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Biological study of fungicides for downy mildew control in melons (*Cucurbitaceae* Family)

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Abstract

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Downy mildew (*Pseudoperonospora cubensis*) is a serious pathogen that causes significant damage to cucurbit crops, including melons. Research on downy mildew is particularly important in the context of increasing environmental regulations and pursuing sustainable agriculture. The present study aims at investigating the efficacy of fungicidal products and their impact on yields under field conditions in Bulgaria. The highest level of disease control was achieved with the application of a combination of Fluoxapiprolin at 0.75 L/ha and Cyazofamid at 0.5 L/ha, resulting in maximum disease suppression and high yield.

Keywords: fluoxapiprolin; cyazofamid; mandipropamid; *Pseudoperonospora cubensis*; fungicides; plant protection

Introduction

Cucurbit crops (*Cucurbitaceae*) hold great significance in global agriculture, encompassing a wide range of vegetables, including melons, watermelons, pumpkins, and cucumbers. They play an important role not only in the nutrition but also in the economy and culture of many nations. Their importance is increasing in the context of the growing global demand for healthy and sustainable food. In many regions of the world these crops demonstrate resilience to adverse climatic conditions and can be cultivated on a variety of soils, making them especially valuable in areas with limited agronomic resources.

Global melon production is approximately 30 million tons per year. Asia dominates this production, primarily due to China, which accounts for roughly half of the world's total melon production. According to 2023 data, China (14.6 million tons), India (1.4 million tons), and Kazakhstan (1.17 million tons) are among the leading melon producers (Report Linker).

Melon production in Bulgaria has gained significant popularity in recent years reaching record levels in terms of cultivated area in 2023. The main reasons behind the growing interest in this crop are related to high consumer demand, the availability of subsidies, and low production costs (Petrova, 2024; Mikova et al., 2022).

Under the new Common Agricultural Policy (CAP) for the period 2023–2027, the European Union provides substantial financial support for farmers, including melon cultivation (European Commission, 2021). At least 35% of rural development funds must be allocated to measures aimed at climate protection, biodiversity and environmental sustainability (European Commission, 2022). These subsidies may include programs for plant protection and disease control, such as downy mildew, as well as support for farmers who implement sustainable melon-growing practices.

Downy mildew (*Pseudoperonospora cubensis*) is a serious pathogen that causes significant damage to cucurbit crops, including melons. The disease is particularly destructive in regions with high humidity and moderate temperatures, which favor the development of the pathogen's spores. Early symptoms include yellow spots on the upper surface of the leaves, which quickly develop into necrotic areas. A characteristic grayish or purplish mold appears on the underside of the leaves indicating active pathogen growth (Savory et al., 2010). Infected plants lose their ability to produce healthy fruit, which directly impacts yield and the economic outcomes for farmers. Since the disease spreads rapidly, especially during rainy weather or through drip irrigation, effective prevention and control are essential.

Research on downy mildew is especially important in the context of increasing environmental regulations and the push toward sustainable agriculture. Reducing the use of chemical treatments and transitioning to safer and more environmentally friendly disease control methods is a priority for many growers. In this regard, the development of new fungicides that are effective against downy mildew while minimizing environmental impact is of paramount importance for agricultural practice.

Traditionally, downy mildew control involves the use of fungicides, which suppress the development of the pathogen and protect the plants from infection. However, not all fungicides are equally effective. The prolonged use of the same product can lead to the development of resistance in the pathogen. This highlights the need to study and test different active substances to identify the most effective methods of disease control. The use of integrated crop protection strategies, which combine chemical and agronomic measures, is also essential for the management of this pathogen.

The objective aim of the study is to investigate the efficacy of fungicidal products and their impact on crop yields.

Materials and Methods

Mineral nutrition was provided through a single pre-sowing fertilization with YaraMila Complex 12-11-18 at a rate of 350 kg/ha. Subsequent foliar feeding was carried out using KAISHI MAX at a rate of 0.3 kg/ha. One herbicide treatment was applied at 01.05.2023 – soil application of the herbicide BAZAMID GRANULATE (Dasomet 965 g/kg) – produced by Kanesho Soil Treatment SRL at a rate of 300.0 kg/ha 30 days before transplanting for weed seed control.

Two insecticide treatments were conducted. At the BBCH stage 13 (third true leaf) incorporation of the insecticide FORCE EVO (Tefluthrin 5 g/kg) was carried out during transplanting at a rate of 20.0 kg/ha. A vegetative application was performed at BBCH stages 22–23 using the insecticide AFINTO (Flonicamid 500 g/kg) at a rate of 0.1 kg/ha.

For the prevention and control of *Pseudoperonospora cubensis* fungicidal products containing the following active substances were used:

Fluoxapiprolin (fig. 1) – an active substance belonging to the class of compounds known as piperidinyl-pyridazines. Its primary mode of action involves inhibition of fungal acetyl-CoA carboxylase (ACCase), an enzyme critical for the biosynthesis of fatty acids in many phytopathogenic fungi. By disrupting this vital metabolic pathway, fluoxapiprolin effectively limits the growth and proliferation of fungal pathogens.

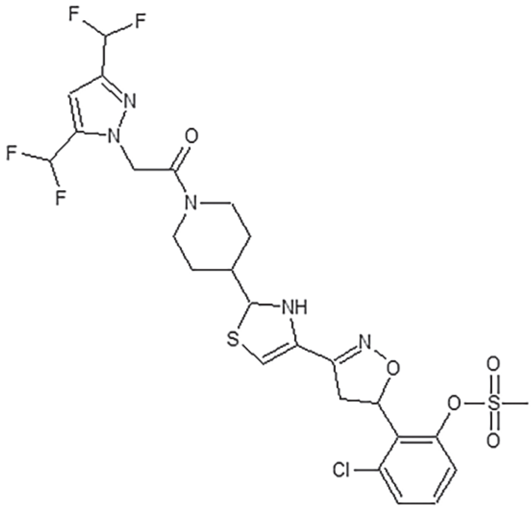

Fig. 1. Fluoxapiprolin
Source: Authors' own elaboration

Fluoxapiprolin, the methanesulfonate of 2-{3-[2-(1-{[3,5-bis(difluoromethyl)-1H-pyrazol-1-yl]acetyl}-4-piperidinyl)-1,3-thiazol-4-yl]-4,5-dihydro-1,2-oxazol-5-yl}-3-chlorophenyl, was synthesized by Bayer Crop Science in 2012 (Gao et al., 2021; Pasteris, et al., 2016). It functions as an inhibitor of oxysterol-binding protein-related proteins (OSBPI).

Its molecular structure is closely related to that of oxathiapiprolin, another OSBPI that demonstrates excellent inhibitory activity against all plant-pathogenic *Oomycetes*, except for certain species of *Pythium*, such as *Pythium aphanidermatum* and *P. delicense* (Miao et al., 2016; Li et al., 2024).

Several studies have shown the strong inhibitory activity of fluoxapiprolin against plant-pathogenic *Oomycetes* such as *Phytophthora capsici* and *P. infestans* (Miao et al., 2016; Li et al., 2024).

Cyazofamid (fig. 2) is the active ingredient in fungicides approved for the protection of certain crops within the *Cucurbitaceae* and *Solanaceae families* (Singh and Tandon, 2015; Mitani, 2001). Cyazofamid ([4-chloro-2-cyano-N,N-dimethyl-5-p-tolylimidazole-1-sulfonamide]) belongs to the phenylimidazole class of fungicides. It has a broad spectrum of activity against *Oomycetes* and plasmodiophoromycetes, acting through a unique mode of action. It is specifically effective for the control of late blight in potatoes and tomatoes, as well as downy mildew in grapes, cucumbers, and melons worldwide (Mitani, 2001).

Its locally systemic properties contribute to the free movement of the active substance into newly developed leaf tissues, making it particularly useful during early leaf growth stages. Cyazofamid acts as an inhibitor of mitochondrial complex III. It blocks the enzyme ubiquinol-cytochrome c reductase (QiI site) disrupting the energy metabolism of the pathogen.

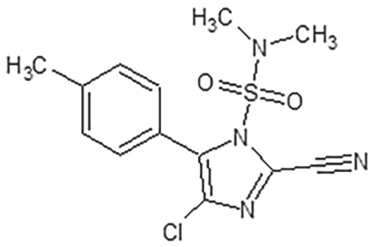

Fig. 2 Cyazofamid
Source: Authors' own elaboration

Mandipropamid (fig. 3) – 2-(4-chlorophenyl)-N-{2-[3-methoxy-4-(prop-2-in-1-yloxy) phenyl] ethyl}-2-(prop-2-in-1-yloxy) acetamide – is a monocarboxylic acid amide. Products based on mandipropamid are used to combat fungi from the *Oomycetes* class. The active ingredient inhibits mycelial growth and its gradual penetration into plant tissue, providing both anti-sporulant and therapeutic effects.

Mandipropamid is rainfast due to its adsorption to the waxy layer of plants, preventing it from being washed off by rain. Its translaminar action protects the underside of the leaves. Laboratory and field trials have shown that mandipropamid effectively controls leaf area expansion. Due to its high ability to redistribute itself within the surface tissues of plants, it protects new leaf growth (Serrati and Cestari, 2006). As a protective fungicide mandipropamid works by preventing fungal infection rather than curing already established diseases. Timely application is crucial – it is recommended to apply the fungicide before the disease appears or at the first signs of infection to stop its spread. Delayed application significantly reduces the product's effectiveness.

The field experiment was conducted in 2023 in the area of the village of Kalekovets, Plovdiv region, at the farm of Polina Hadzhieva. Kehlibar variety was used, which was developed by Bulgarian breeders (Assoc. Prof. Gavril Georgiev, PhD et al.). Kehlibar is an early high-yielding variety suitable for cultivation both in polyethylene greenhouses and outdoors. The plants are vigorous, with strong vegetative growth and good leaf coverage. The fruits are large, elongated, segmented with well-defined lobes, weighing 3–4 kg. The rind is tough, crack-resistant, and intensely yellow with a delicate netting pattern.

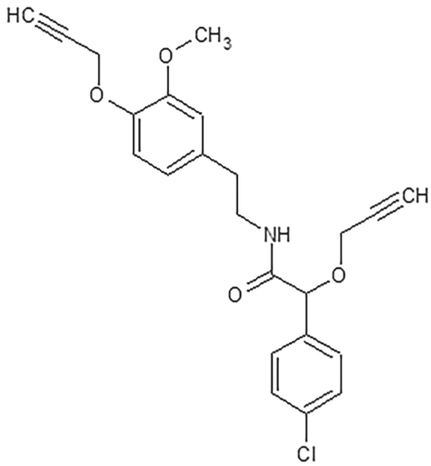

Fig. 3. Mandipropamid
Source: Authors' own elaboration

The experiment consisted of 10 300 plants per hectare transplanted on 2 June, 2023. The preceding crop in 2023 was from the Solanaceae family—potatoes. Transplanting was done manually in double-row beds at BBCH stage 13 of the crop.

According to the requirements of the EPPO standard PP1/065(4), the experiment was set up as a randomized block design with 6 treatments each replicated 4 times.

Figure 4 shows the randomization scheme of the experiment. The area of each plot is 15 m².

Table 1 presents the six different ways of treatment used in the conducted experiment including untreated control

Fig. 4. Randomization of the experiment
Source: Authors' own elaboration

Table 1. Ways of treatment used in the conducted experiment

Trt No.	Treatment Name	Form Conc.	Form Unit	Form Type	Rate	Rate Unit	Other Rate	Other Rate Unit	Appl. Code
1	UNTREATED CHECK								
2	FLUOXAPIPROLIN	20	GA/L	SC	10	g AI/ha	0,5	L/HA	ABCD
3	FLUOXAPIPROLIN	20	GA/L	SC	15	g AI/ha	0,75	L/HA	ABCD
4	FLUOXAPIPROLIN	20	GA/L	SC	12	g AI/ha	0,6	L/HA	ABCD
	CYAZOFAMID	160	GA/L	SC	64	g AI/ha	0,4	L/HA	ABCD
5	FLUOXAPIPROLIN	20	GA/L	SC	15	g AI/ha	0,75	L/HA	ABCD
	CYAZOFAMID	160	GA/L	SC	80	g AI/ha	0,5	L/HA	ABCD
6	MANDIPROPAMID	250	GA/L	SC	150	g AI/ha	0,2	L/HA	ABCD

Source: Authors' own elaboration

plots. The main objective of the treatments was to evaluate the effectiveness of various fungicides applied both individually and in combination. The first treatment served as the untreated control (used for comparison). Treatments 2 to 5 involved the application of Fluoxapiprolin, either alone or combined with Cyazofamid at different concentrations. Treatment 6 included Mandipropamid applied alone.

All variants were treated 4 times, on the same day and under the same conditions.

During the treatment, the following parameters were measured – air temperature; soil temperature at a depth of 10 cm; air humidity; and wind speed and direction. The measurements were taken using a portable combined thermo-hygrometer and anemometer GMH3350.

The application of the products was carried out using an experimental sprayer PULVEXPER at intervals of 7–10 days, counted from each previous treatment, under the conditions specified in Table 2.

The treatments were carried out during the crop growth stages described in Table 3.

Table 2. Air temperature, soil temperature, air humidity, and wind speed and direction

Date	Air Temperature (°C)	Soil Temperature (°C)	Wind Direction	Wind Speed (m/s)	Average Atmospheric Humidity (%)
30.06.2023	22.7	22.3	Southeast	1.1	60
07.06.2023	23.2	22.9	Southwest	1.3	49
18.07.2023	22.4	23.1	Northeast	0.8	50
25.07.2023	21.7	23.5	Northwest	0.6	55

Source: Authors' own elaboration

Table 3. BBCH growth stage

№	BBCH growth stage	Description
1	BBCH 65	Fifth open flower on the main stem
2	BBCH 69	Ninth flower on the main stem
3	BBCH 71	First fruit on the main stem with typical size and shape
4	BBCH 72	Second fruit with typical size and shape

*The phenological development stage, also known as the BBCH growth stage of the plant, was recorded on the day of treatment.

Source: Authors' own elaboration

Table 4. Parameters of the study

Indicator	Description
Visual assessment (percentage of infected leaf area)	Percentage of infected leaf mass on each plant in the different plots (measures the extent of infection on the leaf surface).
Timing and frequency of assessments	– Preliminary assessment (on the day of the first treatment); – First assessment – when visible infection appears in the untreated control; – Before each treatment, the level of infestation is recorded; – Final assessment – 10–14 days after the last treatment to monitor the persistence of the products.
Quantitative measurement of yield	Yield (t/ha)

Source: Authors' own elaboration

Table 4 describes the parameters that were monitored during the experiment in accordance with the requirements of EPPO Standard PP1/065(4).

Results and Discussion

With relation to the studies on melons conducted in 2023 in the region of Plovdiv, Kalekovets village, a total of 7 assessments were carried out weekly to determine the percentage of infestation intensity, efficacy, and phytotoxicity — on days 0, 7, 18, 25, 33, 40, and 48 from the first treatment. The yield was recorded on day 66 after the first treatment.

The initial (day 0) assessment of the % infestation intensity by the targeted pathogen was conducted using a 0 to 100% scale, where a lower percentage indicates less damage to the crop. At the time of the first treatment no visible symptoms of the pathogen were observed on plants (Table 5).

Table 5. Assessment of % infestation intensity on the day of treatment

Plot	Treatment (Trt)/ Dose	LEAF PESSEV, %
103	Untreated Check	0
201		0
301		0
403		0
105	Fluoxapiprolin 0.5 L/ha	0
202		0
306		0
406		0
104	Fluoxapiprolin 0.75 L/ha	0
203		0
302		0
404		0
101	Fluoxapiprolin 0.6 L/ha Cyazofamid 0.4 L/ha	0
205		0
304		0
401		0
106	Fluoxapiprolin 0.75 L/ha Cyazofamid 0.5 L/ha	0
206		0
303		0
402		0
102	Mandipropamid 0.2 L/ha	0
204		0
305		0
405		0

Source: Authors' own elaboration

One week after the first application of the products (Table 6) pathogen development was observed in the untreated control with an average value of 8.75% recorded. Notably, Option 6, which had a single treatment with Mandipropamid, showed an average efficacy rate of 80%. Despite being 20% lower in efficacy compared to the other treated variants, no statistically significant differences were observed among them. No phytotoxicity was recorded.

According to Table 7, the results recorded 18 days after the first and 11 days after the second treatment showed no change compared to the previous assessment. Based on the provided data, it can be concluded that the pathogen is naturally developing at a slower rate due to the lack of favorable weather conditions. No phytotoxicity was observed.

Nearly a month after the first treatment and 7 days after the third treatment (Table 8), disease incidence in the control plots increased by 11.25%. Based on the infection-to-efficacy ratio, Option 3 – the highest applied dose of Fluoxapiprolin at 0.75 L/ha, and Option 4 – a combination of low doses of Fluoxapiprolin and Cyazofamid, showed the best results. Almost complete disease control was observed, with pathogen development being inhibited and efficacy remaining significantly high. No phytotoxicity was recorded.

Table 9 presents the data following the fourth and final application of the tested products. Both options with combined application of Fluoxapiprolin and Cyazofamid at different doses recorded the highest efficacy rates and the strongest pathogen suppression. In comparison, the control plots showed a disease incidence of 26.25% averagely. No phytotoxicity was observed.

A visual comparison of the plants treated with different fungicides was conducted on August 2, 2023 (fig. 5) to evaluate the effectiveness of the products after the last treatment against the pathogen causing downy mildew (*Peronospora cubensis*). In the untreated control (a), disease incidence was recorded at 26.25%. The use of Fluoxapiprolin – 0.5 L/ha (b) resulted in a 20% reduction in disease compared to the control. When treated with Fluoxapiprolin – 0.75 L/ha (c), the efficacy further increased.

The combination of Fluoxapiprolin 0.6 L/ha and Cyazofamid 0.4 L/ha (d) showed excellent plant condition, with very clean and healthy foliage. A visible synergistic effect between both active substances was observed. A slight increase in the concentration of both active ingredients (Fluoxapiprolin 0.75 L/ha combined with Cyazofamid 0.5 L/ha) (e) resulted in outcomes with no statistically significant difference compared to the lower-dose combination. The solo use of Mandipropamid – 0.2 L/ha (f) demonstrated moderate disease control.

Table 6. Assessment of % infestation intensity, efficacy, and phytotoxicity 7 days after the first product application

7 DA-A 07.07.2023						
Plot	Treatment (Trt)/ Dose	LEAF PESSEV%	AVERAGE	ABBOTT%	AVERAGE	RHYGEN%
103	Untreated Check	10		0		0
201		5		0		0
301		10		0		0
403		10	8.75	0	0	0
105	Fluoxapiprolin 0.5 L/ha	0		100		0
202		0		100		0
306		0		100		0
406		0	0	100	100	0
104	Fluoxapiprolin 0.75 L/ha	0		100		0
203		0		100		0
302		0		100		0
404		0	0	100	100	0
101	Fluoxapiprolin 0.6 L/ha Cyazofamid 0.4 L/ha	0		100		0
205		0		100		0
304		0		100		0
401		0	0	100	100	0
106	Fluoxapiprolin 0.75 L/ha Cyazofamid 0.5 L/ha	0		100		0
206		0		100		0
303		0		100		0
402		0	0	100	100	0
102	Mandipropamid 0.2 L/ha	0		80		0
204		3		80		0
305		3		80		0
405		1	1.75	80	80	0

Source: Authors' own elaboration

Table 7. Assessment of % infestation intensity, efficacy, and phytotoxicity 18 days after the first and 11 days after the second product application

18 DA-A/11DA-B 18.7.2023						
Plot	Treatment (Trt)/ Dose	LEAF PESSEV %	AVERAGE	ABBOTT%	AVERAGE	RHYGEN%
103	Untreated Check	10		0		0
201		5		0		0
301		10		0		0
403		10	8.75	0	0	0
105	Fluoxapiprolin 0.5 L/ha	0		100		0
202		0		100		0
306		0		100		0
406		0	0	100	100	0
104	Fluoxapiprolin 0.75 L/ha	0		100		0
203		0		100		0
302		0		100		0
404		0	0	100	100	0

Table 7. Continued

101	Fluoxapiprolin 0.6 L/ha Cyazofamid 0.4 L/ha	0		100		0
205		0		100		0
304		0		100		0
401		0	0	100	100	0
106	Fluoxapiprolin 0.75 L/ha Cyazofamid 0.5 L/ha	0		100		0
206		0		100		0
303		0		100		0
402		0	0	100	100	0
102	Mandipropamid 0.2 L/ha	0		80		0
204		3		80		0
305		3		80		0
405		1	1.75	80	80	0

Source: Authors' own elaboration

Table 8. Assessment of % infestation intensity, efficacy, and phytotoxicity 25 days after the first and 7 days after the third product application

25 DA-A/7DA-C 25.7.2023						
Plot	Treatment (Trt)/ Dose	LEAF PESSEV %	AVERAGE	ABBOTT%	AVERAGE	RHYGEN%
103	Untreated Check	20		0		0
201		15		0		0
301		25		0		0
403		20	20	0	0	0
105	Fluoxapiprolin 0.5 L/ha	3		82.5		0
202		5		82.5		0
306		5		82.5		0
406		1	3.5	82.5	82.5	0
104	Fluoxapiprolin 0.75 L/ha	0		98.75		0
203		0		98.75		0
302		1		98.75		0
404		0	0.25	98.75	98.75	0
101	Fluoxapiprolin 0.6 L/ha Cyazofamid 0.4 L/ha	0		98.75		0
205		0		98.75		0
304		0		98.75		0
401		1	0.25	98.75	98.75	0
106	Fluoxapiprolin 0.75 L/ha Cyazofamid 0.5 L/ha	1		97.5		0
206		1		97.5		0
303		0		97.5		0
402		0	0.5	97.5	97.5	0
102	Mandipropamid 0.2 L/ha	5		80		0
204		5		80		0
305		5		80		0
405		1	4	80	80	0

Source: Authors' own elaboration

Table 9. Assessment of % infestation intensity, efficacy, and phytotoxicity 33 days after the first and 8 days after the final product application

33 DA-A/8DA-D 2.8.2023						
Plot	Treatment (Trt)/ Dose	LEAF PESSEV %	AVERAGE	ABBOTT%	AVERAGE	RHYGEN%
103	Untreated Check	25		0		0
201		20		0		0
301		30		0		0
403		30	26.25	0	0.00	0
105	Fluoxapiprolin 0.5 L/ha	5		76.19		0
202		5		76.19		0
306		10		76.19		0
406		5	6.25	76.19	76.19	0
104	Fluoxapiprolin 0.75 L/ha	3		88.57		0
203		3		88.57		0
302		3		88.57		0
404		3	3.00	88.57	88.57	0
101	Fluoxapiprolin 0.6 L/ha Cyazofamid 0.4 L/ha	1		96.19		0
205		1		96.19		0
304		1		96.19		0
401		1	1.00	96.19	96.19	0
106	Fluoxapiprolin 0.75 L/ha Cyazofamid 0.5 L/ha	3		95.24		0
206		1		95.24		0
303		1		95.24		0
402		0	1.25	95.24	95.24	0
102	Mandipropamid 0.2 L/ha	5		78.10		0
204		5		78.10		0
305		10		78.10		0
405		3	5.75	78.10	78.10	0

Source: Authors' own elaboration

The analysis of the data presented in Table 10 shows a clear change in dynamics for Option 4, which includes a combination of Fluoxapiprolin and Cyazofamid at low doses. Despite the reduced concentration of active substances, the efficacy against the pathogen reaches 88.57%, putting this option on par with the results observed for Option 3. For comparison, in the untreated control optiont, the disease incidence reaches 35%. Significantly higher efficacy is recorded in Option 5, where the same combination is applied at higher doses, and effectiveness reaches 92.86%, representing the highest level of pathogen suppression among all tested options. No phytotoxicity was observed.

On the 23rd day after the last application of the tested products a decline in fungicidal activity levels was observed across all treated options. In contrast, the intensity of disease incidence and spread increased rising by nearly 20% in just over one week. No phytotoxicity was observed. The assessment of % attack intensity, efficacy and phytotoxicity 48 days after the first and 23 days after the last application of the product is presented in Table 11.

The highest average yield was recorded in the options with combined application of high doses of Fluoxapiprolin and Cyazofamid – 24.84 t/ha. Despite differences in the used products and applied doses, no significant statistical differ-

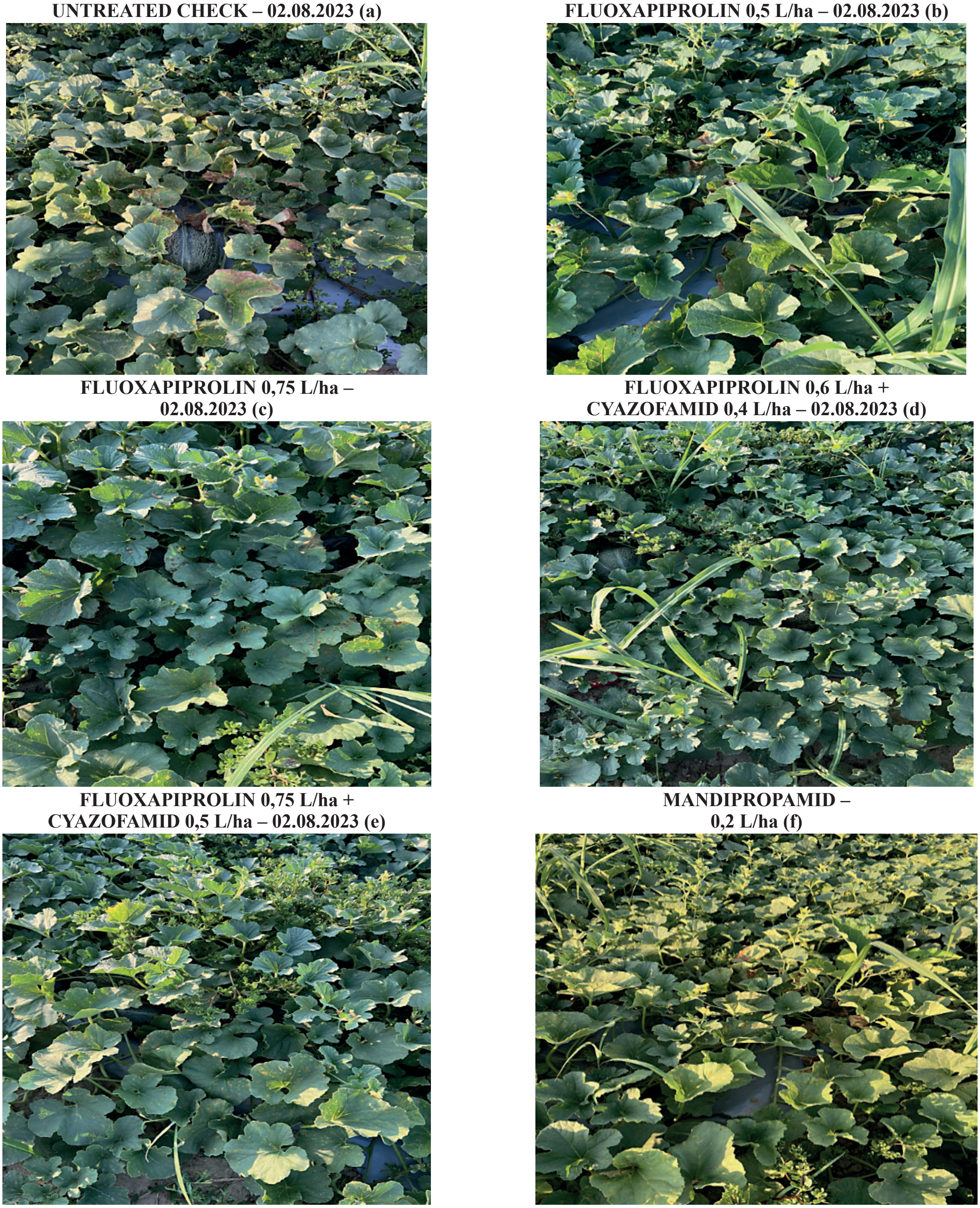

Fig. 5 Pictures of the plants after the last treatment

Source: Authors' own elaboration

Table 10. Assessment of % infestation intensity, efficacy, and phytotoxicity 40 days after the first and 15 days after the last product application

40 DA-A/15DA-D 09.08.2023						
Plot	Treatment (Trt)/ Dose	LEAF PESSEV %	AVERAGE	ABBOTT%	AVERAGE	RHYGEN%
103	Untreated Check	30		0		0
201		30		0		0
301		40		0		0
403		40	35.00	0	0.00	0
105	Fluoxapiprolin 0.5 L/ha	10		75		0
202		5		75		0
306		10		75		0
406		10	8.75	75	75.00	0
104	Fluoxapiprolin 0.75 L/ha	5		87.14		0
203		3		87.14		0
302		5		87.14		0
404		5	4.50	87.14	87.14	0
101	Fluoxapiprolin 0.6 L/ha Cyazofamid 0.4 L/ha	5		88.57		0
205		3		88.57		0
304		5		88.57		0
401		3	4.00	88.57	88.57	0
106	Fluoxapiprolin 0.75 L/ha Cyazofamid 0.5 L/ha	3		92.86		0
206		1		92.86		0
303		3		92.86		0
402		3	2.50	92.86	92.86	0
102	Mandipropamid 0.2 L/ha	5		82.14		0
204		5		82.14		0
305		10		82.14		0
405		5	6.25	82.14	82.14	0

Source: Authors' own elaboration

Table 11. Assessment of % infestation intensity, efficacy, and phytotoxicity 48 days after the first and 23 days after the last product application

48 DA-A/23DA-D 17.08.2023						
Plot	Treatment (Trt)/ Dose	LEAF PESSEV %	AVERAGE	ABBOTT%	AVERAGE	RHYGEN%
103	Untreated Check	50		0		0
201		50		0		0
301		60		0		0
403		50	52.50	0	0.00	0
105	Fluoxapiprolin 0.5 L/ha	15		71.43		0
202		10		71.43		0
306		20		71.43		0
406		15	15.00	71.43	71.43	0
104	Fluoxapiprolin 0.75 L/ha	5		83.33		0
203		5		83.33		0
302		15		83.33		0
404		10	8.75	83.33	83.33	0

Table 11. Continued

101	Fluoxapiprolin 0.6 L/ha Cyazofamid 0.4 L/ha	10		85.71		0
205		10		85.71		0
304		5		85.71		0
401		5	7.50	85.71	85.71	0
106	Fluoxapiprolin 0.75 L/ha Cyazofamid 0.5 L/ha	5		85.71		0
206		10		85.71		0
303		10		85.71		0
402		5	7.50	85.71	85.71	0
102	Mandipropamid 0.2 L/ha	10		80.95		0
204		5		80.95		0
305		15		80.95		0
405		10	10.00	80.95	80.95	0

Source: Authors' own elaboration

Table 12. Yield assessment 66 days after the first and 41 days after the last product application. Yield was recorded in kilograms per plot and converted to tons per hectare

66 DA-A/41DA-D 04.09.2023					
Plot	Treatment (Trt)/ Dose	YEILD KG/15m^2	AVERAGE	YEILD T/HA	AVERAGE
103	Untreated Check	28.20		18.80	
201		22.71		15.14	
301		26.18		17.45	
403		28.41	26.37	18.94	17.58
105	Fluoxapiprolin 0.5 L/ha	30.63		20.42	
202		35.61		23.74	
306		24.63		16.42	
406		29.49	30.09	19.66	20.06
104	Fluoxapiprolin 0.75 L/ha	32.84		21.89	
203		36.90		24.60	
302		32.66		21.77	
404		33.50	33.97	22.33	22.65
101	Fluoxapiprolin 0.6 L/ha Cyazofamid 0.4 L/ha	29.72		19.81	
205		37.50		25.00	
304		32.61		21.74	
401		33.23	33.26	22.15	22.18
106	Fluoxapiprolin 0.75 L/ha Cyazofamid 0.5 L/ha	33.44		22.29	
206		36.92		24.61	
303		38.00		25.33	
402		40.71	37.26	27.14	24.84
102	Mandipropamid 0.2 L/ha	32.85		21.90	
204		36.92		24.61	
305		37.92		25.28	
405		31.32	34.75	20.88	23.17

Source: Authors' own elaboration

ences in yields were found between the individual options. The obtained values are similar with a slight noticeable difference of 2 t/ha. Based on the presented results (Table 12), it can be concluded that both low and high doses of the used products do not have a negative impact on yields.

Conclusions

The conducted experiment shows that 11 days after the start of the trial, all tested products were 100% effective except for the reference product Mandipropamid at a dose of 0.2 L/ha, which showed 80% efficacy. After three treatments, the single application of Fluoxapiprolin at 0.5 L/ha demonstrated similar efficacy to Mandipropamid at 0.2 L/ha. All other products registered better efficacy. It was found that adding an active substance with contact action to Fluoxapiprolin increases its effectiveness. Options 5 and 6 (Fluoxapiprolin + Cyazofamid) showed the longest persistence and efficacy — 85.7%. According to our study, the use of fungicides significantly increases yields. The highest yields were recorded in Option 5 (Fluoxapiprolin 0.75 L/ha + Cyazofamid 0.5 L/ha) — 7.26 t/ha compared to the control. Regarding yields, there were no statistically significant differences between Options 3, 4, and 6.

The expanded application spectrum of Fluoxapiprolin is due to its pronounced fungicidal activity on various economically important crops.

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