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The Effect of Agricultural Byproduct of Olive Tree on Horticultural Substrate of Strawberry (*Fragaria ananassa*) Grown in Soilless Crop System

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ABSTRACT

In order to study the physical and chemical characteristic of 4 horticultural substrates and their behavior on strawberry plant cultivated in inert media, a study was carried during 2009 to 2010. Four substrates were tested in this experiment. They were composed by the byproduct oil cake and the vermiculite with the proportions [100:0], [90:10], [80:20] and [70:30] for T1, T2, T3 and T4, respectively. In the laboratory, the physical and chemical properties of these 4 blends are studied. In the greenhouse, their behavior on strawberry crop based on pH drainage evolution after each fertigation are controlled. The first supports compounded by 100% of oil cake and the second compounded by 90% of oil cake and 10% of vermiculite had the best physical and chemical characteristics: air filled porosity, percentage of drainage, moisture content, bulk density, pH and Electrical Conductivity (EC). The monitoring of fertigation, by the pH drainage evolution, from 1 to 14 May; period of high photosynthetic activity, shows that the behaviour of the mixtures T1 [100:0] and T2 [90:20] on the strawberry plant, grown in inert media, gave good conditions to uptake the nutrients and relatively optimized, the growth of strawberry plant.

Key words: Strawberry, moisture content, air filled porosity, bulk density, drainage, oil cake, substrate

INTRODUCTION

Advanced technology and restrictions of farmland, in some countries, imposed the introduction of soilless crop. This system provide several advantages for growers such as greater production of crops, reduced energy consumption, better control of growth and independence of soil quality (Vallance *et al.*, 2010). The success of soilless crops depends primarily on two main factors: the nutrient solution and the substrate (Sirin *et al.*, 2010).

During the past 25 years, substrate production of plants has depended almost entirely on quality soil less media derived from both organic and inorganic constituents. Waste products such as biosolids (Guerrero *et al.*, 2002) and wood waste (Hicklenton *et al.*, 2001) have been frequently used. But, the availability of other materials is attracting more attention. In our work, we have chosen the by-product oil cake. We recall that, the Crude oil cake is used in other industrial processes like carotenoid production (Mantzouridou *et al.*, 2006) and oil product of butter (Ciftci *et al.*, 2009).

In the first trial, we compared main physical proprieties of these 4 different substrates: the air filled porosity, percentage of drainage, moisture content, bulk density and chemical characteristics pH and Electrical Conductivity (EC). Tominago *et al.* (2002) reported that soil water content, reasonable rate of drainage and bulk density greatly influence important soil and plant processes like water movement. In the other hand, the chemical proprieties pH and Electrical Conductivity (EC) must be in the range recommended. Thus, nutrient solution supply must be monitored and regulated by the grower.

On the second trial of this study, we have tested, by the evolution of pH leaching, the behaviors of these substrates on strawberry plants under greenhouse. Because, the ideal pH is the principal factor that influences the uptake of all nutrients, particularly trace elements. For vegetables, it must vary between 5.5 and 6.5 (Urrestarazu *et al.*, 2008).

The objective of this work is to determine the, relatively, best physical and chemical characteristic of 4 substrates made by oil cake and the vermiculite and their behavior on the strawberry production.

MATERIALS AND METHODS

Our study was shared between the horticulture laboratory and greenhouse during 2009/2010 at the University of Tiaret (Algeria).

The various operations carried out in the laboratory. It identified the main physical and chemical properties of the 4 mixtures. In the greenhouse, we followed the pH evolution of the drainage solution at each fertigation during a period of high photosynthetic activity.

Plants: The variety of strawberry plant used is Marshall. The runners were planted at 3 leaves stage.

Substrates: The oil cake was recovered in oil mill located in Tlemcen-Algeria. It is an old olive oil mill in the region, which is compound by groves, consists of the Sigoise variety. Its dry matter composition was (%): Mineral 10.80, Nitrogen free extract 38.20, Crude fiber 36.4, Fat 5.50 and Nitrogenous matter 9.10. The vermiculite was taken from clay. Its particles sizes is: 65% = 2 mm, 21% = 1 mm, 10% = 0.5 mm, 0.2 mm = 4%.

Experimental device: In the first trial concerned the physical characteristics of mixture, we have chosen a completely random with 4 treatments. Each treatment represents one of 4 mixtures with 5 repetitions. That means 4×5 repeats, resulting in a total of 20 repetitions.

In the second part of our study, we have prepared and completed 5 pots for each mixture. Then, we have planted the strawberry runners on the pots containing the different substrates. We irrigated these plants with the nutrient solution. At each irrigation, we measured the pH of the solution drainage. Thus, we verify its evolution in real conditions of greenhouse.

The substrates used: Table 1 shows the compositions of the different substrates representing the 4 treatments used in our experiment.

Steering the fertigation: The irrigation was made with tap water since 24 February 2010, date of plantation, to 24 March. After this date, we have used the nutritive solution until the end of experiment. The composition of this solution was (meq L^{-1}): $NO_3^- = 11$, $H_2PO_4^- = 2$, $SO_4^{--} = 2$, $K^+ = 5$ $Ca^{++} = 8$, $Mg^+ = 8$. A contribution of 500 mL was brought. Because, according to Choi and Latigui (2008) and under the same experimental conditions this quantity has enabled us to get

Table 1: Composition of different substrates used

	Products used (%)	
Treatments	Oil cake	Vermiculite
T1 [10:0]	100	0
T2 [9:1]	90	10
T3 [8:2]	80	20
T4 [7:3]	70	30

drainage of 150 mL which corresponds to 30%. Rate drainage from 30 to 40% is necessary to avoid the accumulation of the elements in the substrate; otherwise that causes abrupt variations of the solution (Latigui and Dellal, 2009).

The properties of substrates studied: The physical properties studied were air filled porosity, percentage of drainage, moisture content, bulk density. The chemical characteristics were pH and electrical conductivity.

Behaviour of substrates used on strawberry plant: The study of the behavior of substrates on plants requires monitoring the fertigation. It is to control the evolution of the pH of leaching solution after each irrigation during 5 times. They were carried out after the fifth irrigation representing a period of 15 days. The number of these irrigations and this period are sufficient to know the real chemical state of substrates and their relation with the roots.

For statistical analysis, we used the 7.5 beta software Assista.

RESULTS AND DISCUSSION

Physical characteristics of mixtures: For the five properties studied, analysis of variance showed a very significant differences ($p<0.01$). In light of the various results, we have, using statistical software to compare the averages of five repetitions for each property among the 4 mixtures represented by the rate (oil cake volume:vermiculite volume): [10:0], [9:1], [8:2], [7:3] for T1, T2, T3 and T4, respectively.

Air filled porosity: The multiple comparisons of means (Fig. 1) shows that mixtures T1(a) with 35% is superior to T2 (b), T3 (c) and T4 (c) with 29, 25 and 22%, respectively. T2 is superior to T3 and T4. However, we did not find a difference between T3 and T4.

The substrate T1 and T2 recorded the best volume of air-filled porosity. Because, according to Raviv *et al.* (2002), most culture media and mixtures have a volume occupied by air between 10 to 30%. The optimal volume occupied by the air can change significantly depending on container size and irrigation frequency. Deniel *et al.* (2004) showed oxygen high concentration of the nutrient solutions offer an optimal growth environment. Deniel *et al.* (2006) showed that the using of pump air in the substrate removed bacteria under tomato production in soilless crop conditions.

Percentage of drainage: In Fig. 2 four treatments are different from each other. The histogram shows four groups a-d. The greatest rate of drainage was obtained by T1 (a) with 71%. It is followed by T2 (b), T3 (c) and T4 (d) with 64.8, 59.2 and 54.2%, respectively. This drainage rate observed over the 4 treatments does not allow an accumulation of salts harmful to plants in the

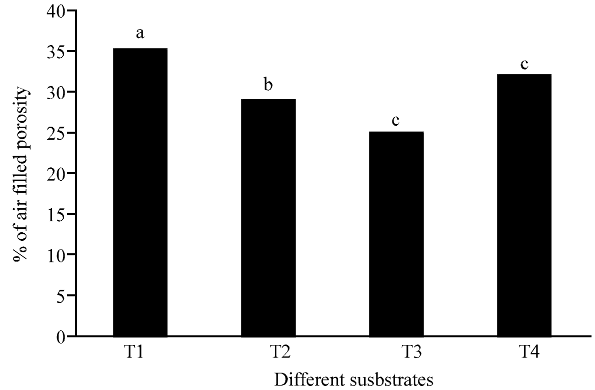

Fig. 1: Percentage of air filled porosity substrates used. Bars with different letters show significant effect at $p<0.01$

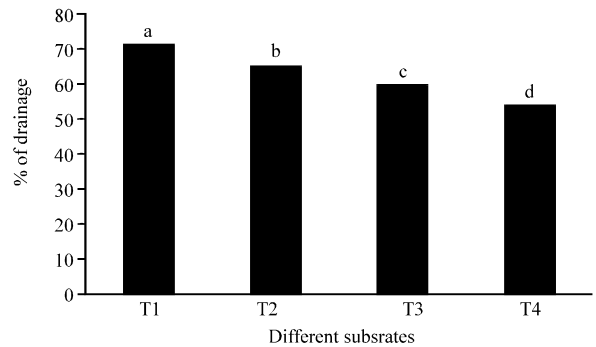

Fig. 2: Percentage of drainage solution substrates used. Bars with different letters show significant effect at $p<0.01$

substrate. Because according to Choi and Latigui (2008) drainage between 30 and 40% strongly supports optimal growth of plants. So, these substrates must be irrigated with a lower dose versus the dose used.

Moisture content: The multiple comparisons of means (Fig. 3) has revealed three distinct groups (a) T3 with 51%, (b) for T1 and T2 with 33 and 37% and finally the group (c) representing 26% for T4, respectively. The moisture content of the substrate 25 and 34% give the highest leaf fresh weight, leaf surface area and yield for strawberry plant. In our case T1 and T2 meet this standard. However, for T3, we must to decrease the dose or the frequency of irrigation. Because, the growth, yield and fruit quality of strawberries can be affected by water supply (Gehrmann, 1985; Karlovich and Fonteno, 1986). T4 with a low rate does not respond to the plant requirement.

Bulk density: The multiple comparison of means (Fig. 4) gave us three distinct groups a, b and c. The first one represents T4 (a) with 0.39 g cm^{-1}. The second represents T3 (b) and T2 (b) with respectively 0.37 and 0.36 g cm^{-1}. T1 (c) with 0.32 g cm^{-1} represented the last one. In this particular case, the densities of our four treatments meet the requirements of soilless crops. Because, according to Timm *et al.* (2006), an increase of bulk density reduces vertical water infiltration and facilitates lateral water movement high bulk density will be necessary for plants grown in fields to prevent wind from forcing them down. In the other hand the low bulk density can cause instability for strawberry which is a creeping herb.

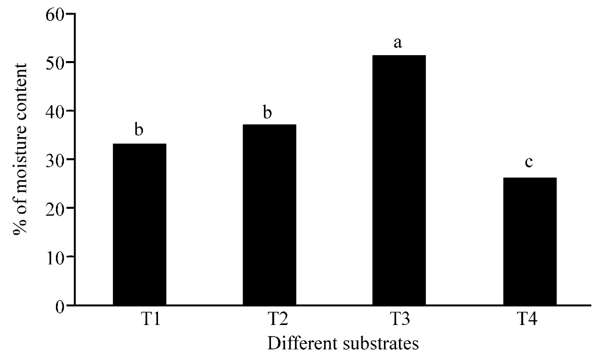

Fig. 3: Percentage of moisture content substrates used. Bars with different letters show significant effect at p<0.01

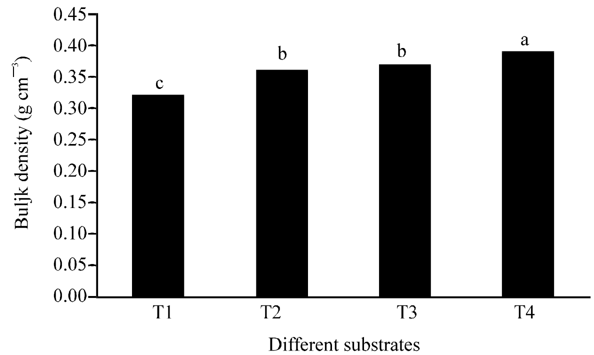

Fig. 4: Percentage of bulk density substrates used. Bars with different letters show significant effect at p<0.01

Chemical characteristics of mixtures

pH: The lowest pH 5.57 and 6.19 (Fig. 5) was obtained respectively by treatment T1 and T2. The highest was obtained by treatment T4 with 6.63. We know according to Gorbe and Calatayud (2001) that, the range of pH favors a total intake of all micronutrients and macronutrients is between 5.5 and 6.5. So, our substrates T1 and T2 have a pH favorable to good growth on plants. This is explained by the high rate of olive cake in these treatments.

Electrical Conductivity (EC): The multiple comparison of means (Fig. 6) has revealed two distinct groups a and b. The first one represents T3 with the highest rate 12.76 mS. It is followed by treatments T2 and T4 with respectively 11.01, 10.99 and finally T1 with 10.55 mS, respectively.

For the 4 substrates we used, the EC ranged from 12.76 to 10.55 mS. The ideal range for hydroponic is between 15 and 25 mS. A greater the EC avoid the absorption of nutrients. This is due to osmotic pressure. A low the EC affects seriously the growth and yield of plants (Choi and Latigui, 2008).

When plants absorb nutrients and water from the solution, the total concentration of mineral in substrate changes. If the EC is greater than the recommended range, the solution should be diluted with water. By cons, if less, we need to add nutrients (Kang and Iersel, 2001). In our case, we can increase significantly the concentrations of intake solution for all substrates used without the risk of salinity or phytotoxicity.

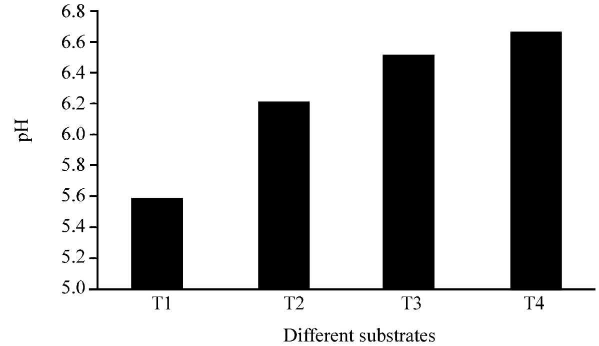

Fig. 5: pH of substrates used

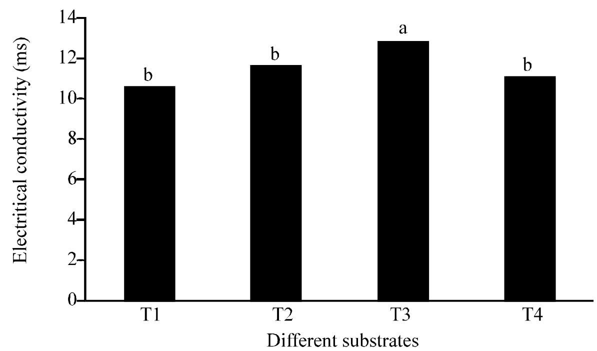

Fig. 6: Electro Conductivity (EC) for drainage solution (mS). Bars with different letters show significant effect at $p<0.01$

Table 2: Evolution of the pH drainage solution during the growth of strawberry plant

Treatments	Sampling dates 1 May	4 May	7 May	11 May	14 May
T1 [10:0]	5.96	6.38	6.45	6.13	6.34
T2 [9:1]	6.38	6.65	6.89	6.44	6.72
T3 [8:2]	6.59	6.80	6.83	6.82	6.50
T4 [7:3]	6.71	6.88	6.90	6.97	6.72

Behavior of substrates on strawberry uptake solution: pH and EC are the main reference for determining the behavior of the substrate, with respect to the relation plant-nutrient solution. Above or below, the recommended range nutritional imbalance is manifested by a non-uptake of micronutrients and nitrogen. To this end, we studied the evolution of pH drainage under real conditions of greenhouse.

We collected and analyzed the pH of the drainage solution once every three days from May 1 to May 14; period of high photosynthetic activity. The reading of pH drainage solution (Table 2) shows that only the T1 and T2 treatment had an optimum pH that met the requirements of the plant. Other treatments had a relatively high pH. Because, according to Latigui and Dellal 2009 they exceeded the recommended range 5.5-6.5.

CONCLUSION

Research on improving the substrates is still valid in order to achieve the best possible products. The demand for these products on the international market is constantly growing.

Our aim was to research the best physical and chemical properties of agricultural by-products of olive tree, to obtain technically and economically an efficient horticultural substrate.

The substrate T1 compounded by 100% of oil cake and T2 by 90% of oil cake and 10% of vermiculite recorded the best volume of air-filled porosity. The drainage rate observed over the 4 treatments does not allow an accumulation of salts harmful to plants in the substrate. Also, the moisture content of these 2 substrates 35 and 29.5% for, respectively T1 and T2 meet the standards. In the other hand, the bulk densities of our four treatments meet the requirements of strawberry grown in soilless crops.

The lowest and the relatively best pH 5.57 and pH 6.19 was obtained respectively by treatment T1 and T2. The range of pH favors a total uptake of all micro and macronutrients are between 5.5 and 6.5. So, the substrates cited have a pH favorable for good growth on plants. For the 4 substrates, we found the EC ranged from 12.76 to 10.55 mS. The ideal range for hydroponic is between 15 and 25 mS. In our case and for the all treatments the EC is low. This will allow us to increase the concentration of input mineral elements without risk of salinity or phytotoxicity.

The analyze of the pH drainage solution from May 1 to May 14, period of high photosynthetic activity, found that only the T1 treatment had a pH optimum that met the requirements of the plant. It is followed by T2.

The mixture T1 and T2 are their composition relatively richer in organic matter. However, after the use of balanced nutrient solutions these treatments with the best physical properties can give better conditions for plants.

Regarding on the basis of various observations and results, we will say that the mixtures compounded by high rate of oil cake are, relatively, the best substrate. Because, it has fostered a very good early plant growth compared to other mixtures. It has, in addition, the best physical properties.

Research on improving the substrates is still valid in order to achieve the best possible products. In the other hand, we can also do more research on the other mixtures to try to rectify their weaknesses.

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