Efficacy evaluation of steaming, plant extracts and composts in open field trials to reduce apple replant disease

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Abstract

In 2014, open field trials were conducted within the Core Organic 2 Project Bio-Incrop at the Research Centre Laimburg to investigate the efficacy of different treatments in reducing apple replant disease after replanting. The different treatments consisted of steaming, used by itself and in combination with calcium oxide (CaO) treatment, soil coverage with Film, and compost application. In addition, also two products based on plant extracts and compost alone were tested. All treatments were evaluated in comparison to an untreated control and the chemical reference soil fumigant Basamid® (active substance Dazomet). In both 2014 and 2015, the highest increase in trunk circumference, and highest shoot length and yield were recorded in plots treated with Basamid. Among the treatments, which are also allowed in organic farming, the treatments consisting of combinations of steaming with other treatments and the plant extract-based treatment Herbie82® were able to significantly increase the above-mentioned parameters in comparison to the untreated control. The yields, which will be achieved in the following years, will show which treatment(s) can be considered economically feasible.

Keywords: Apple replant disease, steaming, calcium oxide, plant extract, compost, Basamid®

Introduction

Recently soil exhaustion or apple replant disease has become a severe problem, which impairs plant growth and decreases yield in apple-growing areas worldwide (Mazzola & Manici, 2012). It can be assumed that intensive apple cultivation systems with continuously increasing plant densities and unchanged spatial arrangement of plant rows due to the use of stationary support and netting structures may be involved in disease occurrence (Rumberger *et al.*, 2004; Kelderer *et al.*, 2012). However, possible causal agents of the disease, and especially potential non-chemical or non-synthetic control tools have not yet been investigated in detail.

Within the Core-Organic 2 Project Bio-Incorp several products based on microorganisms and various composts were tested against apple replant disease on potted plants in greenhouse trials, but no satisfactory result was achieved. Indications on the successful use of steaming for soil fumigation and of plant extract-based biofumigants can be found in literature (Mazzola *et al.*, 2002; Knorst *et al.*, 2012; Meszka *et al.*, 2014). We therefore decided to test these tools in an open-field trial against apple replant disease.

Material and Methods

An open-field trial aiming at evaluating the efficacy of different treatments against apple replant disease was started in spring 2014 at the Research Centre Laimburg in Pfatten (South Tyrol, Italy) in an orchard replanted with apple. The study orchard has been cultivated with apple for many years. In 1998, all trees were cut down, and the apple orchard was replanted with the variety Braeburn on M9 rootstock. Distance between rows

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was 3.2 m, and distance between plants within rows was 1.0 m. In spring 2014, the orchard was replanted with the apple variety 'Cripps Pink' on M9 rootstock by using the same row spacing and planting distance. The soil was a sandy silt soil with 1.63 % organic matter, a pH value of 7.3, and a very high carbonate content. Except for Boron, which was present at very low levels, all other nutrients were present at medium-high levels. The different treatments tested for their efficacy against apple replant disease are listed in Table 1, and a detailed description of the products used and treatments tested is provided below. A randomized block design with 4 replicates of 10 trees each per treatment was used.

Table 1: Tested treatments, manufacturer, and applied rates.

Treatment	**Manufacturer/distributor**	**Applied rate**
Untreated Control	-	-
Compost	Ecorott - Auer (I)	3 kg / tree
Steaming	Celli SPA - Forli (I)	-
Steaming + CaO + Film	Celli SPA - Forli (I)	100 g/m^2
Steaming+ CaO	Celli SPA - Forli (I)	100 g/m^2
Steaming + CaO + Film +Compost	Celli SPA - Forli (I)	100g/m^2 + 3 kg /tree
Herbie82® + Film	Thatchtec BV - Wageningen (NL)	3.4 kg/m^2
Biofence 10® + Biofence FL®	Triumph Italia - Livorno (I)	300 g/m^2+ 2 ml /tree
Basamid®	Certis - Europe - Saronno (I)	70 g/m^2

Product / treatment description

Compost: the tested compost manufactured by Ecorott (Auer, Italy) consisted of composted organic waste mixed with manure and chopped wood. Information on its chemical composition is reported in Table 2.

Table 2: composition of the compost from Ecorott (FW=fresh weight).

pH (in $CaCl_2$)	Dry matter (%)	Ashes (% FW)	N (% FW)	Organic substance (% FW)	C/N - ratio	Soluble salts as KCl (g/L)
8,4	67,3	46,6	1,13	20,7	11	11,3

CAT/colorimetry (mg/L)			CAT/ICP-OES (mg/L)			
NO_3^- nitrogen	NH_4^+ nitrogen	N	P	K	Mg	Na
4	1020,8	1024,7	65	3166	307	829

CAT/ICP-OES (mg/L)				
B	Fe	Mn	Cu	Zn
5,63	215	46,2	6,3	27,1

Steaming: steaming was performed by using the equipment Ecostar SC 600 from Celli SPA (Forlì, Italy). The steam was injected into the soil along the rows over a band of 1.66 m in width.

Film: the plastic film used to cover the soil was black poly-ethylene (PE) film. The film was left on the soil over a period of 2 weeks

CaO: currently calcium oxide is allowed in organic farming neither as fertilizer nor as soil fumigant.

Herbie82®: the product consisted of grinded plant material, but its exact composition is known only to the manufacturer. As recommended by the manufacturer, the product was incorporated into the wet soil along the rows 1 month before planting, and covered with transparent foil.

Biofence: is a fertilizer derived from a specially bred and grinded brassica crop. According to the manufacturer's instructions, Biofence 10 was applied 7 days before planting along the rows, while Biofence FL was applied diluted in water 1 month after planting.

Basamid®: the granular soil fumigant was applied 1 month before planting along the rows. Before planting a rotary tiller was used to allow air into the soil.

Assessments

Soil condition: to evaluate the condition of the soil after the first growing season, in autumn of 2014 (the year of planting), within each treatment, soil samples were collected from the root area. Apple seedlings were then grown on these soil samples, and shoot length and shoot dry weight of the seedlings was assessed

Plant growth: to evaluate plant growth, trunk circumference and sum of the length of all shoots were measured in autumn of 2014 and 1 year later (autumn 2015), and total trunk diameter increase and total shoot length (sum of data from 2014 and 2015) were calculated.

Yield: to assess yield, in both 2014 and 2015, all fruits of each tree within each treatment were harvested and weighed, and the total yield (2014+2015) in kg/tree was determined.

Statistical analysis

The data assessed in the trial were compared across treatments using 1-way ANOVAs, followed by Tukey's test for post-hoc comparisons of means ($p<0.05$). All analyses were performed using the statistics program PASW 17.

Results

Soil condition (autumn 2014): the untreated control apple seedlings showed lowest shoot length and shoot dry weight values, followed by the seedlings grown on compost-treated soil (Table 3). Highest shoot length and shoot dry weight values of seedlings were recorded for the treatment consisting of steaming + CaO + compost + film, followed by the treatment consisting of steaming + CaO + film and the chemical reference treatment Basamid® (Table 3). The plant extract-based treatments showed intermediate and comparable shoot length values, but shoot dry weight was significantly higher for Herbie82® than for Biofence 10 + Biofence FL (Table 3).

Table 3: Shoot length (cm) and shoot dry weight (g) of apple seedlings grown on soil samples of different treatments, collected in autumn 2014.

Treatment	Shoot length (cm)	Dry weight (g)
Untreated control	3,38 a	0,24 a
Compost	3,53 a	0,30 a
Steaming	3,73 ab	0,42 b
Steaming + CaO + Film	4,70 b	0,42 b
Steaming+ CaO	4,08 ab	0,26 a
Steaming + CaO + Compost + Film	5,70 c	0,42 b
Herbie82 + Film	4,25 ab	0,45 b
Biofence 10 + Biofence FL	4,30 ab	0,26 a
Basamid	4,58 b	0,40 b

The results of the open-field trial are summarized in Table 4. The chemical reference soil fumigant Basamid® resulted in highest increase in trunk circumference, and in highest shoot length and yield, and values were significantly higher than those of all the other tested treatments. Among the treatments also allowed in organic farming, the highest increase in trunk circumference was recorded for Herbie82®, followed by the treatments in which steaming was used by itself or in combination with other treatments. A similar trend was observed for shoot length and yield.

Table 4: Total (=sum 2014 + 2015) increase in trunk circumference (mm), shoot length (cm), and yield (kg/ tree) in the different tested treatments.

Treatment	Sum 2014 + 2015		
	Increase in trunk circumference (mm)	Shoot length (cm)	Yield (kg/tree)
Untreated control	4,14 a	322 a	2,21 ab
Compost	5,10 ab	376 ab	2,15 a
Steaming	5,90 bc	467 b	2,83 cd
Steaming + CaO + Film	6,02 bc	440 ab	2,82 cd
Steaming+ CaO	5,83 bc	455 ab	2,87 cd
Steaming + CaO + Film + Compost	6,08 bc	463 b	2,56 abc
Herbie82 + Film	6,50 c	424 ab	2,78 bcd
Biofence 10 + Biofence FL	5,37 abc	354 ab	2,39 abc
Basamid	8,28 d	657 c	3,35 d

Discussion

Initially, the open-field trial conducted within the Core-Organic 2 Project Bio-Incorp at the Research Centre Laimburg should have been aiming at evaluating the best-performing products based on microorganisms and compost, which had been tested on potted plants in greenhouse trials. However, none of the products evaluated in the greenhouse studies proved to be as effective as soil sterilization (data published in the Proceedings of the 17th International Conference on Organic Fruit Growing Ecofruit).

Given the promising results obtained by other researchers with steaming and Brassica extract-based biofumigants against apple replant disease ((Mazzola *et al.*, 2002; Knorst *et al.*, 2012; Meszka *et al.*, 2014), we decided to include treatments based on these tools in our study, and to compare their efficacy against apple replant disease with that of the chemical reference fumigant Basamid® and a compost-based treatment, commonly used

in organic farming. The chemical reference soil fumigant definitely showed the best performance in reducing the impact of apple replant disease on plant growth and yield of trees in the first two years after planting. However, also steaming, applied by itself and in combination with other treatments, and one of the two tested plant extracts positively affected plant growth and yield in comparison to the untreated control. Additional cost and yield evaluations in the years ahead will show whether these treatments are economically feasible, and whether they will become established in practice.

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