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Article

# Optimum Weed Control Method Increases the Yield of Kinnow by Improving the Physical Properties of Soil

*Método Otimizado de Controle de Plantas Daninhas para o Aumento do Rendimento da Tangerina 'Kinnow' através da Melhora das Propriedades Físicas do Solo*

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ABSTRACT - Going towards sustainable fruit culture, it is very important that soil fertility should maintain by adopting the proper weeds control and adding the organic matter. This research was carried out to identify the most suitable weed control method for Kinnow orchard. The plants of Kinnow at the age of 6 years grown under drip irrigation were selected. Weeds of orchard were managed by mulching (wood chip and black polyethylene), mechanical (cultivator and rotavator) and chemical (glyphosate) methods. Mechanical weed control was taken as control treatment. The plants where wood chip mulching was used for weed control showed maximum increase in shoot length (24.00 cm), chlorophyll contents (84.00 SPAD value) and yield (11.88 ton $ha^{-1}$) followed by the plants where weeds were controlled with chemical control while lowest shoot length (12.00 and 12.33 cm), chlorophyll contents (41.00 and 42.67 SPAD value) and yield (3.80 and 4.70 ton) was achieved in cultivator and rotavator treatment respectively. Wood chip mulch also improved soil physical properties by reducing bulk density (1.49 Mg $m^{-3}$), soil penetration resistance (785.33 kPa) and by enhancing soil organic matter (1.17%), hydraulic conductivity (34.50 mm $hr^{-1}$) and soil microbial biomass carbon (159.68 g $kg^{-1}$) followed by glyphosate control while lowest values of soil physical properties were obtained in cultivator and rotavator weed control. Wood chip mulch also reduced weed dry weight (45.25 g) and efficiently controlled weeds (95.66%) as compared to other weed control methods. In this case, wood chip mulch performed better in all studied parameters than plastic mulch, rotavator, cultivator and glyphosate weed control. So, wood chip mulch should be recommended to citrus grower for improving soil physical properties and yield.

**Keywords:** citrus, mulches, glyphosate, mechanical control, soil physical properties, yield.

*RESUMO - Na fruticultura sustentável, é muito importante manter a fertilidade do solo adotando-se o controle adequado de plantas daninhas e adicionando-se matéria orgânica. Assim, esta pesquisa foi realizada para identificar o modo de controle de plantas daninhas mais adequado para pomares de tangerina Kinnow. Foram selecionadas plantas de Kinnow com idade de 6 anos, cultivadas sob irrigação por gotejamento. As plantas daninhas do pomar foram submetidas a controle por meio de cobertura (com cavacos de madeira ou com polietileno preto), controle mecânico (cultivador e enxada rotativa) e métodos químicos (glifosato). O controle mecânico de plantas daninhas foi adotado como tratamento de controle.*

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*As plantas onde foi utilizada a cobertura com cavacos de madeira para controle das plantas daninhas mostraram aumento máximo em comprimento da parte aérea (24,00 cm), teores de clorofila (valor do índice SPAD de 84,00) e rendimento (11,88 t ha$^{-1}$), seguidas pelas plantas nas quais o controle de plantas daninhas foi realizado quimicamente, em comparação com as plantas com controle por meio do cultivador e da enxada rotativa, nas quais houve menor comprimento da parte aérea (12,00 e 12,33 cm), menores teores de clorofila (valores de SPAD de 41,00 e 42,67) e menor rendimento (3,80 e 4,70 t), respectivamente. A cobertura com cavacos de madeira também melhorou as propriedades físicas do solo, reduzindo a densidade do solo (1,49 Mg m$^{-3}$) e a sua resistência à penetração (785,33 kPa); em contrapartida, houve aumento do teor de matéria orgânica do solo (1,17%), da condutividade hidráulica (34,50 mm h$^{-1}$) e do carbono da biomassa microbiana do solo (159,68 g kg$^{-1}$). O segundo melhor resultado foi obtido pelo controle com glifosato, enquanto os menores valores das propriedades físicas do solo foram observados no controle de plantas daninhas com o uso do cultivador e da enxada rotativa. A cobertura com cavacos de madeira também reduziu a massa seca das plantas daninhas (45,25 g) e exerceu controle eficiente delas (95,66%), em comparação com outros métodos de controle. Nesse caso, a cobertura com cavacos de madeira obteve melhor desempenho no controle de plantas daninhas, em todos os parâmetros estudados, do que a cobertura plástica, a enxada rotativa, o cultivador e o glifosato. Assim, recomenda-se a cobertura com cavacos de madeira para que os citricultores consigam melhorar as propriedades físicas do solo e o rendimento.*

**Palavras-chave:** citrinos, cobertura do solo, glifosato, controle mecânico, propriedades físicas do solo, rendimento.

## INTRODUCTION

Weed management operations include conventional practices such as cultivation and application of residual herbicides among the rows of citrus orchards in Pakistan. Herbicides are known as the best option in weed management strategy; however, mishandling this technology can create many problems, e.g., residual contents of herbicides, cropping limitations, contamination of underground water and development of genetically resistant weeds (Verdu and Mas, 2007). Important environmental concerns include repeated tillage on orchard ground, which results in soil erosion, and long-term herbicide application. Questions have been raised concerning the long-term environmental impact of repeated tillage on soil erosion and pesticide application on soil and underground water quality (Duran et al., 2004; Verdu and Mas, 2007).

Alternatively, best management practices, which have been effectively implemented in some of the main citrus growing areas in the world (Sansavini, 1997), combine conventional and modern farming systems in order to optimize both environmental quality and economic profit. Manual weeding is adopted in most developing countries because herbicidal weed control is unaffordable and it also has environmental concerns. Mulching is one of the most profitable methods which can be adopted in citriculture. Mulch is a protective layer of organic or inorganic material which is spread on soil surface. Along with a number of benefits, mulch restricts weed growth.

Living mulches, black polyethylene mulches and dead organic mulches (such as straw, barks and wood shavings) can be used for good weed control. Many researchers have accounted the returns and restrictions of each of them (Liedgens et al., 2004).

Black polyethylene mulches are spread for weed management of many crops in organic growing systems (Bond and Grundy, 2001). Black polythene reduces weed growth and improves fruit yield as a result of improved soil moisture. However, in this type of mulch, organic matter and nutrients are not added to the soil (Bredell, 1973).

Adequate thick layer of organic mulches such as straw and bark can suppress weeds effectively along with enrichment of soil with organic matter and nutrients (Merwin et al., 1995). Microbes decompose organic mulches and produce phytotoxic compounds which kill weed species. Weeds are also suppressed by the physical presence of organic mulches which create hindrance in light and reduce the photosynthetic activity of weed populations (Ozores-Hampton et al., 2001). Decomposition of organic material is a continuous process. Because of this periodic re-application, complete suppression has to be attained. However, decomposition enhances soil aggregation and water-holding capacity (Haynes, 1980).

Mulches are not only used for inhibition of weeds but their main goal is to achieve a better environment with maximum profit. According to the "Guidelines International Organization for Biological and Integrated Control of Noxious Animals and Plants", trials involving mulches, especially loose materials from adjacent crops and furniture industry, are entirely appropriate in view of the modern approach to integrated plant protection in sustainable production systems. Therefore, this work evaluated the performance of mulches, herbicides and mechanical control on soil physical properties and yield of *citrus reticulate* cv. Blanco.

## MATERIAL AND METHODS

The study was conducted on Kinnow mandarin (*Citrus reticulate* cv. Blanko) plants at the Postgraduate Research Station (PARS), University of Agriculture, Faisalabad, Pakistan (Latitude 31°-26°N and longitude 73°-06°E). The long-term average yearly precipitation and the average monthly air temperatures are shown in Table 1 (Water Management Metrological Observatory, PARS). During the study, from February 2013 to January 2015, accumulated rainfall was 22.87 mm, and average monthly temperature was 24.35 °C. The drip-irrigation system in use consisted of one drip line for each plant. Irrigation scheduling was designed based on tensiometer readings in the top 30 cm soil layer. The amounts of fertilizers applied were 700g per tree per year N, 300 g per tree per year P and 300g per tree per year K. The trees in PARS were spaced at 3.35 m while rows were 6.70 m apart.

There were five treatments which were repeated four times and ten trees per treatment were selected. Weed control methods (treatments) included wood chip mulch, plastic mulch, cultivator, rotavator and glyphosate, which were applied in February 2013. The cultivator, the rotavator and glyphosate were applied four times a year. The wood chip mulch and the polyethylene mulch were applied 3 times a year. Thickness of the wood chip mulch and the polyethylene mulch was 3 cm and 0.05 mm, respectively. The depth of the cultivator and the rotavator was 6 inches.

Physio-chemical characteristics of the soil were determined before conducting the experiment (Table 2). During August, 2013, at moisture contents close to field capacity, undisturbed soil cores were taken from the field using a core soil sampler. For core sampling, three equally-spaced points around the plant were marked for sampling. These samples were taken from an area of approximately 65-70 cm radius from the tree trunks within each plot. The total area of each plot where treatments were applied was 0.45 ha. Each value reported in the text is the mean of 10 values (4 replicates x 3 samples). Thus, the samples were taken from an area away from the tracks of tractors (from edges of tree canopy) where machinery had not affected the soil during field operations. Separate sets of core sampling were prepared from each treatment at soil depths of 0-15, 15-30, 30-50 and 50-100 cm for soil bulk density determinations (Klute, 1986). Field saturated hydraulic conductivity (kfs) was measured following the procedures given in Klute (1986). Soil penetration resistance (SPR) was measured using a cone

***Table 1*** - Temporal variations in temperature and rainfall during the two-year study (2013-2014)

| Month | Temperature (°C) | Rainfall (mm) |
|---|---|---|
| January | 10.20 | 1.21 |
| February | 13.80 | 55.0 |
| March | 20.00 | 1.30 |
| April | 26.60 | 21.6 |
| May | 32.00 | 4.61 |
| June | 33.70 | 67.5 |
| July | 33.00 | 4.71 |
| August | 31.31 | 114.8 |
| September | 31.00 | 3.31 |
| October | 27.11 | 0.00 |
| November | 19.00 | 0.51 |
| December | 14.51 | 0.00 |

***Table 2*** - Physico-chemical characteristics of the experimental site before the beginning of the experiment

| Characteristic | Value |
|---|---|
| Sand (% | 55.5 |
| Silt (%) | 16.5 |
| Clay (%) | 22.01 |
| Textural class (%) | Sandy clay loam |
| Total Nitrogen (%) | 0.105 |
| Available Phosphorus (mg $kg^{-1}$) | 7.4 |
| Extractable Potassium ((mg $kg^{-1}$) | 145.7 |

penetrometer. The cone was pressed into the soil until soil surface was leveled with the base of the cone. The measurements of SPR, bulk density (BD) and kfs were carried out in January, after harvesting citrus in each year. Soil microbial biomass carbon (SMBC) was determined using the fumigation–extraction method (Bhatt and Binmeru, 2014). Soil organic matter was determined using the methods described by Moodie et al. (1959). Weed dry weight and weed control percentage were determined by following the procedures of Abouziena et al. (2008).

Shoot growth data were recorded for three flushes (spring, summer and late summer fall flush) each year. Flush length was measured for the tagged branches from four sides of the plant. Shoot growth data were taken at maturity/cease of growth, while canopy diameter and stem diameter were measured in (m) and (cm), respectively. Citrus yield in each treatment was recorded by weighing harvested fruit from each treatment using a WUE-SEP digital electric balance. Yield was recoded in ton ha$^{-1}$. The data were analyzed statistically using five weed control methods and four replications in a randomized complete block design, using the CO-STATS software. There were ten plants in each treatment. The means were compared with the least significant difference (LSD) test at the probability level of 0.05% (Steel and Torrie, 1997).

## RESULTS AND DISCUSSION

### Shoot growth indices (cm)

Wood chip mulch resulted in the greatest increase of shoot length, as compared to all other weed control methods, followed by plastic mulch (Figure 1), while there was minimum shoot length with the rotavator and the cultivator. Among the mulches, the wood chip mulch increased shoot length (24.00 cm) more than the plastic mulch (19.66 cm) during SpF. Lowest SpF was found in plants where weeds were irradiated with the cultivator (12.00 cm) and the rotavator (12.33 cm). During the SF stage, the wood chip mulch enhanced shoot length to 17.50 cm, followed by plastic mulch (13.33 cm). The lowest length of SF was found in plants where weed was irradiated with the cultivator (8.66 cm) and the rotavator (10.66 cm). Wood chip mulch also enhanced LSF to 20.16 cm, followed by plastic mulch, which was 16.66 cm. The lowest LSF was found in plants where weeds were irradiated with the cultivator (10.66 cm) and the rotavator (10.66 cm). Increased shoot growth in plants where weeds were irradiated with wood chip mulch was due to high chlorophyll contents (Nguyen et al., 2013), high organic matter and hydraulic conductivity (Rehman et al., 2012), low soil bulk density (Walsh et al., 1996), low soil penetration resistance (Hoagland et al., 2008), high soil microbial biomass carbon (Ingels et al., 2005) and reduced competition of citrus plants with weeds (Abouziena et al., 2008). Lower shoot length in the cultivator and the

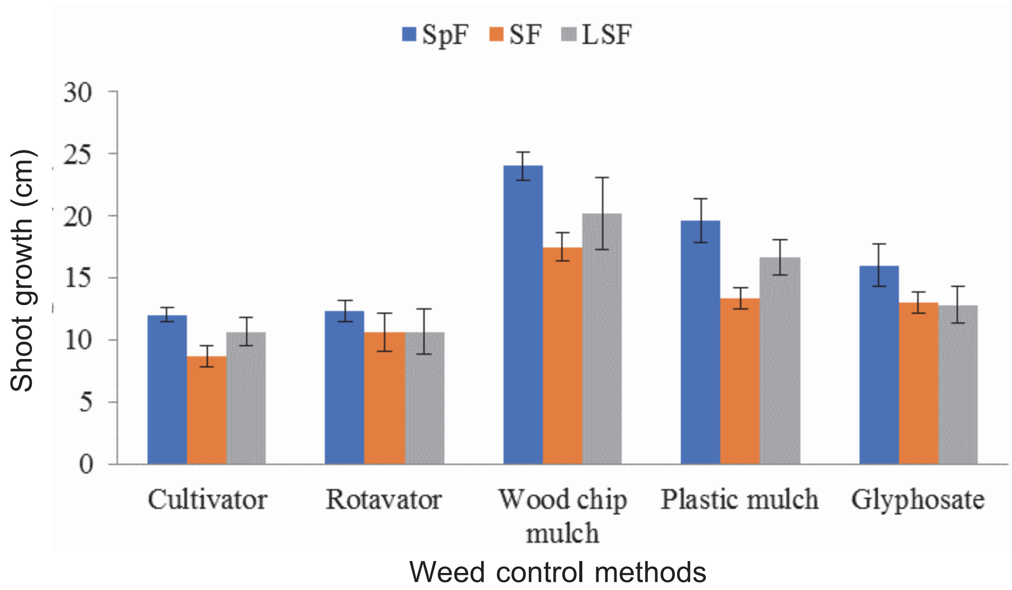


*Figure 1* - Effect of weed control methods on shoot growth of *Citrus reticulata*.

rotavator was due to degradation of soil structure (Rehman et al., 2012), nutrient loss resulting from high volatilization, reduced organic matter (Merwin and Stiles, 1994), higher bulk density (Mari and Chang, 2008), lower hydraulic conductivity (Rehman et al., 2012), lower soil organic biomass carbon (Smith et al., 2008) and higher weed competition with young citrus plants (Abouziena et al., 2008).

**Chlorophyll contents (SPAD Value)**

Data on chlorophyll contents as affected by weed control methods showed that the wood chip mulch led to the highest increase in chlorophyll contents, followed by the plastic mulch, while the lowest amount of chlorophyll contents was achieved in the rotavator and he cultivator (Figure 2). Among the mulches, the wood chip mulch caused the highest increased in chlorophyll contents (84.00 SPAD value) as compared to the plastic mulch (77.50 SPAD value). The lowest amounts of chlorophyll contents were found in the plants where weeds were irradiated with the cultivator (42.16) and the rotavator (43.66). The increased amount of chlorophyll contents in the wood chip mulch was due to improved soil conditions, e.g., improved soil structure (Bredell et al., 1976), bulk density (Laurent et al., 2008), organic matter (Ingels et al., 2005), higher nutrient availability (Patrick et al., 2004), optimum soil moisture (Hembree et al., 2006), low soil penetration resistance (Rehman et al., 2012) and soil microbial biomass carbon (Kabir and Koide, 2002) which, in turn, produced improved root growth to facilitate absorption of nutrients and moisture in order to produce higher chlorophyll contents. Lower chlorophyll contents in plants where weeds were irradiated with cultivator and rotavator were due to destruction of soil structure, loss of nutrient and moisture (Salton and Mielniczuk, 1995) higher compaction and bulk density (Bertol et al., 2004) which, in turn, produced underdeveloped roots, and disturbance in taking moisture and nutrients. Our findings are in agreement with the findings of Yao et al. (2005).

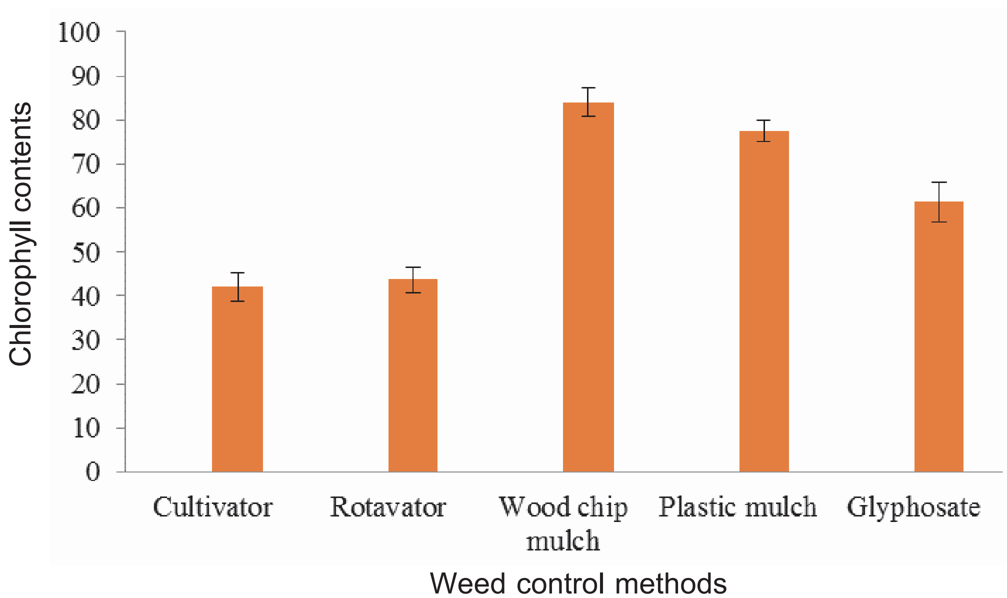


***Figure 2*** - Effect of weed control methods on chlorophyll contents of *Citrus reticulata*.

**Yield (ton ha$^{-1}$)**

The results showed that wood chip mulch gave more yield, followed by the plastic mulch, while lowest yield was recorded in the rotavator and the cultivator treatments. Among the mulches, the wood chip mulch gave higher yield (11.88 ton ha$^{-1}$) as compared to the plastic mulch (10.58 ton) (Figure 3). The lowest yield was found in plants where weeds were irradiated with the cultivator (3.81 ton ha$^{-1}$) and the rotavator (4.71 ton ha$^{-1}$). The higher yield in the wood

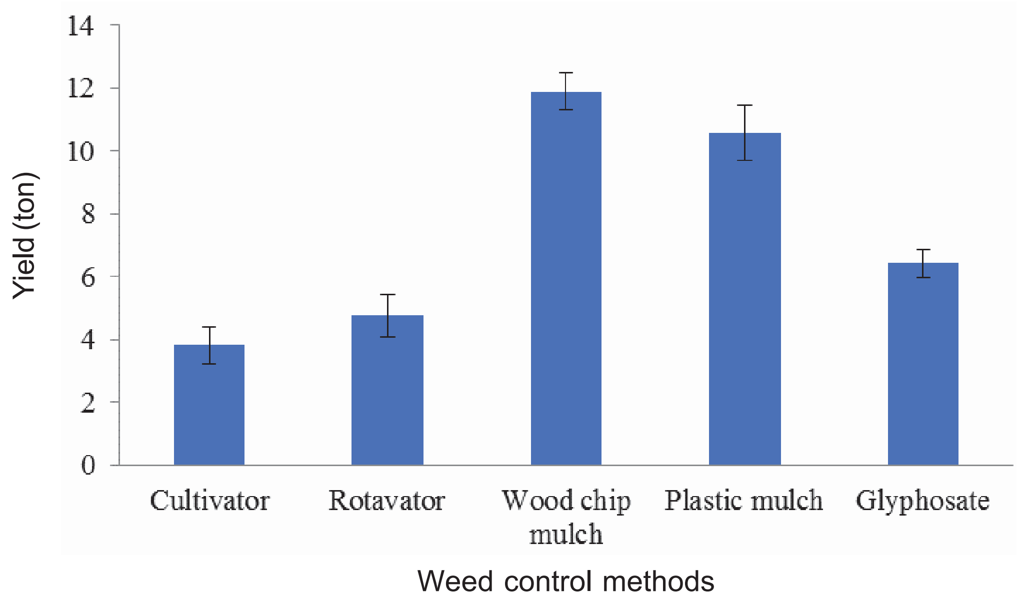


***Figure 3*** - Effect of weed control methods on yield of *Citrus reticulata*.

chip mulch was due to improved physical soil properties (Kirandeep et al., 2010) and availability of optimum moisture and temperature (Shirgure et al., 2003) which, in turn, produced higher growth with high fruit yield (Shirgure, 2012). The reason for the lowest yield in the cultivator and the rotavator is soil degradation, erosion and nutrient loss, because the nitrogen present in the soil is in organic form. Tillage increases the rate of mineralization and causes nitrogen to escape as a result of leaching or volatilization (Varennes, 2003). On the other hand, root injuries caused by tillage are also another yield limiting factor by which plant growth was adversely affected and resulted in poor yield (Hogue and Neilsen, 1987). Our results are in line with those of Sanchez et al. (2006).

**Soil bulk density (Mg m$^{-3}$)**

Bulk density showed little reduction by increasing soil depth in the cultivator and the rotavator while, by contrast, the mulches showed a slight increase in bulk density with increasing soil depth; however, these differences were non-significant (Figure 4). Data on bulk density at 0-15 cm depth showed that the wood chip much produced the lowest bulk density, followed by the plastic mulch, while the highest bulk density was found in the weed control by the rotavator and the cultivator. Among the mulches, the wood chip mulch showed lower bulk density (1.49 Mg m$^{-3}$) as compared with the plastic mulch (1.57 Mg m$^{-3}$) through the soil profile 0-15 cm (Figure 4). The highest bulk density was found in plants where weeds were irradiated with the cultivator (1.72 Mg m$^{-3}$) and the rotavator (1.73 Mg m$^{3}$). Bulk density is defined as weight per unit volume. Lower pore space among soil particle leads to higher compaction, which ultimatly reduced availability of nutrients and reduced root growth (Viera and Klein, 2007). Lower bulk density in plots where weeds were controlled with mulches was due to higher microorganism activities and hydrothermal regulations (Fidalski et al., 2010). On the other hand, higher bulk density was due to the movement of heavy vehicles mounted for tillage implements on wet soils (Mari and Chang, 2008).

**Organic matter (%)**

The results showed that organic matter was reduced through the soil profile. The maximum amount of organic matter was found in the top 0-15 cm layer of soil. Then, it started to decline with increasing soil depth. The minimum amount of organic matter was found in the 50-100 cm depth of soil. Among the weed control methods, the wood chip mulch and plastic mulch showed the highest amount of organic matter, followed by the glyphosate weed control. Among the mulches,

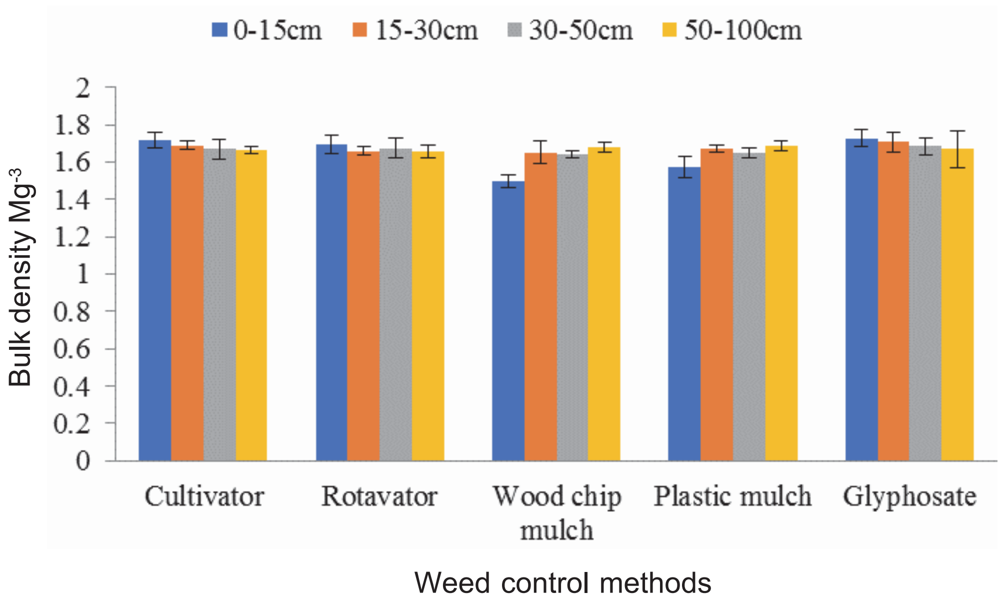


***Figure 4*** - Effect of weed control methods on soil bulk density.

the wood chip mulch showed the highest amount of organic matter (1.17%) as compared to the plastic mulch (1.09%) through the soil profile of 0-15 cm (Figure 5). By comparison, the lowest amount of organic matter was found in the cultivator (0.51%) and the rotavator (0.54%). The higher organic matter content in the plots where the sweed were controlled with the wood chip mulch was due to biological activity, which decomposed wood chips and added organic matter in the soils (Ingels et al., 2005). The lower organic matter in the plots where weeds were removed with the cultivator and the rotavator were due to soil degradation, erosion and nutrient loss. Tillage increases the rates of mineralization and decomposition because of an increase in soil temperature, and it causes the escape of nitrogen because of volatilization (Varennes, 2003). Our results are in line with findings of Merwin and Stiles (1994). They found a significant increase in soil organic matter content after application of organic mulches.

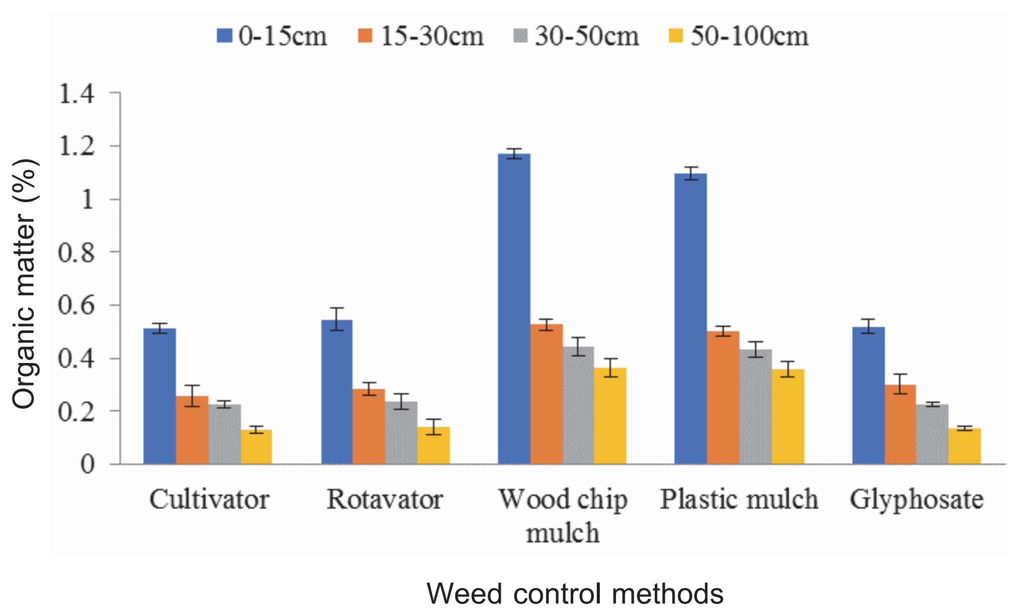


***Figure 5*** - Effect of weed control methods on soil organic matter.

**Hydraulic conductivity (mm hr$^{-1}$)**

Hydraulic conductivity showed reduction trends as soil depth increased. Hydraulic conductivity was maximum at 0-15 cm soil depth and minimum at 50-100 cm soil depth. The wood chip mulch and the plastic mulch showed the highest hydraulic conductivity, followed by glyphosate, while the lowest hydraulic conductivity was found in the weed control by the rotavator and the cultivator. Among the mulches, the wood chip mulch increased hydraulic conductivity (34.50 mm hr$^{-1}$) as compared to the plastic mulch (32.50 mm hr$^{-1}$) (Figure 6). By contrast, the lowest hydraulic conductivity was found in the cultivator (25.50 mm hr$^{-1}$) and the rotavator (26.50 mm hr$^{-1}$) through the soil profile of 0-15 cm. Hydraulic conductivity is the ability of the soil to conduct water through the soil profile. This property affects the flow of water through the soil. Hydraulic conductivity depends upon macrospores and microspores (Wahl et al., 2004). Micropores are often produced as a result of continuous tillage (Holden, 2005). However, macrospores are produced by biological activities in mulched fields (Zhou et al., 2008). It is understood that microspores are responsible for surface ponding, lower infiltration rate and soil compaction (Daraghmeh et al., 2008). Higher hydraulic conductivity in plots where weeds were controlled with mulches was due to macrospores, improved water holding capacity of soil and drainage of extra water to deeper layers (Alvarez and Steinbach, 2009). However, Lower hydraulic conductivity in plots where weeds were removed with the cultivator and the rotavator was due to microspores, reduced transport of water, reduced infiltration rate, surface ponding and compaction of soil (Pagliai et al., 2004). Our findings are in accordance with the findings of Ahmad and Mahmood (2005).

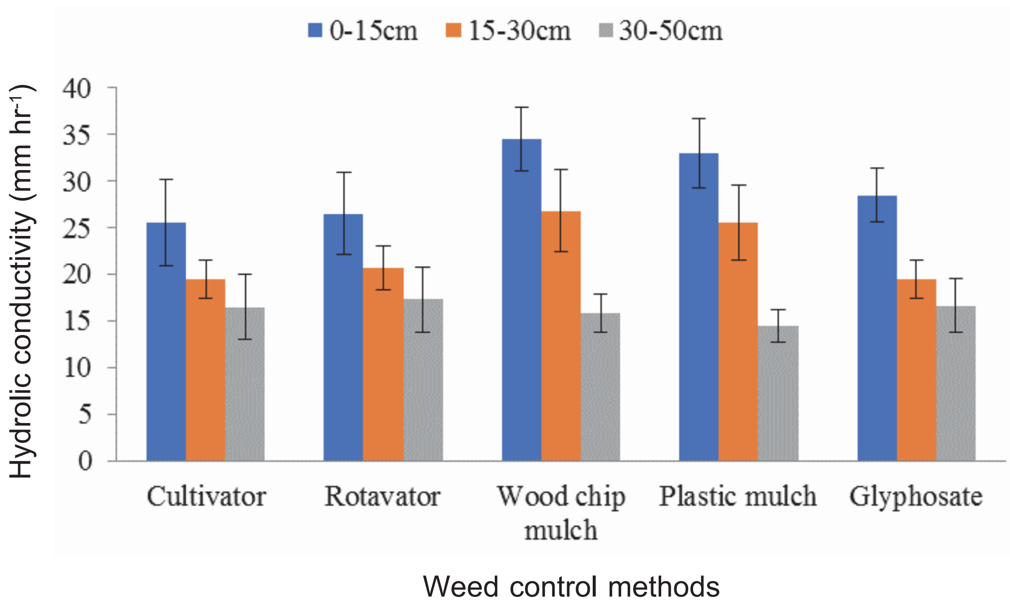


***Figure 6*** - Effect of weed control methods on soil hydraulic conductivity.

**Soil penetration resistance (kPa)**

Lower values of soil penetration resistance (SPR) were found in plants where weeds were irradiated with the wood chip mulch and the plastic mulch, followed by glyphosate, the rotavator and the cultivator. Among the mulches, the wood chip mulch showed lower values of SPR (785.33 kPa) as compared to the plastic mulch (759.81 kPa) (Figure 7). However, the highest values of SPR were found in the rotavator (945.50 kPa) and the cultivator (917.50 kPa). Lower SPR rates in the wood chip mulch might have been due to higher soil organic matter lower bulk density (Henderson et al., 1988), higher hydraulic conductivity (Rayhani et al., 2007), Our results are line with the findings of Pervaiz et al. (2009).

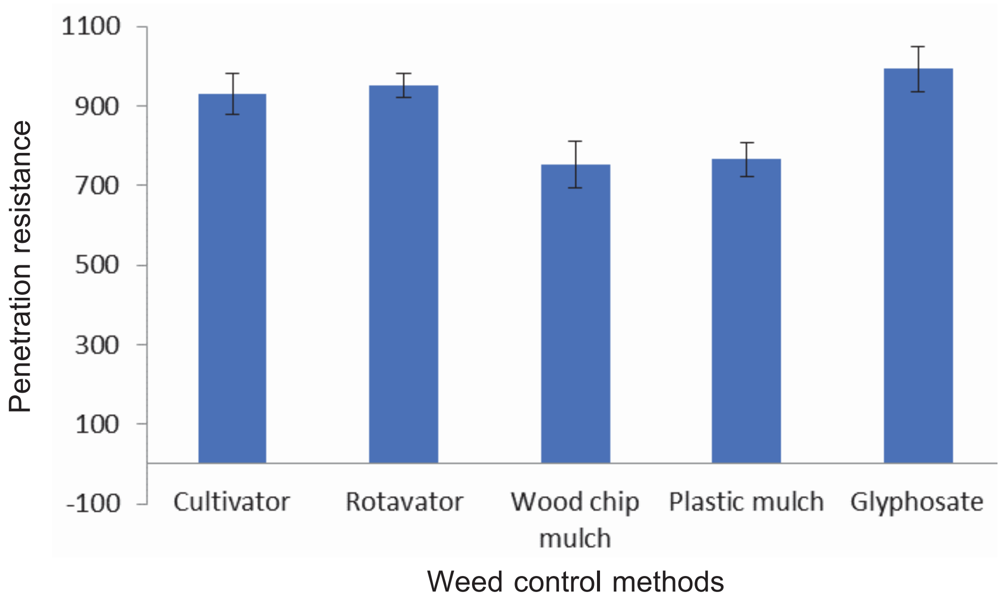


***Figure 7*** - Effect of weed control methods on soil penetration resistence.

## Soil Microbial Biomass Carbon (SMBC) (g kg$^{-1}$)

The wood chip mulch and the plastic mulch showed a higher amount of soil microbial biomass carbon (SMBC), followed by glyphosate, while the minimum amount of SMBC was found in the mechanical control. Among the mulches, the wood chip mulch showed higher SMBC (159.68 g kg$^{-1}$) contents as compared to the plastic mulch (147.45 g kg$^{-1}$) (Figure 8). By contrast, the lowest amount of SMBC was found in the cultivator (128.01 g kg$^{-1}$) and the rotavator (128.20 g kg$^{-1}$). A higher amount of SMBC in the wood chip mulch might be due to addition of organic material to soil, e.g., mulch which enhanced decomposition of that material (Gassen and Gassen, 1996). Similar results were found by Lal et al. (2003).

## Weed control (%)

The results showed that the wood chip mulch and the plastic mulch performed best as compared to glyphosate while the rotavator and the cultivator showed poor weed control. Among the mulches, the wood chip mulch performed more in controlling weeds (95.00%) as compared to the plastic mulch (89.50%) (Figure 9). The lowest weed control was achieved in the cultivator (60.00%) and the rotavator (66.50%). This may have been due to physical barriers provided by the mulches. These barriers caused reduction in weed seed germination and seedling growth by reducing light which, in turn, caused reduction in photosynthesis. Mulches do not allow water contents to escape to the air; in turn, there is an increase in soil moisture, and higher soil moisture does not allow weed seeds to germinate. In some cases, if seedlings emerge, they become chlorotic and die. On the other hand, weed seeds remain in deep layers of soil as a result of no tillage. Our findings are in line with the findings of Mohanty et al. (2002) and Shirgure et al. (2003) in citrus orchards. Lower weed control in the cultivator and the rotavator may have been due to breaking, thus exposing deeper soil layers to surface. Soil deep layers are seed banks of weeds. If tillage is applied, weed seeds come out of deeper layers and starts to germinate. Our findings are in line with the findings of Clements et al. (1996).

## Weed dry weight (g)

The data showed that the wood chip mulch and the plastic mulch produced lower weed dry weight, followed by weed control with glyphosate. The highest weed dry weight was found in the rotavator and the cultivator (Figure 10). Among the mulches, the wood chip mulch showed lower

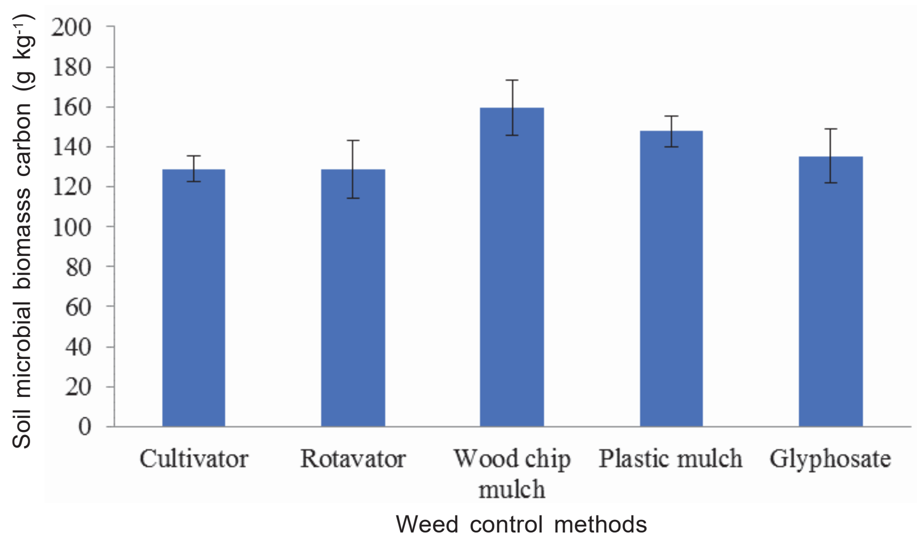


***Figure 8*** - Effect of weed control methods on soil microbial biomass carbon.

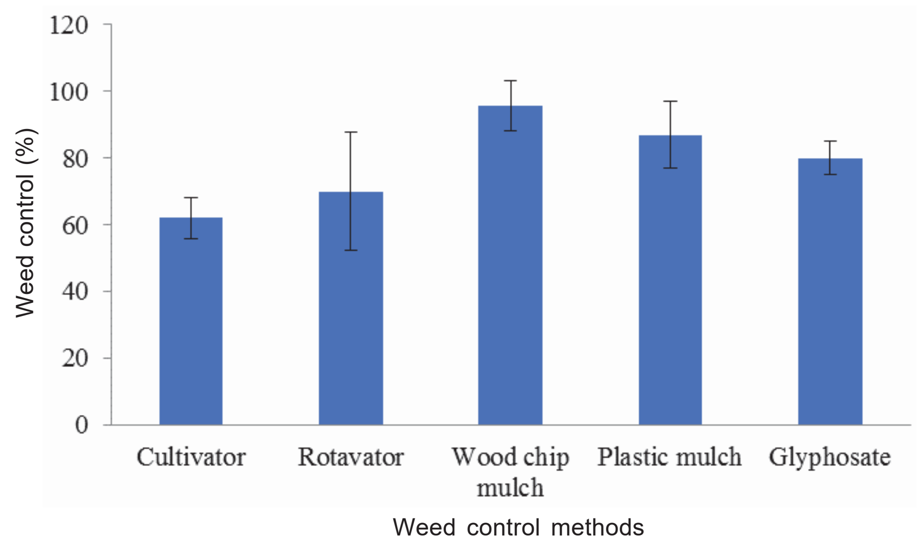


***Figure 9*** - Effect of weed control methods on weed control (%).

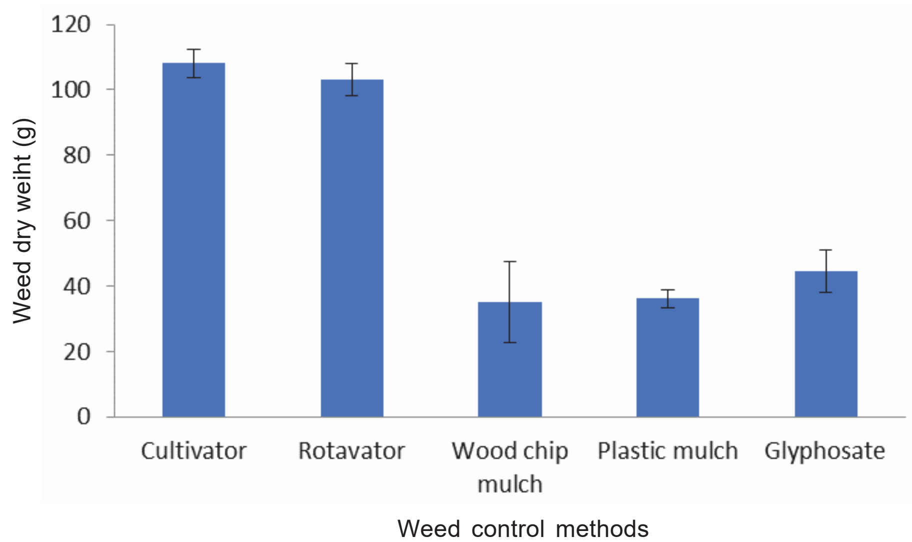


***Figure 10 -*** Effect of weed control methods on weed dry weight (g).

weed dry weight (22.33 g) as compared to the plastic mulch (39.00 g) (Figure 10). Weed dry weight in glyphosate was found to be higher (44.58 g) than in the mulches but lower than in the rotavator and the cultivator. Maximum weed dry weight was found in the rotavator (103.00 g) and the cultivator (108.33 g). Lower weed dry weight in the wood chip mulch may have been due to higher weed control. Our findings are in line with the findings of Radwan and Hussein (2001), who reported that mulches did not allow weeds to flourish which, in turn, produced lower weed dry weights. Higher weed dry weights were also found by Clements et al. (1996), who reported that higher weed dry weight in the rotavator and the cultivator was due to breaking and exposing deeper soil layers to soil surface, which contains a huge amount of weed seeds, which lead to higher weed population and higher weed dry weight.

It is concluded that mulching is the most suitable weed control method in citrus. It improves plant health and yield by improving soil physical properties and microbial biomass carbon. This will also help to reduce the use of weedicides, which le1ave their residual effects in the air as well as in crops.

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## REFERENCES

Abouziena H.F. et al. Efficacy of cultivar selectivity and weed control treatments on wheat yield and associated weeds in sandy soils. **World J Agric Sci.** 2008;5:384-9.

Ahmad R.N., Mahmood N. Impact of raised bed technology on water productivity and lodging of wheat. **Pakistan J Water Res.** 2005;9:7-15.

Alvarez R., Steinbach H.S. A review of the effects of tillage systems on some soil physical properties, water content, nitrate availability and crops yield in the Argentine Pampas. **Soil Till Res**. 2009;104:1-15.

Bertol I. et al. Physical soil properties of conventional tillage and seeding directly in rotation and crop succession, compared to the field native. **Rev Bras Ci Solo**. 2004;28:155-63.

Bhatt M., Banmeru S. Estimates of soil microbial biomass carbon of forest soil types of Gujarat, India. **Inter J Curr Microbiol Appl Sci.** 2014;3:817-25.

Bond W., Grundy A.C. Non-chemical weed management in organic farming systems. **Weed Res.** 2001;41:383-405.

Bredell G.S. Response of citrus trees to plastic mulching. In: Proceedings of International Society of Citriculture Murcia Spain. 1973. p.387-94.

Clements D.R. et al. Tillage effects on weed seed return and seed bank Composition. **Weed Sci.** 1996;44(2):314-22.

Daraghmeh O.A. et al. Near-saturated hydraulic properties in the surface layer of a sandy loam soil under conventional and reduced tillage. **Soil Sci Soc Am J.** 2008;72:1728-37.

Duran Z.V.H. et al. Nutrient losses by runoff and sediment from the taluses of orchard terraces. **Water Air Soil Poll.** 2004;153:355-73.

Fidalski J. et al. Least limiting water range and physical quality of soil under groundcover management systems in citrus. **Sci Agric.** 2010;67:448-53.

Gassen D.N., Gassen F.R. **Tillage**. The way of the future. Village South: 1996.

Haynes R.J. Influence of soil management practice on the orchard agro-ecosystem. **Agro-Ecol.** 1980;6:3-32.

Hembree K.J. et al. **Weed management**. UC IPM Pest Management Guidelines. Available on: http://www. ipm.ucdavis.edu/ PMG/r302700111.html. 2006.

Henderson C. et al. The effects of soil water content and bulk density on the compatibility and soil penetration resistance of some Western Australia soils. **Aust J Soil Res.** 1988;26:391-400.

Hoagland L. et al. Orchard floor management effects on nitrogen fertility and soil biological activity in a newly established organic apple orchard. **Biol Fert Soils**. 2008;45:11-18.

Hogue E.J., Neilsen G.H. Orchard floor vegetation management. **Hortic Rev.** 1987;9:377-430.

Holden J. Piping and woody plants in peatlands: cause or effect. **Water Resour Res.** 2005;41:60-69.

Ingels C.A. et al. Effects of cover crops on grapevines, yield, juice composition, soil microbial ecology, and gopher activity. **Am J Enol Vitic.** 2005;56:19-29.

Kabir Z., Koide R.T. Effect of autumn and winter mycorrhizal cover crops on soil properties, nutrient uptake and yield of sweet corn in Pennsylvania, USA. **Plant Soil**. 2002;238:205-15.

Kirandeep M. et al. Spatial variability of soil physical properties affecting florida citrus production. **Soil Sci.** 2010;175(10):487-99.

Klute A. Methods of soil analysis. In: Klute A. editor**. Physical and mineralogical methods**. 2nd. ed. Madison: American Society of Agronomy, 1986. Part 1. p.988-95.

Lal R. Achieving soil carbon sequestration in the United States: a challenge to the policy makers. **Soil Sci.** 2003;168:827-45.

Laurent A.S. et al. Long-term orchard groundcover management system s affect soil microbial communities and apple replant disease severity. **Plant Soil**. 2008;304:209-25.

Liedgens M. Interactions of maize and Italian ryegrass in a living mulch system: Nitrogen and water dynamics. **Plant Soil**. 2004;259:243-58.

Mari G.R., Chang J. Influence of agricultural machinery traffic on soil compaction patterns, root development and plant growth, Overview. **Am Eur J Agric Environ Sci.** 2008;4:49-62.

Merwin I.A. et al. Comparing mulches, herbicides and cultivation as orchard groundcover management systems. **HortTechnology**. 1995;5:151-8.

Merwin I.A., Stiles W.C. Orchard ground cover management impacts on soil physical properties. **J Am Soc Hortic Sci.** 1994;119:216-22.

Mohanty S. et al. Effect of mulching on Nagpur mandarin cultivation in drought prone region of Central India. **Ind J Soil Conser**. 2002;30:286-9.

Moodie C.D. et al. **Laboratory manual for soil fertility**. Washington: State College, 1959. p.9-31. [não publicado]

Nguyen T.T. et al. Effect of incorporated or mulched compost on leaf nutrient concentrations and performance of Vitis vinifera cv. Merlot. **J Soil Sci Plant Nutr.** 2013;13(2):485-97.

Ozores-Hampton M. et al. Weed control in vegetable crops with composted organic mulches. In: Stoffella P.J., Kahn B.A. editors. **Compost utilization in horticultural cropping systems**. Boca Raton: Lewis, 2001. p.275-86.

Pagliai M. et al. Soil structure and the effect of management practices. **Soil Till Res.** 2004;79:131-43.

Patrick A.E. et al. Grapevine uptake of 15N-labeled nitrogen derived from a winter-annual leguminous cover-crop mix. **Am J Enol Vitic.** 2004;55:187-90.

Pervaiz M.A. et al. Effect of mulch on soil physical properties and N, P, K concentration in maize (Zea mays L.) shoots under two tillage systems. **Inter J Agric Biol.** 2009;11:119-124.

Radwan S.M.A., Hussein H.F. Response of onion (Allium cepa, L.) plants and associated weeds to biofertilization under some plant mulched. **Ann Agric Sci**. 2001;46:543-64.

Rayhani M.H. et al. Desiccation-induced cracking and its effect on the hydraulic conductivity of clayey soils from Iran. **Can Geotech J.** 2007;44:276-83.

Rehman U.H. et al. Growth and yield of Kinnow (Citrus reticulata Blanco) and soil physical properties as affected by orchard floor management practices in Punjab, Pakistan. **Soil Environ.** 2012;31(2):163-70.

Salton J.C., Mielniczuk J. Relations between systems preparation, temperature and humidity of a Podzolic Dark Red Eldorado do Sul (RS). **Rev Bras Ci Solo**. 1995;19:313-9.

Sanchez E.E. et al. Cover crops influence soil properties and tree performance in an organic apple (Malus domestic Borkh) orchard in northern Patagonia. **Plant Soil**. 2006;292:193-203.

Sansavini S. Integrated fruit production in Europe: research and strategies for a sustainable industry. **Sci Hortic.** 1997;68:25-36.

Shirgure P.S. Effect of different mulches on soil moisture conservation, weed reduction, growth and yield of drip irrigated Nagpur mandarin (Citrus reticulata). **Indian J Agric Sci.** 2003;73:148-52.

Shirgure P.S. Sustainable acid lime fruit production and soil moisture conservation with different mulches. **Agric Eng Today**. 2012;36(3):21-6.

Smith R. et al. Vineyard floor management affects soil, plant nutrition, grape yield and quality. **California Agric.** 2008;62(4):11-19.

Steel R.G.D., Torrie J.H. **Principles and procedures of statistics:** a Biometrical approach. 2nd. ed. New York: McGraw Hill Book, 1997.

Varennes A. **Productivity soil and environment**. Lisboa: School Publishing, 2003.

Verdu A.M., Mas M.T. Mulching as an alternative technique for weed management in mandarin orchard tree rows. **Agron Sust Develop.** 2007;27:367-75.

Viera M.L., Klein V.A. physical and hydraulic properties an Oxisol submitted to different systems management. **Rev Bras Ci Solo**. 2007;31:1271-80.

Wahl N.A. et al. Effects of conventional and conservation tillage on soil hydraulic properties of a silty-loamy soil. **Phys Chem Earth.** 2004;29:821-9.

Walsh B.D. et al. Soil nitrate levels as influenced by apple orchard floor management systems. **Canadian J Soil Sci.** 1996;76:343-9.

Yao S. et al. Orchard floor management practices that maintain vegetative or biomass groundcover stimulate soil microbial activity and alter soil microbial community composition. **Plant Soil**. 2005;271:377-89.

Zhou X. et al. Surface soil hydraulic properties in four soil series under different land uses and their temporal changes. **Catena**. 2008;73:180-8.