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# Conditioners for raw rice husk substrate to produce strawberry transplants

## Acondicionadores de sustrato de cascarilla de arroz cruda para producción de plantines de fresa

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### ARTICLE DATA

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## ABSTRACT

The need to produce domestic strawberry transplants leads to the search for low-cost cultivation media in Brazil. Raw rice husk (CAIN) is an abundant and economical material in the south of the country. This study aimed to evaluate three substrate conditioners (35%) [carbonized rice husk (CRH), vermiculite and the commercial substrate S10®] added to RRH (65%) and their effects on growth, production and quality of strawberry transplants grown on benches with recirculation of nutrient solution, in a greenhouse. The experimental design was in causal blocks with three treatments and four replicates. Two mother plants of the Aromas cultivar were grown on each plot between November/2016 and March/2017. Transplants were classified into groups according to crown diameter (Class 1: 3.0-5.0 mm; Class 2: 5.1-8.0 mm; Class 3: >8.1 mm). Similarly, the number of leaves, leaf surface, fresh and dry mass of leaves and crowns of 10 transplants belonging to each class were evaluated. With the addition of CAC and vermiculite to the substrate, the predominance of class 2 transplants was obtained. The addition of S10 to CAIN increased the total number of transplants, as well as the number of leaf surface transplants and the dry mass of the aerial part of plants, in class 3 transplants, as well as S10 and vermiculite, provided a greater number of propagules produced.

**Key words:** Carbonized rice husk; *Fragaria* x *ananassa*; nutrient solution; organic substrate; vegetative propagation; vermiculite.



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## RESUMEN

La necesidad de producir plántulas de fresa nacional lleva a la búsqueda de medios de cultivo de bajo costo en Brasil. La cascarilla de arroz cruda (CAIN) es un material abundante y económico en el sur del país. El objetivo de este trabajo fue evaluar tres acondicionadores de sustrato [cascarilla de arroz carbonizada (CAC), vermiculita y el sustrato comercial S10 ®] adicionados al CAIN en una proporción del 35%, y sus efectos sobre el crecimiento, producción y calidad de plántulas producidas en canales de cultivo, elevados del suelo con recirculación de la solución nutritiva, en un invernadero. El diseño experimental fue en bloques causalizados con tres tratamientos y cuatro repeticiones. Se cultivaron dos plantas madre del cultivar Aromas, en cada parcela, entre noviembre/2016 y marzo/2017. Las plántulas se clasificaron en grupos según el diámetro de la corona (Clase 1: 3,0-5,0 mm; Clase 2: 5,1-8,0 mm; Clase 3: >8,1 mm). Del mismo modo, se evaluó el número de hojas, superficie foliar, masa fresca y seca de las hojas y de la corona de 10 plántulas pertenecientes a cada clase. Con la adición de CAC y vermiculita al sustrato, se obtuvo predominio de plántulas clase 2. La adición de S10 al CAIN aumentó el número total de plántulas, así como el número de plántulas de la superficie de la hoja y la masa seca de la parte aérea de las plantas, en las plántulas de clase 3, así como S10 y vermiculita, proporcionaron un mayor número de propágulos producidos.


**Palabras clave**: Cascarilla de arroz carbonizada; *Fragaria x ananassa*; propagación vegetativa; solución nutritiva; sustrato orgánico; vermiculita.

## INTRODUCTION

The strawberry crop represents an important activity to family farming, since it is a source of income and uses small cultivation areas, especially in Rio Grande do Sul (RS) state, Brazil. Besides, the fruit has high added value (Diel *et al*., 2017). In Brazil, the species is grown in around 4.200 ha$^{-1}$ (Fagherazzi *et al*., 2017), which require annual plant renewal due to the high occurrence of soil pathogens.

It is estimated that, in the country, 250 - 300 million strawberry transplants are planted annually (Fagherazzi *et al*., 2017), it is considered the most important input to the production system. Transplant quality is directly related to fruit yield and quality, i. e., it is the starting point to reach the best response to technologies used in the production process (Oliveira & Scivittaro 2006).

In RS, 80% of transplants have been imported from Argentine and Chilean nurseries. This condition gives transplants better physiological quality and fruit yield by comparison with national transplants (Oliveira *et al*., 2007).

However, since imported transplants have arrived late on farms, crop setting has been delayed and, consequently, harvest has started late. This way fruits are not available in winter, when the price paid for it is higher due to low supply in the market (Cocco *et al*., 2015).

Thus, technologies have recently emerged not only to minimize sanitary problems but also to avoid delayed planting. One of them is local production of strawberry

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transplants in substrate, a fact that guarantees their delivery and enables plant setting in the most suitable period (Schiavon *et al*., 2021).

Production of transplants in substrate can be done by collecting stolon tips, from stock plants grown in slabs, and rooting them in trays (Cocco *et al*., 2010). Another alternative may be planting stock plants on wooden benches filled with substrate. It means a larger surface area for the growth and rooting of stolon tips, thus enabling to produce bare root transplants on cultivation benches and to collect and reuse the solution leached by the system.

One of the most common substrates in horticultural production is carbonized rice husk (CRH) mixed with an organic compost to increase water and nutrient retention. However, the carbonization of the bark requires knowledge and technique (Medeiros, 1998), in addition to an environmental license to carry it out. Another challenge of carbonization is the high concentration of silicon dioxide, when material carbonizes too much, which makes its characteristics interesting for the civil industry, (Iacks *et al*., 2019) in brick building, but undesirable for a good agricultural substrate.

In RS, there is abundance of raw rice husk (RRH). Thus, its use would be an economical alternative with low environmental impact to produce strawberry transplants. Some research has highlighted the successful use of RRH to produce fruit, vegetables and cut flowers, either in mixtures with conditioners or as pure material (Perin *et al*., 2018; Hohn *et al*., 2018). However, studies of RRH that aim at the production of strawberry transplants are unknown since it is assumed that its use alone may not be feasible to produce transplants, due to its low water holding capacity.

Thus, it is believed that the addition of substrate conditioners can be positive for the improvement of physical characteristics of RRH, as they were demonstrated in the work of Perin *et al*. (2018) and Hohn *et al*. (2018). Therefore, this study aimed to evaluate three conditioners added to RRH and their effects on growth, production, and quality of strawberry transplants of the cultivar Aromas, in a fertigation system with collection and recirculation of the drained nutrient solution.

## MATERIAL AND METHODS

The experiment was carried out at the Experimental and Didactic Field of the Department of Phytotechnics, FAEM/UFPel - Campus Capão do Leão, in Capão do Leão, RS, Brazil (31°52’ S; 52°21’ W; altitude of 13m above the sea level) in a symmetric roof greenhouse, which measures 21 x 10m, covered with 150 μm polyethylene plastic film with a has north-south orientation. In the Köppen classification, the climate in the


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region is Cfa, characterized as humid or temperate subtropical with hot summers (Kuinchtner & Buriol, 2001).

Data on air temperature and humidity in the greenhouse were recorded daily by a thermo-hygrometer, which provided average values of temperature (26.7 °C) and relative humidity (67.4%) from November 2016 to March 2017. Maximum values were 33.9°C and 85.8%, while minimum ones were 19.4°C and 49.1%, respectively.

Three substrates were studied; RRH was the main component in the proportion of 65% v/v, while the three conditioners (35% v/v) were: CRH, medium class vermiculite (VM) and the commercial organic substrate S10 Beifort® (S10), formulated from the compound of the decomposition of grape marc and stalk, mixed with CRH and peat.

The experiment had a randomized block experimental design with three treatments and four replications. Each repetition corresponded to a two stock plants, which totaled eight for each treatment.

Certified stock plants of the Aromas cultivar were purchased at the Multiplantas Laboratory, accredited by the Ministry of Agriculture. To carry out stock plants setting, on November 22nd, 2016, twelve wooden benches were constructed. They were 1.00 x 1.70 x 0.12m (width x length x height), with an area of 1.7$m^2$, and covered internally with plastic film so as to become waterproof and drain the nutrient solution. Benches sloping 4% were supported on wooden trestles and placed 1.0 m above the ground at one end. At both ends of the benches, a 100 mm pipe was attached to collect and conduct the dreand to the nutrient solution catchment tank. Conditioners and RRH were mixed to compose the three substrates and subsequently distributed on the benches.

Fertigation was carried out by a motor-pump and a 500 L catchment tank set for each substrate, so that the dreand solution did not mix with them. Three drip hoses were used on each bench. They were arranged equidistantly. Drippers were spaced 10 cm apart and individual flow rate was 1.6 L $h^{-1}$.

The nutrient solution formulated by Sonneveld and Straver (1994) was used. EC (Electrical Conductivity) was 1.4 dS $m^{-1}$, with the following concentrations of macronutrient ions (mmol $L^{-1}$): 6.64 of $NO_3^-$; 1.5 of $H_2PO_4^-$; 2.88 $SO_4^{2-}$; 1.44 $NH_4^+$; 5.06 of $K^+$; 2.20 $Ca^{+2}$; 1.5 $Mg^{+2}$. Micronutrients (mg $L^{-1}$) were: 1.08 Fe; 0.20 Mn; 0.07 Zn; 0.17 B; 0.025 Cu and 0.05 Mo. Stored rainwater was used to prepare the solution.

EC and the pH of the leachate (Figure 1) were monitored daily by a portable conductivity meter and pH meter. Whenever necessary, correction was made. If EC was 20% above or below 1.4 dS $m^{-1}$, either water was used to dilute or concentrated liquid nutrient solution was added, respectively. The pH was maintained between 5.5 and 6.5. As it is a closed system, every month, w The experiment was carried out at the Experimental and Didactic Field of the Department of Phytotechnics, FAEM/UFPel - Campus Capão do Leão, in Capão do Leão, RS, Brazil (31°52' S; 52°21' W; altitude of 13 m above the sea level) in a symmetric roof greenhouse, which measures 21 x 10 m, covered with 150 µm polyethylene plastic film with a has north-south orientation. In the Köppen classification, the climate in the region is Cfa, characterized as humid or temperate subtropical with hot summers.

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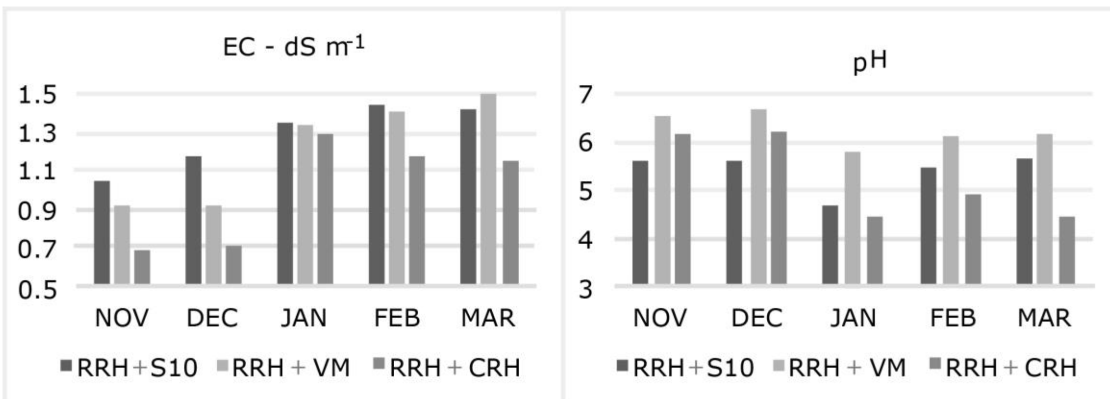


**Figure 1**. Average monthly values of electrical conductivity (EC) and pH of the solution drained from substrates based on raw rice husk (RRH - 65%) mixed with conditioners S10 Beifort® (S10 - 35%), vermiculite (VM - 35%) and carbonized rice husk (CRH - 35%).

Three substrates were studied; RRH was the main component in the proportion of 65% v/v, while the three conditioners (35% v/v) were: CRH, medium class vermiculite (VM) and the commercial organic substrate S10 Beifort® (S10), formulated from the compound of the decomposition of grape marc and stalk, mixed with CRH and peat.

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EC and the pH of the leachate (Figure 1) were monitored daily by a portable conductivity meter and pH meter. Whenever necessary, correction was made. If EC was 20% above or below 1.4 dS m-1, either water was used to dilute or concentrated liquid nutrient solution was added, respectively. The pH was maintained between 5.5 and 6.5. As it is a closed system, every month, when the catchment tank level dropped to its minimum, the remaining solution was discarded, the substrate was washed and a new nutrient solution was added. Hence, the catchment tank level dropped to its minimum, the remaining solution was discarded, the substrate was washed and a new nutrient solution was added.

The experiment was conducted until March 28th, 2017, when removal of rooted transplants and propagules produced during the cycle began, for the beginning of the evaluations. Each rooted transplant was removed from the substrate and separated from the stock plant. Then, the number of primary stolons and the total number of transplants and propagules per stock plant were counted. Propagules were defined as transplants that did not have developed roots and whose length from the base of the crown to the tip of the leaflet of the largest leaf was less than 10 cm.

Plants which were considered transplants were separated into three classes, depending on the crown diameter measured by a pachymeter: Class 1 (3.0 to 5.0 mm), Class 2 (5.1 to 8.0 mm) and Class 3 (≥8.1 mm), according to Cocco *et al*. (2010). Subsequently, the number of transplants belonging to each class was counted. Ten transplants, randomly,

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of each class per repetition were analyzed regarding the number of leaves and fresh and dry mass of leaves and crown. Leaf area was measured by the LI-3100C leaf area meter. Fresh materials were dried in an oven at 60°C until weight stabilization to acquire dry masses.

Substrate samples were collected at the end of the experiment. Their characteristics were analyzed at the Plant Substrate Laboratory that belongs to Departamento de Diagnóstico e Pesquisa Agropecuária da Secretaria de Agricultura, Pecuária e Desenvolvimento Rural (DDPA/SEAPDR) - Porto Alegre, RS, Brazil. Results are shown in Table 1.

**Table 1**. Physical characteristics of three substrates composed of 65% raw rice husk (RRH) and 35% conditioners S10 Beifort® (S10), vermiculite (VM) and carbonized rice husk (CRH) at the end of the strawberry propagation experiment.

| | Substrato | | |
|---|---|---|---|
| Physical characteristics | RRH+S10 | RRH+VM | RRH+CRH |
| Wet density (g $L^{-1}$) | 355 | 377 | 200 |
| Dry matter (g $100g^{-1}$) | 42 | 34 | 50 |
| Dry density (g $L^{-1}$) | 151 | 129 | 101 |
| Total porosity (%) | 78 | 83 | 69 |
| Aeration space (%) | 19 | 22 | 17 |
| Easily available water (%) | 10 | 9 | 10 |
| Buffer water (%) | 11 | 9 | 12 |
| Water holding capacity $_{10cm}$ (%) | 59 | 61 | 52 |
| Water holding capacity $_{50cm}$ (%) | 49 | 52 | 42 |
| Water holding capacity $_{100cm}$ (%) | 38 | 43 | 30 |

Data on growth, production and quality of transplants were subjected to the analysis of variance and means were compared by the Duncan's test at 5% probability, with the use of the statistical program Winstat (Machado & Conceição, 2003).

## RESULTS AND DISCUSION

The substrates significantly affected the number of resulting primary stolons, transplants and propagules. Values found with the addition of S10 and CRH conditioners demonstrated inverse behavior (Table 2). While the substrate with CRH provided a large number of primary stolons (19.8) and small numbers of transplants and propagules (119.9 and 127.4), the substrate with S10 promoted the smallest number of stolons (14), but large numbers of transplants and propagules (192.1 and 180.1). The VM conditioner generated intermediate responses in relation to the others, since its averages were 18.4 stolons, 151.8 transplants and 163.1 propagules per plant. (Table 2).

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**Table 2**. Average number of primary stolons, transplants and propagules per strawberry stock plant and average of transplants and propagules per stolon in substrate based on 65% raw rice husk (RRH) and 35% conditioners S10 Beifort® (S10), vermiculite (VM) and carbonized rice husk (CRH).

| Substrate | Primary stolons | Transplants | Propagules | Transplants stolon$^{-1}$ |
|---|---|---|---|---|
| RRH+S10 | 14.0 B | 192.1 A | 180.1 A | 13.7 A |
| RRH+VM | 18.4 AB | 151.8 AB | 163.1 AB | 8.2 B |
| RRH+CRH | 19.8 A | 119.9 B | 127.4 B | 6.0 B |
| Mean | 17.4 | 154.6 | 156.9 | 9.3 |
| CV % | 12.2 | 17.1 | 9.5 | 15.1 |

Means followed by the same letter in a column do not differ by the Duncan's test ($p<0.05$).

The numbers of stolons and transplants per stock plants produced in the three substrates, based on raw rice husks, are higher than those found by previous studies of the cultivar Aromas under soil cultivation conditions (Guimarães *et al*., 2015) as well as in substrate based on vegetal soil and manure substrate (Oliveira *et al*., 2007).

The number of transplants obtained per primary stolons, shown in Table 2, also distinguishes conditioner S10, which provided 13.7 transplants stolon$^{-1}$. The value was also higher than those found by the previous authors, while treatments with VM and CRH showed 8.2 and 6 transplants stolon$^{-1}$, respectively. The relation between 6 transplants stolon$^{-1}$ and the CRH conditioner was below the data found by Oliveira *et al*. (2007).

Taking account that the production of propagules is an important factor to produce plug plants, whose purposes are to reduce plant mortality soon after setting and to bring forward harvest (Cocco *et al*., 2011), the large number of propagules found by this study in a single evaluation period is a very positive result. The plug plants production method demands high production of propagules in a short time, in order to produce plug plants for transplantation in adequate amount and season (Schmitt *et al*., 2012). Although transplants may be stored in a refrigerated environment until sufficient quantities of material are obtained, some studies, such as the one conducted by Schmitt *et al*. (2012), showed that, depending on the cultivar, storage time may negatively alter production potential of the transplant. It indicates that the ideal is to obtain as many propagules as possible in a short time, likewise found in this research, especially in the CRH+S10 substrate, followed by CRH+VM.

Different responses given to the use of conditioners for the formulation of the RRH substrate can be mainly attributed to physical properties resulting from the mixtures. Thus, in order to better understand the discussion of results, it is important to indicate the reference values of physical characteristics of an ideal substrate. According to De Boodt & Verdonck (1972), an ideal substrate has total porosity (TP) of around 85%, aeration space (AS) between 20 and 40%, easily available water (EAW) between 20 and

30% and buffer water (BW) between 4 and 10%. It is known, however, that associating all these characteristics in a substrate is difficult and that, depending on the container, crop and irrigation management, results of characteristics of substrates and the ones of production and quality of cultivation can be divergent.

The physical characteristics of the substrates at the end of the experiment show a PT of 83, 78 and 69% in the treatments RRH + VM, RRH + S10 and RRH + CRH, while the AS was 22, 19 and 17%, respectively (Table 1). Regarding EAW and BW, the percentage for the substrate RRH+VM was 9% in both parameters. In RRH+S10, values were 10% for EAW and 11% for BW, while for RRH+CRH, EAW was 10% and BW was 12%.

Percentages of TP, AS and EAW were close among the three substrates, but below values that are considered ideal, by De Boodt & Verdonck (1972), while AT was above the ideal. Regarding the water holding capacity (WHC) at different tensions of 10, 50 and 100 cm of water column, the analysis pointed out differences between RRH+CRH and RRH+VM. The first substrate was characterized by containing particles of similar sizes that retained little water, i. e., $WHC_{10}$ was 52%, while $WHC_{50}$ and $WHC_{100}$ showed values of 42% and 30%, respectively. In RRH+VM, $WHC_{10}$, $WHC_{50}$ and $WHC_{100}$ values were higher and corresponded to 61%, 52% and 43%, which were justified by the high water absorption of vermiculite under higher tensions. RRH+S10 exhibited intermediate WHC values (59%, 49% and 38% at 10, 50 and 100 cm, respectively) in relation to the other substrates.

Regardless of the conditioner added to RRH, one of the improvements offered to the substrate was the increase in WHC, a fact also observed by Zorzeto *et al*. (2014). In their study, pure RRH exhibited 10% WHC, while the mixture containing RRH and granulated coconut fiber raised the WHC to 40%, thus, showing the importance that conditioner materials added to RRH have to improve its physical characteristics and potentiate its use.

In all substrates, EAW was much below the ideal referenced by De Boodt & Verdonck (1972). In the substrate with CRH, the percentage of EAW (Table 1) was equal to that of RRH+S10 and close to that of RRH+VM. However, $WHC_{10}$ of RRH+CRH was the lowest among the three substrates, supposedly because its macroporosity was higher than the one of the others and reduced the percentage of water to maintain substrate moisture. It led to deficient water supply for plants, unlike what was observed in RRH+S10 and RRH+VM.

Differences between wet density (WD) and dry density (DD) of the three substrates show that VM and S10 particles are more capable of assisting water retention in compositions than CRH particles. Wet densities of RRH+VM and RRH+S10 were 66% (377 g $L^{-1}$) and 57.3% (355 g $L^{-1}$) higher than their dry densities, which corresponded to 129 and 151 g $L^{-1}$, respectively. However, WD and DD of RRH+CRH were 200 g $L^{-1}$ and 101 g $L^{-1}$, respectively, with increase of 49.5% in volume of WD. In addition, the lower the WHC, the higher the dry matter of substrates (g $100g^{-1}$).

Of moreover, substrates with conditioners S10 and VM presented high TP and low AS, which indicate high micropore content that, consequently, contributed to high $WHC_{10}$.

In addition to the physical characteristics the chemical composition also played a role in the results. Because S10 is an organic material, it contains mineral nutrients in its composition, which can be observed by its EC, informed by the manufacturer, which is around 0.5 dS $m^{-1}$. In contrast, VM and CRH are practically inert and do not have nutrients to offer to the plants initially. Thus, RRH+S10 favored the greatest growth and accumulation of reserves in the crowns of plants, since, right after the transplant, the greatest growth and development of stock plants were observed in the treatment with S10.

The substrate containing VM reached higher values of WHC than the substrate with S10, in addition to higher aeration space (61% of $WHC_{10cm}$ and 22% of AS), and the highest increase in humidity between DD and WD, which reached 66%. Water supply to the substrate with VM may have been higher than necessary for the production of strawberry transplants in soilless growing conditions, making results of some production variables and transplants quality similar to those found by RRH+CRH, which offered less water to plants.

The RRH+CRH substrate is composed of materials that separately have low WHC, which represents low storage capacity for water and mineral nutrients. Based on this characteristic, it can be inferred that, in the first days after the transplant of stock plants, in the initial phase of their establishment and growth, the low water supply provided by the substrate was decisive for the low production of propagating material. It is corroborated by the fact that, 36 days after setting, there was still no stolon in the RRH+CRH treatment, while in RRH+VM and RRH+S10, there were, on average, 1.1 and 4.6 stolons per stock plant, respectively.

Thus, delay observed in growth and at the beginning of stolons generation of the stock plants in the RRH+CRH treatment led to a highest number of stolons. However, there was decrease in the number of transplants rooted in each stolon.

Additionally, EC values of the drain solution of this substrate were always below the standard value of 1.4 dS $m^{-1}$. This fact associated to the low pH value (Figure 1) found in the last three months of the experiment (below 5.0), indicates low availability of nutrient ions for plant growth.

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As for variables of transplants quality, classified into groups of crown diameter (Table 3), there was a statistical difference among substrates in the number of transplants classified in both Class 1 (3.0 to 5.0 mm) and Class 3 (≥8.1 mm). Comparing among treatments showed that RRH+S10 and RRH+VM presented a higher number of transplants classified in Class 1 than RRH+CRH (50.9 and 41.8, respectively) and RRH+S10 had a larger number of in Class 3 transplants (72.0) than the other two substrates. Considering that the standard crown diameter for imported transplants is ≥ 8 mm, and since this parameter is related to the physiological quality of transplants, it is interesting to develop further research on the organic substrate S10 as a conditioner for RRH.

Although Class 1 transplants (3.0 to 5.0 mm) meet standards of national transplants, they have less commercial value, since low resistance to transplantation in the field has been attributed to them. Treatments with addition of S10 or VM were similar and showed higher production of Class 1 transplants than the substrate with CRH as a conditioner. It can be explained by the rapid establishment of the stock, triggering faster emergence of stolon and rooting of transplants than in RRH+CRH. As the surface for rooting and growth became limited on the cultivation bench, after some time, there was greater competition for light and space, which made part of the transplants keep small.

As previously mentioned, in the substrate with CRH, due to lower water availability and, consequently, more difficulty in the initial establishment of stock plants, there was delay in stolon emergence. Thus, there was a lower total number of transplants per stock plant that exhibited proportionally smaller number of Class 1 transplants (3.0 to 5.0 mm).

Treatments did not differ in the number of Class 2 transplants (5.1 to 8.0 mm), i. e., they exhibited 70.4, 69.2 and 53.9 transplants per stock plant in RRH+VM, RRH+S10 and RRH+CRH, respectively. These transplants, which have an intermediate crown diameter, can be sold with good yield results all over the country. It is reinforced by results found by Cocco *et al*. (2011), whose analysis of fruit production from cv. Arazá originated from bare root transplants classified into Class 2 (5.1 to 8.0 mm), which showed higher production than Class 3 plants (≥ 8.1 mm).

The largest number of transplants in RRH+S10 prevailed in Class 3 (≥ 8.1 mm), followed by Class 2 (5.1 to 8.0 mm) and by Class 1 (5.1 to 8.0 mm). Treatments with VM and CRH, on the other hand, exhibited mostly Class 2 transplants, followed by Class 3 and Class 1 ones (Table 3).


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**Table 3**. Number of bare root strawberry transplants in substrates based on 65% raw rice husk (RRH) and 35% S10 Beifort® (S10), vermiculite (VM) and carbonized rice husk (CRH), classified into groups of crown diameters [**Class** 1 (5.1 to 8.0 mm), **Class** 2 (5.1 to 8.0 mm) and **Class** 3 (≥8.1 mm)].

| Substrate | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| RRH + S10 | 50.9 A | 69.2 A | 72.0 A |
| RRH + VM | 41.8 A | 70.4 A | 43.5 B |
| RRH + CRH | 15.0 B | 53.9 A | 45.5 B |
| Mean | 35.9 | 64.5 | 53.7 |
| CV % | 17.0 | 23.1 | 17.5 |

Means followed by the same letter in a column do not differ by the Duncan's test ($p<0.05$).

In relation to the leaf area (LA) and the shoot dry mass (SDM), shown in Table 4, transplants in the RRH+S10 treatment classified into Class 3, which exhibited 564. cm$^2$ LA and 7.2g plant$^{-1}$ SDM, were also statistically superior to transplants of the same class produced in the other substrates. The relation between high LA and SDM in Class 3 and the superiority in this class transplant production (Table 3), enables to state that the RRH+S10 mixture provided higher productivity and better quality of transplants than the other substrates.

**Table 4**. Average values of leaf area (LA) and shoot dry mass (SDM) of strawberry transplants produced in substrates based on 65% raw rice husk (RRH) and 35% conditioners S10 Beifort® (S10), vermiculite (VM) and carbonized rice husk (CRH), classified into groups of crown diameters [Class 1 (G1; 3.0 to 5.0 mm), Class 2 (G2; 5.1 to 8.0 mm) and Class 3 (G3; ≥ 8.1 mm)].

| Substrate | LA G1 | LA G2 | LA G3 | SDM G1 | SDM G2 | SDM G3 |
|---|---|---|---|---|---|---|
| | ------------------cm$^2$.plant$^{-1}$------------------- | | | -------------------- g.plant$^{-1}$---------------------- | | |
| RRH+S10 | 49.2 A | 84.2 A | 564.1 A | 0.4 A | 0.9 A | 7.2 A |
| RRH+VM | 40.7 A | 85.0 A | 260.3 B | 0.4 A | 1.1 A | 4.7 B |
| RRH+CRH | 35.5 A | 74.1 A | 370.3 B | 0.4 A | 0.8 A | 4.0 B |
| Mean | 41.8 | 81.1 | 398.2 | 0.4 | 0.9 | 5.3 |
| CV % | 24.6 | 19.8 | 16.6 | 24.3 | 19.4 | 23.9 |

Means followed by the same letter in a column do not differ by the Duncan's test ($p<0.05$).

Addition of S10 to the substrate also had a positive statistical effect on the other growth variables, i. e., the number of leaves, fresh and dry mass of leaves and fresh and dry mass of crown, which were 10.8 leaves, 37.4, 6.0, 7.1 and 1.2 g plant$^{-1}$, respectively, (not shown data) for Class 3 transplants. Concerning Class 1 and 2 transplants, none of the three substrates had significant statistical effect on previously mentioned growth variables.

This way, transplants in RRH+S10 showed a large number of leaves, which responded to high LA (Table 4 and, consequently, to a presumably high photosynthetic rate, generating high production of photoassimilates, which led to a higher SDM Table 4).


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The best physical and chemical characteristics (Table 1) presented in RRH+S10 may also have helped and justify the maintenance of its humidity and nutrient supply. In addition, because it is organic material and contains small amounts of nutrients, growth of stock plants and, consequently, of transplants was favored, in relation to the other substrates. It is shown in Figure 1, since monthly averages of EC in RRH+S10 were higher in the initial months of the experiment than in the other substrates. A pH stability was observed, with monthly values around 5.4. In the mixture with VM, EC values were lower in the first two months by comparison with those of S10, but higher than those in CRH. RRH+CRH showed instability in the drainage EC, with increase only in January and decrease in the final two months again. As for pH, VM helped to maintain values in the range from 5.8 to 6.5, while, in CRH, values around 6.0 were initially recorded, but went below 4.9 in the last three months. Issues related to EC and the pH are also important when choosing conditioners, since the addition of 35% of each to the same material, RRH 65%, gave different chemical characteristics, in addition to distinct physical characteristics of resulting substrates.

Results show that RRH, with the addition of conditioner material, can be successfully used as basic material in the composition of substrates for strawberry propagation. They also reinforce the idea that the potential for producing stolons, propagules and quality transplants depends a lot on characteristics of the root growth environment, i. e., the substrate. Differences in physical and chemical characteristics of the substrates support their influence on transplant production. Choosing the appropriate conditioner can result in better optimization of spaces and gains in the transplant production sector.

## CONCLUSIONS

Addition of the commercial substrate S10 to the raw rice husk substrate provides an increase in the growth, production and quality of the propagation material produced from the strawberry plant, in comparison with vermiculite and carbonized rice husk, for class 3, this difference not occurring for class 2 transplant. CHR+S10 and CHR+VM have good potential for the production of propagules, which can later be cultivated for transplant in clod.

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**Conflict of interest**: The authors declare that there is no conflict of interest.


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