A first survey on the health quality of soils in Martell valley with the prospective of implementing organic production of strawberries

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Abstract

*In the mountain valley Martelltal (Bolzano province, Italy), a classical area for strawberry cultivation in high mountain areas, the interest for organic production is increasing. Due to the very limited availability of land, strawberries have been grown very intensively and with very narrow crop rotations. In order to understand soil heath in these areas, a survey was carried out in four long term strawberry fields which had been subjected to different crop rotation in the past. Three of them have been intensively cultivated with strawberry since more than 25 year, whilst one since only 7 years. A greenhouse growth test on soil samples from the selected fields was performed in greenhouse using young strawberry plants. Plant growth parameters and root fungal colonization were evaluated aiming at investigating the effect of different crop rotations on plant health. Plants grown on soil samples coming from the three older strawberry fields did not differ in plant growth and strawberry production, although one of them had been left fallow over the last 4 years. Conversely, plants grown on soil samples taken from the more recent strawberry cultivation (7 years), showed significantly higher plant vigour and production than those grown in soil from the other fields. In addition, strawberry plants of the more recent specialized cultivations also showed the highest diversity of root-colonizing fungi and a slightly, though not significantly lower incidence of the agents of strawberry root rot (*Pythium *spp.,* Cylindrocarpon *like fungi and binucleate* Rhizoctonia*) as compared those of the fields cultivated with strawberry over a long term. Findings of this study suggest that leaving a field fallow for four years does not result in a significant modification of fungal community composition in long-term strawberry cultivations. Therefore, in rural areas devoted to high quality crops, which play a key role for local economy, rotation and cropping practices aiming at preserving soil diversity should be planned since the beginning in both conventional and organic agriculture.*

Keywords: Microbial diversity, crop decline, soil borne fungal pathogens, root rot

Introduction

In the mountain valley Martelltal, a lateral valley of the wider well known Vinschgautal, in the Bozen province (Italy) strawberries have been produced successfully since decades (Zago, 2005). It is the highest altitude strawberry cultivation area in Europe (from 1000 m up to 1700 m above sea level), and the peculiarity of the agro-environment allows a production of high quality strawberries, which is very requested in Italy, and has become an important part of the local economy since the late 1980's.

Given the limited availability of new land due to the altitude and morphology of the valley, the considerable investment and the high degree of specialization of the farmers required, as well as the need of suitable platforms for marketing force, the farmers commonly grow strawberries over a long period on the same plots.

In crops such as strawberry, this can cause quality and yield losses due to decline in soil quality over a medium-long period, which can vary depending on the rotation plan and the

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soil management adopted by the farmers. Although crop rotation and practices of organic agriculture are able to mitigate this effect, also organic cultivations do not totally escape the above described crop decline which is mainly of biotic origin (Manici *et al*., 2005; Xiangling *et al*., 2007). In this context, a trial was performed to evaluate the health of the soils and their suitability for organic production.

Material and Methods

Four fields cultivated with strawberry (*Fragaria* x *ananassa*), which showed vigour decline over the last years, were selected based on a short survey among the strawberry producers in the Martelltal. One field has been cultivated with strawberry since 2010 (J), while the other 3 have been cultivated with the same crop since the end of the 1980s - beginning of the 1990s. The first of these latter 3 fields has been cultivated with strawberry continuously (F), the second was left fallow intermittently but was cultivated with strawberry over the last four years (E), and the third was left fallow over the last 4 years (P). Soil texture was sandy-loam in two cases (P and J) and silty-loam in the other two cases (F and E) (Table 1, A).

In late March 2017, soil samples were collected from the 0-30 cm top soil layer in a total of ten sampling sites along two field diagonals. These subsamples were mixed, small sub-samples were picked up for soil analysis, while the rest was used for the greenhouse growth test, which was carried out in a greenhouse at the Laimburg Research Centre (Ora, Bozen, Italy; 46° 41 ’N, 11° 30’ E).

Twelve pots (10 x 10 x 15 cm) per treatment filled with approximately 2 kg of soil each were transplanted with strawberry frigo plants A++ (cv. Elsanta) and arranged in an open greenhouse according a randomized block design with three replicates of four pots each per treatment. The trial started in mid-April, the number of total and mature fruits was recorded weekly from the first fruit harvest (6 June 2017) up to the last in late June. At the end of the trial, plants were collected and handled as follows: the above-ground part was divided from roots to measure dry matter, whereas roots were gently separated from soil, and then processed for estimating root fungal colonization according the culture-based methodology described in Kelderer *et al. (*2012). Root colonization frequency was inferred from a total of 504 root explants measuring from 0.3 to 0.6 mm. Plant growth parameters were subjected to a one way ANOVA and mean separation was performed by using Fisher's least significant difference (LSD) test. Species/abundance data of root fungal endophytes were analysed with multivariate analysis using the PAST program software for data analysis (Hammer *et al.*, 2001). Diversity of root-colonizing fungal communities was compared using a graphical method-based diversity profile (Tothmeresz, 1995).

Results

Strawberry plants grown in soils coming from four fields differed significantly in dry weight of the above-ground part and weight of mature fruits; whilst the number of total and mature fruits did not (P<0.05). Mean separation tests and contrast analysis showed that the soil from field J, which was the youngest strawberry cultivation, gave the best growth and productive performance (Table 1 B). Conversely, plants grown in the soil from field P, which had been left fallow for four years before this study, did not differ from those grown in soil from the other two long-term fields. Vegetative growth and weight of mature fruits were positively correlated to soil organic matter (Coeff. Corr from 95%, 4 counts).

Table 1: **A**. Soil features and long-term cropping history of the four specialized farms (SOM = soil organic matter). **B** Plant growth parameters of strawberry plants grown in soils sampled from different farms. Data were obtained in greenhouse after strawberry cultivation in pot up the end of first production cycle.

Farm **(A)**	SOM (%)	pH	C/N	Stawberry since	2013-2017	Dry Weight (g) **(B)**	Fruit Weight (g)	Total Fruit (N.)
P	4.8	6.4	8	1992	Fallow	14.0 b[a]	201 ab[a]	37 ab
J	6.1	6.1	9	2010	Strawberry	21.4 a	230 a	44 a[b]
F	3.3	6.9	7	1987	Strawberry	12.5 b	190 ab	33 ab
E	3.9	6.9	8	1993	Strawberry	10.2 b	148 b	28 b

[a] means within the same column followed by different letterssignificantly differ according to LSD test at 95%; [b] J differed from E at 95% according to contrast analysis

The diversity profiles of root-colonizing fungal communities differed among the four fields. Specifically, field J showed a significantly higher fungal diversity (P=95%) as compared to the other fields. The lather finding can be inferred from the highest trend of diversity profile in figure 1; whilst, diversity profiles of the fungal communities of the fields P, F, E did not differ, showing similar values of the α indices (Fig. 1).

As far as the composition of fungal communities associated with the roots is concerned, one way PERMANOVA indicated that it did not significantly differ among the four fields under study. In fact, all treatments shared the main strawberry root rot agents: *Cylindrocarpon*-like fungi, *Pythium* spp. and binucleate *Rhizoctonia* sp. (bn*Rhizoctonia*), However, PCA with vectors corresponding to the weight of diverse variables (fungal species) in the communities of each of four fields indicated that the above-mentioned soil borne pathogens primarily affected communities of plants grown in the strawberry fields cultivated for more than 25 years with strawberry (P, E, and F, Fig. 2). To the contrary, saprophytic non-pathogenic and beneficial fungal species, such as *Paecilomyces*, *Trichoderma* (Trich), *Stachybotris*, and *Mucor*, mainly characterized field J (Fig. 2).

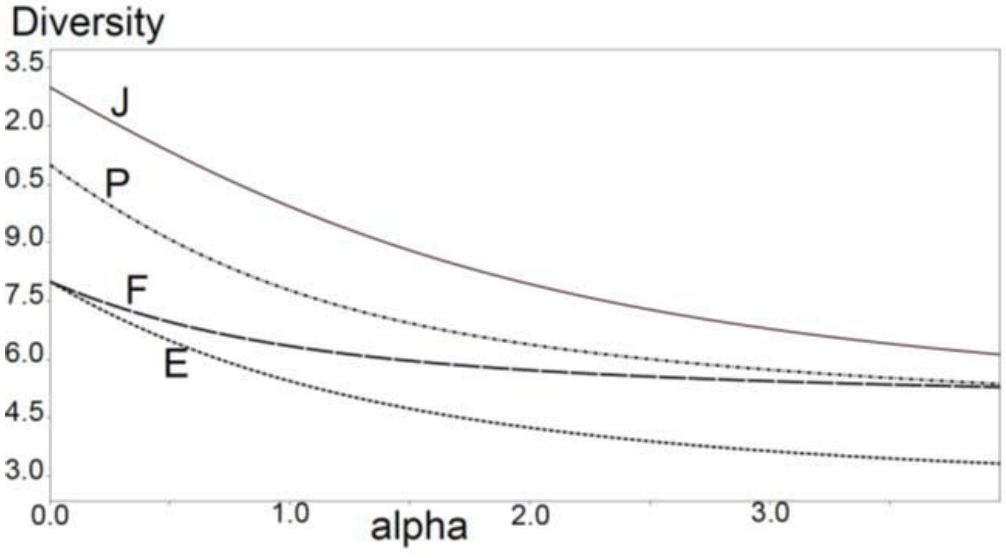

Figure 1: Diversity profile of fungal communities which colonized roots of strawberry plants grown in greenhouse on soil samples taken from 4 fields (J, P, F, E).
Alpha indices: a α=0 gives the total species number; α=1 is index proportional to the Shannon index; α=2 is an index proportional to Simpson index

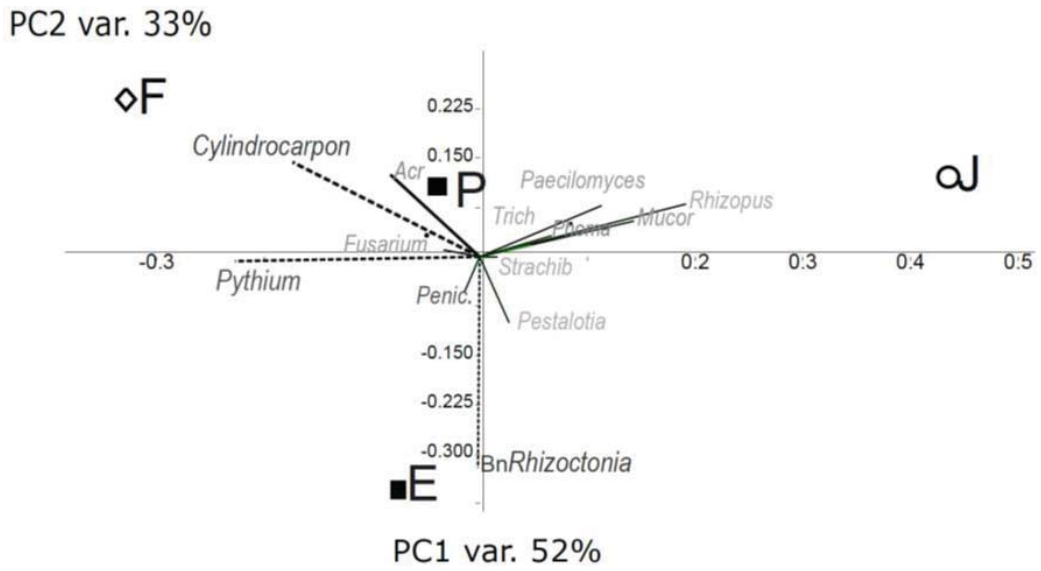

Figure 2: PCA displays composition of fungal communities which colonized strawberry roots grown on soil samples from the four fields under survey. Vector orientation and length indicates in which way variables (fungal species) impacted on the composition of root colonizing fungal communities in each field. *Cylindrocarpon*, *Pythium* and bn*Rhizoctonia* (in dark grey letters), soil borne fungal pathogens causing root rot, mostly influence the communities of field which has been cultivated with strawberry since 90s (F, E, P); whilst non-pathogenic soil fungi (in light grey letters) strongly characterized communities of plants grown in the more recent (since 2010) specialized cultivation (J)

Discussion

Our findings suggest that, even in growing areas, where soil organic matter (SOM) is not a limiting fertility factor, cultivating strawberry for decades on the same field can result in progressive decline of crop health, thus threatening the high quality standards and yield of a specialized production area. Strawberry production in Martelltal begun on almost virgin soil and SOM was maintained thanks to the large local availability of animal manure, which is periodically applied to the strawberry fields, and may have supported high soil resilience along with good production standard over almost three decades.

The diversity of root-colonizing fungal communities proved to be a good indicator of crop health and soil suppressiveness. Indeed, the field showing the higher diversity indices (Field J, Fig. 1) was also characterized by the higher number of beneficial non-pathogenic fungal species (Field J, Fig. 2). Conversely, the other fields, which did not differ in diversity (E, F, P, Fig. 1), were characterized by typical root-rot agents of strawberry, such as *Pythium* and *Cylindrocarpon*-like fungi (E, F, P, Fig. 2).

However, the weak effectiveness of 4-year fallow period to increase soil diversity and improve soil health in a long term cultivated field such as field P, indicate that continuous strawberry with short break dramatically decreases soil diversity. Therefore, in areas devoted to the cultivation of high quality crops with a key role for the local economy in rural areas, such as strawberry in Martelltal, rotation and cropping practices aiming at preserving soil diversity should be planned since the beginning in both conventional and organic agriculture.

Acknowledgements

This study was funded by the Italian Ministry of Agricultural, Food and Forests (MiPAAF) through the AGROENER project.

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