit consisted of five rows (1.2m width x 7m in long), with 50 cm between seedlings, using three replicates for each treatment. Disease severity percentage (DS %) of natural infection with downy mildew was recorded one time weekly till final harvest or death of the plant. DS as mentioned in Table (1) was recorded from the leaves using the 0-5 rating scale as mention by Thind and Mohan (2001), at the end of season, at the three locations, averages of DS% were calculated.

Table (1): Disease scale for downy mildew.

Grade	Category
0	Healthy (no disease)
1	1-10% average leaf area infected
2	11-25% average leaf area infected
3	26-50% average leaf area infected
4	51-75% average leaf area infected
5>	75% average leaf area infected

1.1. Disease severity assessment.

Disease severity was determined according to the following equation (Descalzo *et al.*, 1990):

$$R\% = \frac{\Sigma (a \times b)}{N \times K} \times 100$$

Where:

R = disease severity percentage
a = number of leaves within infection grade
b = numerical value of each grade
N = total number of the examined leaves and
K = the highest degree of infection in category.

1.2. Effect of some whither parameters on severity of downy mildew:

To study the relationship between some whither parameters and disease severity of cucumber downy mildew, air temperature (°C) and relative humidity (RH%) were daily monitored then the monthly averages were counted, and disease severity was recorded in Fayoum, Ismailia and Kafr Elsheikh Governorates at summer (1st March) and fall (1st September), during 2018 and 2019 seasons.

2- Fungicides efficacy assessment:

Efficacy of five fungicides *i.e.*, Previcur N 72.2 SL, Veulet 80 WP, Previcur Energy 840 SL, Infinito 68.75 SC and Profiler 71.1 WG commercial fungicides, as mentioned in (Table2) was determined. The experiment was carried out at Kasasin Research Station, (ARC), Ismailia. Three replicates were used for each treatment, and three replicates were left without application as control. DS% was recorded 10 days after previous application and a day before next application, for five times. Fungicides efficacy were calculated.

Efficacy % =

$$\frac{\text{DS\% in control} - \text{DS\% in treatment}}{\text{DS\% in control}} \times 100$$

Final disease severity % (FDS %) measured using the aforementioned formulae, the mean of area under disease progress curve (AUDPC) for each replicate was calculated as suggested by (Pandy *et al*., 1989).

$$AUDPC = D\,[1/2(Y_1+Y_K) + (Y_2+Y_3+\ldots +Y_{k-1})]$$

Where:

D= Time interval
Y_1= First disease severity
Y_k= Last disease severity
$Y_2, Y_3, \ldots Y_{k-1}$= intermediate disease severity.

Table (2): Common Name and Formulations of five fungicides used to control downy mildew of cucumber.

Trade Name	**Common Name	**Chemical Name	Chemical Group	***dose rate /100L
Previcur N 72.2 SL	Propamocarb HCl 722g/l	Propyl 3-(dimethylamino) propylcarbamate hydrochloride	carbamates	250cm
Veulet 80 WP	Fosetyl Aluminum 800g/l	aluminum tris (O-ethyl phosphonate)	phosphonate	250gm
Previcur Energy 84 SL	Propamocarb HCl 53g/l + Fosetyl Aluminum 31g/l	Propyl 3-(dimethylamino) propylcarbamate hydrochloride + aluminum tris (O-ethyl phosphonate)	Carbamates + phosphonate	250 cm
Infinito 68.75 SC	Propamocarb HCl 625g/l + Fluopicolide 62.5 g/l	Propyl 3-(dimethylamino) propylcarbamate hydrochloride + 2,6-dichloro-N-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl] methyl] benzamide	Carbamates + benzamide	125 cm
*Profiler 71.1 WG	Fluopicolide 4.44 g/kg + Fosetyl-Al 66.7 g/kg	2,6-dichloro-N-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl] methyl] benzamide + aluminum tris (O-ethyl phosphonate)	Benzamide + phosphonate	250g

*Under test, **According to MacBean (2012) ***According to Anon. (2019)

3. Scanning Electron microscope (SEM) examination:

At fall in the open field at Kasasin Agricultural Research Station, Agricultural Research Center, Ismailia Governorate, cucumber infected leaves with downy mildew were sampled 24h after application with the tested fungicides. Samples were prepared and transferred for SEM examination. Treated and untreated leaves were microscopically observed to study the effect of fungicides on sporangiophores and sporangia of *P. cubensis*. Cucumber leaves bearing lesions of downy mildew (with and without treatment) were processed according to Harley and Fergusen (1990). Tissue pieces of ~4 mm^2 were fixed in 3% glutaraldehyde in 0.2 M phosphate buffer (pH 7.2) for 24 h at 4°C, followed by exposure to osmium tetroxide (1% OsO_4) for 1 h at 25°C. Samples were dehydrated by passing through ascending concentrations of acetone and dried till the critical point. Samples were sputter coated with gold and examined by scanning electron microscope. Scanning and photographing samples were done by electron microscope (Joel JSM-T. 330 A) at the Central Lab., Faculty of Agric. Mansoura Univ. Mansoura, Egypt.

4. Assessment of growth parameters:

The interaction effects of downy mildew and five fungicides on cucumber plants were studied at summer and fall during two successive seasons (2018 and 2019), at Kasasin Agriculture Research Station, Agricultural Research Center, Ismailia Governorate. Some of botanical and yield measurements were determined. Plant fresh and dry weights (g): using cleaned uprooted plants free from lateral root-hairs were freshly weighted, then after7days drying at 70ºC. Average number of fruits/plant and the accumulated yield were expressed as fruit yield/feddan (ton), fruits at marketable size were harvested and weighted every three days till the season end.

Statistical analysis:

Complete randomized design was used for the experiments. All the experiments were repeated twice. The experimental unit consisted of five rows and three replicates for each treatment. Analysis of variance (ANOVA) by EKUSERU-TOUKEI 2010 software (Social Survey Research Information Co., Ltd) was used. Means were compared using Fisher's least significant difference (LSD) test at a significance value of $P \leq 0.05$. Principal component analysis and correlation were determined for some treatments. Analysis of variance (ANOVA) was carried out by WASP software and the different between means were compared, by using least significance differences (L.S.D).

RESULTS AND DISCUSSION

1. Survey of cucumber downy mildew under field conditions at the three Governorates.

Environmental factors play a great role in buildup pathogen population and subsequent disease development. Temperature, relative humidity RH (%), rain fall, evaporation, wind velocity, bright sunshine and leaf wetness effect on the causal pathogen and disease spread. Accordingly, during the progress of the present study, temperature, and RH (%) and their relationship with disease severity were studied. Data in Table (3) show that during summer, the lowest temperatures were 23.8 and 24.2 on the average compared with fall which recorded 26.0 and 27.0 during the two successive seasons 2018 and 2019, respectively. While, during season 2018 the lowest temperature recorded 24.9 on the average compared with season 2019, being 25.6, on the respect of governorates, Kafr Elsheikh recorded the lowest temperatures on the average, being 23.8 compared to Fayoum and Ismailia which recorded 26.9 and 25.1 on the average, respectively during the two successive seasons 2018 and 2019.

On the other hand, relative humidity RH (%) during summer was the lowest RH (%), being 48.0 and 45.0% compared to the fall which recorded 61.7 and 55.5% on the average during the two successive seasons 2018 and 2019, respectively. While the highest, being 54.8% on the average was recorded in 2018 season compared with season 2019, being 50.2, on the respect of governorates, Kafr Elsheikh was the highest, being 53.3% on the average compared with Fayoum and Ismailia, being 52.5 and 51.9% on the average, respectively during the two successive seasons.

During summer, the highest values were recorded of DS (%), being 41.4 and 38.0 on the average compared to the fall that recorded 27.0 and 27.4 during the two successive seasons, 2018 and 2019, respectively. Meanwhile, during season 2018 the highest average of DS (%), being 34.2 was recorded compared with season 2019, (32.7), on the respect of governorates, Kafr Elsheikh was the highest on the average of

DS (%) being 35.3 compared with Fayoum and Ismailia, being 34.2 and 30.9 on the average, respectively during the two successive seasons.

Generally, DS (%) was higher in summer than in the fall season at the three surveyed Governorates during the two successive seasons. This explains that the causal pathogen development, disease spread, and DS (%) increase depend on optimum temperature and high RH (%). Summer showed the lowest temperatures on the average than the fall season so, DS (%) was higher in summer than in the fall. In respect of governorates, the highest average of DS (%) was recorded from Kafr Elsheikh where the lowest average of temperature and the highest average of RH (%) were dominated. These results are in agreement with Granke and Hausbeck (2011), Neufeld and Ojiambo (2012) and Granke *et al.*, (2014) who mentioned that numbers of airborne sporangia detected in 1-h periods were not significantly correlated with RH recorded in the same 1-h periods for the entire day. Ghosh *et al.* (2015) reported that the weekly average weather value during disease initiation indicated that high night RH (> 93%) more than 8 hours night leaf wetness duration and night relative humidity and slightly lower temperature trigger the initiation of downy mildew of cucumber.

Collected data during the progress of the present study show that summer and Kafr Elsheikh governorate were the highest in DS (%) during 2018 and2019 growing seasons. It could be concluded that increasing of relative humidity and low or moderate temperature resulted in increasing disease severity.

Table (3): Relative humidity, temperature and disease severity (%) of cucumber downy mildew at summer and fall in the three Governorates, during 2018 and 2019 seasons.

Location	Temperature				Mean	Relative humidity				Mean	Disease severity				Mean
	2018		2019			2018		2019			2018		2019		
	*S.	F.	S.	F.		S.	F.	S.	F.		S.	F.	S.	F.	
Fayoum	23.0	30.0	24.5	30.0	26.9	47.5	62.0	44.5	56.0	52.5	39.8	28.7	38.0	30.4	34.2
Kafr El-Sheikh	24.5	23.0	23.5	24.0	23.8	48.5	62.0	45.5	57.0	53.3	42.7	31.2	40.4	27.0	35.3
Ismailia	24.0	25.0	24.5	27.0	25.1	48.0	61.0	45.0	53.5	51.9	41.8	21.2	35.6	24.8	30.9
Means	23.8	26.0	24.2	27.0		48.0	61.7	45.0	55.5		41.4	27.0	38.0	27.4	
	24.9		25.6			54.8		50.2			34.2		32.7		
$LSD_{0.05}$															
Location (L)	0.38					0.28					0.75				
Years (Y)	0.35					0.33					0.32				
Sowing date (S)	0.56					0.31					0.29				
L × Y	0.31					0.72					0.43				
L × S	0.34					0.43					0.51				
Y × S	0.28					0.52					0.41				
L × Y × S	0.34					0.46					0.73				

* Sowing date [S= summer (1st Marsh); F= fall (1st September)]

2. Fungicides evaluation:

2.1. Efficacy assessment:

Data in Table (4), show that the fungicide Infinito decreased the average of final disease severity (FDS%), area under disease progress curve (AUDPC) in the summer and in the fall of 2018 compared with the control, being 6.6, 142.3 for the two disease parameters, respectively followed by Profiler, Previcur Energy, Previcur N and Veulet, being 7.1 and 151.8, 7.6 and 163.0, 9.5 and 207.0 and, 10.1 and 219.0, respectively. On the other hand, the highest efficacy% on the average was 81.8 for the fungicides Infinito followed by Profiler, Previcur Energy, Previcur N and Veulet, being 80.6, 79.1, 73.5 and 72.0% on the average, respectively.

Table (4): Final disease severity (%), area under disease progress curve and fungicides efficacy (%) for five fungicides used for controlling cucumber downy mildew during 2018 season.

Fungicide	*FDS (%)		Mean	**AUDPC		Mean	Efficacy %		Mean
	***S.	F.		S.	F.		S.	F.	
Previcur N	12.3	6.7	9.5	266.0	148.0	207.0	66.1	80.8	73.5
Veulet	13.1	7.1	10.1	281.5	156.5	219.0	64.2	79.7	72.0
Previcur Energy	9.8	5.5	7.6	201.0	125.0	163.0	74.4	83.8	79.1
Infinito	9.1	4.2	6.6	180.5	104.0	142.3	77.1	86.5	81.8
Profiler	9.4	4.8	7.1	188.5	115.0	151.8	76.0	85.1	80.6
Control	48.3	37.7	43.0	786.5	774.0	780.3	00.0	00.0	00.0
LSD 0.05									
Treatment (T)	0.89			8.43			2.11		
Sowing date (S)	0.77			9.32			1.54		
T × S	2.23			7.65			8.54		

* FDS=Final disease severity, ** AUDPC=Area under disease progress curve, *** Sowing date [S= summer (1st Marsh); F= fall (1st September)].

In Table (5), similar results were observed, Infinito decreased the average of FDS%, AUDPC in the summer and in the fall of 2019 compared with the control, being 6.3, 163.0 for the two disease parameters, respectively followed by Profiler, Previcur Energy, Previcur N and Veulet being 7and 171.8, 7.6 and 181.5, 8.2 and 210.3 and, 9.3 and 223.0, respectively. On the other hand, the highest efficacy%, on the average, was 80.3 for the fungicide Infinito followed by Profiler, Previcur Energy, Previcur N and Veulet, being 79.1, 78.0, 74.3 and 72.3% on the average, respectively.

Table (5): Final disease severity (%), area under disease progress curve and fungicides efficacy (%) for five fungicides used for controlling cucumber downy mildew during 2019 season.

Fungicide	*FDS (%)		Mean	**AUDPC		Mean	Efficacy %		Mean
	***S.	F.		S.	F.		S.	F.	
Previcur	9.1	7.3	8.2	244.5	176.0	210.3	73.6	74.9	74.3
Veulet	10.4	8.2	9.3	262.0	190.0	226.0	71.7	72.9	72.3
Previcur Energy	8.8	6.4	7.6	230.0	133.0	181.5	75.1	80.9	78.0
Infinito	7.6	5.1	6.3	208.5	117.5	163.0	77.4	83.2	80.3
Profiler	8.2	5.9	7.0	209.0	134.5	171.8	77.4	80.8	79.1
Control	43.7	37.1	40.4	926.5	701.5	814.0	00.0	00.0	00.0
LSD 0.05									
Treatment (T)	0.76			9.23			2.43		
Sowing date (S)	0.76			5.43			1.23		
T × S	2.32			8.97			1.67		

* FDS=Final disease severity, ** AUDPC=Area under disease progress curve, *** Sowing date [S= summer (1st Marsh); F= fall (1st September)].

It might be concluded that Infinito was the best fungicide which recorded the highest efficacy% and decreased DS% and AUDPC followed by Profiler, Previcur Energy, Previcur N as well as Veulet which recorded the lowest efficacy% and, DS% and AUDPC still increasing. That might be due to Infinito (Propamocarb HCl + Fluopicolide) and Profiler (Fluopicolide + Fosetyl Aluminum) having multi-site modes of action, While Previcur N (Propamocarb HCl) and Veulet (Fosetyl Aluminum) having single-site mode of action. Thus, fungicides with single-site mode of action are relatively high risk for resistance development compared to those with multi-site modes of action**.** Similar results were obtained by Mueller and Bradley (2008). Two active ingredients of Infinito (Propamocarb HCl +

Fluopicolide) and Profiler (Fluopicolide + Fosetyl Aluminum) were more effective than Previcur N (Propamocarb HCL) and. Veulet (Fosetyl Aluminum), with only one active ingredient.

Some scientific researchers showed that the fungicides having new modes of action (preferably with low resistance risk), play modern and important role in controlling diseases, and in strategies of resistance management, (Chao *et al*., 2011 and Nabi *et al*., 2017). Also, these fungicides are systemic and moved trans laminarly from the upper surface to the abaxial side of the leaf then to the upper part of the plant. After application, the systemic fungicides penetrate into the plant and migrate acropetally even into the non-sprayed plant parts as explained by Fernandez *et al.*, (2000)**.** Perez and Forbes (2008) mentioned that systemic fungicides penetrated the leaflets and mobilized into potato. Consequently, it banned the synthesis of some or more specific stages of metabolism (nucleic acids, lipids, and amino acids) of zoospores. Thus, the fungicide which is double-acting compound is able to create a physical barrier preventing the germination and penetration of the inoculum.

2.2. Correlation analysis between the two disease parameters and efficacy (%) of five fungicides:

The association between each of FDS (%), AUDPC and efficacy (%) were determined through correlation analysis over the two seasons. Data illustrated in Fig. (1) show that there was a significant negative correlation between each of FDS (%), AUDPC with efficacy (%). The estimated values of correlation coefficient (R^2) were (0.9994 and 0.9496) and (1 and 0.9998) for FDS (%), AUDPC in 2018 and 2019 seasons, respectively. Similar results were previously obtained when correlation statistics were performed between different disease parameters of wheat rusts and grain yield of the studied wheat genotypes Boulot *et al*., (2015) and Omara *et al*., (2018).

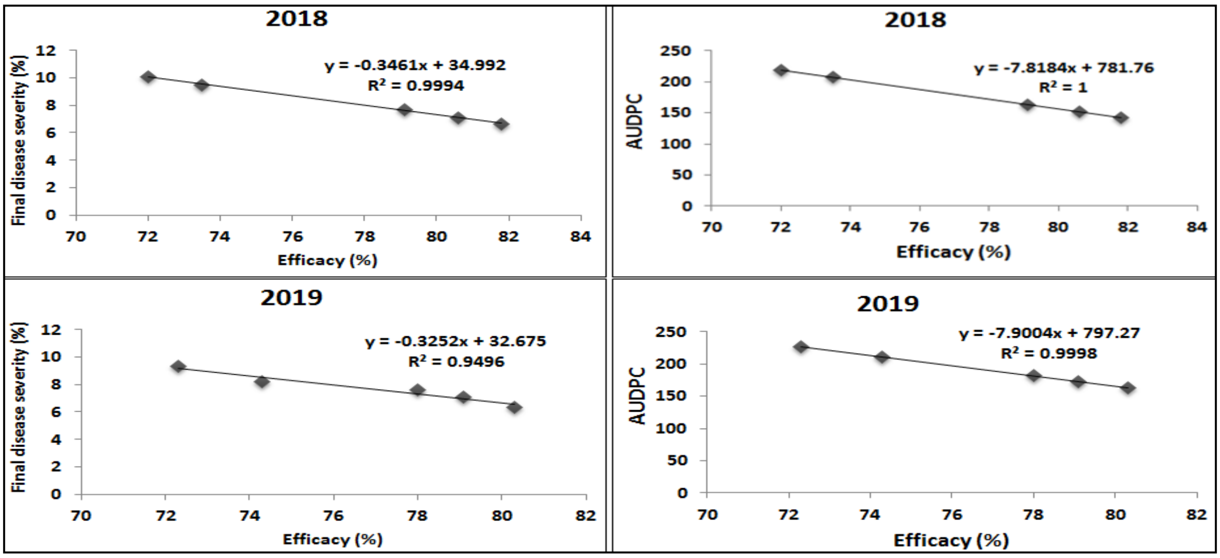

Fig (1). Correlation coefficient between each of FDS (%), AUDPC and efficacy (%) of cucumber plants treated with different fungicides during 2018 and 2019 seasons.

2.3. Principal component analysis (PCA) for five times spray with fungicides against cucumber downy mildew:

Principal component analysis was performed on five times spray against downy mildew (Table 6). For the PCA1, all the five sprays explained, 71.673 % of the total variation in the pooled data of the two seasons of the study. The data showed antagonistic relationships between spray5, spray4, spray3 and spray2. Meanwhile, there were synergetic relationships between the aforementioned sprays and spray1. Also, the PCA2; all the five sprays explained, 21.145 % of the total variation in the pooled data of the two seasons. The data showed antagonistic relationships between spray5, spray3, spray2 and spray1. Meanwhile, there were synergetic relationships between the aforementioned sprays and spray4. Summing up the results recorded by Kamel and Afifi (2020) cleared that the factor-loading matrix, extracted from a Varimax rotation with Kaiser normalization gave clear evidence to the importance of all sprays in this study, especially spray 5.

It might conclude that obtained data from scree plot graph of eigenvalues the fourth and fifth sprays of five fungicides, has eigenvalues more than one.

Table (6): Total variance and Loadings between the two principal components of the five fungicides sprays extracted from Varimax with Kaiser Normalization for cucumber downy mildew in the pooled data in 2018 and 2019 seasons.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			PCA1	PCA2
	Total	% of Variance	% Cumulative	Total	% of Variance	% Cumulative		
Spray 5	3.584	71.673	71.673	3.584	71.673	71.673	0.954	0.052
Spray 4	1.057	21.145	92.818	1.057	21.145	92.818	0.928	-0.196
Spray 3	0.294	5.875	98.693				0.973	0.035
Spray 2	0.050	0.995	99.689				0.928	0.177
Spray 1	0.016	0.311	100.000				-0.067	0.992

3. Electron microscope examination:

Direct suppression or killing was noticed as the main effect of fungicides on sporangiophores and sporangia of *Pseudoperonospora. cubensis*. Electron microscope photographs were taken 24h post application time to determine the changes on sporangiophores and sporangia of our pathogen. Results in Fig. (3A) clearly show the normal growth of sporangia and also the sporangiophores in control treatment. Fig. (3B) shows collapsed sporangia of *P. cubensis* and hyphae in cucumber tissue sprayed with fungicide Infininto while (Fig.3C) shows turgor loss sporangia and hyphae in cucumber plant sprayed with fungicide Prpfiler**.** It seems that current results are similar to those obtained by Belal *et al*. (2013); El-Gremi *et al*. (2013) and Ketta *et al*. (2016) who showed that the loss turgor and collapse in sporangiophores of *P. cubensis* treated with *Bacillus subtilis* resulted in twisting, loss turgor and collapsing of sporangiophores in broth medium tested and excreted in sporangium explosion might be attributed to the secondary metabolites.

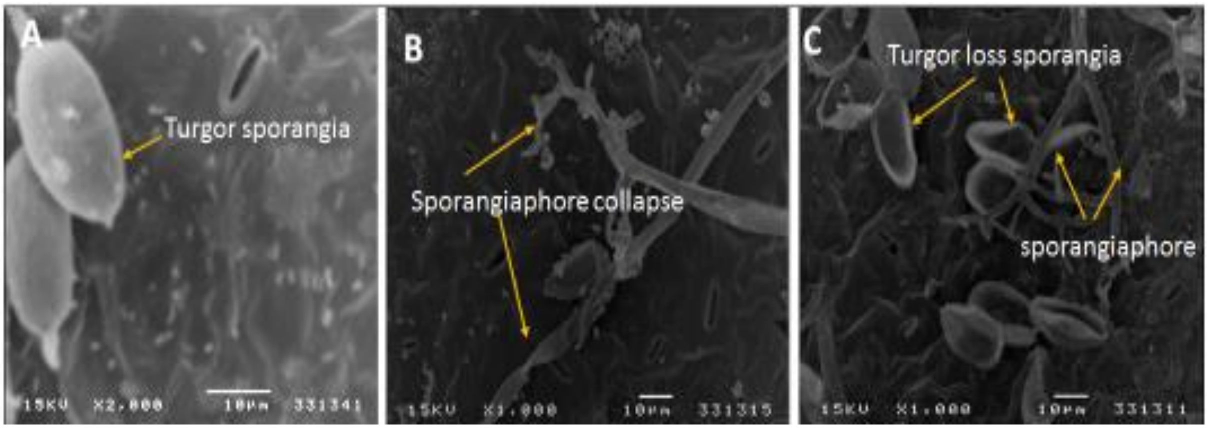

Fig. (3): Scanning Electron Microscopy (SEM) of *Pseudoperonospora cubensis* on cucumber leaves sprayed with fungicide. (A)= Control (untreated) showing *P. cubensis* growth callose encasements of sporangia. (B)= Collapsed sporangiophores and hyphae sprayed with fungicide Infininto. (C)= Turgor loss sporangia and hyphae sprayed with fungicide Prpfiler.

4. Yield parameters:

Relationship between some yield parameters and fungicides effect was considered positive relationship; therefore, fungicides protect cucumber plants against infection, increase and improve yield parameters were observed. Results in Table (7) show a significant increase of the number of fruits per plant, fruit yield per feedan and, fresh and dry weight (g)/plant. Plant treatments attained the highest values during season 2018 relative to control. The highest value was recorded with Infinito application followed by Prpfiler, Previcur Energy, Previcur and Veulet, Infinito caused increasing and improving number of fruits per plant and recorded 24.5 and 26.5 fruits per plant in summer and fall during 2018 season, respectively compared with untreated plants, being 18.0 and 19.5 fruits per plant in summer and in fall during 2018 season, respectively. Fruit yield recorded 14.9 and 15.3 ton per feedan in summer and in fall during 2018 season, respectively compared with untreated plants, being 11.5 and 12.1 ton per feedan in summer and fall during 2018. The same trend was observed for fresh and dry weight (g)/plant compared with untreated plants.

Table (7): Average of some yield parameters over control with five fungicides against cucumber downy mildew in summer and fall during 2018 season.

Fungicide	No. of fruits /plant		Fruit yield/ feddan(ton)		Fresh weight (gm)/plant		Dry weight (gm)/plan	
	S	F	S	F	S	F	S	F
Previcur	22.2	24.2	14.4	14.6	200.7	203.6	10.5	11.0
Veulet	21.5	23.5	14.2	14.5	198.7	200.5	10.1	10.4
Previcur Energy	29.2	31.2	15.2	15.4	260.2	264.0	13.6	13.8
Infinito	24.7	26.7	14.9	15.3	245.7	246.4	12.7	13.5
Profiler	24.5	26.5	14.4	15.1	205.4	246.6	11.5	13.4
Control	18.0	19.5	11.5	12.1	140.0	146.5	9.6	9.9
$LSD_{0.05}$	1.10	0.65	0.32	0.32	5.62	6.75	0.45	0.42

Sowing date [S= summer (1st Marsh); F= fall (1st September)].

Results in Table (8) show that in 2019 season, the relationship between some yield parameters and fungicides effect was similar in 2018 season. Infinito caused increasing and improving number of fruits per plant, being 23.8 and 26.5 fruits per plant in summer and in fall during 2019 season, respectively compared to untreated plants, being16.3 and 19.1 fruits per plant in summer and in fall during 2019 season, respectively. Fruit yield recorded 14.8 and 15.2 ton per feddan in summer and in fall during 2019 season, respectively compared with untreated plants, being11.1 and 12.0 ton per feddan in summer and in fall during 2019. The same trend was observed for fresh and dry weight (g)/plant compared with untreated plants.

Table (8): Average of some yield parameters over control with five fungicides against cucumber downy mildew in summer and fall during 2019 season.

Fungicide	No. of fruits /plant		Fruit yield/ feddan (ton)		Fresh weight (gm)/plant		Dry weight (gm)/plan	
	S	F	S	F	S	F	S	F
Previcur	21.3	24.0	14.2	14.5	199.3	203.3	10.3	11.1
Veulet	21.1	23.4	14.0	14.4	197.8	200.1	10.1	10.2
Previcur Energy	27.5	31.2	14.9	15.4	259.6	264.4	13.3	13.4
Infinito	23.8	26.5	14.8	15.2	245.1	246.0	12.5	13.4
Profiler	23.1	26.0	14.4	15.1	204.8	246.2	11.1	13.2
control	16.3	19.1	11.1	12.0	138.5	146.4	9.1	9.6
$LSD_{0.05}$	1.21	0.43	0.22	0.23	6.54	7.54	0.33	0.31

Sowing date [S= summer (1st Marsh); F= fall (1st September)].

This may be due to the significant reduction in the DS under different treatments relative to control which subsequently resulted in increasing crop yield. Obtained results are in agreement with these reported by Cardwell *et al.*, (1997) who mentioned that foliar application of fungicides showed increase of both yield and particularly, crop quality. Khoshgoftarmanesh *et al.* (2010) and Xiao-Fang *et al.* (2011) found that cucumber yield was differed in the first and in the second season which may be due to the variation in DS during seasons, subsequently affecting the crop yield. Essa *et al.* (2017) recorded that the fungicide (Amistar) gave the best growth and yield parameters, which slightly surpassed some bio-agents during the 2nd season.

CONCLUSION

Parameters like average night temperature, night relative humidity from sowing time were key weather parameters for predicting disease initiation and development may be epidemic. Groups of pesticides may be aggressive because of multi-site modes of action, while fungicides with single-site modes of action are at relatively high risk for resistance development. For improving the crop quality and reduce disease severity, important factors should be considered in mind such as climates, level, and fungicide group.

CONFLICTS OF INTEREST:

The authors declare no conflict of interest exists.

REFERENCES

Adam, D.C. and Todd, C.W. 2013. Effects of host plant resistance and fungicides on severity of cucumber downy mildew. HortScience, 48(1):53-59.

Ahmed, G.A. 2016. Biochemical changes in treated cucumber plants with some elicitors against downy mildew disease in protected houses. International Journal of Scientific & Engineering Research, 7(2): 1026-1035.

Anonymous, 2019. The Egyptian Agric. Pest. Committee. APC- Egypt Accredited Recommendations for Agricultural Pest Control, http://www.apc.gov.eg

Bardsley, E.; Wegener, M. and Tafforeau, S. 2006. Field development of Infinito for late blight control in potatoes. Pflanzenschutz-Nachr. Bayer, 59:281-291. [cited from, Sahoo, S.K., Mandal, K., Kumar, R. and Singh, B. 2014. Analysis of Fluopicolide and Propamocarb residues on tomato and soil using QuEChERS sample preparation method in combination with GLC and GCMS. Food Anal. Methods, 7:1032-1042.]

Belal, E.B.; Kamel, S.M.H. and Hassan, M.M. 2013. Production of antimicrobial metabolites by *Bacillus subtilis* and their applications. Biotechnology, 12: 14-24.

Bhat, J.A.; Rashid, R.; Dar, W.A. and Bhat, R.A. 2018. Efficacy of different fungicides for the management of downy mildew of cucumber grown under low plastic tunnel. Int. J. Pure App. Biosci., 6 (2): 884-890.

Boulot, O.A.; El-Naggar, D.R. and Abd El-Malik, N.I. 2015. Partial resistance to powdery mildew caused by *Blumeria graminis* f.sp. *tritici* and yield loss in four Egyptian wheat cultivars. Zagazig J. Agric. Res., 42(4): 713-725.

Cardwell, K.F.; Schultless, F.; Ndemah, R. and Nogok, Z. 1997. A system approach to assess crop health and maize yield losses due to pests and diseases in Cameron. Agriculture, Ecosystems & Environment, 65: 33-47.

Chao, Y.H.; Vladimir, V.C. and Yantai, G. 2011. Fungicides: Modes of action and possible impact on nontarget microorganisms. Ecology, 21: 1-8.

Cooke, L.R. and Little G. 2006. Evaluation of fluopicolide containing formulations for the control of potato late blight in Northern Ireland. Pflanzenschutz-Nachr-Bayer, 59: 303-316. [cited from, Sahoo, S.K., Mandal, K., Kumar, R. and Singh, B. 2014. Analysis of Fluopicolide and Propamocarb residues on tomato and soil using QuEChERS sample preparation method in combination with GLC and GCMS. Food Anal. Methods, 7: 1032-1042.]

Daunde, A.T.; Magar, S.P. and Navgire, K.D. 2017. Correlation of weather factors with downy mildew of cucumber. Agric. Updates, 12(1) 105-108.

Descalzo, R.C.; Roe, J.E. and. Mauza, B. 1990. Comparative efficacy of induced resistance for selected diseases of greenhouse cucumber. Can. J. Plant Pathol., 12: 16-24.

El-Gremi, Sh.M.A.; Ghoniem, K.E.; Mohamed, H.A. and Kamel, S.M.H. 2013. Mode of action of *Bacillus pumilus* in suppressing *Pseudoperonospora cubensis* (Berk and Curt) Rostow, the pathogen of downy mildew of cucumber. Egypt. J. Biol. Pest Control, 23(1): 71-77.

Essa T.A.; El-Gamal, M.A.H. and Afifi, M.M.I. 2017. Control of cucumber downy mildew by some plant growth promoting rhizobacteria under greenhouse conditions. Middle East J. Agric. Res., 6(2): 395-408.

Fernandez-Northcote, E.N.; Navia, O. and Gandarillas 2000. Basis of strategies for chemical control of potato late blight developed by PROINPA in Bolivia. Fitopatologia, 35(3) 137-149.

Ghosh, D.; Bhattacharya, I.; Dutta, S.; Saha, A. and Mujumdar, D. 2015. Dependence of the weather on outbreak of cucumber downy mildew (*Pseudoperonospora cubensis*) in Eastern India. Journal of Agrometeorology, 17 (1): 43-50.

Gouot, L.M. 2006. Field efficacy of Profiler, a fluopicolide and fosetyl-Al fungicide combination for the control of grape downy mildew (*Plasmopara viticola*). Pflanzenschutz-Nachric Bayer, 59(2-3): 293-302.

Granke L.L.; Morrice, J.J. and Hausbeck, M.K, 2014. Relationships between airborne *Pseudoperonospora cubensis* sporangia, environmental conditions, and cucumber downy mildew severity. Plant disease, 98(5): 674-681.

Granke, L.L. and Hausbeck, M.K. 2011. Aerobiology of *Pseudoperonospora cubensis* sporangia in commercial cucurbit fields. Plant Disease, 95: 1392-1400.

Harley, M.M. and Ferguson, I.K. 1990. The role of the SEM in pollen morphology and plant systematics. In: Claugher, D. (Ed.) Systemic association special volume. Scanning Electron Microscopy in Taxonomy and Functional Morphology, Clarendon Press, Oxford. UK. Pp. 45-68.

Hembram, S.; Dutta, S.; Bhattacharya, I.; Saha, A. and Majumder, D. 2014. Influence of weather variables on morphological structures of *Pseudoperonospora cubensis* in cucumber. Journal of Agrometeorology, 16(2): 219-221.

Kamel, S.M. and Afifi, M.I. 2020. Controlling cucumber powdery mildew using cow milk and whey under greenhouse conditions. Egypt. J. Phytopathol., 48(1): 58-70.

Ketta, H.A.; Kamel, S.M.; Ismail, A.M. and Ibrahem, E.S. 2016. Control of downy mildew disease of cucumber using *Bacillus chitinosporus*. Egypt. J. Biol. Pest Control, 26(4): 839-845.

Khoshgoftarmanesh, A.H.; Schulin, R.; Chaney, R.L.; Daneshbakhsh, B. and Afyuni, M. 2010. Micronutrient efficient genotypes for crop yield and nutritional quality in sustainable agriculture. A review. Agron. Sustain. Dev. 30: 83-107.

Latorse, M.P.; Holah, D. and Bardsley, R. 2006. Fungicidal properties of fluopicolide-based products. Pflanzenschutz-Nachric Bayer, 59: 185-200.

Lebeda, A. and Cohen, Y. 2011. Cucurbit downy mildew (*Pseudoperonospora cubensis*) biology, ecology, epidemiology, host-pathogen interaction and control. Eur. J. Plant Pathol., 129: 157-192.

Metwally, E.I. and Rakha, M.T. 2015. Evaluation of selected *Cucumis sativus* accessions for resistance to *Pseudoperonospora cubensis* in Egypt. Czech J. Genet. Plant Breed., 51: 68-74.

MacBean, C. 2012. The Pesticide Manual, 16th Ed. BCPC (British Crop Protection Council), 7 Omni Business Center, Omega Park, Alton, Hampshire, GU34 2QD, UK. http://www.bcpc.org

Mohamed, A.; Hamza, A. and Derbalah, A. 2016. Recent approaches for controlling downy mildew of cucumber under greenhouse conditions. Plant Protect. Sci., 52(1):1-9.

Mueller, D.S. and Bradley, C.A. 2008. Field Crop Fungicides for the North Central United States. Ames, IA and Urbana- Champaign, IL: Iowa State University and University of Illinois North Central Integrated Pest Management Center. [C.F., El-Tawil, M.F. and Mohamed I.M. 2019. Evaluation of mancozeb-based fungicides in potato late blight control under field conditions in Ismailia governorate**.** Egyptian Scientific Journal of pesticides, 5(2**):** 7-20.]

Nabi, S.U.; Raja, W.H.; Dar, M. S.; Kirmani, S. N. and Magray, M.M. 2017. New generation fungicides in disease management of horticultural crops. Indian Horticulture Journal, 7(1): 01-07.

Neufeld, K.N. and Ojiambo, P.S. 2012. Interactive effects of temperature and leaf wetness duration on sporangia germination and infection of cucurbit hosts by *Pseudoperonospora cubensis*. Plant Disease, 96: 345-353.

Ojiambo, P.S.; Paul, P.A. and Holmes, G. 2010. A quantitative review of fungicide efficacy for managing downy mildew in cucurbits. Phytopathology, 100: 1066-1076.

Omara, R.I.; Abu-Aly, A.A.M. and Abou-Zeid, M.A. 2018. Characterization of partial resistance to stripe rust (*Puccinia striiformis* f. sp. *tritici*) in some Egyptian wheat cultivars. J. Plant Prot. and Path., Mansoura Univ., 9(2):111-119.

Palti, J. and Cohen, Y. 1980. Downy mildew of cucurbits (*Pseudoperonospora cubensis*). The fungus and its hosts, distribution, epidemiology and control. Phytoparasitica, 8: 109-147.

Pandey, H.N.; Menon, T.C.M. and Rao, M.V. 1989. A simple formula for calculating area under disease progress curve. RACHIS, 8: 38-39.

Perez, W. and Forbes, G. 2008. Manual Tecnico El tizon tardio de la papa. Centro Internacional de la Papa, Lima, Peru, 41pp. [cited from, El-Tawil, M.F. and Mohamed I.M. (2019) Evaluation of mancozeb-based fungicides in potato late blight control under field conditions in Ismailia governorate**.** Egyptian Scientific Journal of pesticides, 5 (2**)** 7-20.]

Rani, A.; Singh, R.; Kumar, P. and Shukla, G. 2017. Pros and cons of fungicides: An overview. Int. J. Engin. Sci. & Res. Technol., 6(1): 112-117.

Rekanović E.; Potočnik, I.; Stepanović, M.; Milijašević, S. and Todorović B. 2008. Field Efficacy of Fluopicolide and Fosetyl-Al Fungicide Combination (Profiler®) for Control of *Plasmopara viticola* (Berk. & Curt.) Berl. & Toni. in Grapevine. Pestic. Phytomed. (Belgrade), 23:183-187.

Sahoo, S.K., Mandal, K., Kumar, R. and Singh, B. 2014. Analysis of Fluopicolide and Propamocarb residues on tomato and soil using QuEChERS sample preparation method in combination with GLC and GCMS. Food Anal. Methods, 7: 1032-1042.

Sharma, D.; Gupta, S.K. and Shyam, K.R. 2003. Studies on downy mildew of cucumber caused by *Pseudoperonospora cubensis* and its management. Journal of Mycology and Plant Pathology, 33(2): 246-251.

Thind, T.S. and Mohan, C. 2001. Disease weather relationship and relative activity of some new fungicides in different application schedules against muskmelon downy mildew. Journal of Mycology and Plant Pathology, 31(2):174-179.

Toquin, V.; Barja, F.; Sirven, C.; Gamet, S.; Latorse, M.P.; Zundel, J.L.; Schmitt, F. and Beffa, R. 2006. A new mode of action for fluopicolide: modification of the cellular localization of a spectrinlike protein. Pflanzenschutz-Nachric Bayer, 59:171-184. [cited from, Rekanović E.; Potočnik, I.; Stepanović, M.; Milijašević, S. and Todorović B. 2008. Field Efficacy of Fluopicolide and Fosetyl-Al Fungicide Combination (Profiler) for Control of *Plasmopara viticola* (in Grapevine Pestic. Phytomed. (Belgrade), 23:183-187].

Xiao-Fang, G.; Ze-Bin, W.; Qi-Tang, W.; Jin-Rong, Q. and Jian-Li Z. 2011. Cadmium and zinc accumulation in maize grain as affected by cultivars and chemical fixation amendments. Pedosphere, 21: 650-656.