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EFFECT OF VEGETABLE AND MINERAL OILS ON THE DEVELOPMENT OF *SPHAEROTHECA PANNOSA* VAR. *ROSAE* – THE CAUSAL AGENT OF POWDERY MILDEW OF ROSE

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Abstract

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The study assessed the efficacy of vegetable cooking oils (corn, olive, rapeseed, sunflower, soybean, and grape seed), ready-made vegetable oils designed for use in plant protection (Adpros 850 SL, Dedal 90 EC, Olejan 85EC), and mineral oils (Atpolan 80 EC, Ikar 95 EC, Olemix 84 EC, Para Sommer 75 EC, Promanal 60 EC, Sunspray 850 EC) in the protection of roses grown under cover against powdery mildew (*Sphaerotheca pannosa* var. *rosae*). In the first experiment, the oils: rapeseed, sunflower, Atpolan 80 EC, and Sunspray 850 EC at concentrations of 0.25%, 0.5%, 1.0% and 2%, used for spraying rose shrubs twice, showed an efficacy from 52% (Sunspray 850 EC at 0.25%) to 100% (Atpolan 80 EC at 2%). In the remaining six experiments, the efficacy of the tested oils used at a conc. of 1% ranged from 76.4% (rapeseed oil) to 100%. However, it should be emphasized that the effectiveness of the various oils varied depending on the experiment and time of observation. The results of the experiments suggest a slightly higher efficacy of mineral oils in comparison with vegetable oils, although the data obtained are not always supported by statistical calculations.

The oils used in the experiments were not found to cause phytotoxicity to the rose varieties on which they were tested.

Key words: Sphaerotheca pannosa var. *rosae*, vegetable and mineral oils, control, rose

Introduction

Powdery mildew, caused by *Sphaerotheca pannosa* var. *rosae*, is one of the most serious diseases in the cultivation of roses in the field and under cover. In view of the high incidence of powdery mildew in roses cultivated under cover, an average of more than 20 spray treatments with various fungicides are carried out throughout the year. However, repeated application of some of these fungicides can cause phytotoxicity (mainly shortening of the stems), and could cause selection of resistant populations of *S. pannosa* var. *rosae* (Pasini et al., 1997). In the last century, pesticides were largely adopted to counteract the action of pests and diseases and to increase plant health and yield. However, the continuous use of chemical fungicides for plant defence had a great environmental impact, the onset of resistance phenomena within some populations of fungal pathogens, as well as acute and general toxicity to humans and non-target organisms (Rongai et al., 2009).

In addition, a European Union directive in force from 1 January 2014 imposes on all plant producers an obligation to implement integrated pest management. Therefore, the search for alternative protection methods limiting or eliminating the use of chemical plant protection products seems to be particularly valuable. Cultivation of resistant or low-susceptible varieties on a production scale may not always be a priority because of the productivity and quality requirements for cut flowers (Wojdyła and Wiśniewska-Grzeszkiewicz, 1999). For this reason, when selecting varieties for planting, the producers of cut rose flowers consider their susceptibility as less important. In the studies conducted to date, good results in controlling the development of powdery mildew have been achieved by spraying rose shrubs with fungicides (Wojdyła, 1999), grapefruit extract (Wojdyła, 2001a), chitosan (Wojdyła, 2003a), garlic juice (Wojdyła, 2001b), and fertilizers containing in their composition potassium carbonate and monopotassium phosphate (Wojdyła et al., 2010).

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Horst et al. (1992) demonstrated high efficacy of a mixture of Sunspray ultrafine oil and sodium bicarbonate in the control of some pathogens of roses such as *Diplocarpon rosae* and *S. pannosa* var. *rosae*. The author's own studies conducted to date have shown high efficacy of vegetable and mineral oils in the protection of ornamental plants against rust, leaf spot, and grey mould (Wojdyła, 2003b, 2005, 2012, 2013; Wojdyła et al., 2010). Therefore, in addition to the already mentioned fungicides and bio-preparations, vegetable and mineral oils may prove useful in the protection of roses against powdery mildew. The literature data indicate that oils might be used as alternatives to conventional fungicides, and integrated into programmes that include other necessary materials, thereby reducing the frequency of use of and risk of resistance to all the fungicide groups in the programme (Northover and Schneider, 1996). Oils have excellent spreading and leaf surface adhesion characteristics, and because of their rapid biodegradation they have low toxicity to humans and make little environmental impact (Rongai et al., 2009). The authors cited reported that vegetable oil showed no phytotoxicity, while the formulations based on mineral oil showed a significant effect on lowering fresh and dry weight of tomato plants. Northover and Schneider (1996) demonstrated that oils decreased photosynthesis and transpiration, but increased respiration. Those results were not confirmed by the experiments conducted by Goszczyński and Tomczyk (2003) on rose shrubs in which no significant effect of 1% and 2% Sunspray 850 EC oil solutions on the intensity of photosynthesis in mature rose leaves was found 24 hours after spraying.

The aim of this study was to assess the efficacy of vegetable and mineral oils in the protection of roses grown under cover against *S. pannosa* var. *rosae*.

Materials and Methods

The following compounds were used in the experiments:

Vegetable oils (cooking oils) used as food: corn seed oil, grape (fruit) oil, olive (fruit) oil, rapeseed oil (canola oil), soya seed oil, and sunflower seed oil. The exact composition of these oils is given in Table 1 - www.scientificpsychic.com/fitness/fattyacidsl.html.

Vegetable oils recommended for plant protection: Adpros 850 SL (850 g fatty acid methyl of rapeseed oil per dm^3) – produced by Varichem T. Ostrowski – Huta Żabiowolska, Poland; Dedal 90 EC (90% vegetable oil) – produced by Danmark Łódź, Poland; Olejan 80 EC (85% rapeseed oil) – produced by Danmark Łódź, Poland.

Mineral oils: Atpolan 80 EC (76% SN mineral oil) – produced by Agromix Niepołomice, Poland; Ikar 95 EC (95% SAE mineral oil) – produced by Danmark Łódź, Poland; Olemix 84 EC (84% DSA mineral oil) – produced by Danmark Łódź, Poland; Para Sommer 75 EC (75% mineral oil) – produced by Stahler Agrochemie GmbH & Co. KG Germany; Promanal 60 EC (60% mineral oil) – produced by Neudorff GmbH KG Germany; Sunspray 850 SL (85% paraffinic oil) – produced by Sun Oil Company, Belgium.

Fungicide: Saprol 190 EC (190 g triforine per dm^3) produced by American Cyanamid Company, USA.

Surfactant: Tergitol™ 15 – S-9 (surfactant) – produced by DOW Chemical Co.

Roses of the cultivars 'Escimo' and 'Mercedes' were grown in a greenhouse, in 1 dm^3 pots positioned on tables covered with capillary mats. Roses cv. 'Madelon' were grown in soil in a plastic tunnel. The temperature during the experiments fluctuated between 17 and 21°C, and air humidity was above 92%. In order to increase the humidity of the

Table 1
Percent by weight of total fatty acids

Oil	Unsat./Sat. ratio	Saturated		Mono unsaturated	Poly unsaturated	
		Palmitic Acid C16:0	Stearic Acid C18:0	Oleic Acid C18:1	Linoleic Acid (ω 6) C18:2	Alpha Linolenic Acid (ω3) C18:3
Canola Oil (Rape Oil)	15.7	4	2	62	22	10
Corn Oil (Maize Oil)	6.7	11	2	28	58	1
Grape seed Oil	7.3	8	4	15	73	-
Olive Oil	4.6	13	3	71	10	1
Soybean Oil	5.7	11	4	24	54	7
Sunflower Oil*	7.3	11	5	28	51	5

http://www.scientificpsychic.com/fitness/fattyacidsl.html air, the mats and the passageways in the greenhouse, and the soil substrate in the plastic tunnel were moistened with water several times during the day. In the greenhouse, the roses were watered by directing the stream of water from the hose directly into the pots and on the capillary mat, while in the plastic tunnel the plants were watered by means of a capillary irrigation system.

All the experiments were performed in a greenhouse or plastic tunnel belonging to the Research Institute of Horticulture in Skierniewice. After the onset of the symptoms of powdery mildew (*Sphaerotheca pannosa* var. *rosae*), the shrubs were sprayed with the test oils twice at an interval of 7 or 14 days. A special kind of surfactant recommended for vegetable oils – Tergitol™ 15-S-9 at a conc. of 0.3% was added to the suspensions of the vegetable cooking oils. The plants were sprayed with an Apor pneumatic laboratory sprayer with a 1.5 dm^3 reservoir and liquid pressure of 0.2 MPa, designed for spraying plots of such a surface area. While spraying, the nozzle was maintained at a height of 30 cm above the plants. In all the experiments, the plants were sprayed in the mornings using 1 dm^3 of working liquid per 10 m^2, with which the upper and lower side of the leaf blade was thoroughly covered. The degree of infection of the shrubs was determined before each experiment and, depending on the experiment, after 1, 3, 7, 10, 14 or 28 days from the beginning of the spray treatment using a ranking scale (Table 2). Observations of possible phytotoxicity of the tested oils were carried out within 14 days of the execution of spraying. During the observations, attention was paid to whether there were signs of yellowing or browning of plant tissues or inhibition in growth. When analyzing the results using a simplified Abbott's formula, the percentage efficacy of the oils relative to the control was calculated (Abbott, 1925).

The experiments were conducted in a randomized block design with 4 replications of 3 or 5 rose bushes each.

Results

In the initial period of the study, efforts were made to determine the optimum concentration of the tested oils which could be recommended in practice to protect plantations of roses against *S. pannosa* var. *rosae*. The rapeseed and sun-

Table 2
Effectiveness of oils in the control of *Sphaerotheca pannosa* var. *rosae* on rose cv. Madelon. – (2-times at 7-day intervals) Beginning of experiment and initial infection level: 2002.07.25 = 5.0.

Treatments	Conc., %	Mean degree of shoots infection after days from beginning of experiment	
		1	10
Control	-	5.0 l	5.00 m
Triforine	0.03	1.10 g-i	1.60 g
Plant oils used as a food (Cooking oil)			
Canola Oil (Rape Oil)	0.25	1.65 k	2.30 kl
Canola Oil (Rape Oil)	0.5	1.25 h-j	2.15 jk
Canola Oil (Rape Oil)	1.0	0.34 de	1.40 f
Canola Oil (Rape Oil)	2.0	0.00 a	0.45 b
Sunflower Oil	0.25	1.50 jk	2.15 jk
Sunflower Oil	0.5	1.10 g-i	2.00 ij
Sunflower Oil	1.0	0.20 c	1.15 d
Sunflower Oil	2.0	0.00 a	0.80 c
Mineral oils			
Atpolan 80 EC	0.25	1.05 gh	1.85 hi
Atpolan 80 EC	0.5	0.55 f	1.20 de
Atpolan 80 EC	1.0	0.00 a	0.70 c
Atpolan 80 EC	2.0	0.00 a	0.00 a
Sunspray 850 EC	0.25	1.30 ij	2.40 l
Sunspray 850 EC	0.5	0.59 f	2.00 ij
Sunspray 850 EC	1.0	0.24 cd	1.45 fg
Sunspray 850 EC	2.0	0.11 b	1.10 d

Note: Means in columns, followed by the same letter, do not differ with 5% of significance (Duncan's multiple range test)
Disease index: 0 – no symptoms, 1 – up to 1% of shoot area covered with mycelium, 2 – 1.1 up to 5%, 3 – 5.1 up to 10%, 4 – 10.1 up to 20%, 5 – over 20% of shoot area covered with mycelium.

flower oils, and the mineral oils Atpolan 80 EC and Sunspray 840 EC, as well as the ready-made vegetable oil Olejan EC 85 caused at all the working concentrations significant inhibition of the infection of rose bushes by powdery mildew compared to the control (Tables 2 and 4). Immediately after spraying the bushes with all the tested oils, the white powdery mycelium coating was seen to fall off the leaves. After the treatment with the oils, the mycelium adhered closely to plant tissues and became less visible. The leaves, in turn, took on an extra glossy appearance, which soon raised their decorative value. No disease symptoms were found during the observations of the bushes sprayed with Olejan 85 EC and the mineral oils Atpolan 80 EC, Ikar 95 EC and Olemix 84 EC at a conc. of 2.0% (Table 4). The tested oils used at a concentration of 1%

Table 3
Effectiveness of oils in the control of *Sphaerotheca pannosa* var. *rosae* on rose cv. Mercedes. – (2-times spray at 7-day intervals) Beginning of experiment and initial infection level: 2002.08.30 = 5.0.

Treatments	Conc., %	Mean degree of shoots infection after days from beginning of experiment			
		3	7	14	28
Control	-	5.00 d	5.00 e	5.00 d	5.00 h
Triforine	0.03	3.70 c	3.45 d	3.25 c	2.95 g
Plant oils used as a food (Cooking oil)					
Canola Oil (Rape Oil)	1.0	0.20 b	0.11 a-c	0.33 b	1.18 f
Corn Oil (Maize Oil)	1.0	0.11 ab	0.05 ab	0.20 b	0.11 c
Grape seed Oil	1.0	0.01 a	0.20 b-c	0.29 b	0.45 de
Olive Oil	1.0	0.01 a	0.05 ab	0.20 b	0.60 e
Soybean Oil	1.0	0.11 ab	0.20 bc	0.34 b	0.29 d
Sunflower Oil	1.0	0.01 a	0.01 a	0.34 b	0.34 de
Mineral oils					
Atpolan 80 EC	1.0	0.05 ab	0.20 bc	0.01 a	0.01 ab
Para Sommer 75 EC	1.0	0.01 a	0.05 ab	0.05 a	0.00 a
Sunspray 850 EC	1,0	0.05 ab	0.24 c	0.01 a	0.05 bc

Note: see Table 2

Table 4
Effectiveness of oils in the control of *Sphaerotheca pannosa* var. *rosae* on rose cv. Madelon. – (2-times spray at 14-day intervals). Beginning of experiment and initial infection level: 2002.09.23 = 1.52.

Treatments	Conc., %	Mean degree of shoots infection after days from beginning of experiment	
		14	28
Control	-	5.00 e	5.00 d
Triforine	0.03	0.65 c	0.35 c
Plant oils recommended in plant protection			
Dedal 90 EC	1.0	0.15 ab	0.10 ab
Dedal 90 EC	2.0	0.00 a	0.05 ab
Olejan 85 EC	0.5	1.15 d	0.40 c
Olejan 85 EC	1.0	0.70 c	0.15 b
Olejan 85 EC	1.5	0.10 ab	0.00 a
Olejan 85 EC	2.0	0.00 a	0.00 a
Mineral oils			
Atpolan 80 EC	1.0	0.00 a	0.00 a
Atpolan 80 EC	2.0	0.00 a	0.00 a
Ikar 95 EC	1.0	0.15 ab	0.10 ab
Ikar 95 EC	2.0	0.00 a	0.00 a
Olemix 84 EC	1.0	0.20 b	0.10 ab
Olemix 84 EC	2.0	0.00 a	0.00 a

Note: see Table 2

or higher exhibited similar or higher effectiveness compared to the standard fungicide (Tables 2 and 4).

The effectiveness of the oils was found to increase significantly with increasing concentration of the oils. However, in view of the cost of using the oils per unit surface area and a greater risk of phytotoxicity, a concentration of 1% was used in subsequent tests. It should be emphasized that the use of oils with a frequency of every 14 days resulted in an efficacy of 95 to 100% in the observation made 14 days after the last treatment (Table 4). In subsequent tests, the vegetable cooking oils, mineral oils, and the ready-made vegetable oils used for spraying plants twice at a 7-day interval showed a 95% to 100% efficacy even 21 days after the last spraying (Tables 3, 5). High efficacy of the tested oils was also evident in the observation made after the completion of the protection programme – it ranged from 88% to 100% (Tables 3, 4, 5, 6 and 7).

Even at a very high initial intensity of the disease symptoms, the vegetable and mineral oils still exhibited high effectiveness (Tables 2, 3, 7). Only in 2002, in the cultivar ‘Mercedes’, the degree of infection of the shrubs sprayed with rapeseed oil at a conc. of 1% was above 1 and equalled 1.18 (Table 3). On the other hand, in the first experiment (Table 2), in the final observation, the degree of infection of the shrubs by powdery mildew was above 2 on the shrubs sprayed with rapeseed oil, sunflower oil, and Sunspray 850 EC at conc. of 0.25 and 0.5%, and their efficacy ranged from 62 to 76%. In the observations made 7 and 21 days after the completion of the treatments, there was evidence of an increase in the severity of disease symptoms relative to the previous assessment (Tables 3, 5, 6). After that period of time from the last treatment, the mycelium was active again and able to form conidiophores and conidia. The efficacy of the various oils varied depending on the experiment and the time of observation. The results of the experiments may suggest slightly higher effectiveness of mineral oils in comparison with vegetable oils, although the data are not always supported by statistical calculations.

In each of the experiments and observations, the tested oils used at a concentration of 1% or higher had a significantly higher efficacy compared to the standard fungicide containing the active substance triforine.

Discussion

The tested vegetable cooking oils, oils of plant origin and mineral oils all showed excellent effectiveness against pow-

Table 5
Effectiveness of oils in the control of *Sphaerotheca pannosa* var. *rosae* on rose cv. Escimo (2-times spray at 7-day intervals). Beginning of experiment and initial infection level: 2002.10.01 = 3.16

Treatments	Conc., %	Mean degree of shoots infection after days from beginning of experiment		
		1	14	28
Control	-	4.10 c	4.70 d	5.00 e
Triforine	0.03	2.90 b	2.65 c	2.65 d
Plant oils used as a food (Cooking oil)				
Canola Oil (Rape Oil)	1.0	0.25 a	0.10 b	0.20 bc
Corn Oil (Maize Oil)	1.0	0.15 a	0.00 a	0.25 c
Grape seed Oil	1.0	0.10 a	0.05 ab	0.25 c
Olive Oil	1.0	0.10 a	0.00 a	0.20 bc
Soybean Oil	1.0	0.15 a	0.05 ab	0.20 bc
Sunflower Oil	1.0	0.10 a	0.00 a	0.10 ab
Plant oils recommended in plant protection				
Dedal 90 EC	1.0	0.10 a	0.00 a	0.05 a
Olejan 85 EC	1.0	0.20 a	0.00 a	0.10 ab
Mineral oils				
Atpolan 80 EC	1.0	0.20 a	0.00 a	0.10 ab
Ikar 95 EC	1.0	0.10 a	0.00 a	0.00 a
Olemix 84 EC	1.0	0.20 a	0.05 ab	0.05 a
Para Sommer 75 EC	1.0	0.15 a	0.00 a	0.20 bc
Sunspray 850 EC	1.0	0.10 a	0.00 a	0.10 ab

Note: see Table 2

Table 6

Effectiveness of oils in the control of *Sphaerotheca pannosa* var. *rosae* on rose cv. Escimo (2-times spray at 7-day intervals). Beginning of experiment and initial infection level: 2003.06.01 = 3.1

Treatments	Conc., %	Mean degree of shoots infection after days from beginning of experiment			
		3	7	10	14
Control	-	3.44 f	4.69 c	4.37 c	5.00 f
Triforine	0.03	3.37 f	4.69 c	4.31 c	5.00 f
Plant oils used as a food (Cooking oil)					
Canola Oil (Rape Oil)	1.0	0.06 bc	0.01 ab	0.02 ab	0.25 c-e
Corn Oil (Maize Oil)	1.0	0.06 bc	0.01 ab	0.00 a	0.25 c-e
Grape seed Oil	1.0	0.00 a	0.00 a	0.00 a	0.02 ab
Olive Oil	1.0	0.25 de	0.01 ab	0.02 ab	0.25 c-e
Soybean Oil	1.0	0.06 bc	0.06 b	0.06 b	0.30 de
Sunflower Oil	1.0	0.00 a	0.01 ab	0.00 a	0.14 b-d
Plant oils recommended in plant protection					
Dedal 90 EC	1.0	0.14 cd	0.00 a	0.00 a	0.06 a-c
Olejan 85 EC	1.0	0.00 a	0.00 a	0.00 a	0.14 b-d
Mineral oils					
Atpolan 80 EC	1.0	0.00 a	0.00 a	0.00 a	0.06 a-c
Ikar 95 EC	1.0	0.00 a	0.00 a	0.00 a	0.06 a-c
Olemix 84 EC	1.0	0.01 ab	0.00 a	0.00 a	0.14 b-d
Para Sommer 75 EC	1.0	0.00 a	0.00 a	0.00 a	0.14 b-d
Sunspray 850 EC	1.0	0.00 a	0.00 a	0.00 a	0.06 a-c

Note: see Table 2

Table 7

Effectiveness of oils in the control of *Sphaerotheca pannosa* var. *rosae* on rose cv. Madelon (2-times spray at 7-day intervals). Beginning of experiment and initial infection level: 2003.09.23 = 3.8

Treatments	Conc., %	Mean degree of shoots infection after days from beginning of experiment		
		1	7	10
Control	-	3.87 f	4.37 g	4.75 e
Triforine	0.03	2.69 e	2.25 f	2.19 d
Plant oils used as a food (Cooking oil)				
Canola Oil (Rape Oil)	1.0	1.19 a-c	1.12 cd	0.00 a
Corn Oil (Maize Oil)	1.0	1.37 cd	1.19 d	0.06 a
Olive Oil	1.0	1.25 bc	1.37 e	0.12 a
Soybean Oil	1.0	1.19 a-c	1.19 d	0.06 a
Sunflower Oil	1.0	1.31 b-d	1.00 bc	0.06 a
Plant oils recommended in plant protection				
Adpros 850 SL	1.0	1.31 b-d	1.19 d	0.37 b
Dedal 90 EC	1.0	1.19 a-c	1.12 cd	0.06 a
Olejan 85 EC	1.0	1.19 a-c	1.00 bc	0.06 a
Mineral oils				
Atpolan 80 EC	1.0	1.12 ab	0.69 a	0.06 a
Ikar 95 EC	1.0	1.19 a-c	0.94 b	0.12 a
Olemix 84 EC	1.0	1.12 ab	1.06 b-d	0.06 a
Promanal 60 EC	1.0	1.50 d	1.44 e	0.69 c
Sunspray 850 EC	1.0	1.00 a	1.00 bc	0.06 a

Note: see Table 2

dery mildew of rose. Particularly noteworthy is the very high effectiveness of vegetable cooking oils and ready-made oils of vegetable origin, and therefore posing little threat to the environment and people performing the spray treatments. The author's own data confirm the high efficacy of oils in the control of the pathogens that are the causal agents of powdery mildews in other plant species. Also Jee et al. (2009) found that among the different cooking oils, soybean, canola (rapeseed), safflower, olive, and corn oil showed over 95% control values against powdery mildew of cucumber in greenhouse tests. However, Northover and Shneider (1996) showed in a series of greenhouse experiments that the petroleum oils used against powdery mildew on grapevines provide moderate protection, excellent pre-lesion and post-lesion curative action, and were antisporulative. The plant oils showed significant action only in pre-lesion treatments and as antisporulants in treatments applied to established lesions. The direct action of mineral oils on pathogens involves dehydration and deformation of the cells of the mycelium and spores, and disintegration of the cell walls (Wojdyła, 2000).

Literature data on the mechanism of action of oils indicate that oils have a fungistatic rather than fungicidal effect, possibly indicating a temporary effect on host physiology (Northover and Schneider, 1996). McGrath and Shishkoff (2000), in a study conducted on cucumber, showed that although oil appeared to cause abnormalities in conidiophores and spores of *Sphaerotheca fusca* immediately after application, this effect was temporary. Earlier studies of the present author on the influence of various compounds on the mycelium and spores of *Sphaerotheca pannosa* var. *rosae*, the causal agent of powdery mildew, had shown that Atpolan 80 EC and a fungicide containing triforine almost completely destroyed conidia and hyphae (Wojdyła, 2000). Likewise, Hafez (2008) demonstrated that the protective effect of oils against powdery mildew resulted mainly from the inhibition of conidia germination and suppression of the mycelial growth of the pathogens, with slight activation of host defence mechanisms.

The mechanism of indirect action applies to vegetable oils and is associated with the induction of resistance in the protected plants. Elicitors of induced systemic resistance (ISR) mentioned in the literature include: oleic acid, linoleic acid, and linolenic acid, which are the main components of the vegetable oils used in this study (Table 1) (Kuć, 2001). In an experiment by Cohen et al. (1990), five unsaturated fatty acid were tested for their ability to induce systemic resistance in potato plants to the late blight fungus *Phytophthora infestans*. Linoleic acid, linolenic acid and oleic acid applied to leaves 1-3 of potato plants at a dose of about 1 mg per plant induced (provided) 82%, 39% and 42% protection in leaves 4-11, respectively. These results are not always confirmed by other authors. Ko et al. (2003) found that sunflower oil applied to halves of the upper leaf surface did not induce resistance against the pathogen in the non-treated halves. When applied to halves of the lower leaf surface, it also failed to reduce the severity of powdery mildew on the upper leaf surface right above the treated area, indicating that the control of powdery mildew by sunflower oil did not result from activation of host defence mechanisms.

In experiments by Northover and Schneider (1993) there was no difference in fungicidal activity between two groups of oils with composition either high or low in linoleic acid toward three foliar pathogens: *Podosphaera leucotricha*, *Venturia inaequalis* and *Albugo occidentalis*. Similarly, in the present study, there was no correlation between the composition of the vegetable oils tested and their effectiveness in the protection of roses against *S. pannosa* var. *rosae*.

With the passage of time after the completion of the spray treatments in this study, the mycelium was observed to reappear in places where it had previously been destroyed by the oils used. On the basis of those observations, a direct action of the oils through their contact with the mycelium and spores might be suggested. Also Northover and Schneider (1996) found that the regrowth and reappearance of powdery mildew lesions after treatment with plant oils, and to a lesser extent with petroleum oils, showed that these oils had a fungistatic rather than fungicidal effect, possibly indicating a temporary effect on host physiology.

Conclusions

The study has demonstrated high effectiveness of the tested oils in inhibiting the development of powdery mildew on rose shrubs. With increasing concentration, the efficacy of the tested oils was seen to rise. However, for practical reasons, particularly the purchase cost of the oil used for spraying, increasing the concentration above 1% appears to be rather pointless. Depending on the severity of the disease symptoms, the susceptibility of the cultivar, and the weather conditions, the oils used in a protection programme should be applied every 7 to 14 days (the lowest interval recommended if there is a high risk of powdery mildew developing).

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