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# Long-term application of biomass and reduced use of chemicals alleviate soil compaction and improve soil quality

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ABSTRACT

The heavy traffic of agricultural equipment in citric orchards as a result of frequent application of pesticides and fungicides have led to soil compaction and a biological imbalance in these agricultural ecosystems, decreasing crop yields and increasing production costs. The purpose of this work was to assess the effects of spontaneous vegetation (weed) management in interrows following the replacement of agrochemicals with alternative inputs known to have a low impact on the environment. This experiment was conducted in a commercial orchard of 'Murcott' tangor (*Citrus reticulata*, Blanco × *Citrus sinensis*, Osbeck). Highly soluble sources of NPK were substituted with a mixture of 65% rice bran + 35% castor bean meal (3.0% N), thermophosphate (17.5% $P_2O_5$) and potassium sulfate (48% $K_2O$). Synthetic pesticides were replaced with alternative pest controls, such as Bordeaux mixture and lime sulfur. Mechanical mowing was used instead of herbicides, and the mowed weeds were spread under the citrus plants canopy for mulch. This treatment, referred to as alternative management (AM), was performed for three years and compared with a control area, referred to as conventional management (CM), in which conventional cultivation practices and pesticide applications were maintained. The soil compaction, the fruit yield and select biological parameters were used for our assessment. When compared to the CM treatment, AM provided a higher vegetation cover and species diversity (especially for grasses), reduced soil resistance to penetration, better root growth in the topsoil layer, increased root colonization by arbuscular mycorrhizal fungi (AMF), increased viable spores in the soil and a higher leaf boron (B) concentration. Furthermore, the infestation of the AM plots with the mealybug, *Orthezia praelonga*, was significantly lower, and the fruit yield was higher in the third year. These results indicate that agricultural management practices focused on a reduced impact on the agroecosystem, mainly with regard to biological processes, are promising techniques for sustainable agriculture.



## 1. Introduction

Sustainable technologies, such as interrow grass management practices, have significantly improved soil conservation and plant growth in Brazilian citrus production. Several studies have demonstrated that spontaneous vegetation management practices, especially with grasses, in orchard interrows provide soil protection, add organic matter, increase soil aggregates, alleviate soil compaction (Oades, 1984; Fidalski and Tormena, 2007), improve water infiltration rates and favor root growth (Clark et al., 2003; Fidalski et al., 2010). However, a high frequency of agricultural equipment traffic in orchards due to the intensive application of agrochemicals to control pests and disease has limited these benefits on the soil (Becerra et al., 2010); indeed, a high traffic frequency has caused more soil compaction, affecting both root growth and nutrient uptake (Bengough et al., 2006; Ahmad et al., 2009). Such conditions have caused biological imbalances in agroecosystems, necessitating further chemical controls (Ghorbani et al., 2008).

Among the biological processes in the soil, those attributed to mycorrhizae are notably the most disturbed by such imbalances. These endophytic symbionts play important roles in the evolution and survival of plant communities, mainly by increasing the supply of low-mobility mineral nutrients in the soil (van der Heijden et al., 2006); AMF are usually affected by heavy NPK fertilization (Rivera and Fernandez, 2006) and by the application of insecticides and fungicides (Abd-Alla et al., 2000; Giovannetti et al., 2006). Several studies have concluded that no-tillage management practices and vegetation cover provide substantial benefits for AMF (Eriksson, 2001; Carpenter-Boggs et al., 2003), and there is considerable evidence suggesting that AMF may change the diversity of weeds,

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specifically favoring mycotrophic species (Vatovec et al., 2005; Rinaudo et al., 2010).

Compaction of the soil can lead to a biological imbalance in the orchard ecosystem, and the biological imbalance can contribute to soil degradation. One potential approach for breaking the negative cycle of soil compaction, biological imbalance and soil degradation is by changing the conventional methods of pest and disease control, plant fertilization and weed management. Several studies have indicated that there are significant correlations between the incidence of plant pests and diseases and the application of highly soluble chemical fertilizers, mainly nitrogen-based fertilizers. In contrast, organic fertilizers, when combined with ecological soil management, can reduce plant pests and diseases (Altieri and Nicholls, 2003). Of additional importance are the diversified vegetation strips in agricultural landscapes, which can host natural predators that contribute toward maintaining the balance of the pest population (Bianchi et al., 2006).

The aim of this study was to assess the long-term effects of the management of spontaneous vegetation in the interrows of a commercial orchard of 'Murcott' tangor using agricultural practices that have less of an impact on the ecosystem. The soluble fertilizers normally used were replaced with less soluble alternatives, and chemical insecticides, fungicides and herbicides were changed to alternative methods that are less harmful to the environment. The soil compaction, fruit yield and selected biological parameters were evaluated for the assessment.

## 2. Materials and methods

This experiment was carried out over three years, from 2002 to 2005, in a ten-year old orchard of 'Murcott' tangor, on Rangpur lime rootstock (*Citrus limonia* Osbeck), at 7 m $\times$ 4 m spacing. This orchard has a uniform topographical condition, and it is located near Araras City, in São Paulo State, Brazil (22°25′07.6″S latitude and 47°11′04.53″W longitude). The soil is an Oxisol; samples were collected from planting rows at a depth of 0 to 20 cm, and a chemical analysis was performed as described by Raij et al. (2001). The results from the analysis are as follows: SOC = 12.2 g $dm^{-3}$; pH = 6.4 (in $CaCl_2$); P = 36 mg $dm^{-3}$; Ca = 35 mmolc $dm^{-3}$; Mg = 10 mmolc $dm^{-3}$; K = 2.5 mmolc $dm^{-3}$; H + Al = 13 mmolc $dm^{-3}$; Al = 1 mmolc $dm^{-3}$; CEC = 60.5 mmolc $dm^{-3}$; base saturation (V) = 78.5%; B = 0.38 mg $dm^{-3}$; Cu = 5.0 mg $dm^{-3}$; Fe = 31 mg $dm^{-3}$; 3; Mn = 10.9 mg $dm^{-3}$ and Zn = 2.7 mg $dm^{-3}$.

The experimental area encompassed 2 ha, divided into two parts. In one, referred to as alternative management (AM), pesticides were replaced with less harmful alternative controls, and highly soluble chemical fertilizers were replaced with less soluble alternatives (Table 1). In addition, mechanical mowing was used instead of herbicides, and the mowed weeds were spread under the canopy of the citrus plants. The results of the AM area were compared with those of the other half, the conventional management (CM) area, in which the use of soluble fertilizers and other conventional agrochemicals were continued. Ten plots, each containing three plants, were assessed for both treatments. The soil resistance to penetration, root growth in the topsoil layer (0–15 cm), root colonization by AMF, presence of viable AMF spores in the soil, the amount of phytomass and diversity of weed species in the interrows, citrus leaf B concentration, occurrence of *Orthezia praelonga* and fruit yield were measured and compared between the treatments.

The soil resistance to penetration was measured every August throughout the experimental period using an impact penetrometer, Model IAA/Planalsucar-Stolf, according to Stolf (1991). Each plot was assessed at three points (R1, R2 and R3), positioned at 0, 70 and 140 cm, respectively, from the midpoint of two plants in the same row and toward the interrow. The soil moisture was determined at depths of 0–20, 20–40, and 40–60 cm and was used to validate the penetrometer data. The rates of colonization by AMF in thin roots were assessed in April and August using the clarification and coloration method (Phillips and Hayman, 1970),

**Table 1**
Management procedures and input for the supply of nutrients, soil amendments, pest and disease control and weed control in the CM and AM treatment areas.

| Conventional management | | Alternative management | |
|---|---|---|---|
| Input | kg $year^{-1}$ | Input | kg $year^{-1}$ |
| *Soil amendment* | | *Soil amendment* | |
| Dolomitic limestone[a] | 875.0 | Dolomitic limestone[a] | 875.0 |
| *Fertilizer* | | *Fertilizer* | |
| Superphosphate | 120.0 | Rice bran and castor bean meal[b] | 2.625.0 |
| Urea | 125.0 | Thermophosphate[a] (17.5% $P_2O_5$) | 300.0 |
| Potassium chloride | 25.0 | Potassium sulfate (48% $K_2O$) | 200.0 |
| Potassium nitrate | 420.0 | Ulexita (10% B) | 20.0 |
| Boric acid | 3.0 | Foliar spray[c] | 5.0 |
| Foliar fertilizers | 26.0 | Biofertilizer (1% N) | 8.0 |
| *Pest and disease control* | | *Pest and disease control* | |
| Carbendazim | 3.0 | Lime sulfur | 10.0 |
| Copper oxychloride | 15.0 | Sulfur | 15.0 |
| Mancozeb | 6.0 | Bordeaux mixture | 7.0 |
| Propineb | 2.5 | *Weed control* | |
| Pyraclostrobin | 0.5 | Mowing (rows and interrows) | 3× |
| Abamectin | 0.8 | | |
| Acephate | 1.0 | | |
| Deltametrin | 0.6 | | |
| Dimethoate | 3.0 | | |
| Ethion | 1.5 | | |
| Methidathion | 0.6 | | |
| Sulfur | 50.0 | | |
| Thiamethoxan | 3.1 | | |
| *Weed control* | | | |
| Gliphosate (only in the rows) | 5.0 | | |
| Mower (only in the interrows) | 3× | | |

[a] Used only in the first year on the interrows.
[b] A mixture of 65% rice bran + 35% castor bean meal (2.5% N; 2% $P_2O_5$ and 1% $K_2O$) applied on the interrow weeds in the dosage of 800 kg $ha^{-1}$ before mowing.
[c] Content: 0.1% $CuSO_4$ 0.1% $MnSO_4$ and 0.1% $ZnSO_4$.