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# Water-Saving Technologies in Galapagos Agriculture: A Step towards Sustainability

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**Abstract:** Water scarcity and salinity pose significant challenges for agriculture in the Galapagos Islands, severely limiting crop yields needed to sustainably meet the growing demands of the human population in the archipelago. To address this issue, environmentally friendly water-saving technologies such as Hydrogel and Groasis Growboxx were considered to be potential solutions. This study focused on evaluating the effectiveness of Hydrogel application on five crops: Broccoli (*Brassica oleracea*), Cucumber (*Cucumis melo*), Pepper (*Capsicum annuum*), Tomato (*Solanum lycopersicum*), and Watermelon (*Citrullus lanatus*), from 2017 to 2018. The experiment stopped due to the pandemic in 2019–2020. When the study continued in 2021, Growboxx® was introduced as a treatment for Pepper and Tomato. This study revealed that the application of Hydrogel resulted in enhanced yields, with the degree of improvement varying across different crops and cultivation periods. Notably, when comparing Hydrogel and Growboxx treatments, differences of up to 30% in fruit weight were observed. However, it is important to note that these results can vary in different environments. For example, in Tomato cultivation, Growboxx exhibited 10% higher fruit weight in San Cristobal compared to Santa Cruz Island. Our findings provide valuable insights for stakeholders in the Galapagos Islands, offering crop-specific guidance to support informed decisions on adopting the most appropriate technologies for their farms.

**Keywords:** Galapagos; Groasis Growboxx®; Hydrogel; individual fruit weight; maximum height; number of fruits; productivity; farms; vegetative traits; productive traits

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## 1. Introduction

Agriculture in the Galapagos Islands is crucial for the local economy and the sustainability of the ecosystem. In addition, agriculture plays a key role in meeting the local population's food needs and providing a source of income for residents [1–3].

The unique geography of the islands, including the volcanic soil and diverse microclimates, allows for a variety of crops to be grown, such as coffee, bananas, citrus fruits, and vegetables [4]. In addition to providing local food and economic benefits, sustainable agriculture practices also play a significant role in preserving the fragile ecosystem of the Galapagos [5].

Sustainable agriculture practices in the Galapagos, such as agroforestry and organic farming, can promote soil health, conserve biodiversity, and reduce the negative impact of agriculture on the environment [6].

The Galapagos Islands face several challenges in agriculture, including water scarcity and soil degradation. Water scarcity is a severe problem in the islands due to low precipitation rates and the absence of surface water sources. This scarcity affects agricultural productivity and sustainability, as well as the health of the local ecosystems [7].

In addition to water scarcity, soil degradation is another significant challenge facing agriculture in the Galapagos Islands. Soil degradation results from overgrazing, deforestation, and erosion caused by inappropriate land-management practices. This degradation reduces soil fertility, leading to lower crop yields and further exacerbating the water scarcity problem [8].

Agriculture in the Galapagos is concentrated on the four populated islands of Floreana, Isabela, San Cristobal, and Santa Cruz [9], with a total agricultural area of approximately 20,000 ha, or 2.38% of the total area of the islands. High food demand caused by accelerated demographic growth has led to the necessity to innovate traditional agricultural practices using sustainable and environmentally friendly production. A major focus of crop production are vegetables considered essential in the daily diet of Galapagos residents [10]: Broccoli (*Brassica oleracea*), Cucumber (*Cucumis sativus*), Green Pepper (*Capsicum annuum*), Tomato (*Solanum lycopersicum*), and Watermelon (*Citrullus lanatus*).

Changes in land use for agricultural production have led to an increase in freshwater consumption. Water is generally very scarce in this arid archipelago [11], a reality that is similar in other islands. Floreana was the first island to be inhabited; however, today the island has the lowest population of the four inhabited islands, with approximately 150 settlers [12]. The water supply for agriculture in Floreana derives from rainfall and springs. However, due to inadequate management, the springs are depleted [13] and the water supply now derives only from rainfall. In San Cristobal, the supply comes from surface waters, as there are freshwater sources (such as a natural lagoon in the highland area, which is of high quality) [14]. However, the water availability is not enough to meet the needs of the local agriculture [13]. According to interviews with farmers on the island, the majority of the water used for irrigation is collected from rainfall in water reservoirs located in the highlands. In Santa Cruz, water to supply agriculture is scarce and comes from rainfall and underground wells [15–17]. All in all, a general problem across all islands is the lack of knowledge on sustainable aquifer management [13].

Therefore, other less-expensive alternatives need to be considered. Water-saving technologies show promise, given the analysis of their use and cost-effectiveness in tropical dry forests on several islands in the archipelago, which was based on previous analyses [18].

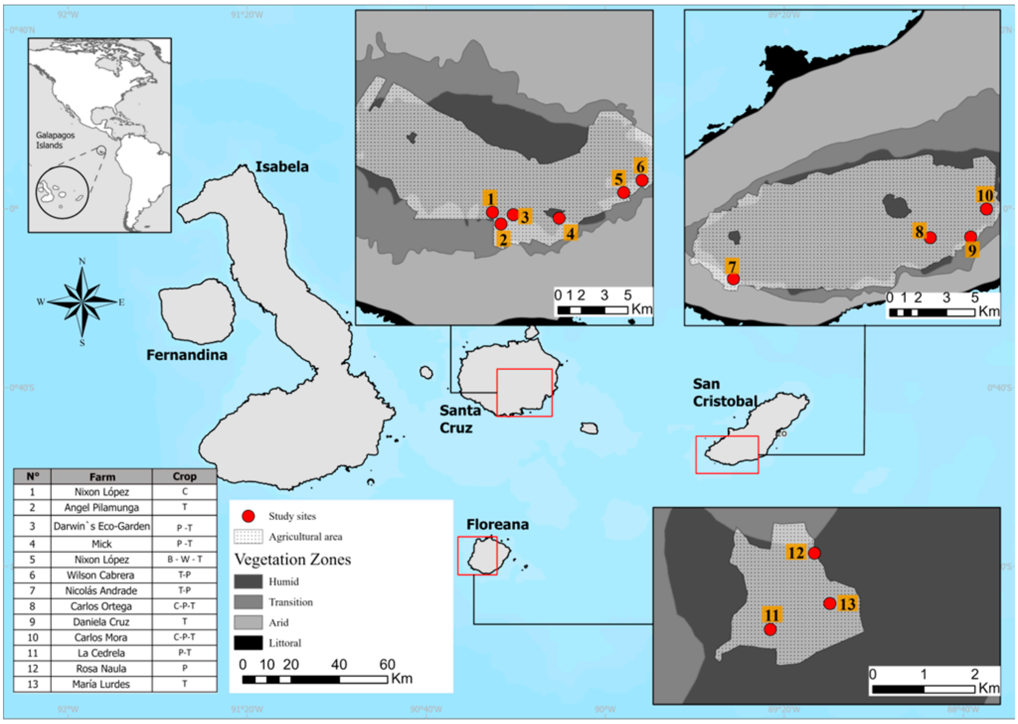
Improving the efficiency of water usage for irrigation can reduce water waste and contribute to mitigating the water scarcity problem on the islands. Various water-saving technologies offer alternatives for achieving this goal. One such technology is Hydrogel [19,20], a polymer that has the capacity to retain water in the soil, making it highly versatile for afforestation purposes [21]. Hydrogel has demonstrated its efficiency in Tomato cultivation on Santa Cruz Island [22]. Another technology is the Groasis Growboxx®, a device designed to provide water and shelter to plants, thereby enhancing their growth and survival [23]. A third is the Groasis Waterboxx® technology, which was previously evaluated for Cucumber, Pepper, and Tomato from 2016 to 2018 on the islands of Santa Cruz and Floreana [2]. Here, we extend these studies to examine the effectiveness of the Hydrogel and Groasis Growboxx® technologies for enhancing the productivity of five economically important crops in two periods: 2017–2018 and 2021. The study encompasses three populated islands within the archipelago: Floreana, Santa Cruz, and San Cristobal. The study was originally designed to span from 2017 to 2021. However, as a result of the global pandemic, the study faced a temporary interruption during the period of 2019–2020. Fortunately, research activities were able to resume in 2021, allowing for the continuation of the study.

## 2. Materials and Methods

### *2.1. Study Site*

The study was carried out in the agricultural area of three Galapagos Islands: Floreana (1°18′16″ S, 90°26′22″ W), San Cristobal (0°54′27″ S, 89°31′26″ W), and Santa Cruz (0°38′13″ S, 90°22′14″ W). We carried out this study in collaboration with local farmers from these islands.

The three islands have similar climatic conditions. In Floreana, the three farms were in the humid agricultural zone (337 to 364 m.a.s.l.), with a mean temperature of 22–32 °C and an annual precipitation range of 0 to 400 mm. In San Cristobal Island, the four farms were located in the transition–humid agricultural zone (160 to 240 m.a.s.l.), with 24–33 °C temperatures and annual precipitation of up to 430 mm. In Santa Cruz Island, the six farms were located in the transition agricultural zone (160 to 200 m.a.s.l.), with a temperature range of 25–33 °C and annual precipitation of up to 405 mm [24]. The study sites and their descriptions are displayed in Figure 1.




| N° | Farm | Crop |
|---|---|---|
| 1 | Nixon López | C |
| 2 | Angel Pilamunga | T |
| 3 | Darwin`s Eco-Garden | P -T |
| 4 | Mick | P -T |
| 5 | Nixon López | B - W - T |
| 6 | Wilson Cabrera | T-P |
| 7 | Nicolás Andrade | T-P |
| 8 | Carlos Ortega | C-P-T |
| 9 | Daniela Cruz | T |
| 10 | Carlos Mora | C-P-T |
| 11 | La Cedrela | P-T |
| 12 | Rosa Naula | P |
| 13 | María Lurdes | T |

**Figure 1.** Location of the study sites and the vegetation zones on each island. The agricultural area of each island is displayed. The table provides an overview of the names of the study sites, represented as farms, along with the crops grown at each site (B = Broccoli, C = Cucumber, P = Pepper, T = Tomato, and W = Watermelon).

### 2.2. Crop Selection

In this study, we focused on five economically important crops in the Galapagos Islands: Broccoli (*Brassica oleracea*), Cucumber (*Cucumis sativus*), Green Pepper (*Capsicum annuum*), Tomato (*Solanum lycopersicum*), and Watermelon (*Citrullus lanatus*). These crops were chosen based on their proven role in generating income for Galapagos farmers, as indicated by previous studies [9,25,26]. The selection process considered multiple factors, including the availability of seedlings during the study period and the expressed interest of farmers in cultivating these crops.

### 2.3. Water-Saving Technologies

In these farms where specific crops were cultivated (Figure 1), we applied water-saving technologies to the crops as treatments and compared their effect to Control. These technologies are described as follows:

### 2.4. Hydrogel

This polymer is made of soft and elastic materials characterized by their hydrophilic capacity and water insolubility [19,27]. Hydrogel has a high capacity to retain water, allowing more efficient use of water for plants by reducing soil infiltration [27,28]. Specifically, for this study we used a local brand of Hydrogel (Cosecha de Lluvia®, El Rancho, Cotacachi, Ecuador) [29] containing 96% potassium polyacrylate, which can hold up to 500 times its weight in water [30].

## 2.5. Growboxx

The Growboxx® (Groasis, Steenbergen, The Netherlands), is a biodegradable box (with dimensions of 40 cm wide × 40 cm long and a height of 16 cm) that provides shelter and a stable temperature to seedlings by giving them with a constant water supply (Figure 2) [23,31]. Growboxx was only used in the 2021 period by farmers who cultivated Pepper and Tomato, as they decided to continue the experiment after the global pandemic.


**Figure 2.** Set-up process of the Growboxx technology in the field. (1) Digging a hole and humidifying it with water. (2) Placing the box in the hole and filling it with approximately 15 L of water and soil. (3) Covering the box with the lid and adding soil to the small holes for planting seedlings. Tomato seedlings can be observed as a result of this process.

## 2.6. Experimental Design

This experiment was an applied investigation. Farmers were interviewed, and they decided which water technologies to use on their crops. Below, we displayed the applied treatments according to the crops they were used on and the periods during which they were cultivated (Table 1).

**Table 1.** Periods and crops in which different water-saving technologies were applied.

| Period | 2017–2018 | | 2021 | | |
|---|---|---|---|---|---|
| Crop | Treatments | | | | |
| Broccoli | Hydrogel | Control | N/A | N/A | N/A |
| Cucumber | Hydrogel | Control | N/A | N/A | N/A |
| Pepper | Hydrogel | Control | | Growboxx | Control |
| Tomato | Hydrogel | Control | Hydrogel | Growboxx | Control |
| Watermelon | Hydrogel | Control | N/A | N/A | N/A |

## 2.7. Before Planting

Before sowing each plant, we dug a hole large enough to house the plant. For Hydrogel, we prepared a solution with a ratio of 1.75 g of powder per liter of water. This specific ratio was determined based on previous studies using Hydrogel conducted in the Galapagos [18,22] and other places [21,32–37]. Afterward, we placed 5 L of this solution into the dug hole. For Growboxx application, we dug a hole big enough to house the Growboxx device (40 × 40 × 16 cm), humidifying the soil with 5 L of water. For the Control condition, we just humidified the soil with the same amount of water after digging a hole.

### 2.8. During Planting

For Hydrogel application, following the sowing of the plant in the hole, we proceeded to fill the hole with 15 L of Hydrogel solution. Afterward, we covered the hole with soil. For Growboxx application, we placed in the hole a fine paper layer whose role was to prevent water evaporation. Then, we placed the box and filled it with soil and water until it was 3/4 filled (approximately 15 L of water). Finally, we proceeded to cover the box with a lid. Each lid had four holes, and we placed one seedling in each hole, covering them with moist soil. Even though four plants were cultivated in each Growboxx, each seedling was considered to be one unit with a respective code, generating independent data from the others. For the Control condition, we sowed the plant in the pre-humidified soil and finished with 15 L of water after sowing. These same procedures were carried out for all the treatments in the selected crops on the three islands.

A total of 2279 plants were sown, including 420 Broccoli, 158 Cucumber, 513 Pepper, 1064 Tomato, and 124 Watermelon plants. Detailed information is summarized in Table S1.

### 2.9. Harvesting

At harvest, we collected the fruits, weighed them, and measured plant height. For Broccoli, harvesting was carried out only once, as the edible part is the flower head. From the total plants sown, fewer plants had productivity; a total of 873 plants produced: 239 Broccoli, 40 Cucumber, 32 Pepper, 462 Tomato, and 25 Watermelon. Detailed information is summarized in Table S1.

### 2.10. Statistical Analysis

In this study, we investigated the effects of different treatments on plant growth and fruit production by analyzing three criteria: sowing period (2017–2018 and 2021), crop type (Broccoli, Cucumber, Pepper, Tomato, and Watermelon), and treatment type (Hydrogel, Growboxx, and Control). In 2017–2018, we had all five crops available with Hydrogel and Control as treatments, while in 2021, we had two crops (Pepper and Tomato) with an additional treatment (Growboxx). In 2021, the number of crops under study was reduced to two. This decision was made by farmers who had successfully achieved good yields using Hydrogel in the cultivation of the two selected crops. Encouraged by their positive outcomes, these farmers wanted to delve deeper into the study. Additionally, farmers from other islands heard about these positive results and joined the study, showing interest in participating and contributing to the research on Pepper and Tomato crops. Our investigation focused on both vegetative and productivity traits, which are important indicators of plant performance and can help inform crop-management practices. The vegetative traits we measured were the maximum plant height reached in centimeters (HMAX) and the age of the plant in days since sowing (plant age). The productivity traits included the age at which the plant commenced fruit production (productivity age), the total fruit yield in kilograms (productivity), the total number of fruits produced by each plant (fruits), and the average individual fruit weight produced by the plant (IFW).

In order to assess the impact of the various treatments (independent variables) on our selected traits (dependent variables), which exhibit a linear relationship based on residuals, we employed linear regressions (LM). Since our dependent variables are numerical and the independent variables are categorical, we utilized one-way ANOVA to identify significant differences among the treatments. To further evaluate the significance and identify specific variations among means between treatments, we conducted Tukey's honestly significant difference test (Tukey's HSD) as a post-hoc test. This allowed us to uncover any significant differences and make informed conclusions about the effects of the treatments. The analyses were performed using version 4.3.0 of the R package "stats" (R Core Team) [38].

## 3. Results

### *3.1. Broccoli*

During the 2017–2018 period, we conducted a cultivation experiment with Broccoli plants to assess the impact of Hydrogel application on their growth and productivity. The results indicated that the Broccoli plants treated with Hydrogel exhibited higher values than the Control group (Table 1). This overall difference was particularly evident in the vegetative traits we measured, such as maximum plant height and age. The Broccoli plants grown with Hydrogel showed significant improvements of 20% and 48% in these respective traits when compared to the Control group (Table S2).

However, it is important to note that we did not find any statistical differences in the productive traits between the Hydrogel-treated and non-treated plants. Surprisingly, the non-treated plants demonstrated slightly higher productivity, by approximately 5%, compared to the Hydrogel-treated plants, which took 18% more time to be ready for harvesting (Table 1).

These findings suggest that while Hydrogel application positively influenced the vegetative growth of the Broccoli plants, it did not translate into significant enhancements in their overall productivity during the specific cultivation period.

### *3.2. Cucumber*

During the 2017–2018 period, we conducted a study on Cucumber plants to investigate the effects of Hydrogel treatment on their growth and productivity. Surprisingly, we did not observe any significant differences concerning the studied traits between the Hydrogel-treated plants and the Control group. However, our results did reveal a slight improvement in productivity for the Hydrogel-treated plants compared to the Control group, with a 3% increase observed in all productivity traits except for IFW (Table 1). Additionally, the harvesting time for the Hydrogel-treated plants was slightly delayed by 3% compared to the Control group. Regarding vegetative traits, such as plant height and age, the Hydrogel-treated plants exhibited slightly higher values of 5% and 3%, respectively, than the non-treated plants. Nevertheless, these differences were not statistically significant (Table S2). Although the observed improvements in productivity and vegetative traits were modest and non-significant, they suggest a potential positive impact of Hydrogel treatment on Cucumber plants.

### *3.3. Pepper*

This crop was cultivated in the period 2017–2018 and 2021. In the first period, Hydrogel treatment resulted in higher values for productivity age, productivity, and fruits per plant than the Control group (Figures 3 and S1, Table 1). However, in the second period, the Control group had higher values in the mentioned traits than both the Hydrogel and Growboxx treatments (Table 2, Figure S1). Specifically, when compared to the Control group, Hydrogel-treated plants were 24% smaller in "HMAX." Growboxx-treated plants were 47% smaller in "HMAX," 25% lower in plant age (Table S3), and 36% lower in "IFW" (Table 2). Comparing Hydrogel and Growboxx, Hydrogel-treated plants were 44% taller in "HMAX" than Growboxx-treated plants (Table S2). During the initial period (2017–2018), green Pepper cultivation was conducted only on Santa Cruz Island. However, the crop yielded satisfactory results with the implementation of Hydrogel as a water-saving technology. Encouraged by these outcomes, the study expanded in the 2021 period to include a new island: San Cristobal. The aim was to assess the performance of green Pepper cultivation on both islands using different cultivation methods.

The results obtained from the evaluation revealed significant variations between the two islands. When Hydrogel was utilized, Pepper cultivation in Santa Cruz exhibited higher values in four out of six measured traits compared to San Cristobal. Conversely, when Growboxx was employed, San Cristobal demonstrated higher values in four out of six traits compared to Santa Cruz. In the Control group, where no treatment was applied, Santa Cruz displayed higher values in five out of six traits compared to San Cristobal.

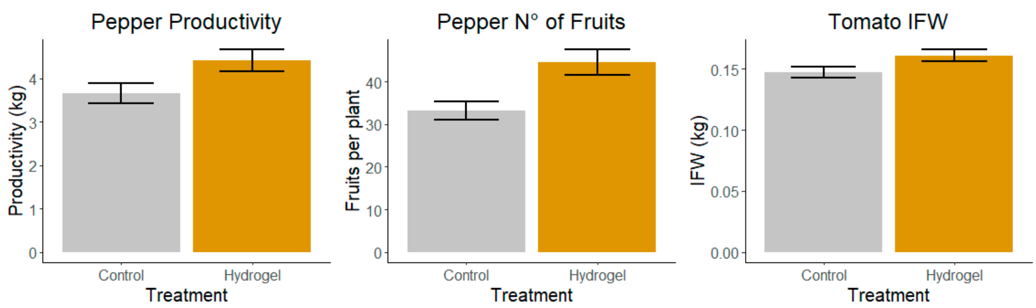



**Figure 3.** Positive effects of Hydrogel on productivity traits in Pepper and Tomato. All results show statistically significant differences (Tukey HSD, $p \leq 0.005$). Results presented for the 2017–2018 season.

**Table 2.** Comparison of average values of productivity traits in crops grown with Hydrogel and without it (Control) in the period 2017–2018. Underlined values mean that Hydrogel resulted in better outcomes than the Control. Bold values show statistical differences. For specific statistical values, see Table S4. Values in italics represent the percentage difference between treatments.

| Trait | Treatments | Broccoli | Cucumber | Pepper | Tomato | Watermelon |
|---|---|---|---|---|---|---|
| Productivity age (days) | Hydrogel | 202.408 | 59.401 | 82.214 | 101.215 | 89.181 |
| | Control | 171.471 | 57.751 | 79.277 | 95.835 | 88.5 |
| | Difference | *18%* | *3%* | ***4%*** | *6%* | *1%* |
| Productivity (kg) | Hydrogel | 0.455 | 2.255 | 4.418 | 2.255 | 4.049 |
| | Control | 0.479 | 2.197 | 3.666 | 2.365 | 4.492 |
| | Difference | *5%* | *3%* | ***21%*** | *5%* | *10%* |
| Fruits per plant | Hydrogel | - | 6.851 | 44.501 | 14.556 | 1.181 |
| | Control | - | 6.651 | 33.222 | 17.247 | 1.285 |
| | Difference | - | *3%* | ***34%*** | *16%* | *8%* |
| Individual fruit weight (IFW) (kg) | Hydrogel | - | 0.323 | 0.101 | 0.161 | 2.954 |
| | Control | - | 0.333 | 0.111 | 0.147 | 3.404 |
| | Difference | - | *3%* | ***9%*** | ***10%*** | *13%* |

Among these differences, the most remarkable disparities were observed in productivity and fruits per plant, with values in Santa Cruz exceeding those in San Cristobal by more than 80%. Furthermore, the use of Growboxx led to notable differences in plant height and age between the two islands (Table S5).

### *3.4. Tomato*

This crop was cultivated during the periods of 2017–2018 and 2021. In the 2017–2018 period, Hydrogel-treated plants were 10% heavier than the Controls when assessing IFW, and this difference was significant (Figures 3 and S2, Table 2). In 2021, Growboxx-treated plants were significantly 26% smaller than plants without treatment and 21% smaller than Hydrogel-treated plants when assessing HMAX (Table S3, Figure S2). When evaluating "IFW," plants grown with Growboxx were significantly lower than the Control by 22% and significantly lower than Hydrogel-treated plants by 30% (Table 3). Similar to Pepper, Tomato crops also showed good yields in Santa Cruz during the period of 2017–2018. Encouraged by these results, the cultivation of Tomatoes was expanded to include Floreana and San Cristobal for the 2021 period.

Among the different cultivation methods, Hydrogel-treated Tomatoes in Santa Cruz exhibited the best results in four out of six measured traits, with notable improvements in productivity and fruit quantity, reaching up to a 79% increase. On the other hand, when Growboxx-treated plants were used, San Cristobal demonstrated the best results in four out of six traits. However, the differences observed with Growboxx were not as significant as those seen with Hydrogel.

**Table 3.** Differences between average values of productivity traits among Hydrogel (H), Growboxx (G), and Control (C) in 2021, classified by crop. Underlined values show that the treatment had better results than its respective Control (HC or GC). When Hydrogel and Growboxx are compared (HG), the underlined value shows that Hydrogel had a better outcome than Growboxx. Bold values show statistical differences (for *p* values, see Table S4; for specific differences between treatments, check Figures S1 and S2). Values in italics represent the percentage difference between treatments.

| | | Treatment | | | Comparison | | |
|---|---|---|---|---|---|---|---|
| | **Traits** | **H** | **G** | **C** | **HC** | **GC** | **HG** |
| **Pepper** | Productivity age (days) | 93.801 | 95.666 | 94.115 | *0%* | <u>*2%*</u> | *2%* |
| | Productivity (kg) | 0.171 | 0.256 | 0.306 | *44%* | *16%* | *33%* |
| | Fruits per plant | 2.251 | 3.111 | 3.653 | *38%* | *15%* | *28%* |
| | Individual fruit weight (IFW) (kg) | 0.084 | 0.065 | 0.101 | *17%* | ***36%*** | <u>*29%*</u> |
| **Tomato** | Productivity age (days) | 107.458 | 109.962 | 107.008 | *0%* | <u>***3%***</u> | *2%* |
| | Productivity (kg) | 0.281 | 0.216 | 0.302 | *7%* | *28%* | <u>*30%*</u> |
| | Fruits per plant | 3.166 | 3.012 | 3.463 | *9%* | *13%* | <u>*5%*</u> |
| | Individual fruit weight (IFW) (kg) | 0.087 | 0.067 | 0.086 | <u>*1%*</u> | ***22%*** | <u>***30%***</u> |

In terms of the Control group, Santa Cruz yielded the best results overall. The most pronounced differences were observed in productivity and the number of fruits, with variations of up to 70% between Santa Cruz and the other islands (Table S5).

### *3.5. Watermelon*

In the 2017–2018 period of Watermelon cultivation, our investigation into the effects of various treatments on the studied traits yielded no statistically significant differences. However, it is noteworthy that the non-treated plants consistently exhibited superior outcomes compared to the treated plants.

Specifically, when comparing the productivity, fruits per plant, and individual fruit weight (IFW), the Control group demonstrated significantly higher values, surpassing the Hydrogel-treated plants by 10%, 8%, and 13%, respectively (Table 3). Although there was a marginal difference of 1% in the initial harvesting time, favoring the non-treated plants, this disparity is of minimal significance. Regarding the vegetative traits, the Control plants exhibited notable advantages, with an 11% increase in plant height and a slightly higher plant age of 2% compared to the treated plants.

In summary, while our findings indicate an absence of significant variations in the studied traits between the different treatments during the 2017–2018 period of Watermelon cultivation, it is worth emphasizing that the non-treated plants consistently displayed superior outcomes. These results shed light on the potential influence of treatment methodologies on Watermelon growth and productivity, underscoring the importance of further investigations to refine and optimize the efficacy of the treatments.

## 4. Discussion

In previous studies, the use of water-saving technologies on the Galapagos Islands was mainly focused on ecological restoration purposes [8,18,39]. Our goal for this study was to evaluate how well our studied crop traits performed when we used technologies that help conserve water. One is Hydrogel, and the other is Growboxx. Both technologies help to mitigate the water scarcity problem that severely affects the ecosystems on the islands.

In Broccoli cultivation, the use of Hydrogel as a soil amendment holds significant promise in the context of water conservation. Our study reveals that incorporating Hydrogel has a notable positive impact on the vegetative traits of the plants, resulting in increased plant height and extended productive time. These findings suggest that Hydrogel has the potential to enhance the productivity of Broccoli crops, offering practical implications for agriculture. It is interesting to note that while statistical differences in vegetative traits were observed in Broccoli during the 2017–2018 period, similar effects were not found in the other crops. This highlights the specific responsiveness of Broccoli to Hydrogel application compared to the other crops studied during that period. The effectiveness of Hydrogel as a soil amendment in improving soil properties and enhancing water use efficiency has been reported in arid regions, leading to increased crop yields [36]. A study was conducted in the Cotopaxi province of Ecuador, where Hydrogel (Potassium polyacrylate) was utilized. The findings unequivocally demonstrate that Broccoli plants treated with Hydrogel exhibited significantly higher yields compared to the control group. The optimal dosage determined for maximum yield was found to be 90 kg/Ha. These results firmly affirm the remarkable efficacy of this product [40]. These findings emphasize the potential of Hydrogel as a valuable tool in water-saving strategies for agricultural practices, particularly in crops like Broccoli. Further research and exploration of Hydrogel application in Broccoli cultivation can provide valuable insights into optimizing water use efficiency and improving crop yields in water-limited environments.

In Cucumber cultivation, the results of our study during the 2017–2018 period showed no significant differences between crops treated only with Hydrogel and Controls. However, these findings contrast with previous studies [41,42] demonstrating significant improvements in Cucumber plant growth and yield with Hydrogel application. It is important to consider various factors that could have influenced our study's lack of significant differences. Environmental conditions and cultural practices impact plant growth and performance. In this case, these factors masked the potential effects of the Hydrogel treatment on Cucumber crops during the first period of the experiment. Water use in Cucumber cultivation can be maximized by further investigation into the specific conditions and practices under which Hydrogel application can effectively enhance yields. Enabling the development of targeted strategies to optimize water use efficiency and improve Cucumber crop productivity aligns with the goal of water-saving approaches in agriculture.

Pepper was cultivated in two periods: (a) 2017–2018 and (b) 2021. In the first period, Hydrogel showed better yields than the Control (Figure 3); however, in the second period, non-treated plants had better yields. When we compared Hydrogel and Growboxx, Hydrogel-treated plants had a better effect in most traits, showing that Pepper plant performance may vary depending on the year of cultivation. A similar study showed that Hydrogel-treated Pepper plants obtained higher biomass than the Control; however, this depends on the Hydrogel concentration [32]. Building on the success observed in the initial period, the cultivation of Peppers was expanded from Santa Cruz to San Cristobal Island, offering a new opportunity to evaluate and compare yields between the two islands using Hydrogel and Growboxx technologies. The outcomes of our study indicate that Peppers treated with Hydrogel demonstrated superior performance in Santa Cruz, while Growboxx proved more effective in San Cristobal. These results suggest that the choice of technology can significantly impact Pepper yields, depending on the specific conditions of each island. Moreover, a previous study conducted by Jaramillo et al. in 2022 supports our findings, confirming that the utilization of water-saving technologies can vary based on the unique environmental factors present on each island [2]. These findings underscore the importance of considering local conditions and selecting appropriate cultivation methods to optimize Pepper production.

Tomato was grown in both periods: 2017–2018 and 2021. Similar to Pepper, in the first period, Hydrogel-treated plants showed better yield in individual fruit weight (IFW) than non-treated plants (Figure 3). In 2021, Control plants showed better results than those treated with Hydrogel and Growboxx. Comparing treatments, Hydrogel-treated plants had better outcomes than those treated with Growboxx. Similar to Pepper, the results vary according to the year of cultivation. A related study suggests using Hydrogel to obtain better Tomato yields [43]. Tomato cultivation was carried out exclusively in Santa Cruz during the initial period. However, in 2021, owing to the successful implementation of water-saving technologies resulting in improved production, the cultivation of Tomatoes was expanded to two additional islands: Floreana and San Cristobal. Similar to the trends observed in Pepper yields, Hydrogel-treated Tomatoes exhibited superior performance in Santa Cruz, while Growboxx showed better results in San Cristobal. Unfortunately, in Floreana, we encountered low performance. This can be attributed to the scarcity of water for agricultural purposes on the island, with limited access to rainwater, which is insufficient to sustain acceptable yields in agriculture [5]. Other studies conducted in the Galapagos Islands have reported similar trends when utilizing water-saving technologies [2,22,44].

For Watermelon, it is an unexpected finding that non-treated plants generally showed higher outcomes. Contradicting these results, a study reported that the application of different Hydrogel concentrations increased the yield and quality of fruits [45]. Watermelon, being a crop with high water requirements, poses a significant challenge in arid ecosystems like the Galapagos Islands, where water conservation in the cultivation of water-demanding crops is crucial. Watermelon plants are particularly sensitive to water stress conditions, which can significantly reduce their productivity. A study in 2015 exposed Watermelon to different water deficit levels, confirming that plants exposed to drier conditions had significantly lower productivity [46]. Although the Hydrogel-treated Watermelon plants in our study showed lower yields than Controls, it is important to note that this crop was cultivated solely on a farm located east of Santa Cruz Island. To gather comprehensive insights into Watermelon cultivation and the effectiveness of water-saving technologies, further research should be conducted on multiple farms and islands. This expanded research should include the use of Hydrogel and other water-saving technologies such as Growboxx to evaluate productivity and determine the overall effectiveness of these approaches in conserving water while sustaining Watermelon crop yields. Such investigations will provide valuable information for guiding future water-saving strategies in Watermelon cultivation throughout the Galapagos Islands.

In 2018, for vegetative traits, the Hydrogel treatment generally led to higher values than the Control treatment. For productivity traits, the effects of the Hydrogel treatment were mixed. For productivity (in kg), the Hydrogel treatment resulted in higher productivity in Cucumber and Pepper crops. However, in terms of fruit per plant, we identified a greater number of fruits in all Hydrogel-treated crops except Broccoli, since Broccoli only produces one brassica head as an edible part. For individual fruit weight (IFW), Hydrogel showed better results in Pepper and Tomato crops.

In 2021, for vegetative traits, the Growboxx treatment resulted in the shortest plant height and plant age for both of the two crops. On the other hand, for productivity traits, Growboxx crops took longer to start producing. In general, Hydrogel-treated plants showed better outcomes than Growboxx-treated plants [22]. These results are consistent with another study performed in 2021, which found that Hydrogel application significantly improved plant survival and water use efficiency compared to Cocoon, which is very similar to Growboxx as both are made of biodegradable material [18].

Studies that have investigated the effect of Hydrogel treatment have reported positive results. As an example, a comprehensive survey was conducted in the province of Santa Elena, Ecuador, targeting local farmers specializing in fruit, grain, and vegetable cultivation. The purpose of the survey was to ascertain whether the utilization of Hydrogel (Potassium polyacrylate) had discernible impacts on crop yields when compared to non-treated plants. Remarkably, 100% of the respondents unequivocally confirmed the notable differences in crop yields resulting from the application of Hydrogel [47]. On the other hand, in the Galapagos Islands, a previous study estimated that the use of Hydrogel in Tomato can reduce the consumption of water by 48.3% compared to conventional methods [22]. Similarly, when water consumption was evaluated with the yield of beans (*Phaseolus vulgaris* L.), other high-grade Hydrogel (i.e., specific for the study) had a water efficiency almost double that of conventional watering [48]. Likewise, a study conducted in the province of Pichincha, Ecuador, aimed to assess the effectiveness of Hydrogel, specifically potassium polyacrylate, on the growth of broad beans (*Vicia faba*). The results revealed significant positive effects, with the optimal dosage determined to be 0.6 g per kilogram of substrate [49]. Moreover, several studies show promising results of Hydrogel use in the survival of woody species [35,50,51].

For Growboxx, there is no previous research on the effect of this technology on crop yields. Yet, comparable technologies such as the Waterboxx can reach up to 71% reduction in water consumption [22]. In summary, our study suggests that Hydrogel treatment could be an effective strategy to enhance plant survival under various conditions.

Overall, considering both periods (I) 2017–2018 and (II) 2021, different treatments can have significant effects on the vegetative and productivity traits of different vegetable crops, and the optimal treatment may vary depending on the specific crop and trait of interest. Other studies confirm that crop yield and plant growth increase with Hydrogel use [34,41,52–54]. However, it depends on the type of crop and the environmental conditions [19,20,22].

## 5. Conclusions

This study assessed the effectiveness of water-saving technologies, Hydrogel and Growboxx, on different vegetable crops, including Broccoli, Cucumber, Pepper, Tomato, and Watermelon, in two different periods (2017–2018 and 2021). The results showed that Hydrogel had a positive impact on the growth and productivity of most crops, particularly Tomato and Pepper, whereas the use of Growboxx did not result in better outcomes. The study also found that the effects of water-saving technologies vary depending on the year of cultivation, possibly due to environmental conditions, seed quality, and cultural practices. Therefore, the optimal treatment may vary based on the specific crop and trait of interest (vegetative and productivity traits). Overall, the use of water-saving technologies can be beneficial in improving the productivity of vegetable crops, particularly in regions facing water scarcity. Further research can provide a better understanding of the mechanisms behind the effect of our applied treatments and explore the potential applications of Hydrogel and Growboxx as water-saving technologies in agriculture. Finally, our study highlights the potential of water-saving technologies as an innovative solution to improve crop yields for the Galapagos Islands as well as their further applicability in other insular ecosystems.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/horticulturae9060683/s1. Table S1. Total number of plants sown and productivity of plants by crop and period of cultivation. Table S2. Comparison of average values of vegetative traits in crops grown with Hydrogel and without it (Control) in 2017–2018. Underlined values mean that Hydrogel resulted in better outcomes than the Control. Bold values show statistical differences. For specific statistical values, see Table S3. Table S3. Comparison of average values of vegetative traits in crops grown with Hydrogel and without it (Control) in 2021. Underlined values mean that Hydrogel resulted in better outcomes than the Control. Bold values show statistical differences. For specific statistical values, see Table S3. Table S4. Variability in vegetative and productivity traits based on the effect of treatments separated by time periods. In 2017–2018 the treatment was Hydrogel, and in 2021 Hydrogel and Growboxx. Significant values are represented in bold. Table S5. Comparison between islands in Pepper and Tomato productivity during the 2021 period. Figure S1. Boxplots of treatment differences for Pepper in both cultivation periods. Figure S2. Boxplots of treatment differences for Tomato in both cultivation periods.

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