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Use of Biological and Chemical Compounds for the Integrated Management of Apricot Powdery Mildew in Egypt

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to evaluate an integrated management program for powdery mildew caused by *Sphaerotheca pannosa* in apricot trees *Prunus armeniaca*, where four fungicides Copper, Carbendazim, Praiz and Topas) and three biocides (Bio Z , Bio Arc and Activator Yeasts) were evaluated in the first season 2020 in Ismailia and Beheira governorates in the regions of South Tahrir and Nubariya. All compounds significantly reduced the percentage of disease severity on

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leaves and flowers compared to the control, and the activator yeasts was among the best treatments, as it recorded in the last spraying a percentage of disease severity on leaves and flower 28.5% and 27.6% respectively compared with control 52.7 %and 56.2%, followed by the biocides Bio Z and Bio Arc.In the second season 2021, the compounds were evaluated during the flowering period, which led to their precipitation and the occurrence of plant toxicity for flowers at their highest rates with copper. As for the biocides compounds, they were completely safe.From here, an integrated control program was designed for two seasons 2022 and 2023 that combines fungicides and biocides. It is applied early before flowering. It gave excellent results, reduced the rate of fungicide use, and was safer and cost-saving.

Keywords: Apricot; powdery mildew; biological and chemical control.

1. INTRODUCTION

Apricot *Prunus armeniaca* L. has the greatest control in the governorates of the Republic, and universally accepted by people from all governorates of Egypt, whether eaten fresh, dried, or used in the production of juices and jams, is a type of stone fruit grown in sub-temperate and temperate regions worldwide. However, in Egypt, it ranks second in the Arab world and ninth globally, with an annual production of 102 thousand tons [1]. The area dedicated to cultivating these fruits is expanding each year, but unfortunately, the production isn't increasing proportionally due to various abiotic and biotic stresses, including fungal and bacterial diseases.

Powdery mildew, caused by different species of *Sphaerotheca pannosa* Wallr.and Lev., poses a significant threat to apricot cultivation. The severity of the disease is particularly pronounced in nurseries, where infected seedling stocks remain stunted. Studies by Khan et al. [2], Sharma [3], Kaul [4], and Pandotra *et al*. [5] have reported that the fungus affects young leaves, shoots, and fruits. On young leaves, the disease initially manifests as blister-like areas that eventually become covered with grayish-white patches of fungus growth. This leads to leaf distortion, curling, and premature leaf fall. White patches of fungus also appear on green shoots, potentially causing them to become curved at the tips. Additionally, buds and flowers may be directly attacked, resulting in buds failing to open properly and flowers becoming discolored, stunted, and eventually drying up. Infected fruits display circular spots, initially pinkish and later turning dark brown.

To control this disease effectively, three sprays of wetable sulphur or carbendazim/thiophanate methyl are recommended first before the opening of blooms, then at petal fall, and finally two weeks later [6]. New fungicides such as myclobutanil, fenarimol, flusilazole, pyrifenox, triademefon, captafol, and tebuconazole have shown promising control of powdery mildew in stone fruits [7,8,9,10]. Biological fungicides, such as Bio Arc and Bio Z, contain beneficial microorganisms formulated to inhibit or destroy fungal pathogens. Bio Arc, containing the bacterium *Bacillus megaterium*, helps prevent powdery mildew infection, while Bio Z, containing the fungus *Trichoderma album*, acts to kill the powdery mildew organism. Both products are nontoxic to people, pets, and beneficial insects.

Radwan, M. A., and D. R. Darwesh [11], aim to implement an integrated control program for powdery mildew in apricot, combining chemical and biological control methods. The program takes into account the climatic variations from one region to another in Egypt, with the primary goal of reducing the number of chemical sprays per week, lowering costs, preserving the environment and health, and increasing exports.

2. MATERIALS AND METHODS

2.1 Field Experiments

Field experiments were conducted on apricot trees Canino cultivarat Ismailia and South of Tahrir and Nubariya at Behera governorates during 2020-2021, and 2022- 2023 growing seasons to evaluate the effect of biocides and fungicides against the natural infection of apricot powdery mildew. In 2020 evaluated four fungicides (Copper, Carbendazim, Praiz (cholorothalonil) and Topas (Penconazol) (chemical name) which were the trees were subjected to four foliar sprays, each applied at 15-day intervals, utilizing both biocides and yeast, including three commercial products Bio Z, Bio Arc, and Activator Yeasts produced at the Agricultural Research Center. These were sprayed individually four times each, and

Table 1. Application programs and test treatments

Treatments	Rate/100liter water	Active ingredient
Cobox 50% WP	250g	Copper oxchloride contact fungicide
Praiz 54%SC	250 g	Chlorothalonil contact fungicide
Carbendazim 80%WP	30g	carbendazim systemic fungicide
Topas 10%EC	25 ml	Penconazol systemic fungicide
Bio Z	250g	*Trichoderma album* biocides
Bio Arc	250g	*Bacillus megaterium* biocides
Activator Yeasts	10L/ acre	*Saccharomycescerevisiae*and *Candidatropicalis*biocides

alternation among them was also conducted. Table 1 displays all the treatments. The trees were allowed to undergo natural infection by powdery mildew, receiving the same cultural practices as recommended.

The experiment followed a complete randomized design with three replicates, and five trees served as the experimental unit. The four foliar sprays were administered during the spring seasons, starting in the first February. In the second season of 2021, spraying commenced during the flowering period to evaluate all treatments on flowers. In the third season of 2021-2022, the integrated management program was implemented, with sprays in November during the dormancy period. Fungicides were sprayed twice to reduce the number of sprays, alternating with biocides. The fourth season of 2022/2023 replicated the same program.

At the end of the experiment, infected leaves and flowers were examined to estimate disease severity. Twenty leaves were randomly selected from each tree five days after the last application, and their condition in terms of the presence or absence of mildew was assessed. Disease severity percentage was recorded using a disease scale

Disease severity % was assessed according to the modified scale (0-5) by Reuveni and Reuveni, [12] 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

Disease severity % $=\sum nxv/5N$ X100

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

2.2 Statistical Analysis

All experiments were analyzed by Wasp computer program. Least significant difference (LSD0.05) was calculatedaccording to Gomez and Gomez [13].

3. RESULTS

The effect of three types of commercial biocides and three chemical pesticides on the percentage of powdery mildew disease severity on apricot trees was evaluated, as symptoms appeared on the leaves and the flower cluster. The treatments began to be sprayed 4 times in February after the dormancy period hence the leaves and flowers appeared in each of Ismailia, South Tahrir and Nubariya. The results are shown in Table 2 in Ismailia data indicated that, All compounds significantly reduced the percentage of disease severity on leaves and flowers compared to the control, and the activator yeasts was among the best treatments, as it recorded in the last spraying a percentage of disease severity on leaves and flower 28.5% and 27.6% respectively compared with control 52.7 %and 56.2%, followed by the biocides Bio Z and Bio Arc, which recorded on leaves and flowers 29% and 30%, respectively on leaves and 29% and 30.6% on flowers.

Table 3 showed the effect of spraying three biocides and three chemical fungicides on the percentage of powdery mildew disease severity on leaves and flowers, Where the best treatments were the biocide compounds, as they reduced the disease clearly and significantly in

Table. 2 Evaluation of fungicides and biocides on % disease severity of powdery mildew in apricot at Ismailia governorate in 2020

Treatments	First Spray		Second Spray		Third Spay		Fourth Spray	
	leaves	Bloom	leaves	bloom	leaves	bloom	leaves	bloom
Copper	40.4^{ab}	39.6^{bc}	35^{bcd}	36^{bc}	31.5^{c}	36.2^{b}	35.8^{b}	34.7^{b}
Topas	39^{bc}	38^{bcd}	34^{cd}	32^{bcd}	31.7^{c}	33.3^{bc}	35.2^{b}	35.6^{b}
pleas	38^{bc}	35.6^{cd}	35.3^{bcd}	32^{cd}	33.8^{bc}	33.6^{bc}	35.5^{b}	35^{b}
Carbendazem	37^{bc}	35.8^{bcd}	33^{cd}	34^{bcd}	33.8^{bc}	33.6^{bc}	33.3^{bc}	34^{b}
Bio Arc	40^{ab}	39.7^{b}	36^{bc}	38^{b}	32.4^{bc}	33.6^{bc}	30.8^{cd}	30.6^{c}
Bio Z	41^{ab}	37.1^{bcd}	38^{b}	33^{bcd}	36.2^{b}	34.3^{bc}	29.8^{d}	29^{cd}
Activator Yeasts	35^{c}	34.8^{d}	33^{d}	32^{d}	30.4^{c}	30.3^{c}	28.5^{d}	27.6^{d}
Control	43^{a}	46.3^{a}	50 ^{a}	49.6^{a}	44.7^{a}	50.2^{a}	52.7^{a}	56.2^{a}
LSD.05	3.947	4.14	3.76	3.844	4.165	4.182	2.794	2.966

Table 3. Evaluation of fungicides and biocideson % disease severity of powdery mildew in apricot at South of Tahrir in Behera governorate in 2020

Treatments	First Spray		Second Spray		Third Spay		Fourth Spray	
	Leaves	Bloom	leaves	bloom	leaves	bloom	leaves	bloom
Copper	40.4^{b}	40^{b}	35^{b}	36.2^{bc}	36^{b}	36^{b}	36^{b}	34.7^{bc}
Topas	39^{bc}	37^{bc}	34^{b}	32^{d}	33^{bc}	36^{b}	35^{b}	35.6^{b}
Praiz	38^{c}	35.6^{c}	35.3^{b}	31.7^{d}	34^{bc}	33^{bc}	35.5^{b}	35^{bc}
Carbendazem	37^{c}	35.8^{c}	33.4^{b}	33.8^{cd}	33^{bc}	31^{c}	33^{bc}	34^{bc}
Bio Arc	40^{b}	39.7^{b}	36.2^{b}	38^{b}	34^{bc}	33^{bc}	31^{cd}	32.4^{c}
Bio Z	40.5^{bc}	37^{bc}	37.9^{b}	33^{cd}	34^{bc}	31^{c}	30^{d}	27^{d}
Activator Yeasts	35.6^{c}	34.8^{c}	32.7^{b}	32^{d}	30^{c}	31^{c}	28.4^{d}	29^{d}
Control	43^{a}	47^{a}	45^{a}	50^{a}	50^{a}	50^{a}	52.5^{a}	56^{a}
LSD 0.05	3.420	3.640	5.447	3.844	4.133	3.207	2.794	2.966

Table 4. evaluate fungicides and biocides on % disease severity of powdery mildew in apricot at Nubariya in Behera governorate in 2020

Treatments	First Spray		Second Spray		Third Spay		Fourth Spray	
	Leaves	Bloom	leaves	bloom	leaves	bloom	leaves	bloom
Copper	43.7^{b}	40^{bcd}	41^{a}	38^{bc}	33.6^{bc}	36^{b}	32^{de}	34^{b}
Topas	43^{b}	40^{bcd}	35.6^{bc}	34^{c}	35^{bc}	33^{b}	38^{b}	35^{b}
Praiz	41^{b}	36.5^{d}	36^{bc}	34^{c}	31.7^{c}	35.8^{b}	36^{cde}	36^{b}
Carbendazem	40^{b}	37^{d}	38^{b}	36^{bc}	35^{bc}	34.5^{b}	36^{bc}	36^{b}
Bio Arc	40^{b}	41^{bcd}	38^{b}	38.6^{b}	37^{b}	35^{b}	34^{bcd}	34^{b}
Bio Z	41^{b}	41^{bc}	34^{c}	37^{bc}	33^{bc}	36^{b}	32^{e}	33^{bc}
Activator Yeasts	34^{c}	36^{d}	32^{c}	36^{bc}	32^{c}	33^{b}	31^{e}	30^{c}
Control	50^{a}	48.7^{a}	47^{a}	55^{a}	52^{a}	55^{a}	57^{a}	54.4^{a}
LSD 0.05	4.550	4.176	4.394	4.521	4.315	4.156	3.323	4

Table 5. Effect of spraying fungicides and biocides at flowering period on % disease severity of powdery mildew in apricot at Ismailia and Behera governorate in 2021

Treatments	Ismailia		South of Al-Tahreer		Nubariya	
	%Toxicity	bloom	%Toxicity	bloom	%Toxicity	bloom
Copper	100%TOXICITY					
Topas	15-20%	34^{bc}	20-25%	33^{bcd}	25%	33.627^{cd}
Praiz	15-20%	33^{bc}	20	32^{cd}	25	32.957^{cd}
Carbendazem	20	35^{bc}	30	33^{bc}	39-40	38.326^{b}
Bio Arc	0	37^{ab}	0	36^{b}	0	36.672^{bc}
Bio Z	0	33^{bc}	0	34^{bc}		32.24^{d}
Activator Yeast	0	32^{c}	0	30^{d}	0	30^{d}
Control	0	40.819^{a}	0	41.98^{a}	0	42.693^{a}
LSD.0.05		4.466		3.326		4.104

Table 6. Effect of applying integrated control program on % disease severity of powdery mildew in apricot at Ismailia and Behera governorate in 2022

Treatments	Time and Sprays		Ismailia		South of Tahrir		Nubariya	
			leaves	bloom	leaves	bloom	leaves	bloom
Copper	15/11	1						
	30/11	2	Dormancy period					
	15/12	3						
Topas	15/12	1	Dormancy period					
	30/12	2						
Bio Z	8/1	1	Dormancy period					7.25
	15/1	2						
	22/1	3						
	30/1	4						
Control			not excite	7.75	not excite	7.5	not excite	11.25
Bio Arc	5/2	1	8.25	8	8	11.5	14.5	10.75
	12/2	2						
	19/2	3						
	26/2	4						
Control			22.25	25	26.25	29.75	26.75	34.75
Praiz	5/3	1	5	7.75	8.75	7.75	9.5	8.5
	20/3	2						
Control			28.25	32.5	34.25	34.25	39.75	41
Activator Yeasts	20/3	1	5.25	4.25	5.75	5	4.25	7.5
	6/4	2						
	13/4	3						
	20/4	4						
Control			38.25	39.25	36.25	47.25	52	52
Carbendazem	20/4	1	1.25	2	3.5	1.25	5	5.75
	30/4	2						
Control	10/5		55.75	69	67	80.75	74	87

Table 7. Efficacy of integrated management program on % disease severity of powdery mildew in apricot at Ismailia and Behera governorate in 2023

Treatments	Time and Sprays		Ismailia		South of Tahrir		Nubariya	
			leaves	bloom	leaves	bloom	leaves	bloom
Copper	15/11	1						
	30/11	2	Dormancy period					
	15/12	3						
Topas	15/12	1	Dormancy period					
	30/12	2						
Bio Arc	5/1	1	Dormancy period					
	12/1	2						
	19/1	3						
	26/1	4						
Control	3/2		not excite	2	not excite	4	not excite	5.75
Bio Z	3/2	1	Dormancy period					
	10/2	2						
	17/2	3						
	24/2	4						
Control	2/3		not excite	15.75	not excite	20.5	not excite	23.75
Praiz	5/3	1	4	7	5	10.25	5	6.25
	20/3	2						
Control	25/3		27.5	25.5	27.75	32.75	33	24
Activator Yeasts	25/3	1	1.5	5.75	6	1.75	8.5	2.5
	2/4	2						
	9/4	3						
Control	15/4		44.75	49.5	43.75	44.5	46	52.5
Carbendazem	15/4	1	1.75	0.5	1.25	4	4.5	1.5
	25/4	2						
Control	5/5		66.5	72	58.75	71	84	74

comparison with the control, as well as all the biocides were effective and there were no significant differences between them, as the best of them was the activator yeasts compound, then it was followed by Bio Z and Bioarc on both leaves and flowers the data recorded 28%,30 %and 31% on leaves and 29%,27%and 32% on flowers respectively.The results were the same in Table 4, where the best treatments were also the biocides compounds in reducing the percentage of disease severity on leaves and flowers, where the percentage were 31%,32%and 34% on leaves and 30%,33%and 34% on flowers on the test in each of the activator yeasts, BioZ and Bio arc respectively.

Table 5 showed the result of spraying all treatments early before the leaves appear and the time when the flowers are revealed. The results indicated a high percentage of toxicity and flower fall in the case of Copper fungicide the toxicity was 100% and it was 15%-25% in case of Topas ,Praiz and it was 40% with Carbendazim in Nubaria, but the organic compounds did not affect the growth of flowers at all, but the percentage of disease severity was largely controlled.

Activator yeasts was the best treatment in reducing percentage of disease severity on flowers also Bio Z and Bio arc gave good results comparing with fungicides .

The integrated control program with biological and chemical fungicides was applied during two consecutive years 2022/2023 in Ismailia and Beheira governorates in the regions of South Tahrir and Nubariya.IN tables 6 and 7, the chemical fungicides of Copper and Topas were sprayed early in the dormancy period before the flower buds were revealed, on the wood as a form of prevention before the infection with powdery mildew, where spraying was done in mid-November three sprays of Copper every 15 days and two sprays of Topas every 15 days as well, then after that it was Interfering with biocides to protect the flowers from toxicity and falling off. Four sprays were sprayed every 10 days and then fungicide Praiz was sprayed twice before biocide Activator Yeasts, at the end of the season, a chemical fungicide Carbendazim was sprayed in May, two sprays between 15 days, in order to preserve the fruits from powdery mildew and post-harvest rot.In table 6,it was clear in the results after each treatment a significant decrease in the percentage of disease severity compared to the control. At the end of the program, the percentage of disease severity on leaves reached 1.2% compared to 55.75% in the control and on flowers 2% in the treatments and 69% in the control in Ismailia and the rest of the regions were in the same way. In the second season of applying the program 2023, as shown in Table 7, decrease in % disease severity compared to the control, where it was on leaves was 1.75%, and in the control 66.5%, while the flowers, the percentage of disease severity was 0.5%, and the control was 72%.

4. DICUSSION

Powdery mildew disease caused by the *Sphaerotheca pannosa* fungus is one of the most important and dangerous diseases that affect apricot trees, as the disease appears on the laves, flowers and fruits, and the fungus spores remain dormant for the next season in the wood and begin to attack the flower buds and new leafy shoots, and the disease leads to a heavy loss in the crop Mabrouk,*et.al* [14].In this study, four chemical fungicides were evaluated, including preventive such as Copper and Praiz (Chlorothalonil), and systemic such as Topas (pencoconazole) and Carbidazem, and three biocides, namely BioZ (*Trichoderma album*) ,Bio arc (*Bacillus megaterium*) and Activator Yeasts (*Saccharomyces cerevisiae* and *Candida tropicalis*) .The start of spraying was in February and chemical fungicides were sprayed four times .The results showed in the first season 2020 in Ismailia and Buhaira governorates in the regions of South Tahrir and Nubaria, the high significant effect in reducing the disease severity, whether treated with fungicides or biocides. The results showed that there were no significant effect on controlling the disease after the second spray. Hassan *et.al* [14],Yousef. (2021)and El-Morsi *et al*. [15].In the second season 2021, spraying took place in the presence of flowers, and this led to toxicity and falling off as a result of spraying with copper, as well as the rest of the fungicides that showed toxicity when sprayed. On the other hand, the biocides fought the disease, and no toxicity appeared on the flowers. Radwan, and Darwesh [11]. When we applied the program of controlling powdery mildew in season 2022 we started spray early before flowering hence the spray start in half November 2021,the program began with two protective fungicides just with two sprays and then we applied the biocides to protect flowering and also controlling the disease, within heart of flowering process we applied the biocide Activator Yeasts Whereas the yeasts act on the fungi and lead to the decomposition of the hypha tissues, as mentioned with Hartati et.al [16], some Yeast species were reported to produce chitinolytic enzymes Sugiprihatini,et.al. [17] which produce β -1,3-glucanase and chitinase in controlling powdery mildew Urquhart and Punja [18].In the second season of implementing the program 2022/2023, the results followed the same pattern.

Thus, the program achieved excellent control of the disease, and at the same time, the number of chemical pesticide sprays was reduced, environmentally friendly bio-compounds were introduced, and the residual effect of pesticides on fruits was reduced, whether for local consumption or export, as well as reducing the final cost.

5. CONCLUSION

The main objective of this study ***was the integrated control*** of powdery mildew disease in apricot and at the same time limiting the use of fungicides and introducing biological control, but with a system that does not prejudice the control and at the same time reaching the highest levels of efficiency in eradication and increasing the yield, for the sake of public health first, then export and open a door for the global market.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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