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Stem injection of triazoles for the protection of *Vitis vinifera* L. ('Riesling') against powdery mildew (*Uncinula necator*)

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Summary

The aim of this study was to find suitable substances to control powdery mildew by means of stem injection. The triazoles myclobutanil, penconazol and tebuconazol were used as test substances. In the first experiment, single xylem injections of these triazoles were carried out to test their effect against powdery mildew. The injections were carried out on field-grown grapevines using the ChemJet® tree injector. Applications invariably yielded efficiency factors of over 60 %. A practice-oriented effect on leaves and grapes was most notably gained using tebuconazol. In the second experiment, the repeated xylem injection of myclobutanil, penconazol and tebuconazol was carried out on field-grown grapevines with a prototypal stationary injection system to evaluate the longer-term effects. Grapevines sprayed with formulated myclobutanil (Systhane 20 EW®), penconazol (Topas®) and tebuconazol (Folicur 250 EW®) enable the methods to be compared. Applications using the prototypal stationary injection system only yielded moderate efficiency factors. A practice-oriented effect was gained using the sprayed application. Future options for stem injection, such as combating wood-destroying fungi and phytoplasmosis, were discussed.

K e y w o r d s : Fungicide, powdery mildew, stem injection, triazole, viticulture, xylem.

Introduction

Powdery mildew (*Uncinula necator*) is one of the most, if not *the* most, significant problem in numerous countries with regard to protecting grapevines. In order to control this pest, several plant protection treatments are required per year. The crucial disadvantage of application by means of spraying and sprinkling methods is the emission of plant protective agents into the environment (Kookana *et al*. 1998, Bermudez-Couso *et al*. 2007). This occurs in the form of drift as soon as such substances are applied. Furthermore, agricultural chemicals applied to the leaves also end up in the air due to volatilisation or in the soil due to drip down, wash off and infiltration. What is more, plant protective agents are also transported into adjacent bodies of surface water by way of driftage. For this reason, modern plant protection concepts envisage a reduction in the use of plant protective agents and hence a decrease in the emission of agricultural chemicals into the environment (Klingauf and Pallutt 2002). In order to comply with these guidelines, the lowest possible amounts of pesticide should increasingly be used in a situational manner (Kookana *et al*. 1998). In this context, the stem injection of suitable substances could be an ecologically sound alternative to previous methods. So far, however, only a few studies have been published on this subject. Viglierichio *et al*. (1977) injected the nematocides sulfocarb und Oxamyl® into the vessels of six-month-old greenhouse-grown *Vitis vinifera* L. and two-and-a-half-year-old field-grown *Vitis rupestris* in pots. The nematodes (*Pratylenchys vulnus*) cultivated in the potting soil of the test plants were successfully prevented from sucking on the roots of the grapevines. Magaray and Wachtel (1986) managed to achieve a therapeutic effect with regard to Australian Grapevine Yellows in *Vitis vinifera* L ('Riesling') by means of the stem application of oxytetracycline-hydrochloride (OTC). In doing so, they provided control for six seasons with a single stem injection. Di Marco *et al*. (1998) carried out the repeated use of several injections of fosetyl-al to 'Sangiovese', 'Riesling' and 'Lambrusco' over a period of two to five years. Thanks to the treatment, the damage symptoms of esca on the leaves of the test plants were considerably reduced during these periods. In a further study, Di Marco *et al*. (2000) achieved promising results with fosetyl-al against *Phaeacremonium spp.* under laboratory and greenhouse conditions, with the prospect of a favourable effect on esca control. Düker and Kubiak (2009) reported about the stem application of metalaxyl to protect *Vitis vinifera* L. ('Riesling') against downy mildew (*Plasmopora viticola*). The efficiency factors with regard to the control of downy mildew in leaves and grapes were very similar in both approaches, with values of practical relevance of over 70 %. The aim of the present study was to find suitable agents from the triazole family to control powdery mildew (*Uncinula necator*) by means of stem application. To achieve the aims of this study, the following experiments were conducted: a) single xylem injections of three triazoles (myclobutanil, penconazol and tebuconazol) to test their effect against powdery mildew. b) the repeated xylem injection of suitable triazoles with a prototypal long-term injection system to evaluate the longer-term effects with regard to controlling powdery mildew in the leaves of treated grapevines.

Material and Methods

M a t e r i a l : Powdery mildew (*Uncinula necator*) was used as the test organism. Tests were performed on 21-year-old field-grown 'Riesling' grapevines. General plant

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protection was discontinued five weeks before tests commenced. At this time, the plants were not affected by powdery mildew because of the low disease pressure, probably due to the low temperatures and failed rainfall in the month of April 2007 (Tab. 1). Since the potential occurrence of downy mildew (*Plasmopora viticola*) and grey mould (*Botrytis cinerea*) on the test plants outdoors would have negatively influenced the growth of powdery mildew, the field-grown grapevines were treated with the fungicides Delan® WG (700 g·l^{-1} dithianon), Scala® (400 g·l^{-1} pyrimethanil), Ridomil Gold® MZ (640 g·l^{-1} mancozeb and 40 g·l^{-1} metalaxyl) and Electis® (670 g·l^{-1} mancozeb and 80 g·l^{-1} zoxamide) several times in the period leading up to the commencement of the experiment. These fungicides were selected because they did not possess any additional effects against powdery mildew.

Methods - injection: In the first experiment, the stem injections were carried out using two ChemJet® tree injectors per grapevine. The injectors were purchased from CHEMJET® Trading, Pty. Ltd., P.O. Box 318, Caboolture QLD 4510, Australia. A ChemJet® is a device containing a coil spring, resembling an application syringe. By dipping the tip into the fluid to be applied and simultaneously drawing back the piston against the power of a coil spring, the fluid is drawn up into the chamber of the injector. The uptake volume is approximately 20 ml. By turning the piston clock-wise, it can be locked into the appropriate apparatus. In order to mount the injectors, a 4 mm hole is drilled into the narrow side of each grapevine trunk. The tree injectors are then affixed into the drilled holes by rotation. Once the catches on the ChemJets® are released, the actual application of the fluid commences. Single stem injections in three variants - with the triazoles myclobutanil (0.14 g / l H_2O), penconazol (0.07 g / l H_2O) and tebuconazol (0.06 g / l H_2O) - were performed on five field-grown grapevines each on 18 May 2007. 5.7 mg myclobutanil, 2.8 mg penconazol and 2.4 mg tebuconazol, respectively, was injected per grapevine. The amounts of myclobutanil and penconazol corresponded to the quantities applied in practice by sprinkling and spraying per grapevine for the respective stage of development. The amount of tebuconazol corresponded to approximately 10 % of the amount applied in conventional leaf application. Water was applied to five further grapevines, which served as control plants.

Table 1

Meteorological data of Neustadt (Rhineland-Palatinate, Germany). Source: Dienstleistungszentrum Ländlicher Raum (DLR) Rheinpfalz, Breitenweg 71, D-67435 Neustadt, Germany

2007	Average temperatures monthly average (°C)	Rainfall monthly totals (mm)
January	6.6	36
February	6.2	59
March	7.7	79
April	14.9	0
May	16.8	73
June	19.6	102
July	19.3	92
August	18.5	54
September	13.8	33
October	10.1	10
November	5.1	55
December	2.2	54

In the second experiment, repeated stem injections were applied using a prototypal stationary injection system, intended for use over several years (Düker *et al*. 2006, 2007). This system was already affixed to seven field-grown grapevines (prototype 1) two years previously and to fifteen field-grown grapevines (prototype 2) one month prior to the experiment. In this system, water from a stainless steel tank is initially conveyed via an ultraviolet lamp, for sterilisation purposes, to a membrane pump, which drives the system. The water is subsequently pushed through tubing to the grapevines. Regularly spaced individual inlet pipes lead from the main inlet pipe, which was laid along the lower wire frame in the grapevine row, to the grapevines. Three series connected injector units, each consisting of a needle and its attachment, are affixed to each of these inlet pipes. The needles, which are pressed into the vine stem during assembly using special pliers, facilitate direct access to the grapevine vessels. The pressure of the system is kept constant at 400 hPa by a valve. Plant protection takes place according to requirements via a dosage loop, which is connected upstream of the main inlet pipe. To this aim, the fluid to be applied is initially drawn up using a syringe and is introduced into the dosage loop via a valve. The stem injections with myclobutanil (0.14 g / l H_2O) took place on 18 May 2007 and 30 May 2007; the xylem injections with penconazol (0.07 g / l H_2O) were carried out on 12 June 2007 and 22 June 2007; and the stem injections with tebuconazol (0.06 g / l H_2O) took place on 2 July 2007 and 13 July 2007, always on both prototypes. 285 ml (prototype 1) and 611 ml, respectively, (prototype 2) of the application solution with myclobutanil, or 430 ml (prototype 1) and 922 ml, respectively, (prototype 2) of the application solution with penconazol, or 280 ml (prototype 1) and 600 ml, respectively, (prototype 2) of the application solution with tebuconazol was introduced into the prototypal injection system via the dosage loop. Under the proviso that the application solution is distributed evenly to each inlet pipe, 5.7 mg myclobutanil, or 4.3 mg penconazol and 2.4 mg tebuconazol, respectively, was injected per grapevine with each application. The amounts of myclobutanil and penconazol corresponded to the quantities applied in practice by sprinkling and spraying per grapevine for the respective stage of development. The amount of tebuconazol corresponded to approximately 10 % of the amount applied in conventional leaf application. Twenty-five further untreated grapevines acted as control plants. Furthermore, in order to enable the direct comparison of the stem injection method and the other conventional methods of application by means of spraying and sprinkling, 22 grapevines were treated with formulated myclobutanil (Systhane 20 EW®), or formulated penconazol (Topas®) and formulated tebuconazol (Folicur 250 EW®), respectively, per application. The plants were sprayed six times successively at the same time as the stem injections. The quantity applied was adjusted to the plants' respective stage of development, and amounted to 5.7 mg myclobutanil/grapevine for

Table 2

Schedule and experimental design for applying the agent in the second experiment

Test variant	Number of replicates	Applied compounds	Dates of application	Amount of compounds [mg]
Prototype 1	7	myclobutanil	18 May 2007	5.7
Prototype 1	7	myclobutanil	30 May 2007	5.7
Prototype 1	7	penconazol	12 June 2007	4.3
Prototype 1	7	penconazol	22 June 2007	4.3
Prototype 1	7	tebuconazol	2 July 2007	2.4
Prototype 1	7	tebuconazol	13 July 2007	2.4
Prototype 2	15	myclobutanil	18 May 2007	5.7
Prototype 2	15	myclobutanil	30 May 2007	5.7
Prototype 2	15	penconazol	12 June 2007	4.3
Prototype 2	15	penconazol	22 June 2007	4.3
Prototype 2	15	tebuconazol	2 July 2007	2.4
Prototype 2	15	tebuconazol	13 July 2007	2.4
Spray-applied	22	myclobutanil	18 May 2007	5.7
Spray-applied	22	myclobutanil	30 May 2007	5.7
Spray-applied	22	penconazol	12 June 2007	4.3
Spray-applied	22	penconazol	22 June 2007	4.3
Spray-applied	22	tebuconazol	2 July 2007	24
Spray-applied	22	tebuconazol	13 July 2007	24

the first and second spray, 4.3 mg penconazol/grapevine for the third and fourth and 24 mg tebuconazol/grapevine for the fifth and sixth spray. The main details concerning the scheduling and design of the trials of the second experiment are summarised in Tab. 2.

I n o c u l a t i o n : Powdery mildew (*Uncinula necator*) was used as the test organism. Due to the incompatibility with water of the powdery mildew spores no defined suspensions could be applied for inoculation. The grapevines were inoculated by rubbing the leafy wall with cut-off shoots from nursery plant grapevines that had already been highly infected with powdery mildew. The shoots were rubbed along the front and back of the leafy wall in close curvy lines. A vine leaf infected with powdery mildew was also attached to each vine.

In the first experiment, inoculation took place three times in series on a weekly basis, starting on 25 May 2007. In the second experiment, inoculation also took place three times in series on a weekly basis, starting on 1 June 2007. The plants were already in blossom at this stage (Tab. 3).

R a t i n g a n d i n t e r p r e t a t i o n : In the first experiment, a one-off estimation of 10 leaves and 6 clusters per grapevine of control and test variants took place on 22 June 2007.

In the second experiment, infestation estimations were performed on a weekly basis on 150 leaves per variant. An exception to this was the stem application variant prototype 1, since only seven grapevines were connected to this long-term injection system. In this case, estimations were performed on 100 leaves. The infestation estimations commenced on 18 June 2007.

The leaves and clusters to be estimated were classified into groups according to the percentage of affected leaf area (0 %, up to 5 %, up to 10 %, up to 25 %, up to 50 %, up to 75 % and up to 100 %). The infestation frequency of the individual variants is yielded from the following formula:

$$IF\ [\%] = ((A + B + C \ldots / N) \times 100),$$

whereby the free variable parameters A, B, C, … represent the number of leaves and clusters that were classified to the respective estimation groups, and N denotes the total number of leaves and clusters of each respective variant. The intensity of infestation of the individual variants was calculated using the following formula:

$$IOI\ [\%] = (mc_1 \times A) + (mc_2 \times B) + (mc_3 \times C) \ldots / N,$$

where mc represents the mid-point of the class, the free variable parameters A, B, C, … are the number of leaves and clusters that could be classified to the respective mid-point of the class, and N represents the total number of leaves and clusters of each respective variant. The efficiency factor of the agents and/or application methods was derived using the following formula:

$$EF\ [\%] = ((IOI_{CP} - IOI_T) / IOI_{CP}) \times 100,$$

where IOI_{CP} is the intensity of infestation of the control plants and IOI_T is the intensity of infestation of the treated

Table 3

Phenological development of grapevines in Neustadt (Rhineland-Palatinate, Germany). Source: Dienstleistungszentrum Ländlicher Raum (DLR) Rheinpfalz, Breitenweg 71, D-67435 Neustadt, Germany

Grapevine phenology	2007
Bud swelling	1 April
Shoot	12 April
Commencement of blossoming	23 May
Pea-sized berries	20 June
Commencement of maturity	2 August

grapevines. The data collected in the first experiment were subjected to Tuckey's test (Alpha ≤ 0.05) or the Kruskal-Wallis test (Alpha < 0.05), if no meaningful statistical difference was achieved using Tuckey's test. The values gained from the second experiment underwent a simple linear regression.

Results and Discussion

Selection of suitable triazoles: Fig. 1 a illustrates the resulting infestation frequency of powdery mildew on the leaves of each respective variant from the first experiment. As expected, the value of the control plants (80.0%) was highest. The infestation frequencies of the test variants with myclobutanil (52.5 %), penconazol (50.0 %) and tebuconazol (56.7 %) revealed lower values, which differ significantly from the value gained by the control plants. Fig. 1 b presents the intensity of infestation of powdery mildew on the leaves of the individual variants from the first experiment. The value of the control plants was 10.7 %. The intensity of infestation of the test variants with myclobutanil (2.8 %), penconazol (3.5 %) and tebuconazol (2.8 %) was significantly lower than that of the control plants. The efficiency factor of the stem injected fungicide agents are shown in Fig. 1 c. Myclobutanil and tebuconazol achieved a value of 73.7 % and 74.3 % respectively, which is of practical relevance. Penconazol (67.8 %) achieved a lower efficiency factor which, however, was not significantly different to the other two values. The infestation frequency of powdery mildew on the clusters of the individual variants from the first experiment is shown in Fig. 2 a. The value of the control plants was 70.0 %. The infestation frequency of the test variants with penconazol (43.3 %) and tebuconazol (44.4 %) was lower than that of the control plants. The test variant with myclobutanil (37.5 %) generated the lowest value in this case, which differs significantly from the infestation frequency of the control plants. Fig. 2 b illustrates the resulting intensity of infestation of powdery mildew on the clusters of each respective variant from the first experiment. The value of the control plants (5.8 %) was highest. Although the intensity of infestation of the test variants with myclobutanil (2.0 %), penconazol (2.1 %) and tebuconazol (1.4 %) revealed lower values, they did not differ significantly from the value gained by the control plants. A more precise result may perhaps have been achieved using a higher number of replicates. But for this reason, the results in this case and the efficiency factors calculated from them can only be viewed as a tendency. Fig. 2 c shows the efficiency factor of the stem injected triazoles. Once again, the test variant with tebuconazol (75.8 %) generated the highest value in this case. The efficiency factor of the test variants with myclobutanil (65.6 %) and penconazol (63.8 %) was lower than that of the variant with tebuconazol, but did not differ significantly from them. Hence the results yielded with clusters resemble the previous findings gained for leaves.

The stem injection of selected triazoles (myclobutanil, penconazol and tebuconazol) by the ChemJet® tree in-

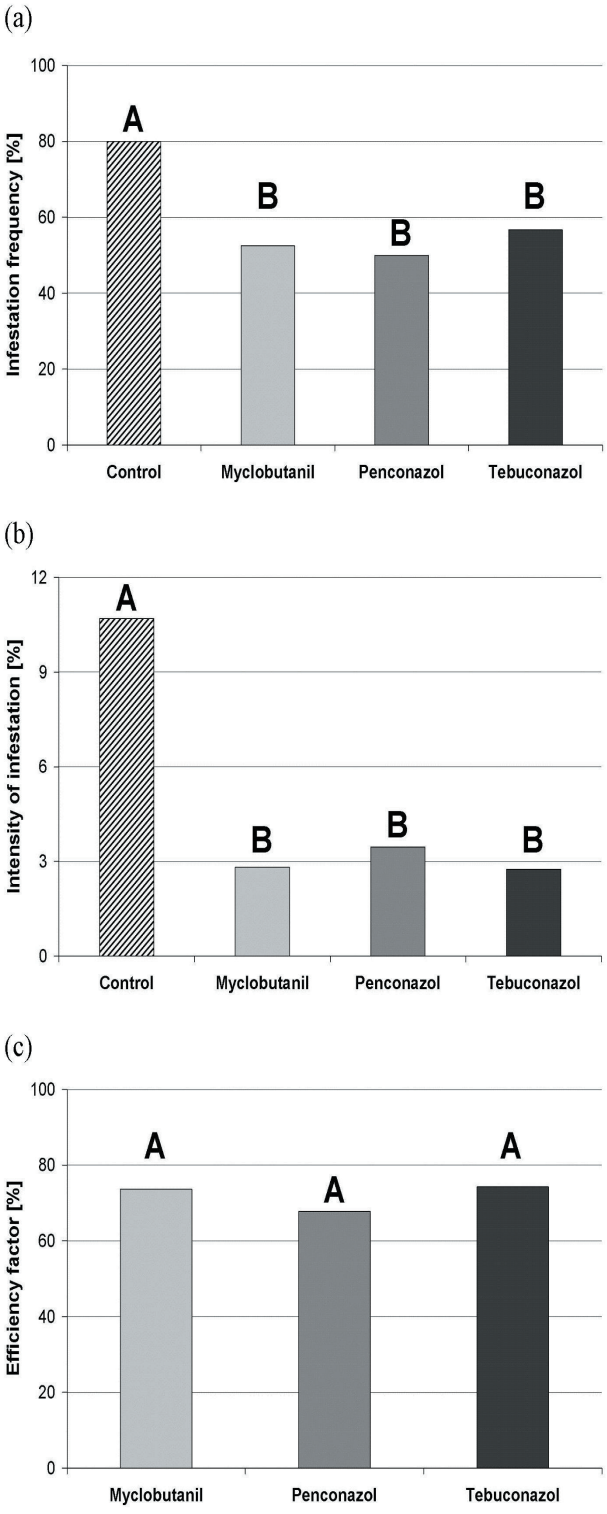

Fig. 1: Results of individual injections of fungicide agents (myclobutanil, penconazol, tebuconazol) into the xylem of field-grown grapevines. Injections were carried out using two ChemJet® injectors per grapevine. The values resulted from five repetitions (control plants, penconazol), four repetitions (myclobutanil) and three repetitions (tebuconazol), respectively. Capital letters above the columns represent the statistical difference Alpha ≤ 0.05 (Tuckey's test) within each test variant. (**a**) Infestation frequency of powdery mildew on the leaves of test variants and control plants. (**b**) Intensity of infestation with powdery mildew on the leaves of test variants and control plants. (**c**) Efficiency factors of the test variants.

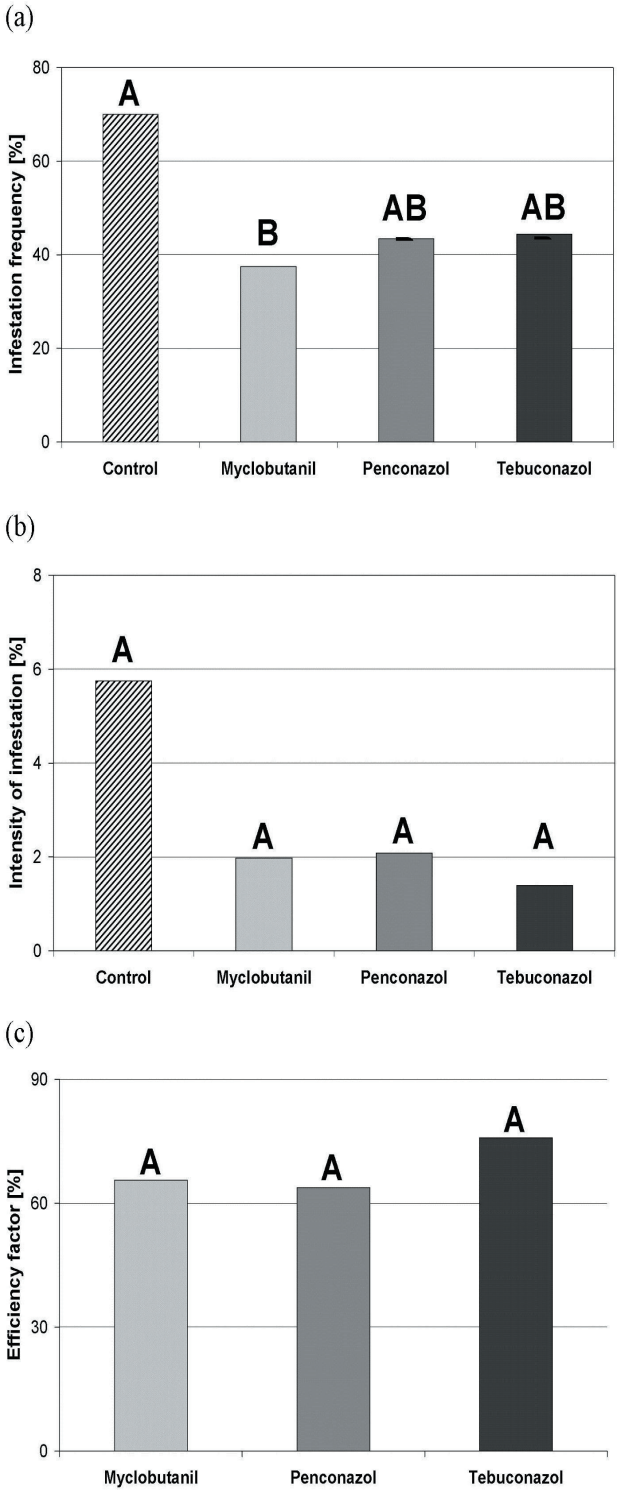

Fig. 2: Results of individual injections of fungicide agents (myclobutanil, penconazol, tebuconazol) into the xylem of field-grown grapevines. Injections were carried out using two ChemJet® injectors per grapevine. The values resulted from five repetitions (control plants, penconazol), four repetitions (myclobutanil) and three repetitions (tebuconazol), respectively. Capital letters above the columns represent the statistical difference Alpha < 0.05 (Kruskal-Wallis test) within each test variant. Kruskal-Wallis was applied because no meaningful statistical difference was achieved using Tuckey´s test. (**a**) Infestation frequency of powdery mildew on the clusters of test variants and control plants. (**b**) Intensity of infestation with powdery mildew on the clusters of test variants and control plants. (**c**) Efficiency factors of the test variants.

jector to control *Uncinula necator* invariably yielded efficiency factors of over 60 %. Practice-orientated values (> 70 %) were gained using myclobutanil and tebuconazol on leaves and using tebuconazol on clusters. The tests demonstrate that it is fundamentally possible to carry out grapevine protection against powdery mildew by means of stem injection. In the case of stem injected tebuconazol, the relevant effect was gained with a fraction (10 %) of the amounts conventionally sprayed in practice. As with the conventional practice of spraying and sprinkling, a further increase of efficiency can probably be achieved by combining different agents. In this context, for example, the combination of a triazole, which inhibits sterol biosynthesis of *Uncinula necator*, with a strobilurin, which inhibits mitochondrial respiration, is conceivable.

The effect of repeated stem injected triazoles: The resulting infestation frequency of powdery mildew on the leaves of each variant from the second experiment is presented in Fig. 3 a. Although the values of the stem injected variants were slightly lower than the values of the control plants for most of the estimation period, no relevant protective effect with regard to the infestation frequency was achieved by means of the repeated stem injection of triazoles. In contrast, the variant with sprayed triazoles revealed a low infestation frequency throughout the entire estimation period that differed considerably from the other variants.

Fig. 3 b illustrates the respective intensity of infestation on the leaves of the control and test variants from the second experiment. At the start of the estimations, the value of the control plants was 3.9 %. The intensity of infestation of all test variants was below this amount (2.3 % for the injected variant prototype 1, 2.0 % for the injected variant prototype 2 and 0.7 % for the sprayed variant). During the tests, the intensity of infestation of all variants increased. Towards the end of the estimations, values of 19.6 % (control plants), 12.2 % (prototype 1), 10.3 % (prototype 2) and 3.8 % (sprayed application) were generated. The intensity of estimation resulting from the sprayed variant was by far the lowest. This development was also reflected in the portrayed regression lines: the intensity of infestation of the control variant revealed the greatest tendency to increase and the intensity of infestation of the sprayed variant revealed the lowest tendency to increase.

The efficiency factor of the three test approaches is illustrated in Fig. 3 c. The values of the three variants were subjected to a certain amount of fluctuation, but showed an increased tendency throughout the estimation period. Inclusion of the linear regression confirmed this tendency. The sprayed variant achieved a maximum value of 81.2 %, which is by all means of practical relevance. The maximum efficiency factor of the injected variant prototype 1 was 42.4 %. The injected variant prototype 2 achieved a maximum value of 48.6 %, which was slightly above the value of the injected variant prototype 1. Hence only moderate efficiency factors were yielded with the injected variants in experiment 2, failing to reach the values of practical relevance (> 70 %) achieved in experiment 1. It was insignificant whether the prototypal stem injection system had already been connected to the trial grapevines for two

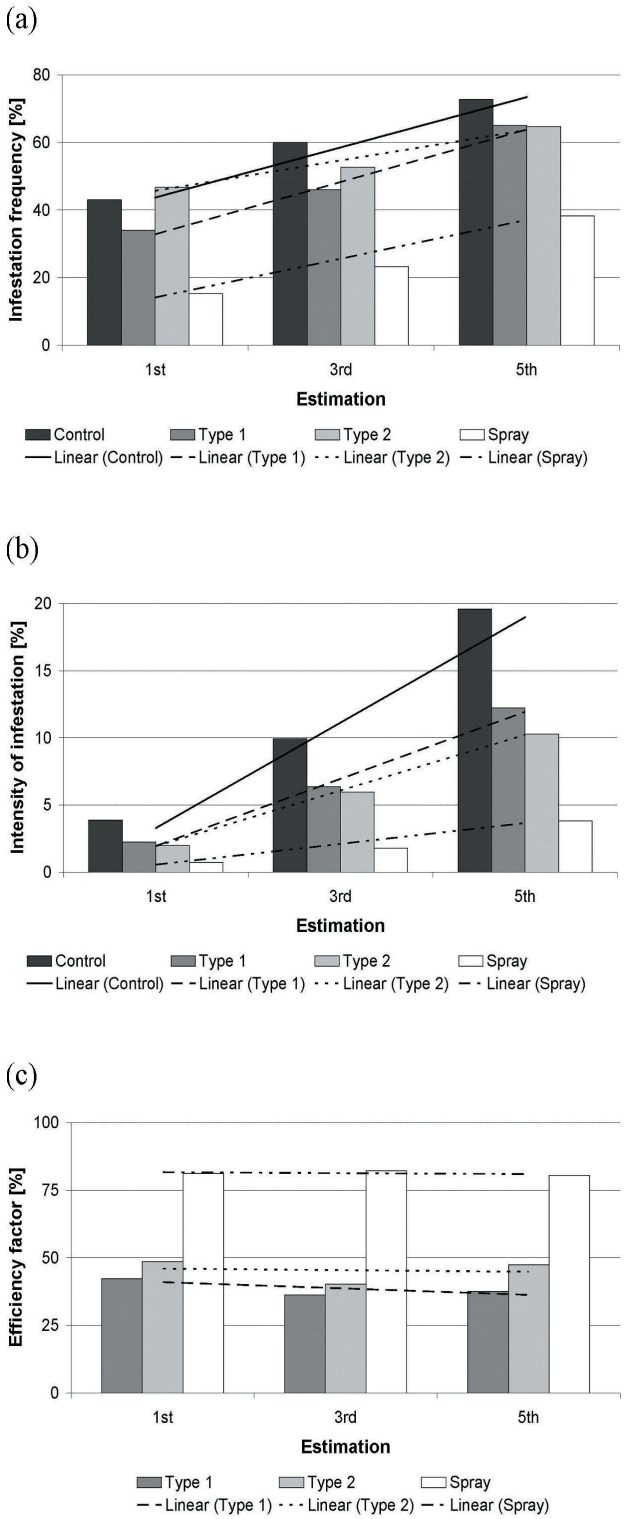

Fig. 3: Results of the repeated xylem injection of myclobutanil, penconazol and tebuconazol with two prototypal long-term injection systems compared with the simultaneous spraying of the formulated products (Systhane 20 EW®, Topas® and Folicur 250 EW®). The values were determined from the estimations of 150 (control plants, prototype 2, spray application) and 100 (prototype 1) leaves per variant. The regression lines were generated using Microsoft Office Excel 2003. (**a**) Infestation frequency of powdery mildew on the leaves of test variants and control plants. (**b**) Intensity of infestation with powdery mildew on the leaves of test variants and control plants. (**c**) Efficiency factors of the test variants.

years (prototype 1) or for just two months (prototype 2), since similar efficiency factors were achieved with both prototypes. Perhaps the injected agents were not distributed evenly over the individual grapevines? Maybe the cross-linking of the inlet pipes led to a delayed uptake of the agents into the grapevine xylem? The results previously gained with injected metalaxyl indicate that this is not the case (Düker and Kubiak 2009). Nevertheless, a higher adsorption of triazoles, which are less water-soluble than metalaxyl, on the walls of the inlet pipes cannot be ruled out. In this case, the dosage of the agent applied was probably too low.

Future options of the method: In practice, the control of powdery mildew relies on the alternating application of various groups of agents with different types of action. In this regard, the combination of triazoles with strobilurins, for instance, would be conceivable for application by means of stem injection. However, like many other agents, most strobilurins are not very water-soluble and are therefore less suited for use by means of stem injection. These substances could possibly be made more suitable for the transport through the xylem by means of microencapsulation. However, adequate anti-resistance management to control powdery mildew by means of stem injection is rather improbable at present. Earlier investigations to control downy mildew by means of stem injection led to a similar conclusion (Düker and Kubiak 2009).

Nonetheless, in the current work on powdery mildew, it was proven that the prototype stationary injection system (prototype 1) is able to function for three years (compared to prototype 2, Fig. 3 c). Moreover, practice-oriented values in the control of downy mildew were previously achieved with prototype 1 (Düker and Kubiak 2009). The question therefore arises whether this system could initially be used in areas where conventional spraying and sprinkling methods have little or no effect. The potential control of wood-destroying fungi (*Phaeomoniella chlamydospora*, *Phaeoacremonium aleophilum*, *Fomitiporia mediterranae, Eutypa lata, among others*) is of importance here, since grapevine diseases such as esca and eutypiosis inflict considerable economic damage (Feliciano *et al*. 2004, Christen 2006). Di Marco *et al*. (1998) have already managed to significantly reduce the damage symptoms of esca on grapevine leaves of 'Sangiovese', 'Riesling' and 'Lambrusco' through the repeated application of fosetyl-al by means of single term stem injection for two to five years. In a further study, Di Marco *et al*. (2000) achieved promising results with fosetyl-al against *Phaeacremonium spp.* under laboratory and greenhouse conditions, with the prospect of a favourable effect on esca control. In both studies, fosetyl-al was applied using specially designed syringes (two per plant) driven inside the trunk by means of a cordless drill. However, in the method applied by Di Marco *et al*. (1998; 2000), new injuries were inflicted on the vine stems every year. There were already six and ten drilled holes per vine stem after three and five years, respectively. The prototype stationary injection system presented in this study, however, was only affixed to the grapevines once with three needles, and already proved its functional ability in the third experimental year. In particular, the combination of the

results of these two studies could represent the basis for a less invasive injection method to control wood-destroying fungi in the vessels of grapevines. Likewise, the control of phytoplasmoses (Bois noir, Flavescence Dorée, among others) is also conceivable with the prototype stationary injection system. Magaray and Wachtel (1986) achieved suitable protection against the Australian Grapevine Yellows on *Vitis vinifera* L ('Riesling') by annually applying oxytetracycline-hydrochloride (OTC) by means of single term stem injection. Since, however, the application of antibiotics in plant protection is highly controversial, due to the assumption of undesirable effects on the environment and reductions in effectiveness due to the formation of resistance, the use of resistance-inducing agents with the prototype stationary injection system would have to be reconsidered in the control of phytoplasmoses.

R e s u m e : These tests demonstrate that it is fundamentally possible to carry out grapevine protection against powdery mildew by means of stem injection. Efficiency factors of practical relevance (> 70 %) were achieved by injecting myclobutanil or tebuconazol with the ChemJet® injector. Extensive anti-resistance management, however, first requires the determination of other agents suitable for use in stem injection. A particularly suitable field of application for the prototype stationary injection system could be the control of wood-destroying fungi and phytoplasmoses.

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