In search of alternatives to copper and sulphur

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Abstract

The fungal diseases apple scab (Venturia inaequalis), powdery mildew (Podosphaera leucotricha), and Gleosporium (G. album, G. perennans and G. fructigenum) are the main challenges in organic apple growing. The traditionally used means of regulation like copper, sulphur, lime-sulphur, and acid clay are increasingly coming under criticism due to various problems. Therefore, the working group Organic farming at Laimburg Research Centre has been intensively searching for alternatives in recent years. Several plant extracts, plant strengthening agents, and other alternatives have been tested in the field. It was found that the alternatives available to date could hardly achieve the effect of the traditional reference products.

Keywords: apple scab, powdery mildew, gleosporium spp., alternatives

Introduction

Apple growing has a big economic and social importance in South Tyrol. In contrast to other fruit-growing areas, apple cultivation is mainly carried out by small, family-run farms, which are organized in powerful cooperatives (Autonome Provinz Bozen – Südtirol 2019). Due to the high revenues that have been achieved for organic products in the last decade and due an increased environmental awareness, the area cultivated according to the guidelines of organic farming has increased in the recent years. The assortment consists mainly of marketable standard varieties. The share of fungus-resistant varieties is increasing but is still relatively small (Erschbamer M. 2019).

The regulation of fungal diseases is still one of the main challenges in organic apple cultivation. The most important diseases are apple scab (*Venturia inaequalis*), powdery mildew (*Podosphaera leucotricha*), and *Gleosporium* spp. (*G. album*, *G. perennans*, and *G. fructigenum*). A large part of the phytosanitary treatments carried out is due to the need to regulate these three diseases. Mainly products based on copper, sulphur, lime sulphur, and acid clay are used, which under the given climatic conditions have proven effective in regulating fungal diseases (Kelderer et.al. 1997; Waibel F. et. al. 2003). However, all four active substances are increasingly coming under criticism due to various problems. In particular, the use of copper represents an Achilles' heel of organic apple cultivation in the public debate due to its ecotoxicological properties and accumulation in the soil. The other substances used are also increasingly being viewed critically (Kienzle J. et. al. 2017).

Organic farming has reacted to this criticism and alternatives have been sought for some time now, partly in international (e.g., CoFree) and national projects (e.g., ALTRAMEinBIO). However, this search is very costly and time-consuming as the alternatives must meet the demands of both critics and farmers. For this reason, alternative products and approaches have been regularly tested by the working group organic farming at the Laimburg Research Centre for a long time (Kelderer et.al.2018).

Material and Methods

The experiments were carried out from 2009 to 2017 in several apple orchards of the Laimburg Research Centre, Vadena, South Tyrol, Italy, coordinates 46°22'59''N 11°17'18''E, 222 m above sea level, Ø annual precipitation 815 mm, Ø T 11.5°C, the predominant soil

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texture is silty, loamy sand. A detailed description of the experimental orchards is given in the tables 1 and 2. With the exception of the blocks 1 and 12, which are managed according to the guidelines for organic farming, the orchards are managed according to the guidelines for integrated cultivation (www.agrios.it), whereby the experimental plots with sufficient buffer trees are excluded from treatments with plant protection products which may influence the experimental results. All orchards are equipped with frost irrigation and drip irrigation.
All spraying treatments were carried out with a spraying device – specifically, a standard blower device (transverse current blower) from Waibl company (Waibl Diethart, 39012 Meran - Sinich BZ, Italy). The treatments were generally carried out in the morning hours. The amount of water applied was 15 or 5hl/ha, depending on the treatments.
A detailed description of the tested treatments is given in table 3.
Except for the trials concerning *Gleosporium spp*., the trial design consisted of 4 randomized trial blocks of 12 trees each, separated by 2 buffer trees. The 2016 trial on *Gleosporium spp.* consisted of 6 randomized trial blocks of 7 study trees each, separated by 2 buffer trees.
The evaluations were performed by visual controls. From the collected data, the infestation intensity was calculated as a weighted average in % for infested leaves (*V. inaequalis* 2016, 2018, 2019 and *P. leucotricha* in 2018 and 2019). For the assessment of the fruits infested by *V. inaequalis*, infested fruits were calculated as % infested fruits for 2016 and infestation intensity for 2019 as a weighted average in %. In 2018, the infestation of the fruits was too low for a serious assessment. The intensity of fruit russeting was calculated as a weighted average in % for *V. inaequalis* in 2016, 2018, and 2019, for *P. leucotricha* in 2018 and 2019. The fruits infested by *Gleosporium spp*. after storage (20.02.2018) were calculated as % infested fruits.
The evaluated data were compared over the different treatments using a 1-way ANOVA followed by a Tukey test ($P<0.05$) for post-hoc comparisons of the agents. All analyses were performed using IBM SPSS Statistics 24 software.

Table 1: Description of the experimental orchards in which the trials on *Venturia inaequalis* were carried out

Trial	***V. inaequalis* 2016**	***V. inaequalis* 2018**	***V. inaequalis* 2019**
Orchard	Laimburg Block 45 + 41	Laimburg Block 45 + 41	Laimburg Block 62
Cultivar	Fuji	Fuji	Golden Del.
Rootstock	M 9	M 9	M9
Planting distance	3,2 m x 1,0 m	3,2 m x 1,0 m	3,2m x 1,0m
Planting year	2003	2003	2003
Training system	Spindle	Spindle	Spindle

Table 2: Description of the experimental orchards in which the trials on *Gleosporium spp.* and *Podosphaera leucotricha* were carried out

Trial	***Gleosporium* 2017**	***P. leucotricha* 2018**	***P. leucotricha* 2019**
Orchard	Laimburg Block 1	Laimburg Block 12	Laimburg Block 12
Cultivar	Pinova (Evelina)	Jonathan	Jonathan
Rootstock	M9	M9	M9
Planting distance	3,4m x 1,0m	3,4m x 1,0m	3,4m x 1,0m
Planting year	2012	2010	2010
Training system	Spindle	Spindle	Spindle

Table 3: The tested treatments for the regulation of *Venturia inaequalis*

Treatments Venturia inaequalis						
Year	**Product**	**Distributor**	**Active substance**	**Dose / hl**	**Mode of use**	**Treatments**
2016	Poltiglia selecta	UPL	Copper	50 g	preventive	11
	Polisulfuro di Calcio	Polisenio	Lime Sulphur	1200 g	preventive	11
	Equiseto	Cerrus	Extract of Equisetum arvense	400 g	preventive	11
	Untreated	-	-	-	-	-
2018	Polisulfuro di Calcio	Polisenio	Lime Sulphur	1200 g	400-500 d.h. targeted	4
	Limolene	Manica S.p.a.	Citrus oil	800 ml	400-500 d.h. targeted	4
	Verde Nora	Verde Nora	Electrolytic water	10000 ml	400-500 d.h. targeted	4
	Test product 1	n.a.	Salicylic acid	1000 ml	400-500 d.h. targeted	4
	Limolene	Manica S.p.a.	Citrus oil	800 ml	preventive	9
	Poltiglia disperss	UPL	Copper	50 g	preventive	9
	Untreated	-	-	-	-	-
2019	Poltiglia disperss	UPL	Copper	50 g	preventive	14
	3logy	Sipcam	Eugenol + Geraniol + Timol	266 ml	preventive	14
	Test product 2	n.a.	Biostimulant	200 ml	preventive	14
	Prev-Am	Nufarm	Citrus oil	200 ml	250-300 d.h. targeted	18
	3logy	Sipcam	Eugenol + Geraniol + Timol	266 ml	250-300 d.h. targeted	18
	Untreated	-	-	-	-	-

Table 4: The tested treatments for the regulation of *Podosphera leucotricha*

Treatments Podosphaera leucotricha						
Year	**Product**	**Distributor**	**Active substance**	**Dose / hl**	**Mode of use**	**Treatments**
2018	Thiovit Jet	Syngenta	Sulphur	200 g	preventive	8
	Armicarb 85	Scam	Potassium bicarbonate	333 g	preventive	8
	Vitikappa	Biogard	Potassium bicarbonate	333 g	preventive	8
	Vitikappa + Thiovit Jet	Biogard + Syngenta	Potassium bicarbonate + Sulphur	333 g + 100 g	preventive	8
	Vacciplant	Arysta	Laminarin	67 ml	preventive	8
	Vacciplant + Thiovit Jet	Arysta + Syngenta	Laminarin + Sulphur	68 ml + 100 g	preventive	8
	3logy	Sipcam	Eugenol + Geraniol + Timol	266 ml	preventive	8
	Untreated	Untreated	-	-	-	-
2019	Thiovit Jet	Syngenta	Sulphur	200 g	preventive	7
	3logy	Sipcam	Eugenol + Geraniol + Timol	266 ml	preventive	7
	Test product 1	n.a.	Salicylic acid	1000 ml	preventive	7
	Ibisco	Gowan	COS-OGA	200 ml	preventive	7
	Prev-Am plus	Nufarm	Citrus oil	200 ml	preventive	7
	Untreated	-	-	-	-	-

Table 5: The tested treatments for the regulation of *Gleosporium spp.*

Treatments Gleosporium spp.						
Year	**Product**	**Distribiutor**	**Active substance**	**Dose / hl**	**Mode of use**	**Treatments**
2017	Boni protect	Manica	Aureobasidium pullulans	100 g	preventive	8
	Keep in Touch	Boscato reti	Physical barrier	-	preventive	8
	Poltiglia disperss + Vacciplant	UPL + Arysta	Copper + Laminarin	50 g + 70 ml	preventive	8
	Ulmasud	Geofin	Acetic clay	1000 g	preventive	8
	Untreated	-	Untreated	-	-	-
	Hot water (after harvest)	-	Hot water 52° C, 3min	-	-	-

Results

Table 6: The results (affected leafs, affected fruits, fruit russeting) of the field trials concerning *Venturia inaequalis* 2016.

Results Venturia inaequalis 2016						
Treatments	**affected leafs**		**affected fruits**		**fruit russeting**	
	infestation intensity in % (weighted average)		affected fruits in %		infestation intensity in % (weighted average)	
Poltiglia selecta	0,00	a	0,00	a	11,79	a
Polisulfuro di Calcio	0,00	a	0,50	a	12,83	a
Equiseto	0,06	b	17,23	b	16,41	a
Untreated	0,05	b	23,03	b	9,54	a

Table 7: The results (affected leafs, affected fruits, fruit russeting) of the field trials concerning *Venturia inaequalis* 2018

Results Venturia inaequalis 2018					
Treatments	**affected leafs**		**affected fruits**	**fruit russeting**	
	infestation intensity in % (weighted average)		affected fruits in %	infestation intensity in % (weighted average)	
Polisulfuro di Calcio	0,02	a	Infestation level to low	6,51	a
Limolene	0,02	a	Infestation level to low	9,31	a
Verde Nora	0,68	a	Infestation level to low	6,46	a
Test product 1	0,58	a	Infestation level to low	9,26	a
Limolene	0,02	a	Infestation level to low	16,34	b
Poltiglia disperss	0,02	a	Infestation level to low	4,79	a
Untreated	2,84	b	Infestation level to low	5,41	a

Table 8: The results (affected leafs, affected fruits, fruit russeting) of the field trials concerning *Venturia inaequalis* 2019

Results Venturia inaequalis 2019						
Treatments	**affected leafs**		**affected fruits**		**fruit russeting**	
	infestation intensity in % (weighted average)		infestation intensity in % (weighted average)		infestation intensity in % (weighted average)	
Poltiglia disperss	0,00	a	0,00	a	50,20	b
3logy	0,73	d	0,71	a	29,51	a
Test product 2	0,39	bc	0,65	a	27,54	a
Prev-am	0,32	b	0,74	a	31,64	a
3logy	0,59	cd	0,64	a	29,05	a
Untreated	1,37	e	2,08	b	28,26	a

The trials on alternative products for the regulation of *V. inaequalis* in the year 2016 were characterized by a rather low infestation pressure. The results on infested leaves for the year 2016 show significantly that the product “Equiseto” cannot compete with the two standard products. This result is also confirmed in the evaluation of the infested fruits. The results on fruit russeting even show an increased, although not significant, fruit russeting caused by the product compared to the two standard products. Due to a very low infection pressure, a trial planned for 2017 was not evaluated.

In the evaluation of the infected leaves in 2018, only a significant difference between the treated treatments and the untreated control could be found. The small differences (not significant) between the standard products "Polisulfuro di Calcio" and “Poltiglia disperss” and the alternative products are probably due to the very low infestation pressure this year, which also led to the fact that no evaluation could be carried out on the fruits. The alternative product "Limolene" showed significantly higher values compared to the other products when evaluated for fruit russeting.

In 2019, the standard product "Poltiglia disperss" showed relatively clearly the best result in the evaluation of leaf infestation; it differs significantly from the alternatives, with “Prev-AM” and the “test product 2” coming closest to the standard. In the evaluation of the infested fruits, only the untreated control differs significantly; a consideration of the absolute values confirms the result of the leaf scab evaluation. The significantly increased fruit rust which caused the standard product is conspicuous in this test year.

Table 9: The results (affected leaves, fruit russeting) of the field trials concerning *Podosphaera leucotricha* 2018 and 2019

Results Podosphaera leucotricha					
Year	Treatments	affected leafs Infestation intensity in % (Weighted average)		fruit russeting Infestation intensity in % (Weighted average)	
2018	Thiovit Jet	0,56	a	8,70	a
	Armicarb 85	1,07	abc	8,79	a
	Vitikappa	2,02	d	8,18	a
	Vitikappa + Thiovit Jet	1,16	abc	10,81	a
	Vacciplant	1,17	abc	7,93	a
	Vacciplant + Thiovit Jet	1,42	bcd	6,80	a
	3logy	0,67	ab	9,42	a
	Untreated	1,67	cd	8,43	a
2019	Thiovit Jet	0,05	a	16,00	a
	3logy	0,06	a	16,48	a
	Plantonik	0,03	a	17,89	a
	Ibisco	0,09	a	17,84	a
	Prv-Am plus	0,05	a	18,61	a
	Untreated	0,12	a	16,55	a

In the trials concerning the regulation of *P. leucotricha* in 2018 and 2019, only in 2018 were significant differences in leaf infestation detected. The standard product “Thiovit Jet” based on sulphur proved to be the most effective. Of the alternative products, “3logy” followed by products based on potassium bicarbonate were the most likely to catch up with the standard. Combinations of alternative products and the standard product proved to be less useful. In 2019, there are no significant differences between the treatments, but the year showed a very low infestation pressure. However, the results of the products “3logy” and “Prev-AM plus” are on the same level as the standard product, therefore it seems to be reasonable to test the two products in further experiments.

Table 10: The results (affected fruit in % after storage 20.02.2018) of the field trials concerning *Gleosporium spp.*

Results Gleosporium spp.			
Year	Treatments	affected fruits in % (rotten after storage)	
2017	Boni protect	33,39	b
	Keep in Touch	9,45	a
	Poltiglia disperss + Vacciplant	31,72	b
	Ulmasud	24,99	b
	Untreated	38,79	b
	Hot water (after harvest)	35,08	b

The results of the trial on the regulation of *Gleosporium spp*. from 2017 in Table 10 clearly speak for the physical method Keep in Touch. Only the plastic rain covers differ significantly from the other variants and the untreated control. Of the spraying treatments, the standard product “Ulmasud” gave the best result, but this is exceeded by Keep in Touch.

Discussion

In general, it must be said that, except for the trial concerning *Gleosporium spp*., the presented results speak a relatively clear language. No alternative product which was applied in the classical way was able to achieve approximately the same or better results than the standard products used so far against the fungal diseases *V. inaequalis* and *P. leucotricha*, which are key diseases in organic apple cultivation. The results for the regulation of *P. leucotricha* from 2019 have a reduced informative value and are to be evaluated under the aspect of the low infestation rate.

Although the alternative products consistently delivered better results in the regulation of *V. inaequalis* than the untreated control, they hardly meet the requirements of South Tyrolean farmers. The example of "Limolene” used preventively in the 2018 trial shows that although a similar efficacy is given, other problems such as fruit russeting can occur. This clearly shows that when evaluating an alternative product, not only the effectiveness should be considered, but that the most comprehensive approach possible should be chosen.

A similar picture emerges in the experiments on the regulation of *P. leucotricha*, with the products “3logy” and “Prev-Am”, being further tested in orchards and years with higher infestation pressure. The use of products based on potassium bicarbonate showed only a small benefit in the regulation of *P. leucotricha*.

Concerning *Gleosporium spp*., the Keep in Touch treatment provided better results than any alternative. Since this alternative is a physical measure and its implementation requires a very high effort for the farmers compared to the standard products, a direct comparison is difficult. In an overall assessment, in addition to the financial aspect, other relevant effects such as impact on the landscape, lifetime and disposal, and CO2 footprint must also be considered (Boschiero et.al. 2018).

These results show that the replacement of the plant protection products previously used in organic apple cultivation to regulate *V. inaequalis*, *P. leucotricha*, and *Gleosporium spp.* needs to be carefully considered. The use of alternative products with a similar efficacy may open new problem areas, which requires a holistic approach in the evaluation of the alternatives. The short-term abandonment of the standard products for fungal control used to date in organic apple cultivation would probably lead to massive yield losses and would hardly be accepted in practice. The results can be read as a clear mandate to politicians and researchers to act with a sense of proportion in this area, which is essential for organic apple cultivation, and to step up efforts in the search for alternatives to the standard products

References

Autonome Provinz Bozen Südtirol, Ressort Landwirtschaft, Forstwirtschaft, Tourismus und Bevölkerungsschutz (2019). Obstbau. In *Agrar- & Forstbericht 2018* (Aichner - Kössler, Asam, Hack, Blasbichler, Raffl, Möltner) pp. 27-28. Bozen: Autonome Provinz Bozen.

Boschiero M., Casera C., Kelderer M. (2018): Carbon footprint of innovative plastic covers used as insects and pests control system in organic apple orchards. Proceedings of the 18th International Conference on Organic Fruit-Growing: 71-76.

Erschbamer, M. (2019). Jeder vierte europäische Bio-Apfel wächst in Italien. ObstbauWeinbau 56/7:12-13.

Kelderer M., Casera C., Lardschneider E. (1997). Schorfregulierung: Verschiedene Kupferformulierungen, Alternativen zum Kupfer – gezielte Behandlungen. Proceedings of the 8th International Conference on Organic Fruit-Growing: 9-14.

Kelderer M. Casera C., Lardschneider E., Telfser J. (2018). Field trials in apple orchards with different covering methods to reduce plant protection treatments and yield losses due to pests and diseases. Proceedings of the 18th International Conference on Organic Fruit-Growing: 64-70.

Kienzle J., Kelderer M. (2017). Disease Control. In *Achieving sustainable cultivation of apples* (Evans), pp. 560-562. Philadelphia: Burleight Dodds Sience Publishing.

Weibel F., Häseli A. (2003). Plant protection. In *Apples – Botany, Production and Uses* (Ferrree, Warrington), pp. 571-577. Cambrige: CABI Publishing.