Effect of White clover (*Trifolium repens* cv. Huia) cover crop on agronomic properties and soil biology in an organic peach orchard

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Abstract

In orchards, cover crops are interesting alternative strategies to tillage or chemical herbicides for managing weeds in the tree row. However, little is known about the effect of cover crops on agronomic properties and soil biology in organic orchards. To fill this gap, the effects of two weed managements, a White clover cover crop (CC) versus classical tillage practice (T) on the tree row, were assessed in an irrigated organic Peach orchard. White clover was sown in 2004, 2006 and 2009 in the tree row and ploughed in 2006 and 2008. Root density, earthworm density, water infiltration rate, nitrogen content and water availability were measured in the soil, in the tree row. In 2009, peach root density observed in the superficial layers was higher in CC treatment. Sampling dates and treatment have a significant effect on total earthworm density with higher abundance observed in CC. However, no difference was observed between CC and T anecic earthworm groups known to make large and vertical burrows. Infiltration rate measured with the simplified Beerkan method was higher in CC treatment. This could be explained by the thick superficial root mat which was associated to a significant higher epigeic earthworm density in CC. Whereas nitrogen supplies were twice lower in CC treatment since 2005, soil nitrogen availability was equivalent in both treatments. These results demonstrate the agronomic interest of nitrogen-fixing plants used as a cover crop in organic peach orchards.

INTRODUCTION

In organic orchard systems, tillage-based methods are commonly used by growers to remove weeds competing with the trees for water and others nutrients. However, tillage-based soil management for weed control has some drawbacks: it can interfere with the development of superficial roots; the physical, chemical and biological properties of the soil can be disturbed (Stagnari et al., 2009) and erosion and runoff potentially increased (Duran Zuazo et al., 2008; Gomez et al., 2009).

The effect of a ground cover management on tree growth and pest populations (Parker and Meyer, 1996) and on biotic and abiotic interactions (Meagher and Meyer, 2003), has already been assessed in peach orchards. However, the effect of ground management on agronomic performance and soil biology has been mainly assessed in conventional systems where a bare soil managed with herbicide treatments is the reference. Only a few studies were conducted on organic orchard systems (Sanchez et al., 2007; Hoagland et al., 2008).

Because herbicides could have an effect on biotic parameters such as superficial root density and earthworm density and distribution, a multi-criteria assessment of the effect of ground cover management is required in organic orchards (Barberi et al., 2001).

The purpose of this study was to test the effect of a White clover cover crop *versus* a tillage-based practice in the tree row on agronomic performances and soil biology of an organic peach orchard. Spatial root distribution, water infiltration rate, earthworm density, nitrogen dynamic and agronomic performances were analysed to assess the effect of a nitrogen-fixing cover crop plant in an organic orchard system.

MATERIAL AND METHODS

Experimental design

The experimental design was located at the INRA Gotheron experimental station in the Rhône Valley production area, in the South-East of France. Peach trees cv. 'Benedicte' grafted on *Prunus* cv. 'Montclar' rootstock were planted in 1999 at 4 x 5 m planting distances in a sandy loam soil. Each treatment was composed of 38 trees split into four repetitions per treatment.

In the tillage treatment (T), weed control was managed by five to seven tillage operations per year using an automatic retractable cultivator (Ommas ®, ideal ARR). Tillage depth was 15 cm. In T treatment, total yearly nitrogen supply was 120, 90, 68 and 75 $kg.ha^{-1}$ applied in 2006, 2007, 2008 and 2009, respectively. In the cover crop treatment (CC), total yearly nitrogen supply was 60, 45, 34 and 38 $kg.ha^{-1}$. These total nitrogen amounts were fractionated in three (2006) or two (all the other years) applications. White clover (*Trifolium repens* Cv. Huia) was sown in 2004, 2006 and 2009 in the tree row and ploughed in 2006 and 2008.

All cropping practices except within-row soil management and nitrogen supply were the same for T and CC. Since 2005, total nitrogen supplies have been two fold lower in CC than in T. Water supply was achieved with microjet and drived by tensiometers with a 50 kPa threshold value. Soil water availability was monitored by three tensiometers at 25 cm and 50 cm depth in both treatments. In 2010, water supply was started on 1st June.

Peach root density

One soil profile was realised in both treatments on 10 June 2009 at a distance of 40 cm from the trunk. The peach root density was observed in a 1.0 x 1.3 m surface area. Roots with a diameter less than 1 cm were counted in a grid of 0.1 m² frame. White clover roots were easily differentiated from the peach roots by colour and size criteria.

Earthworms sampling

Earthworm communities and abundance were estimated using hand-sorting. At each sampling date (10 January, 13 April and 20 May 2010), the soil was excavated in four or six sampling points per treatment (40 x 40 x 20 cm). Earthworms were kept alive in water. The sampling points were located in the tree row between two adjacent trees. At the first date, earthworms were weighted and sorted at the species level using Bouché (1972) identification key. At both following dates, earthworms were weighted and identified at the ecological group level (anecic, endogeic and epigeic) following visual criteria (size, coloration of the skin). Abundance was expressed by individuals per square meter ($ind.m^{-2}$).

Simplified Beerkan test

Water infiltration was determined using the single-ring infiltration method also called Beerkan method (Braud et al., 2005). Firstly, 2-3 cm of the top soil was removed using a spade and a flat horizontal plane was prepared and refreshed using a knife. This method was applied in this study to a quite large area (0.125 m^2) to take into account the heterogeneity of the spatial distribution of earthworm macropores. PVC rings (diameter = 0.3 m) were inserted in the soil to a depth of about 1-2 cm. A fixed volume of water (in this case 0,75 l which corresponds to a height of 1 cm) was poured into the ring at time zero and the time elapsed for the given volume of water to infiltrate was measured. When the first volume had infiltrated completely, a second fixed volume of water was added. The procedure was repeated for a series of about 12 to 14 given volumes until an apparent steady state of infiltration (i.e. the time elapsed between two volume additions was constant) to measure water infiltration rate ($mm.s^{-1}$).

Yield and fruit grade

Yield was measured at the plot scale from 2004 to 2009 for T and CC. Fruit grade distribution was assessed from a sample of 200 fruits per treatment. The proportion of fruits with a diameter higher than 67 mm (A, AA and AAA commercial fruit grades) was assessed from this sample.

Statistical analyses

Statistical analysis and root density maps were computed using R software (R Development core Team, 2009). The level of significance was set at 5% for all the statistical tests performed. Because normality conditions were not fulfilled for root density and earthworm density data sets, non parametric tests were used. Wilcoxon test was used to assess the difference of mean root density. Two factors Kruskal-Wallis test was used to assess the difference between the studied factors for earthworm density data set. Water infiltration rates were estimated at steady state (i.e. for iteration > 3) by a linear regression. Wilcoxon test was realised to compare water infiltration rates.

RESULTS AND DISCUSSION

Peach root density

In CC and T treatments, 71 and 76% of the roots were located in the 0-40 cm layer of the soil, respectively. Roots were observed until 100 cm depth (Fig. 1) and isolated roots could be observed up to 150 cm. In the 0-40 cm layer, root density was 2.9±1.3 and 1.8±1.5 roots per dm² in CC and T treatments, respectively. A significant higher root density was observed in CC ($p=2.10^{-4}$, Wilcoxon test). Moreover, a better vertical distribution of root density was observed in CC profile (Fig. 1).

In T treatment, a local soil settling was observed in the 0-20 cm superficial layers, possibly explaining the differences in root density and distribution between CC and T treatments. A positive effect of White clover roots on the soil structure of the 0-20 cm layer in CC treatment could also be mentioned. Indeed, White clover roots set up a 15 cm very thick root mat inducing less clustering between soil aggregates.

Studies analysing the effect of cultural practices on root distribution are increasing (Gong et al., 2006; Sokalska et al., 2009; Kadayifçi et al., 2010). Whereas simple procedures to assess soil and root parameters are being developed (Ball and Douglas, 2003), measurements of *in situ* root density and spatial distribution in orchard systems are still scarce, especially for Peach tree. Comparison of root distribution with others species is tricky because parameters such as cultural practices, soil structure, rootstock and also rootstock x cultivar interaction could have a strong effect on the observed root pattern (Kadayifçi et al., 2010). Most of the root distribution studies performed in orchard systems have focused on the effect of irrigation methods (Tanasescu and Paltineanu, 2004) and water availability (Sokalska et al., 2009). An increase of root density and a higher root distribution by a manual tillage method ('mini-catchment') has been demonstrated in apricot tree when compared with no tillage (Ruiz-Sanchez et al., 2005). In peach orchard, Parker and Meyer (1996) observed that the effect of ground management on root pattern depends of the cover crop species: nimblewill grass (*Muhlenbergia schreberi*) increased root density and improved root distribution when compared with others species such as brome (*Bromus mollis*) and bahiagrass (*Paspalum notatum*).

Earthworms ecological groups and soil porosity

The earthworm community was dominated by the anecic species *Aporrectodea nocturna* and *Lumbricus terrestris*, the endogeic species *A. caliginosa* and *Allolobophora chlorotica* and the epigeic species *L. castaneus*. These 6 species represent more than 90% of all the earthworms sampled. The statistical analysis revealed an obvious and significant effect of the date of sampling. The soil water potential measured on 5 January, 13 April and 20 May 2010 at 25 cm depth were -10, -5 and -20 kPa in CC and -8, -4 and -20 kPa in T, respectively. The highest earthworm density was observed on 13 April when soil moisture and temperature were the highest, whereas the low earthworm abundances in May were due to drought conditions. Interestingly, we observed a significant effect (p=0.038) of the treatment on total earthworm abundance (mean 176 individuals.m^{-2} in T versus 446 individuals.m^{-2} in CC). This was mainly due to significant higher abundance of endogeic (p=0.019) and epigeic (p <0.01) in CC. This latter earthworm ecological group was located within the thick superficial White clover root mat.

For the three sampling dates in 2010, water infiltration rates for CC treatment were significantly higher than for T treatment (Table 2). This difference could be either explained by the thick superficial White clover root mat or by the higher abundance of earthworms and then probable higher number of earthworm macropores in CC.

Nitrogen soil availability and agronomic performances

Total soil nitrogen measured between July 2006 and March 2010 (fifteen sampling dates) varied from 17 to 81 kg.ha^{-1} and 1 to 62 kg.ha^{-1} in CC and T, respectively. Nitrogen leaf content analysed each year 100 days after bloom, showed no nitrogen deficiency (data not shown). The ammoniacal form prevailed in the mineral soil nitrogen content of CC and T (Fig. 3). Ammoniacal form appeared to increase in spring as a possible response to organic supplies. Observed summer nitrification varied according to years: particularly warm periods (summer 2009) seemed to favour nitrification.

Whereas nitrogen supplies have been two fold lower in CC than in T treatment since 2005, soil nitrogen availability was equivalent in both treatments, suggesting Fabaceous cover crop was an efficient nitrogen source in this situation. This result was supported by the measured tree trunk sectional area which did not significantly varied under CC and T (data not shown). The higher ammoniacal content in the soil was detected under CC, which supported the assumption of a significant ammoniacal release thanks to Fabaceous cover crop. This ammoniacal form is of interest in the orchard soil because less exposed to leaching than the nitric form (Goode et al., 1979). The risk of soil acidification under ammoniacal nutrition (Bar-Yosef et al., 2009) was not observed in our conditions, pH being maintained around 7.5. Thus, nitrogen-fixing White clover used as a cover crop in the row is an efficient nitrogen source in our experimental field condition.

Yield was equivalent in both treatments during the 2004-2009 period and no effect of the treatment on fruit grade was observed (Table 2). Moreover, damages due to the *Monilia spp.* fungi, which are one of the most serious damages observed in organic peach orchards, were reduced under CC treatment in 2004 and 2007 (Gomez and Mercier, 2008).

CONCLUSIONS

No negative effect of the White clover cover crop was observed on yield and fruit grade for the 2004-2009 period. Moreover, no damage intensity and fruit quality differences were observed between both treatments (data not shown). Thus, we showed that a two fold decrease in organic nitrogen quantity did not alter agronomic performances. Because organic nitrogen supplies are expensive inputs when not produced on the farm, nitrogen-fixing plants could be of great interest in organic orchards. However, the increase of water infiltration rate observed in the White clover treatment demonstrated its contribution to erosion and runoff control in hillside orchards. The choice of the cover crop species and cultivar and its adequation to pedoclimatic and cultural practices is a keystone (den Hollender et al., 2007). The increasing numbers of studies on the characteristics of various cover crops will be helpful to design sustainable cover crop systems.

This study proposed an assessment of the effect of a White clover cover crop sown in the row on a set of agronomic and soil biology variables. Such approaches, including an assessment of cover crop on a major disease problem, are still scarce in organic orchard systems. This alternative of ground cover management could also be used in conventional orchards systems where herbicides are still commonly used although they represent a major source of water pollution.

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Tables

Table 1. Mean water infiltration rate ($mm.s^{-1}$) derived from the simplified Beerkan test in CC and T treatments. P-values from Wilcoxon test are given.

	CC	T	*p-value*[1]
12th November 2009	0.15±0.08	0.08±0.04	*0.06*
19th April 2010	0.52±0.14	0.16±0.07	2.10^{-3}
28th April 2010	0.39±0.15	0.24±0.07	*0.09*

Table 2. Yield ($T.ha^{-1}$) and proportion of fruit with fruit grade higher than 67 mm for the CC and T treatments from 2004 to 2009. No measure is indicated by '-'.

	Yield ($t.ha^{-1}$)		Fruit diameter > 67 mm (%)	
Year	CC	T	CC	T
2004	18.9	17.3	-	-
2005	20.0	21.1	-	-
2006	19.5	17.5	97.5	97.5
2007	21.2	18.3	85.0	92.5
2008	18.2	19.2	97.5	82.5
2009	39.2	39.5	55.7	62.3

Figures

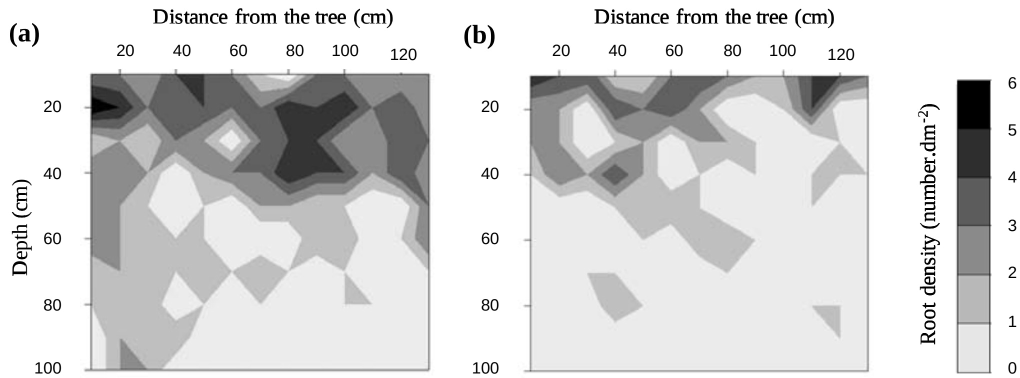

Fig. 1. Map of the peach root density in CC (a) and T (b) treatments observed on 9 June 2009. The peach roots of section larger than 1cm have not been considered. The peach tree is located at the origin of the graph.

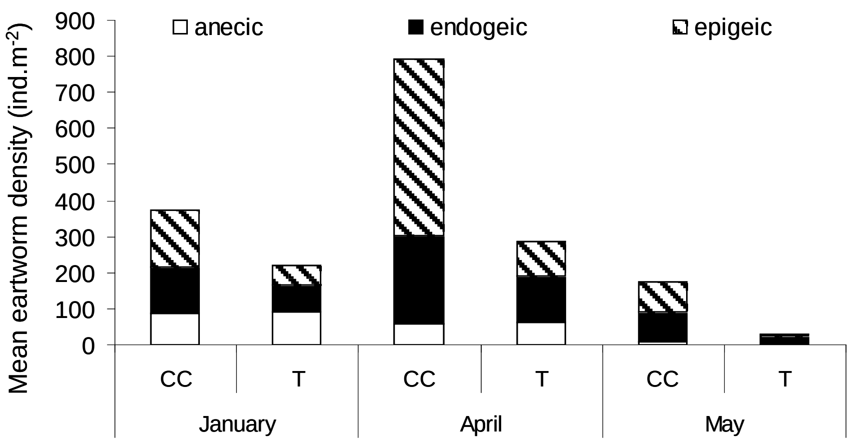

Fig. 2. Mean earthworm density (ind.m^{-2}) in CC and T treatments on 5 January, 13 April and 20 May 2010 sampling dates. Earthworm ecological groups are distinguished.

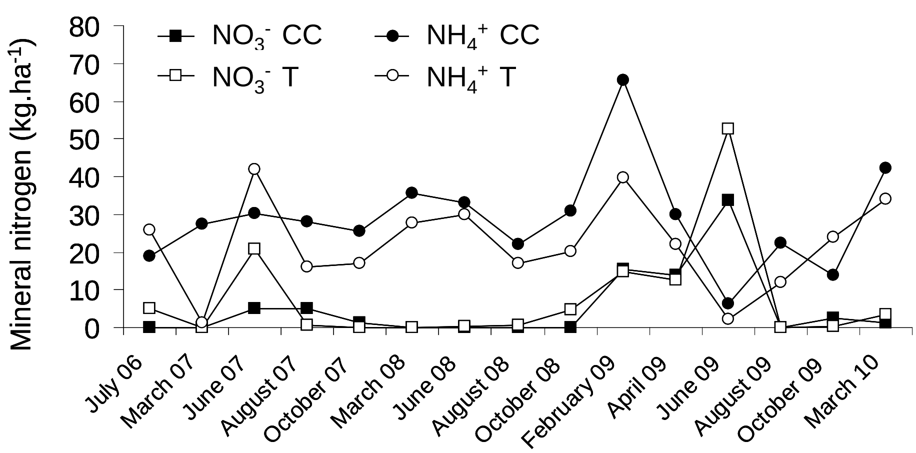

Fig. 3. Mineral soil nitrogen dynamic in CC and T treatments from July 2006 to March 2010.