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INFLUENCE OF SOME COMPOUNDS ON GERMINATION AND DEVELOPMENT OF *PUCCINIA PELARGONII-ZONALIS* AND PELARGONIUM GROWTH

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Abstract: The effectiveness of 7 fungicides (Amistar 250 SC, Bayleton 5 WP, Bumper 250 EC, Discus 500 WG, Folicur BT 225 EC, Folicur Multi 50 WG, Score 250 EC) and 2 bioproducts (Biochikol 020 PC and Biosept 33 SL) in the control of *Puccinia pelargonii-zonalis* was tested on pelargonium cv. Pulsar F1 Salmon. Additionally, their influence on plant growth, size of pustules, percentage of germinated spores and phytotoxicity were assessed. Plants were sprayed 4 times at weekly intervals. Among tested compounds the most effective in suppressing new uredia formation were Amistar 250 SC, Bayleton 5 WP, Biosept 33 SL, Bumper 250 EC, Folicur BT 225 EC and Score 250 EC. Furthermore, some fungicides inhibited germination of urediospores on PDA medium. Fourteen days after the last spraying more than 76% of germinating urediospores were found on control leaves. At the same time spores collected from plants protected with Amistar 250 SC, Bayleton 5 WP, Folicur BT 225 EC and Folicur Multi 50 WG germinated sporadically in 1.5 to 4.0%. In the next part of experiment, plants with visible sporulation of *P. pelargonii-zonalis* were sprayed with tested compounds. After 1, 7 and 14 days of incubation, total number of spores and number of germinating spores were counted. After 1 or 7 days, urediospores collected from untreated plants germinated in more than 80% whereas from plants sprayed with tested fungicides except Amistar 250 SC in 20–66.6%. Amistar 250 SC was the most effective in suppressing urediospore germination. All fungicides used in protection of young pelargonium plants, except Amistar 250 SC and Biochikol 020 PC, decreased plant growth. None of tested compounds showed phytotoxicity toward tested pelargonium cultivar.

Key words: *Puccinia pelargonii-zonalis,* rust, pelargonium, control, fungicides, biofungicides, spore germination

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INTRODUCTION

Daughtrey et al. (1995) indicated that *Puccinia pelargonii-zonalis* Doidge has been reported on *Pelargonium* x *hortorum*, *P. zonale*, *P. inquinans*. *P. endlicherianum*, *P. quercifolium*, *P. salmoneum*, *P. elongatum*. *Pelargonium domesticum* is not a host for *P. pelargonii-zonalis*, and some cultivars of *P. peltatum* are resistant. Also, the disease has not been reported on *Geranium* spp. Prevention of disease occurrence is based on reducing relative air humidity, keeping leaves as dry as possible and using for propagation healthy material. Rytter et al. (1989) showed that *Bacillius subtilis* inhibited spore germination and reduced the incidence of geranium rust pustules on inoculated leaves in the greenhouse. Also plant or mineral oils could strongly inhibit disease symptoms and suppress uredospore germination (Wojdyła 2005). Research on the efficacy of fungicides for controlling geranium rust has been very limited (Jeffers and Luszcz 1998). Experiments conducted so far showed a possibility of use of the following compounds: mancozeb (Glaser et al. 1974; Jeffers and Luszcz 1998), triforine (Harwood and Rabbe 1979), triadimefon (Harwood and Raabe 1979; Meeus 1980), zineb (Spencer 1976). Jeffers and Luszcz (1998) found that out of seven tested fungicides bitertanol, chlorothalonil and mancozeb completely protected plants against disease incidence.

The aim of the conducted investigation was to evaluate the development of *P. pelargonii-zonalis* on pelargonium leaves in relation to 7 fungicides and 2 bioproducts, their influence on plant growth, diameter of pustules, spore germination and potential phytotoxic effect.

MATERIALS AND METHODS

The following compounds were used in the experiments:

Fungicides: Amistar 250 SC (250 g azoxystrobine per dm^{-3}), Bayleton 5 WP (5% triadimefon), Discus 500 WG (500 g kresoxim methyl per kg), Folicur BT 225 EC (125 g tebuconazole +100 g triadimefon per dm^{-3}), Folicur Multi 50 WG (40% tolyfluanid +10% tebuconazole), Score 250 EC (250 g difenoconazole per dm^{-3}) – standard.

Biological agents: Biochikol 020 PC (2% chitosan), Biosept 33 SL (33% grapefruit extract).

Surfactant: Citowett AL (100% alkylarylpolyglycol ester).

The experiments were carried out on pelargonium cv. Pulsar F1 Salmon. Plants, about 5 cm (Table 1) and 12 cm high (Table 2), planted into 1 dm^{-3} pots filled with peat +composted pine bark and sand in ratio 1:1:0.5 and pH 6.5 with addition of 2 g/dm^{-3} of "Azofoska". The pots were put on greenhouse bench cushioned with fibre mat. The temperature in the glasshouse was maintained between 20–25°C (day) and 16–18°C (night) and relative air humidity over 90%. All plants received full natural sunlight and in the experiment (Table 1) supplementary light was used from 4 p.m. up to 9 p.m. (Philips SON-T Agro 400 lamp). At 7-day intervals fertilizer "Novokont" 0.25% was applied in the rate of 0.05 dm^{-3}/pot. Water was supplied directly to the pots or on fibre mat. When the first disease symptoms (uredinia of the fungus on lower side of leaves) were noted, plants were sprayed 4 times at 7-day intervals with tested compounds at

concentrations recommended on product labels (Tables 1, 2). Citowett AL at concentration 0.02% was added to spraying mixture of tested compounds. The observation of severity of disease symptoms was performed before treatment of plants and after 4 weeks of protection. During observation the number of uredia per leaf, diameter of uredia, percentage of diseased leaves and destroyed pustules were counted and height of plants were determined. Three days after the second and fourth spraying of plants and 7 or 14 days from the end of protection, spores were collected from leaves and percentage of germinating spores was assessed using the same method as in the next experiment (Table 3).

In the next trial, plants of the same cultivar with visible disease symptoms were sprayed with tested compounds (Table 4). The experiments were done during the summer time. One, 7 and 14 days after treatment leaves with visible disease symptoms were sampled. In the laboratory a droplet of sterilized water was put on a leaf surface and urediospores were scraped with razor blade into potato-dextrose agar (PDA) medium. A second droplet of water was added to the suspension of spores and then it was spread over the medium surface. For reduction of bacteria development, rose bengal 0.5 mg/dm^{-3} and 80,000 units of penicillin per dm^{-3} were added to the medium. After 18 h of incubation at 18–20°C, total number of urediospores and number of germinating spores were counted in the observation field of light microscope at magnification of 125x. For counting, places with 30–60 urediospores in the observation field were selected. In the case of high number of urediospores they were counted only from a half or 1/4 of observation field and next the percentage of germinating spores was calculated.

The experiment was set in randomised block design with 4 replicates and 10 plants or one plate of PDA comprised a replicate. The results were calculated statistically using analysis of variance. Mean differences were evaluated with Duncan's test at 5% significance.

RESULTS AND DISCUSSION

Influence of tested products on mean number of uredia per leaf

In the first trial the results obtained after 4 weeks revealed an average of about 23 uredia per leaf on control plants (Table 1). At the same time, on plants protected with tested compounds significantly less pustules per leaf were found. The most effective in suppressing new uredia formation were Amistar 250 SC, Bayleton 5 WP, Folicur BT 225 EC, Folicur Multi 50 WG and Score 250 EC. After using these products more than 5-times less uredia per leaf were observed than on control plants. The tested bioproducts suppressed formation of new uredia by half as compared to the control.

In the second trial the results obtained after 4 weeks revealed an average of about 8 uredia per leaf on control plants (Table 2). The most effective in suppressing new uredia formation were Amistar 250 SC, Bayleton 5 WP, Biosept 33 SL, Bumper 250 EC, Folicur BT 225 EC and Score 250 EC. In case of these products less than half of number of uredia per leaf were noted as compared to control plants. At the same time on plants protected with Biochikol 020 PC the number of pustules per leaf were about 13, so even more than on control plants. Also in previous experiments triadimefon (Bayleton 5 WP) provided good protection against pelargonium rust (Harwood and Raabe 1979; Jeffers and Luszcz 1998). High effectiveness of other tested fungicides

Table 1. Effectiveness of some fungicides, applied curatively, in the control of *P. pelargonii-zonalis* on pelargonium
First spraying: 25.02.2004 (4 sprayings at 7-day intervals)

Treatments	Conc. [%]	Mean number of uredia/leaf	Diam. of spots [mm]	% of dried up uredia	Height of plants [cm]	Diam. of plants [cm]
Control	–	22.84 e	6.85 e	0.00 a	11.00 d	17.95 ab
Biofungicides						
Biochikol 020 PC	2.5	8.03 cd	4.40 cd	1.20 a	11.50 d	19.10 b
Biosept 33 SL	0.1	13.20 d	4.47 d	0.00 a	8.75 bc	17.47 ab
Fungicides						
Amistar 250 SC	0.05	4.09 a–c	3.47 ab	100.0 c	10.00 cd	15.37 ab
Amistar 250 SC	0.1	1.94 a	3.22 a	100.0 c	10.00 cd	17.30 ab
Bayleton 5 WP	0.2	2.48 ab	4.30 cd	35.01 b	7.50 b	15.90 ab
Bumper 250 EC	0.05	7.07 b–d	4.05 b–d	0.30 a	9.12 bc	18.10 ab
Discus 500 WG	0.03	6.99 b–d	3.20 a	0.35 a	8.87 bc	17.27 ab
Folicur BT 225 EC	0.1	2.17 a	4.05 b–d	2.57 a	4.50 a	14.85 a
Folicur Multi 50 WG	0.1	2.12 a	3.80 a–c	0.00 a	7.37 b	16.60 ab
Score 250 EC	0.05	3.06 a–c	4.15 cd	3.08 a	7.75 b	15.72 ab

Means within the column, followed by the same letter are not significantly different at p = 0.05

Table 2. Effectiveness of some fungicides, applied curatively, in the control of *P. pelargonii-zonalis* on pelargonium
First spraying: 02.09.2004 (4 sprayings at 7-day intervals)

Treatments	Conc. [%]	Mean number of uredia/leaf	Diam. of spots [mm]	% of dried up uredia	Height of plants [cm]	Diam. of plants [cm]
Control	–	8.17 b	3.52 ef	0.0 a	19.37 a	20.31 ab
Biofungicides						
Biochikol 020 PC	2.5	12.72 c	3.64 ef	11.96 b	18.12 a	19.56 ab
Biosept 33 SL	0.1	3.55 a	3.88 f	33.38 bc	18.37 a	20.12 ab
Fungicides						
Amistar 250 SC	0.05	1.65 a	2.72 cd	97.11 f	18.75 a	20.81 ab
Amistar 250 SC	0.1	3.60 a	4.13 f	91.16 ef	15.62 a	19.81 ab
Bayleton 5 WP	0.2	3.72 a	3.04 de	60.06 cd	18.25 a	22.12 b
Bumper 250 EC	0.05	3.25 a	2.32 bc	93.99 ef	20.25 a	17.69 a
Discus 500 WG	0.03	4.45 ab	2.44 b–d	44.38 c	17.12 a	20.25 ab
Folicur BT 225 EC	0.1	2.65 a	1.47 a	98.44 f	18.50 a	19.87 ab
FolicurMulti 50 WG	0.1	5.62 ab	2.77 cd	64.02 cd	20.12 a	21.69 b
Score 250 EC	0.05	3.00 a	2.10 b	76.65 de	20.12 a	20.31 ab

Means within the column, followed by the same letter are not significantly different at p = 0.05

was confirmed in earlier trials, which showed their excellent effectiveness in controlling *P. horiana* on chrysanthemum (Wojdyła 2002; 2004a). This author found that a particularly good effect was obtained with Amistar 250 SC. However, bioproducts used in experiments were also effective against chrysanthemum rust (*P. horiana*) and *Melampsora epitea* on willow (Wojdyła 2004b,c).

Influence of tested products on average diameter of spots

In the first trial average diameter of spots on leaves of control plants was ca. 6.85 mm (Table 1). At the same time on plants protected with tested fungicides diameter of spots was significantly lower than on control pelargonium plants. In case of Amistar 250 SC, Discus 500 WG and Folicur Multi 50 WG diameter of spots was lower than 4.0 mm.

In the next trial average diameter of spots on the leaves of control plants was ca. 3.52 mm (Table 2). At the same time on plants protected with Amistar 250 SC at conc. 0.1% diameter of spots was 4.13 mm i.e. even more than on control plants, but in case of this product spots on leaves were sporadic, completely browned and destroyed. After the use of other tested fungicides diameter of spots was significantly lower than on control pelargonium plants. However in case of biofungicides diameter of spots was similar as on control plants.

Influence of tested products on average percentage dried up uredia

In the first trial no uredia were dried up on unprotected plants (Table 1). On the leaves of plants protected with Amistar 250 SC or Bayleton 5 WP, 100 or 35% of pustules were dried up, respectively. In case of other tested fungicides or biofungicides pustules were dried up only sporadically.

In the next trial no uredia were dried up on unprotected plants (Table 2). Out of the tested products, the most effective in drying up of uredia were Amistar 250 SC, Bumper 250 EC and Folicur BT 225 EC where, on average, from 93.3 to about 98% of dried up uredia were noted. In case of Bayleton 5 WP, Folicur Multi 50 WG and Score 250 EC more than 60% of pustules were dried up. Also Wojdyła (2002; 2004a) proved that Amistar 250 SC, Bumper 250 EC, Folicur BT 225 EC and Score 250 EC used as a plant spray against *P. horiana* on chrysanthemum caused almost complete drying up of pustules. On leaves protected with Biosept 33 SL or Biochikol 020 PC, about 12 or 33% of uredia were dried up, respectively. These rather mediocre results of Biochikol 020 PC and Biosept 33 SL in drying up of pustules of pelargonium rust were confirmed by earlier experiments, which showed similar effect of these products against *P. horiana* on chrysanthemum or *M. epitea* on willow (Wojdyła 2004b, c).

Evaluation of influence of tested preparations on spore germination

Analysis of *P. pelargonii-zonalis* spore germination showed, that after 2 or 4 plant treatments, spores taken from control plants germinated in 36% or 28.4%, respectively (Table 3). At the same time spores taken from pelargonium protected with Amistar 250 SC, Bayleton 5 WP, Biochikol 020 PC, Discus 500 WG, Folicur BT 225 EC germinated in less than 10%. All used compounds significantly suppressed spore germination.

Table 3. Effectiveness of some fungicides in the control of *P. pelargonii-zonalis* on pelargonium: Percentage of germinating urediospores
Beginning of experiment: 25.02.2004

Treatments	Conc. [%]	Weeks of experiment		Days from the end of experiment	
		2	4	7	14
Control	–	36.22 f	28.43 e	90.60 e	76.85 e
Biofungicides					
Biochikol 020 PC	2.5	5.27 ab	2.70 a	50.00 d	20.93 bc
Biosept 33 SL	0.1	16.23 e	16.55 d	25.30 c	48.10 d
Fungicides					
Amistar 250 SC	0.05	4.02 ab	2.46 a	3.75 a	3.73 a
Amistar 250 SC	0.1	0.00 a	0.95 a	0.93 a	1.53 a
Bayleton 5 WP	0.2	9.67 b–d	9.40 b	4.68 ab	2.78 a
Bumper 250 EC	0.05	18.10 e	14.70 cd	13.13 b	20.30 bc
Discus 500 WG	0.03	9.95 b–d	9.05 b	13.13 b	15.00 b
Folicur BT 225 EC	0.1	8.43 bc	9.35 b	5.93 ab	4.03 a
Folicur Multi 50 WG	0.1	12.46 c–e	10.33 b	3.43 a	3.43 a
Score 250 EC	0.05	14.98 de	12.18 bc	22.50 c	25.58 c

Means within the column, followed by the same letter are not significantly different at p = 0.05

Seven days after the end of experiment, spores taken from control plants germinated in about 90% (Table 3). At the same time spores taken from plants sprayed with Biochikol 020 PC and Biosept 33 SL germinated in 50 and 25%, respectively. Spores taken from plants sprayed with Amistar 250 SC, Bayleton 5 WP, Folicur BT 225 EC and Folicur Multi 50 WG germinated only sporadically, in less than 6%.

Fourteen days after the last spraying, more than 76% of germinating urediospores were found on control leaves (Table 3). At the same time spores collected from plants protected with Amistar 250 SC, Bayleton 5 WP Folicur BT 225 EC and Folicur Multi 50 WG germinated only sporadically, in less than 5%.

One day after treatment, urediospores of *P. pelargonii-zonalis* collected from leaf blades of untreated plants germinated in more than 86% (Table 4). Amistar 250 SC caused inhibition of spore germination to below 9%. Except for Bayleton 5 WP, spores taken from leaves protected with the other tested products germinated in about 40–65%. After 7 days urediospores collected from untreated plants germinated in more than 81% whereas from plants sprayed with Amistar 250 SC only in 2.9 to 14.6%. In case of urediospores taken from plants protected with Bayleton 5 WP, Biochikol 020 PC, Discus 500 WG and Folicur BT 225 EC from 24.69 to 32.35% of germinating spores were found. After 14 days urediospores collected from untreated plants germinated in more than 52% whereas from plants sprayed with Amistar 250 SC in less than 10%. Except for Bayleton 5 WP, spores taken from leaves protected with the other tested products germinated in about 37.4–57.71%, statistically alike to untreated spores (control). Experiments conducted on rose shrubs confirmed very good

effectiveness of Amistar 250 SC and Discus 500 WG in suppression of spore germination (Wojdyła 2000c; Wojdyła and Łyś 2000). The authors found that these products reduced germination of spores of *Sphaerotheca pannosa* var. *rosae* or *Diplocarpon rosae* on rose by ca. 80 per cent.

Table 4. Effectiveness of some compounds in the control of *P. pelargonii-zonalis* on pelargonium: Percentage of germinating urediospores
Mean values from 2 series

Treatments	Conc. [%]	Days after plants treatment		
		1	7	14
Control	–	86.41 f	81.30 g	52.28 c–e
Biofungicides				
Biochikol 020 PC	2.5	50.60 c–e	24.69 bc	57.71 e
Biosept 33 SL	0.1	39.27 c	66.89 fg	37.40 cd
Fungicides				
Amistar 250 SC	0.05	8.62 a	2.94 a	9.10 b
Amistar 250 SC	0.1	2.66 a	14.62 b	1.13 a
Bayleton 5 WP	0.2	20.19 b	28.87 bc	32.94 c
Bumper 250 EC	0.05	45.72 cd	66.63 fg	42.75 c–e
Discus 500 WG	0.03	46.80 cd	32.35 cd	55.84 de
Folicur BT 225 EC	0.1	55.23 de	26.09 bc	51.01 c–e
Folicur Multi 50 WG	0.1	54.18 c–e	55.41 ef	50.20 c–e
Score 250 EC	0.05	64.07 e	46.39 de	40.75 c–e

Means within the column, followed by the same letter are not significantly different at p = 0.05

Influence of tested preparations on plant growth and their diameter

In the first trial, the tested compounds, except for Amistar 250 SC, significantly suppressed growth of plants (Table 1). Plants sprayed with Folicur BT 225 EC were more than 2-times smaller than in the control, but the number of leaves was similar to untreated ones. Also statistically, diameter of plants did not differ between control plants and the ones protected with tested compounds.

In the second trial, no statistically significant influence of the used compounds on growth of plants was found. Also diameter of plants did not differ between control plants and the ones protected with tested compounds. Additionally, in earlier experiments, Wojdyła (2000a, b; 2004a) showed that Folicur BT 225 EC used for control of *S. pannosa* var. *rosae* on roses or *P. horiana* on chrysanthemum significantly reduced growth of plants comparing to the untreated control. In the first trial all compounds except Biochikol 020 PC inhibited growth of pelargonium to a larger extend than in the next trial. In case of the first trial, spraying of plants began directly after planting, when height of plants was about 6 cm i.e. in the phase of intensive lengthening of internodes. Next trial began when height of plants was about 12 cm, when process of lengthening of shoots was not that much intensive and influence of tested products on plant growth was not found.

CONCLUSIONS

1. Amistar 250 SC, Bayleton 5 WP, Bumper 250 EC, Folicur BT 225 EC and Score 250 EC reduced formation of *P. pelargonii-zonalis* new uredia at least 50%.
2. Amistar 250 SC, Bayleton 5 WP and both Folicur forms almost completely inhibited germination of *P. pelargonii-zonalis* urediospores.
3. All fungicides, except Amistar 250 SC and Biochikol 020 PC, applied in early stage of pelargonium development, inhibited the growth of plants.

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POLISH SUMMARY

WPŁYW ZWIĄZKÓW CHEMICZNYCH NA KIEŁKOWANIE ZARODNIKÓW I ROZWÓJ *PUCCINIA PELARGONII-ZONALIS* ORAZ WZROST PELARGONII

W prowadzonych badaniach oceniano skuteczność działania 7 środków chemicznych (Amistar 250 SC, Bayleton 5 WP, Bumper 250 EC, Discus 500 WG, Folicur BT 225 EC, Folicur Multi 50 WG, Score 250 EC) oraz 2 biopreparatów (Biochikol 020 PC, Biosept 33 SL) w zwalczaniu *Puccinia pelargonii-zonalis* na pelargonii odm. Pulsar F1 Salmon uprawianej w szklarni. Preparaty stosowano interwencyjnie w formie 4-krotnego opryskiwania co 7 dni. Przed przystąpieniem do stosowania środków oraz po 4 tygodniach ochrony oceniano liczbę plam/urediów na liściach, procent porażonych liści, wysokość roślin oraz fitotoksyczność.

Z badanych środków najwyższą skuteczność wykazywały Amistar 250 SC, Bayleton 5 WP, Folicur BT 225 EC, Folicur Multi 50 WG. Po 14 dniach od zakończenia programu ochrony pelargonii zarodniki pobrane z roślin opryskiwanych środkami Amistar 250 SC, Bayleton 5 WP, Folicur BT 225 EC, Folicur Multi 50 WG, kiełkowały sporadycznie w 1,5 do 4%. Zarodniki pobrane z roślin kontrolnych kiełkowały w przynajmniej 76%. Natomiast zarodniki pobrane z roślin jednokrotnie opryskanych badanymi środkami, oprócz fungicydu Amistar 250 SC, kiełkowały w 20–66,6%. Z kolei mniej niż 15% kiełkujących zarodników stwierdzono w przypadku opryskania roślin środkiem Amistar 250 SC. Badane środki oprócz fungicydu Amistar 250 SC stosowane na rośliny w fazie sadzonek istotnie ograniczały wzrost roślin. Żaden z badanych środków nie był fitotoksyczny w stosunku do pelargonii.