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THE POTENTIAL OF COMPOSTED AGAVE BAGASSE AS A SUSTAINABLE MEDIUM FOR GROWING STRAWBERRIES AND TOMATOES

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Abstract: *In Mexico, the rapid growth of tequila production has led to a substantial increase in agave utilization, resulting in a surge of agave bagasse, a lignocellulosic by-product. This study explores the potential agricultural applications of agave bagasse, which now accounts for a significant portion of agave processing residues. Over the last 6 years, the production of agave bagasse has risen significantly, aligning with the booming tequila industry and related agave-based products.*

Agave bagasse can be effectively integrated into plant growth substrates, offering numerous advantages over traditional soil cultivation. Common substrates in Mexico, such as coco coir, perlite, and vermiculite, facilitate higher strawberry yields, improved quality, and greater plant density. Substrate-based systems also promote environmental sustainability by reducing chemical usage and enabling the collection and disinfection of runoff water for reuse. Moreover, substrate cultivation allows growers to maintain consistent planting locations and respond swiftly to weather fluctuations.

While substrate cultivation offers substantial benefits, it requires initial investments and a learning curve for growers to adapt to the technique and optimize fertilizer schedules. This study highlights the potential of utilizing agave bagasse in plant growth substrates as a sustainable and productive approach in the context of increasing agave production.

Keywords: *Agave bagasse, Plant growth substrates, Tequila production, Strawberry cultivation, Agricultural sustainability*

1. Introduction

Over the last 6 years in Mexico, the use of agave for tequila production has increased from 756,900 to 1,342,600 tons (CRT, 2020). Agave processing yields a lignocellulosic by-product, commonly called agave bagasse, which constitutes 40% of the weight of ground agave heads (Cedeño, 1995) and that could potentially serve as a substrate for agricultural purposes. The increased tequila production corresponds to an increase from 302,740 to 537,040 tons of produced agave bagasse. Moreover, additional tons of agave bagasse are generated in the production of inulin and mezcal, which also originate from the industrialization of the agave plant. Agave bagasse can be incorporated into plant growth substrates. The most commonly used substrates in Mexico include coco coir (coconut fiber), coco chips, perlite, vermiculite, peat moss, pine bark,

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rice hulls, and sand. Compared to soil planting, there are many advantages of growing strawberries in substrate. Substrate grown strawberries produce higher yields and better quality, and substrate growing systems often have much higher plant density compared to soil planting. Additionally, the use of fresh clean substrate and the protected environmental conditions of the crop can dramatically reduce the use of chemicals. Most substrate growth systems collect runoff water, such that water and fertilizers can be disinfected and reused. Moreover, growing in substrate provides the grower with assurance of being able to grow on the same spot every year. The limited root volume enables the grower to quickly react to weather changes, and makes it possible to steer the plant into vegetative or generative stages. Of course, the cultivation of strawberries in substrate also carries some limitations. Notably, the initial investments are higher than for traditional soil planting, and the grower will have to acquirenew knowledge regarding growing in substrate and steering the crop using appropriate fertilizer schedules (Boot, 2017).

Soil-free culture has also been extensively used in tomato cultivation, on both a commercial and experimental basis. Many researchers have compared, standardized, and otherwise applied various substrates for tomato culture using soil-free hydroponics. In general, it has been demonstrated that soil-free culture greatly increases tomato fruit quality worldwide. In greenhouse tomato production, organic growing media produces a higher yield compared to a conventional growing system (Olle *et al.*, 2012; Rippy *et al.*, 2004).

The objective of our present research was to evaluate the use of composted agave bagasse as substrate for growing strawberries and tomatoes. Strawberries were grown using a gutter closed system with nutrient solution recirculation, and tomatoes with a drip irrigation system.

2. Materials and Methods

2.1. Strawberries

We performed two experiments under the same conditions, varying only the strawberry variety: one experiment with cv. *Albión* and the other with cv. *Camino Real*.For each strawberry variety, we utilized a completely randomized experiment design, with two treatments and two repetitions per treatment. In each repetition, 10 seedlings were individually placed in a hydroponic gutter closed system with nutrient solution recirculation (Picture 1), in plastic bags of ~7 liters with one of the two substrates: commercial substrate or composted agave bagasse substrate. For each repetition, we used a gutter system of PVC pipes (length, 3m; diameter, 20 cm) split in half, through which the nutrient solution flowed from one end to the other over the plants' roots, moistening them, and then draining back into the 60-L hydroponic reservoir. A pump was utilized to feed the nutrient solution as needed to keep the substrates moist. Table 1 describes the balanced nutrient solution used in the experiments.

Throughout the experimental period, the pH and conductivity of the recirculation nutrient solution were constantly monitored for both treatments. We measured pH and conductivity using a portable pH/EC temperature meter (Hanna instruments H1991301). When necessary, the pH was adjusted by adding concentrated H_2SO_4or NaOH 1N. The nutrition solution was renewed with a certain periodicity to avoid nutritional deficiencies. According to supplier recommendations, we used nutritional salts concentrations of 1 and 2 g/L in the growth and fruiting phase, respectively. Data were analyzed by ANOVA.

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2.2. Tomatoes

Tomatoes were cultivated in a 24-hectare commercial nursery, under a hydroponic system with high implementation of technology.We followed a completely randomized experimental design, with four treatments and 10 repetitions per treatment. Each repetition was conducted in one pot containing a tomato seedling (*Bizart* grafted of *Maxifort*) and two guides. The four tested treatments were 1) "La Cofradía" composted agave bagasse;2) "La Regional" composted agave bagasse;3) coconut coir; and 4) a compressed imported coconut substrate, called "cocopeat". In treatments 1, 2, and 3, two shovels of tezontle gravel were added to the bottom of potted plastic bags, followed by approximately 16 liters of the respective substrate. In treatment 4, the substrate was packed into a plastic bag, such that when water was added, it swelled to a volume similar to the other substrates. Once the treatments were randomized, the bags were placed on drain rails, and sufficient tap water was added to lower the conductivity to 0.1 mmhos/cm. Three hoses were placed in each bag to supply the plant with its required nutrients in liquid form.

We evaluated the composts' behavior as a substrate for tomato cultivation during 5 months and 10 days, starting 55 days after transplanting the seedlings. The evaluation included measuring the total kilograms of tomatoes harvested per cut, as well as the tomato quality based on the company's standards regarding size, color, and deformation. Data were analyzed by ANOVA.

3. Results and Discussion

3.1. Strawberries

The virgin nutrient solution at a concentration of 1 and 2g/L, respectively, had a pH of 5.86 and 5.66, and a conductivity of 1.39 and 2.29 mS/cm. In the closed gutters system with nutrient recirculation, the nutrient solution was changed with a certain periodicity. The nutrient solution's conductivity was verified and the pH was adjusted to between 6–7, for both substrates. When using the virgin nutritional solution at a concentration of 1g/L, with commercial substrate and agave bagasse substrate, respectively, the recirculation solution had a pH of5.29(±0.48) and 6.9 (±0.27), and a conductivity of 1.35 (±0.15) and 1.16 (±0.15). When using the virgin nutritional solution with a concentration of 2g/L,with commercial substrate and agave bagasse substrate, respectively, the recirculation solution had a pH of 5.35 (±0.37) and 6.92 (±0.24), and conductivity of 2.37 (±0.29) and 1.91 (±0.18).

Fortunately, for both treatments on the different substrates, the conductivity of the virgin nutritive solution did not exceed the recommendations of Greekgardener (2015) for during the growth and fruiting phase (1.2–1.5 and 1.8–2.5, respectively). Notably, neither of the two substrates contributed to increasing the conductivity of the nutritive solution. In contrast, the pH differed between the two substrates, tending to drop to 4.74 with the commercial substrate, and rising up to 7.3 with the agave bagasse substrate. Thus, it was necessary to adjust the pH to between 6–7, which is considered ideal for growing strawberries in soil (Cornell Cals, 2020).

Importantly, within the hydroponic closed gutter system with recirculation of nutrient solution, we observed nochlorosis, which is a problem that was previously reported in two experimental strawberry crops grown in agave bagasse substrate bags, in the field and greenhouse setting (Oliveros, 2020; Ruvalcaba, 2017). It is likely that chlorosis did not appear due to the pH control of the nutrient solution recirculation.In particular, Fe uptake is depressed by high pH in the nutrient medium (Chen and Barak, 1982). When Fe is present as a positively charged metal ion, it will readily react with oxygen and/or negatively charged hydroxide ions (OH^-). Upon reaction with oxygen or hydroxide ions, Fe formsa new

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compound that is not bioavailable to plants. Both oxygen and hydroxide ions are abundant in soil and soil-free growth media. Plants typically utilize iron as ferrous iron (Fe^{2+}), which can be readily oxidized to the plant-unavailable ferric form (Fe^{3+}) when the soil pH is over 5.3 (Morgan &Lahav, 2007). Iron deficiency often occurs if the soil pH is over 7.4.

Table 2 presents the numbers of flowers per plant at 83, 97, and 111 days after transplanting the cv *Albión* strawberry seedlings, showing no statistically significant difference between the commercial substrate and agave bagasse substrate. Table 3 presents the numbers of flowers per plant at 54 and 68 days after transplanting the cv *Camino Real* strawberry seedlings. We observed no statistically significant difference at 54 days (p<0.05); however, at 68 days there was astatistically significant difference (p>0.05) between the commercial and agave bagasse substrates.The differences in results between Tables 2 and 3, showing higher flowering over time in the commercial substrate with one strawberry variety, indicate the need for additional studies to identify which varieties are best adapted to the agave bagasse substrate.

Table 4 shows the numbers of fruits per plant, the weight per fruit, and the biomass per plant of the *Albión*and *Camino Real* strawberry varieties grown on composted agave bagasse substrate and a commercial substrate. We found no significant difference between substrates in the weight per fruit (p>0.05). For the two other parameters, the commercial substrate was associated with significantly higher productivity in terms of fruits and biomass per plant, indicating that the commercial substrate was superior to the agave bagasse substrate for growing these two strawberry varieties. However this advantage must be considered in terms of the market cost of the commercial substrate, which is 75% higher than the cost of the composted agave bagasse substrate.

3.2. Tomatoes

Table 5 shows the ratio of tomato production from plants grown on coconut coir, cocopeat, and composted agave bagasse substrates for which the bagasse origin was the “La Cofradía” or “La Regional” tequila factories. These four substrates were not associated with any statistically significant differences (p > 0.5) intotal tomatoes or in quality tomatoes based on mean values (g/pot) obtained from 42 cuts from 10 pots per treatment over the 5 month and 10 dayduration of the experiment.

Figures 1 and 2 show the evolution in the productivity of total tomatoes and quality tomatoes during 42 cuts. These figures show the similarity in tomato production between the four substrates, with an increase over the first cuts, especially with the cocopeat substrate, followed by a progressive decrease in the followings cuts. At the end of the experiment, the difference between the cocopeat substrate (Figure 2) and the La Cofradía substrate was less than 2kg of quality tomatoes per pot, and the La Cofradía substrate had the advantage of being 40% cheaper. These results suggest that agave bagasse substrates could be used to replace the coconut coirand/or“cocopeat”, which is an expensive imported substrate.

4. Conclusions

Composted agave bagasse can serve as a substitute for commercial substrates when growing strawberries and tomatoes. For strawberry cultivation, it is necessary to add perlite or vermiculite to improve productivity.

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