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EFFECTIVENESS OF SOIL TREATMENTS TO PREVENT AVOCADO REPLANTING PROBLEMS

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The V Region of Chile has 80% of the avocado area with 14,930 ha, being the most important region for avocado production in the country. Therefore, it is possible to find growers that have many years of avocado monoculture and replanting problems.

During 2005-2007, a trial was carried out at the Experimental Station of the Faculty of Agricultural Sciences of Pontificia Universidad Católica de Valparaíso. The objective was to evaluate the efficacy of ten different soil treatments against the disease caused by *Phytophthora cinnamomi,* thus preventing replanting problems. Two groups of one-hundred avocado plants were selected: (1) Hass grafted on Zutano rootstock, and (2) Hass grafted on Duke-7 rootstock. Plants were distributed in 40 plots, corresponding to the following treatments: (a) flooded soil for one month, (b) methyl bromide (100 g/m^2), (c) organic matter (0,038 m^3/9.4 m^2), (d) *Trichoderma harzianum* (THV) (1g pellets/1L soil) and, (e) the untreated control. A randomized block design was used with a factorial arrangement considering the possible differences in soil inoculums. Four replicates per treatment were considered.

The variables evaluated were: trunk diameter, plant height and foliar area of ten well-developed leaves per plant. After 6 months of initiating the test, the factorial analysis showed no interaction among the factors. Duke 7 rootstock had better performance than Zutano, and methyl bromide was better compared to all the other soil treatments. After 18 months of assay, an interaction among the treatments was observed. Plant height and trunk diameter showed differences for Zutano rootstock with methyl bromide or biological control (*T. harzianum*) compared to others treatments.

EFECTIVIDAD DE TRATAMIENTOS AL SUELO PARA PREVENIR PROBLEMAS DE REPLANTE EN PALTO.

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La V región posee el 80% de la superficie de paltos, con 14.930 ha, siendo esta región la más importante. Por esto es posible encontrar productores con muchos años de monocultivo, teniendo problemas al replante.

Durante 2005-2007 se realizó un ensayo en la Estación Experimental de la Facultad de Agronomía de la Pontificia Universidad Católica de Valparaíso, con el objetivo de evaluar la efectividad de diez tratamientos al suelo sobre la enfermedad causada por *Phytophthora cinnamomi* Rands para evitar problemas en el replante. Para ello se seleccionaron 100 plantas de palto de la var Hass, injertadas sobre portainjerto Zutano y 100 árboles de Hass sobre portainjerto Duke 7, los que fueron distribuidos en 40 parcelas, que correspondieron a los tratamientos: inundación (por periodo de un mes), bromuro de metilo (100 g/m^2), materia orgánica (0.038 $m^3/9,4m^2$) y *Trichoderma harzianum* (THV) (1g de pellets/ 1L de suelo) y el correspondiente testigo. El diseño correspondió a una estructura de bloques con diseño factorial, con cuatro repeticiones por tratamiento.

Las variables evaluadas fueron: diámetro, altura y área foliar de diez hojas maduras de cada planta. Según el análisis multifactorial realizado a los 6 meses de iniciado el ensayo, como no existió interacción entre los tratamientos, el portainjerto Duke 7 tuvo un mayor crecimiento en comparación al portainjerto Zutano, y al comparar el efecto de los tratamientos al suelo, el que presentó diferencias significativas fue bromuro de metilo. Por otro lado, a los 18 meses de iniciado el ensayo, se aprecia que hubo interacción entre los tratamientos, destacándose en forma significativa en las variables altura de planta y diámetro de tronco, los tratamientos en base al portainjerto Zutano combinado con el uso de bromuro de metilo y el empleo de control biológico mediante la incorporación de pellets de *T. harzianum* en comparación a los demás tratamientos.

1. INTRODUCTION

In the last decade, avocado (*Persea americana* Mill) production in central Chile has experienced very strong growth, and is reflected by the large increase in orchard surface area, expanding from 15,050 to 24,000 ha (Lemus *et al*., 2005). Eighty percent of these plantings, equal to 14,930 ha, are located in the Valparaiso Region, making it the most important avocado production area in Chile. This is also the area with the longest tradition of avocado production where the oldest avocado orchards are located, and where monoculture has been common practice over the years. This practice produces conditions leading to replant problems, which can be defined as a progressive inhospitality of the soil to new plantings of the same crop (Zucconi, 1993). Replant is caused by a complex of factors that can be biotic (fungus, bacteria or nematodes) or abiotic (toxins, soil, water, or nutritional problems) (Durán, 1976), and also their associated negative influences on the growth and development of the new plants.

Young avocado trees are frequently affected by replant problems when they are planted in areas where older avocado trees have been taken out. These problems are most commonly associated with soils that have a high level of *Phytophthora cinnamomi* inoculum (Zentmyer, 1949), known to cause avocado tristeza disease, which is the most serious and widely spread avocado disease in Chile (Latorre et al., 1998) and the world (Zentmyer et al., 1994; Erwin and Ribeiro, 1996).

Different control strategies have been employed to avoid this disease complex, some of which include use of: resistant rootstocks, chemical control, application of organic matter, water and irrigation management, biological control and cultural practices. When these replant management strategies are combined as part of an overall integrated strategy (integrated management), they can make possible the long-term, economical production of avocados in locations where *P. cinnamomi* is present (Menge *et al.,* 1999a, Pegg *et al*., 2002). Resistant clonal rootstocks, such as Duke 7, have been used successfully around the world to avoid this type of problem (Menge et al., 1999a). The incorporation of organic matter in soils infested with *P. cinnamomi*, can also increase avocado yields by 43%, due to the great increase in soil micro flora (Menge et al., 1999a). In addition, the inoculation of replanted apple trees (*Malus pumila* Mill) with isolates of the antagonist *Trichoderma harzianum* Rifai, has been shown to reduce the populations of *P. cactorum* (Valdebenito, 1991). Soil fumigation with methyl bromide in combination with chloropicrin has also been used to successfully control avocado replant problems in soils infested with *P. cinnamomi* (Goodall *et al*., 1987). Treating the soil with a combination of these methods and using more than one rootstock variety, should therefore allow us to confront the avocado replant problem.

Considering that no avocado replant studies have been done in Chile to date, this trial was designed to evaluate the effectiveness of ten different soil treatments for the prevention of avocado replant problems under local conditions.

2. MATERIALS AND METHODS

2.1 Orchard Location and implementation**.** The trial was done in the La Palma Experimental Station at the Faculty of Agronomy of the Pontificia Universidad Católica de Valparaíso, located in La Palma, Quillota, in the Valparaíso Region. The trial area included 0.2 ha located in the 17^{th} sector of station, which has a clay loam soil texture with an electric conductivity of 0.70 mMhos/cm, a pH of 7.88, and 5% organic matter. This sector was also chosen as it had previously contained a 26 year old orchard of Hass avocados planted on Mexicola seedling rootstocks. The old trees were taken out in the spring of 2005, and the soil surface was mechanically cleared of weeds and debris, including the majority of roots down to a soil depth of 40 cm. The study area was marked out and divided in four blocks of $564m^2$. Each block was divided into ten 9.4 x 6 m plots. All of the soil treatments were applied to the plots before the new trees were planted.

2.2 Treatments. Ten replant treatments were applied using all of the possible combinations of 5 soil treatments and 2 different rootstocks. In treatments T1 to T5 the rootstock employed was Zutano, and in treatments T6 to T10 the rootstock was Duke 7. Treatments T1 and T6 corresponded to the controls, with no soil treatments applied. Soil treatments T2 and T7 consisted of flooding the soil surface of 9.4 m x 6 m area with water, which was held in by small, hand-built retaining walls (applied on October 14, 2005). The water level in the paddies was maintained at about 40 cm above the soil surface for one month, after which the soil was drained and mounded up to form the planting ridges. Treatments T3 and T8 consisted of methyl bromide application (November 18, 2005), to soil that had been broken up by disc harrow and irrigated in order to obtain a soil humidity between 60-70%. The soil surface was covered with transparent plastic and the gas was injected to a depth of 40 cm using 100 g methyl bromide (Ch_3Br) plus chloropicrin (75:25)/m^2. The plastic cover was retained for one week. After these treatments were done, planting ridges of 1.8 m width and 0.5 m height were built up from the treated soil. Treatments T4 and T9 consisted of the application of organic matter (December 14, 2005) in the form of dried, composted, horse manure that had been thoroughly washed to reduce its electric conductivity (EC) to below 2 mMhos, and was applied in one dose of 38 L per 9.4 m^2. Treatments T5 and T10 consisted of the application of biological control pellets containing the isolate ThV of *T. harzianum*, at a concentration of $1*10^8$ colony forming units per gram (ufc/g), using 27g pellets per planting hole and covering a volume of 27 L of soil. The irrigation system consisted of one micro sprinkler per plant, with a flow of 36 L/hr.

2.3 Planting. In total, 200 new avocado trees were planted for this trial,100 cv. Hass/ Zutano and 100 cv. Hass/Duke 7, distributed in 4 blocks (of 50 plants each) with a total of 40 plots. Five avocados were planted at a distance of 6 m between rows and 2 m within the rows, in each plot, giving every block a total of 50 plants. Planting consisted of digging the hole, introducing a fertilizer mixture of triple super phosphate (46% P205) and potassium sulfate (50% K2O), at a rate of 200 g/plant, placing the 2.6 m treated wooden support posts, painting the trunks (in order to avoid soil burn) and tying the plants to the posts. Fertilization with nitrogen began in April and was applied manually at a dose of 10 g of urea/tree, every 5 days. Weeds were controlled manually throughout the trial.

2.4 Variables Measured. Plant height was measured from the soil surface to the apex of the tree using a tape measure. The trunk diameter was measured at a height of 5 cm from the soil surface with a measuring stick. To determine leaf area (LA), 10 leaves were randomly selected from the central third zone of a shoot that was also randomly selected. To obtain this variable the width and length of every leaf was measured, calculating the LA using an ellipse formula, because of its similarity to the actual shape of an avocado leaf. Each variable was measured at both 5 and 18 months post-replant.

2.5 Statistical design. This trial used a completely randomized block statistical design with a factorial array (2 x 5). This design was chosen to block the possible differences in soil inoculum levels. The factors considered were the two rootstocks (Zutano and Duke 7) and the five soil treatments (control, flooding, fumigation with CH_3Br plus chloropicrin, incorporation of organic matter and biological control with THV isolates of *T. harzianum*). The four blocks were considered replicates.

3. RESULTS AND DISCUSSION

In the analysis of the different variables evaluated at five months post-replant, no interaction was observed between the soil treatment and rootstock factors for the variables: plant height, leaf area or trunk diameter. However, when the variables were measured again at 18 months post-replant, an interaction was observed between the soil treatment and rootstock factors, for all of the variables evaluated.

3.1 Plant Height. In the first measurement done at 5 months post-replant, Duke 7 trees had a 6% greater average plant height than Zutano (Table 1). According to Zentmyer's (1980) report, Duke 7 rootstock comes from the Mexican race and was selected because of its moderate resistance to *P. cinnamomi*. However, Arpaia *et al*. (1987) also describe Zutano rootstock as moderately resistant to this pathogen. A possible explanation for this initial difference could be that the Duke 7 rootstocks were clonally propagated for this trial while the Zutano rootstocks came from seeds. Schieber and Zentmyer (1987) demonstrated the *Phytophthora* resistance of Duke 7 in comparison with mexican Topa-Topa seedling rootstocks in a soil that was heavily infested with the pathogen. Three years after the study began, 45% of the 110 plants avocado plants grafted on Duke 7 were considered healthy, while only 0.9% of the 110 plants grafted on Topa-Topa were healthy.

On the other hand, in this trial at 18 months post-replant, Duke 7 rootstock did not show any significant differences between the different treatments, while the plants grown on Zutano rootstock and treated with methyl bromide plus chloropicrin or with the *T. harzianum* (THV isolate) biological control, showed a significantly greater development than the control (Table 2). On average, plant height in the Zutano-Ch_3Br treatment (T3) increased by 39% in comparison with its control, while in the Zutano-*T. harzianum* THV isolate treatment (T5), it increased by 33%.

From the separate analyses of the soil treatment effects at 5 moths post-replant, it can be seen that average plant height differed between treatments (Figure 1). The greatest height was observed the methyl bromide plus chloropicrin treatment. Gustafson (1954) and Zentmyer (1980), demonstrated that methyl bromide was the most efficient fumigant for the control of *P. cinnamomi*, due to its rapid action and complete destruction of soil inoculum. However, Menge *et al*. (1999a) indicated that although this fumigant reduces the soil inoculum, it does not completely eliminate the pathogen. Studies done by Goodall *et al*. (1987), showed that trees planted in soil that had been pre-treated with methyl bromide clearly benefited in comparison with those planted in non-treated soils, using a visual scale from 0 to 5 (healthy to dead), with 0.5 and 1.7, respectively, in the first year. However, this advantage had decreased by the second and third year.

<u>3.2 Trunk diameter</u>. After completing an analysis of variance (ANOVA) on the 5 month post-replant data for trunk diameter, no significant differences were observed for either rootstock or soil treatment. However, at 18 months post-replant, trees grown on Zutano rootstock in combination with the methyl bromide plus chloropicrin treatment (T3) or the *T. harzianum* THV isolate treatment (T5), had a significantly larger trunk diameter, 26 and 28% greater, respectively, than the controls (T1). At 18 months post-replant, for trees grown on Duke 7 rootstock, only those under the flooding treatment (T7) had a significantly larger diameter than their controls (Table 2).

<u>3.3 Leaf area</u>. From the analysis of the leaf area data (Table 1), differences were seen depending on which rootstock was employed, Duke 7 or Zutano. The greatest leaf area was observed in trees grafted on Duke 7 rootstock, corresponding to a 15% increase in leaf area (from the average of ten leaves) for the Hass scions when this rootstock was used. According to Brokaw (1987) and Lemus *et al*. (2005), Duke 7 is a vigorous rootstock that imparts rapid growth of the scion, which is in agreement with the results obtained in this trial. These results are similar to those seen for tree height, and for which the previous studies had also shown a superior performance of Duke 7 when replanted in soils infested with *P. cinnamomi*. However, at 18 months post-replant, these differences again disappeared in all the treatments using this rootstock with the exception of the flooding treatment (T7). Alternatively, only the Zutano-Ch3Br plus chloropicrin treatment (T3) showed a significantly greater leaf area, 51%, in comparison with its respective control (Table 2).

Despite the promising results that were obtained under the methyl bromide treatments, especially in relation to control of the replant problems associated with *P. cinnamomi*, it is important to consider that this fumigant is on the Montreal Protocol's list of products that damage the ozone layer. According to the protocol, the use of methyl bromide should be completely eliminated by 2015, therefore making it even more important to find effective alternatives (Miller, 2001).

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Table 1. Average height and leaf area (10 leaves) of Hass avocado scions grafted on two rootstocks, at five months post-replant.

Rootstock	**Height (cm)**	**Leaf area (cm^2)**
Duke 7	118.6 a	145.4 a
Zutano	112.4 b	126.9 b

* Different letters indicate significant differences LSD ($P \leq 0.05$).

Table 2. Avocado tree height, leaf area and trunk diameter under ten treatments for controlling replant problems at 18 months post-replant.

Rootstock	Soil treatment	Tree height (cm)	Leaf area (cm^2)	Trunk diameter (cm)
Zutano	Ch3Br (T3)	189.30 a	176.43 a	12.68 ab
Zutano	Th-ThV (T5)	181.80 ab	158.20 ab	12.92 ab
Duke 7	Flooding (T7)	167.15 abc	141.69 ab	12.03 abc
Duke 7	Ch3Br (T8)	153.60 abc	142.71 ab	10.28 cd
Duke 7	Manure (T9)	153.30 abc	159.02 ab	10.66 bcd
Duke 7	Control (T6)	152.20 abc	119.50 b	9.79 d
Zutano	Manure (T4)	152.00 bc	136.70 ab	10.22 cd
Zutano	Flooding (T2)	142.05 c	128.50 b	9.59 d
Duke 7	Th-ThV (T10)	138.85 c	138.99 ab	10.61 bcd
Zutano	Control (T1)	136.55 c	116.9 b	10.10 cd

* Different letters indicate significant differences LSD ($P \leq 0.05$).

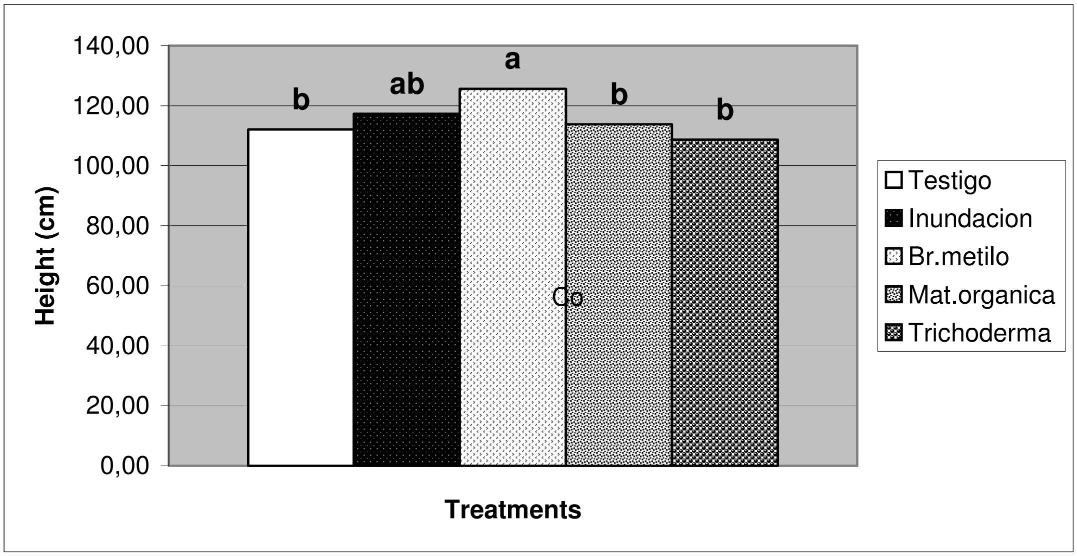

Figure 1. Average height of Hass avocado scions under five soil treatments at five months post-replant.

* Different letters indicate significant differences LSD ($P \leq 0.05$).