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# Application of Hydrogel as an Irrigation Alternative for the Pepper Production System in the Santa Lucía Canton, Guayas

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**Abstract:**

The purpose of this research work is to evaluate the application of hydrogel as an irrigation alternative for the pepper production system (Capsicum annuum L.) to obtain better significant effects in the canton of Santa Lucia, Guayas, where the agronomic behavior of the crop and optimal dosage were determined.

The study factor was developed under a DBCA factorial scheme with a split-plot arrangement; the largest plot being the hydrogel doses and the smallest plot the pepper hybrids with 4 replicates per hybrid, obtaining a trial of 24 experimental units. The evaluated treatments were T1 (Absolute control with the Martha R hybrid), T2 (Absolute control with the Nathalie hybrid), T3 (1 gram of hydrogel with the Martha R hybrid), T4 (1 gram of hydrogel with the Nathalie hybrid), T5 (2 grams of hydrogel with the Martha R hybrid), and T6 (2 grams of hydrogel with the Nathalie hybrid) applying furrow irrigation at 0, 10, 25 and 40 days after transplanting along with fertilization and the absolute control once a week. Among the variables are: plant height (cm), days to flowering, days to harvest, number of fruits per plant, fruit weight (g), crop production in kg/ha and economic analysis in cost/benefit ratio. It was concluded that the best productivity obtained was treatment 5 (2 grams of hydrogel with the Martha R hybrid) presenting high averages in the agronomic variables of the crop, a weight of 479.83 grams in three harvests and a yield of 7485.27 kg/ha. The use of hydrogel is agronomically profitable since it allowed water retention and humidity in the soil for a certain time, allowing the plant to assimilate it.

**Keywords:** Hybrid, hydro, hydrogel, pepper, productivity.

## INTRODUCTION

In Ecuador, the majority of the demand for fresh water is concentrated in the agricultural sector, accounting for over 70% of the total due to evapotranspiration from crops, which is necessary for their full development and thus meet the population's nutritional needs. The rational and efficient use of water is of paramount importance, as the same amount is not available in all seasons of the year.(Benavides, 2019)

Given current trends, various innovative techniques are being developed to safeguard water and prevent its waste. Furthermore, the United Nations' demographic projections show that by 2050 the planet will have low water availability, which will impact agriculture as well as other industries.(Loja, 2021)

(Suasnavas, 2021)In this regard, it is mentioned that there is a microreservoir known as hydrogel that increases the soil's water retention capacity, makes better use of rainwater or irrigation, and reduces filtration losses. This contributes to improving the proper management of water requirements, conserving water in short periods of time, minimizing monetary costs, and protecting ecosystems.

(Figueroa, Andrade, Santana, & Menéndez, 2020) It details that the hydrogel is made from chemical compounds based on 94.13% polyacrylamide (potassium acrylate), 5.87% moisture, and absorbs up to 100% of its weight in water without dissolving, extending the crop's irrigation period.

The use of hydrogels produces a significant increase in soil water retention, which is why implementing these hydroretainers improves the soil's physical characteristics and increases agricultural production yields. Hydrogels have been found to as a possible solution to maintain moisture content in soils (Pozo, 2021).

It should be noted that pepper (Capsicum annuum L.) is a crop with high water requirements; insufficient water produces reduced growth in general, and poor absorption of nutrients in particular, leading to diseases. Therefore, the following research topic was raised, which seeks to determine the productive yield of pepper by applying hydrogel as an irrigation alternative.

Due to the low availability of water, the high energy costs for its extraction, the growing demand of the sector, and the increase in the frequency and intensity of climate change, humans are implementing retainers called hydrogels that allow moisture conservation for the plant, that is, an irrigation alternative for retaining water resources in the soil.

Most crops benefit during the rainy season; however, during the dry season, water shortages become a problem, and irrigation costs become more expensive. Added to this is the often insufficient availability, which leads farmers to transport water from surface sources or wells and must pay for both the water and the transportation costs. Therefore, the lack of awareness of new technological methods to maintain moisture available for crops during low water resources and irrigation periods has led small and medium-sized farmers to increase their labor costs, inputs, and other costs, which has been adversely affected financially.

The use of hydrogel in agricultural fields increases moisture retention for plant growth and yield, improves soil structure, prevents crust formation, reduces nutrient loss due to soil erosion, decreases soil compaction, conserves water when rains cease, and enhances infiltration speed, density, and

evaporation rate, all of which benefit farmers economically.

Thanks to this technological advancement, farmers will be able to use the minimum amounts of water required for their crops, extend irrigation frequencies, and, above all, save water resources if availability is low.

Therefore, this research will aim to detail the benefits, advantages, disadvantages, and other characteristics of hydrogel as an irrigation alternative for pepper production systems and to optimize the efficient use of water resources.

Portal Fruticola (2019) mentions that hydrogel is increasingly being used in agriculture to prevent water shortages for crops and other activities. This gel was already known; however, in recent years, interest has been revived due to population growth, climate change, and other physical factors that affect large-scale food production.

González (2017) indicates that the demand for hydrogel in the field of horticulture and forestry has increased significantly. Likewise, the hydrogel when mixed and added in holes in the soil conserves the nutrients in the water, which allows irrigation to be distributed and keeps plants healthy without the need for constant watering. In an investigation carried out by Ortega (2020) he details that he evaluated different levels of hydrogel in pepper crops to lengthen irrigation periods in a silty loam soil, Pedernales - Manabí province, for which he implemented three treatments with doses of 1.5, 2 and 2.5 g of hydrogel per plant and three irrigation frequencies (8, 12 and 16 days), where the dosage of 2.5 g with irrigation every 12 days presented an excellent ability offield, uniform distribution, and significantly significant water savings. The results obtained were positive, reflecting high yields, reduced total water volume used for irrigation, and, above all, improved quality, ensuring that the application of hydrogel improved production.

In the same way, Cacao (2017) evaluated the effect of the hydrogel on the Cacique hybrid in Tuculutan, Zacapa with three treatments (T1-1.19 gr, T2-1.45 gr and T3- 1.92 gr), the dosage of 1.92 gr per plant allows the development of the plant to be more vigorous in height and root system, reducing water consumption by up to 70%, without affecting production costs, minimizing expenses in labor and other inputs, the implementation of this gel provides great advantages for the crop, farmer and above all giving good soil moisture and facilitating its use in different seasons.

**Materials and methods**

The type of research used in this project is applied, documentary, and exploratory research. The goal was to find solutions to specific and practical problems faced by small farmers in the sector, demonstrating the efficient use and savings of water for crops with the use of hydrogel as an irrigation alternative during the dry season.

This research work details information on the application of hydrogel for pepper production, obtained through a compilation of information from undergraduate theses, scientific articles, books, and the virtual library of the UAE (Agrarian University of Ecuador), where truthful and effective foundations will be obtained. The experimental part was carried out at the Santa Rosa compound, belonging to the jurisdiction of the Santa Lucía canton. This process is carried out through a divided plot design with completely randomized blocks. The objective was to evaluate the pepper production system by

applying hydrogel as an irrigation alternative to maintain water retention and extend the irrigation process during the dry season.

The research design used in this project is experimental.

**Table 1. Treatments to be evaluated**

| **No.** | **Treatments** | **Description** | **Larger plot** | **Minor plot** |
|---|---|---|---|---|
| T1 | a1b1 | Absolute witness | Martha R Hybrid |
| T2 | a1b2 | Absolute witness | Hybrid Nathalie |
| T3 | a2b1 | 1 gr per plant | Martha R Hybrid |
| T4 | a2b2 | 1 gr per plant | Hybrid Nathalie |
| T5 | a3b1 | 2 gr per plant | Martha R Hybrid |
| T6 | a3b2 | 2 gr per plant | Hybrid Nathalie |

Description of hydrogel dosage for each treatment Castro, 2022.

**Experimental delimitation**

- Number of treatments: 6
- Number of repetitions: 4 by hybrid
- Number of experimental units: 24
- Length of plots: 4.0m
- Width of plots: 4.0m
- Number of plants per row: 10
- Number of rows per plot: 5
- Number of plants per plot: 50
- Number of plants to be evaluated: 10floors
- Plant spacing: 0.4m
- Row spacing: 0.8m
- Planting area per plot: $16m^2$
- Total area of the experiment: $624m^2$
- Total number of plants: 1200

A randomized complete block design was used to conduct this study, evaluating a split-plot experiment. In this case, factor A, which occupies the larger plot, is represented by the hydrogel doses; while factor B, which occupies the smaller plots, is represented by two pepper hybrids considered in this trial. The experimental units for the small plots measure 4.0 meters wide and 4.0 meters long, containing 5 rows of plants, each containing 10 plants. The large plots contain 2 small plots, defining a dimension of 9 meters wide and 4 meters long.

**Results**

The data obtained on the height of the plant are detailed in table 4, allowing us to conclude that the measurements show a significant difference, 15 days after transplanting there is no significant difference with p-value 0.6721>0.05 due to the homogeneity of the hybrids with a coefficient of variation of 9.06%.

Plant height at 30 days already shows a significant difference. T5, represented by the 2-gram dose of hydrogel, with the Martha R hybrid having a greater height of 33.58 cm, followed by the Nathalie hybrid with the same gram of 31.40 cm. The coefficient of variation was 11.52%.

At 45 days after transplant, a significant difference is also shown, with T5 (2 grams of hydrogel with the Martha R hybrid) having the greatest height of 35.10 cm, followed by the Nathalie T6 hybrid with the same gram of hydrogel 33.08 cm, in T3 with 1 gram of hydrogel with the Martha R hybrid it also gives a high value of 31.50 cm unlike the Nathalie T4 hybrid. Treatments T1 and T2, which are the control treatments, have lower values of 0 grams, the Martha R hybrid with 23.48 cm and the Nathalie hybrid with 23.25 cm. The coefficient of variation for this data is 9.69%.

**Table 2. Plant height at 15, 30 and 45 days (cm).**

| **Treatment** | **larger plot (Dose of hydrogel) parcel** | **minor (Hybrid)** | **No** | **Height 15 days** | | **Height 30 days** | | | **Height 45 days** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1 | Witness | Martha R | 4 | 12.48 | to | 22.25 | c | | 23.48 | c | | |
| T2 | Witness | Nathalie | 4 | 13.2 | to | 22.35 | c | | 23.25 | c | | |
| T3 | (1 gram) | Martha R | 4 | 13.45 | to | 28.4 | c | b | 31.5 | cb | | |
| T4 | (1 gram) | Nathalie | 4 | 13.3 | to | 24.6 | c | b | to | 27.9 | b | to |
| T5 | (2 grams) | Martha R | 4 | 14.18 | to | 33.58 | | b | to | 35.1 | b | to |
| T6 | (2 grams) | Nathalie | 4 | 13.88 | to | 31.4 | | | to | 33.08 | | to |
| CV (%) | | | | **9.06** | | **11.52** | | | | **9.69** | | |

Means with a common letter are not significantly different (p > 0.05) Castro, 2023

### 1.1.1 Days to flowering

Table 5 describes the days in which the pepper plant reaches flowering and it can be detailed that the T5 treatment established by the Martha R hybrid and two grams of hydrogel presents statistical differences of 63.50 days, this being the closest to the difference in the T6 treatment of the Nathalie hybrid with two grams of hydrogel.

64.50 days. Treatment T2, the absolute control with the Nathalie hybrid, was shorter than all treatments at 68.75 days. A variance analysis for this variable showed a coefficient of variation of 1.00%.

**Table 3. Days to flowering**

| **Treatment** | **larger plot (Hydrogel dose)** | **minor plot (Hybrid)** | **No.** | **Days to flowering** | |
|---|---|---|---|---|---|
| T1 | Witness | Martha R | 4 | 67.25 TO | |
| T2 | Witness | Nathalie | 4 | 68.75 TO | |
| T3 | (1 gram) | Martha R | 4 | 65.00 | b |
| T4 | (1 gram) | Nathalie | 4 | 65.25 | bc |
| T5 | (2 grams) | Martha R | 4 | 63.50 | bc |
| T6 | (2grams) | Nathalie | 4 | 64.50 c | |
| CV (%) | **1.00** | | | | |

Means with a common letter are not significantly different (p > 0.05) Castro, 2023

### 1.1.2 Days to harvest

Regarding the variable days to harvest, it was possible to show that, through an analysis of variance, a coefficient of variation of 0.56% was presented and resulting in no significant difference in the treatments with doses of hydrogel showing an equal value of 90.00 days, the control treatments T1 and T2 also do not show significant difference between them.

**Board 4. Days to harvest.**

| **Treatment** | **larger plot (Hydrogel dose)** | **minor plot (Hybrid)** | **No.** | **Days to the harvest** | |
|---|---|---|---|---|---|
| T1 | Witness | Martha | 4 | 94.75 | to |
| T2 | Witness | Nathalie | 4 | 95.00 | to |
| T3 | (1 gram) | Martha | 4 | 90.00 | b |
| T4 | (1 gram) | Nathalie | 4 | 90.00 | b |
| T5 | (2 grams) | Martha | 4 | 90.00 | b |
| T6 | (2 grams) | Nathalie | 4 | 90.00 | b |
| CV (%) | | | | **0.56** | |

Means with a common letter are not significantly different (p > 0.05) Castro, 2023

### 1.1.3 Number of fruits per plant

Regarding the variable number of fruits per plant, an analysis of variance shows a p-value of 0.9952>0.05, showing that there is no significant difference between the treatments, as shown in Table 7. However, the data do show numerical significance between the treatments, where the highest value was the T5 treatment with two grams of hydrogel with the Martha R hybrid, showing an average of

8.23 fruits compared to the T2 control of the Nathalie hybrid, which presented an average of 4.68 fruits, being the lowest; likewise, the T1 control treatment with the hybrid Martha R. showed an average of 5.25 fruits proportionally. This shows a coefficient of variation of 23.65%.

**Table 5. Number of fruits per plant 1st 2nd and 3rd harvest.**

| **Treatment** | **larger plot (Dose hydrogel)** | **minor plot (Hybrid)** | **No.** | **Number of fruits** | |
|---|---|---|---|---|---|
| T1 | Witness | Martha R | 4 | 5.25 | TO |
| T2 | Witness | Nathalie | 4 | 4.68 | TO |
| T3 | (1 gram) | Martha R | 4 | 8.08 | TO |
| T4 | (1 gram) | Nathalie | 4 | 7.48 | TO |
| T5 | (2 grams) | Martha R | 4 | 8.23 | TO |
| T6 | (2 grams) | Nathalie | 4 | 7.78 | TO |
| CV (%) | | | | **23.65** | |

Means with a common letter are not significantly different (p > 0.05) Castro, 2023

### 1.1.4 Weight of fruits

The fruit weight shown in Table 8 shows that the results obtained for this variable showed a numerical difference between the hydrogel treatments and the control treatments, where treatment T5 of the Martha R hybrid with 2 grams of hydrogel had a higher value of 479.83 grams and treatment T6 of the Nathalie hybrid with the same gram of hydrogel of 442.13 grams, followed by treatment T3 (1 gram of hydrogel per Martha R hybrid) of 420.43 grams and T4 (1 gram of hydrogel per Nathalie hybrid) with 398.73 grams. The controls indicated the lowest values in the evaluation without presenting significance. The coefficient of variation obtained through this analysis is 16.23%.

**Table 6. Fruit weight 1st 2nd and 3rd harvest**

| **Treatment** | **larger plot (Hydrogel dose)** | **minor plot (Hybrid)** | **No.** | **Fruit weight** | |
|---|---|---|---|---|---|
| T1 | Witness | Martha R | 4 | 352.10 | b |
| T2 | Witness | Nathalie | 4 | 328.28 | b |
| T3 | (1 gram) | Martha R | 4 | 420.43 | to |
| T4 | (1 gram) | Nathalie | 4 | 398.73 | ab |
| T5 | (2 grams) | Martha R | 4 | 479.83 | to |
| T6 | (2 grams) | Nathalie | 4 | 442.13 | to |
| C.V (%) | | | | **16.23** | |

Means with a common letter are not significantly different (p > 0.05) Castro, 2023

## 1.2 Determination of optimal hydrogel dosage for pepper cultivation.

### 1.2.1 Production (kg/ha)

Table 9 shows the averages obtained from the production of the pepper crop, treatments T6, T5, T4, T3 did not show significant differences between them, but numerical differences are shown where treatment 6 of the Martha R hybrid with two grams of hydrogel obtained an average greater than 7485.37 kg / ha, and the Nathalie variety 6897.15 kg / ha, also treatments T3 (1 gram of hydrogel with the Martha R hybrid) with 6558.63 kg / ha and T4 (1 gram of hydrogel with the Nathalie hybrid) with 6220.11 kg / ha. The control treatments showed lower values, also without significant differences, T1 5492.76 kg / ha and T2 5121.09 kg / ha. The coefficient of variation was 15.26%.

**Table 7. Pepper crop production (kg/ha).**

| **Treatment** | **larger plot** | **smaller plot (Hybrid)** | **No.** | **Production kg/ha** | |
|---|---|---|---|---|---|
| **(Hydrogel dose)** | | | | | |
| T1 | Witness | Martha R | 4 | 5492.76 | B |
| T2 | Witness | Nathalie | 4 | 5121.09 | B |
| T3 | (1 gram) | Martha R | 4 | 6558.63 | TO |
| T4 | (1 gram) | Nathalie | 4 | 6220.11 | TO |
| T5 | (2 grams) | Martha R | 4 | 7485.27 | TO |
| T6 | (2 grams) | Nathalie | 4 | 6897.15 | TO |
| CV (%) | | | | **15.26** | |

Means with a common letter are not significantly different (p > 0.05)

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## 1.3 Carrying out an economic analysis of the benefit/cost ratio of the research treatments

In the economic cost analysis projection of pepper cultivation that includes income, expenses, profits, and cost benefit ratio, they were estimated for one hectare in eight crop cycles derived from two years that the hydrogel yields, specifying it in dry season and rainy season where it is detailed in Table 10. The profitability of the witnesses in the initial stage indicates being the most profitable with a value of $ 1.30 in the Martha R hybrid and $ 1.29 in the Nathalie hybrid, respectively, in the following crop cycles, the best profitability that is projected is in treatment T5 (2 grams of hydrogel with the Martha R hybrid) followed by treatment T6 (2 grams of hydrogel with the Nathalie hybrid).

**Table 8. Economic analysis in relation to benefit/cost in pepper cultivation.**

**First cycle / Dry Season**

| | Income | Expenses | Utilities | Benefit/cost |
|---|---|---|---|---|
| Absolute Witness / Hybrid Martha R | 4668.846 | 3625.00 | 1043.85 | 1.30 |
| Absolute Witness / Hybrid Nathalie | 4352.9265 | 3625.00 | 727.93 | 1.29 |
| 1 gr per plant / Martha R Hybrid | 5574.8355 | 4274.90 | 1299.94 | 1.20 |
| 1 gr per plant / Nathalie Hybrid | 5287.0935 | 4274.90 | 1012.19 | 1.24 |
| 2 gr per plant / Martha R Hybrid | 6362.4795 | 5054.90 | 1307.58 | 1.26 |
| 2 gr per plant / Nathalie Hybrid | 5862.5775 | 5054.90 | 807.68 | 1.16 |

**Second cycle / Dry Season**

| | Income | Expenses | Utilities | Benefit/cost |
|---|---|---|---|---|
| Absolute Witness / Hybrid Martha R | 5135.7306 | 3625.00 | 1510.73 | 1.42 |
| Absolute Witness / Hybrid Nathalie | 4788.21915 | 3625.00 | 1163.22 | 1.32 |
| 1 gr per plant / Martha R Hybrid | 6132.31905 | 4574.90 | 1557.42 | 1.34 |
| 1 gr per plant / Nathalie Hybrid | 5815.80285 | 4574.90 | 1240.90 | 1.27 |
| 2 gr per plant / Martha R Hybrid | 6998.72745 | 4574.90 | 2423.83 | 1.53 |
| 2 gr per plant / Nathalie Hybrid | 6448.83525 | 4574.90 | 1873.94 | 1.41 |

**third cycle / Rainy Season**

| | Income | Expenses | Utilities | Benefit/cost |
|---|---|---|---|---|
| Absolute Witness / Hybrid Martha R | 5392.51713 | 3505.00 | 1887.52 | 1.42 |
| Absolute Witness / Hybrid Nathalie | 5027.630108 | 3505.00 | 1522.63 | 1.43 |
| 1 gr per plant / Martha R Hybrid | 6438.935003 | 4514.90 | 1924.04 | 1.43 |
| 1 gr per plant / Nathalie Hybrid | 6106.592993 | 4514.90 | 1591.69 | 1.35 |
| 2 gr per plant / Martha R Hybrid | 7348.663823 | 4514.90 | 2833.76 | 1.63 |
| 2 gr per plant / Nathalie Hybrid | 6771.277013 | 4514.90 | 2256.38 | 1.50 |

**Fourth cycle / Rainy Season**

| | Income | Expenses | Utilities | Benefit/cost |
|---|---|---|---|---|
| Absolute Witness / Hybrid Martha R | 5554.292644 | 3505.00 | 2049.29 | 1.38 |
| Absolute Witness / Hybrid Nathalie | 5178.459011 | 3505.00 | 1673.46 | 1.48 |

| | | | | |
|---|---|---|---|---|
| 1 gr per plant / Martha R Hybrid | 6632.103053 | 4514.90 | 2117.20 | 1.47 |
| 1 gr per plant / Nathalie Hybrid | 6289.790782 | 4514.90 | 1774.89 | 1.39 |
| 2 gr per plant / Martha R Hybrid | 7569.123737 | 4514.90 | 3054.22 | 1.68 |
| 2 gr per plant / Nathalie Hybrid | 6974.415323 | 4514.90 | 2459.52 | 1.54 |

**Fifth cycle / Dry Season**

| | **Income** | **Expenses** | **Utilities** | **Benefit/cost** |
|---|---|---|---|---|
| Absolute Witness / Hybrid Martha R | 5554.292644 | 3806.25 | 1748.04 | 1.46 |
| Absolute Witness / Hybrid Nathalie | 5178.459011 | 3806.25 | 1372.21 | 1.36 |
| 1 gr per plant / Martha R Hybrid | 6731.584598 | 4803.65 | 1927.94 | 1.40 |
| 1 gr per plant / Nathalie Hybrid | 6384.137644 | 4803.65 | 1580.49 | 1.33 |
| 2 gr per plant / Martha R Hybrid | 7682.660593 | 4803.65 | 2879.02 | 1.60 |
| 2 gr per plant / Nathalie Hybrid | 7079.031553 | 4803.65 | 2275.39 | 1.47 |

**Sixth cycle / Dry Season**

| | **Income** | **Expenses** | **Utilities** | **Benefit/cost** |
|---|---|---|---|---|
| Absolute Witness / Hybrid Martha R | 5554.292644 | 3806.25 | 1748.04 | 1.46 |
| Absolute Witness / Hybrid Nathalie | 5178.459011 | 3806.25 | 1372.21 | 1.36 |
| 1 gr per plant / Martha R Hybrid | 6765.242521 | 4803.65 | 1961.60 | 1.41 |
| 1 gr per plant / Nathalie Hybrid | 6416.058332 | 4803.65 | 1612.41 | 1.34 |
| 2 gr per plant / Martha R Hybrid | 7721.073896 | 4803.65 | 2917.43 | 1.61 |
| 2 gr per plant / Nathalie Hybrid | 7114.42671 | 4803.65 | 2310.78 | 1.48 |

**Seventh cycle / Rainy Season**

| | **Income** | **Expenses** | **Utilities** | **Benefit/cost** |
|---|---|---|---|---|
| Absolute Witness / Hybrid Martha R | 5554.292644 | 3855.50 | 1698.79 | 1.44 |
| Absolute Witness / Hybrid Nathalie | 5178.459011 | 3855.50 | 1322.96 | 1.34 |
| 1 gr per plant / Martha R Hybrid | 6785.538249 | 4560.05 | 2225.49 | 1.49 |
| 1 gr per plant / Nathalie Hybrid | 6435.306507 | 4560.05 | 1875.26 | 1.41 |
| 2 gr per plant / Martha R Hybrid | 7744.237118 | 4560.05 | 3184.19 | 1.70 |
| 2 gr per plant / Nathalie Hybrid | 7135.769991 | 4560.05 | 2575.72 | 1.56 |

**Eighth cycle / Rainy Season**

| | Income | Expenses | Utilities | Benefit/cost |
|---|---|---|---|---|
| Absolute Witness / Hybrid Martha R | 5554.292644 | 3855.50 | 1698.79 | 1.44 |
| Absolute Witness / Hybrid Nathalie | 5178.459011 | 3855.50 | 1322.96 | 1.34 |
| 1 gr per plant / Martha R Hybrid | 6765.181634 | 4560.05 | 2205.13 | 1.48 |
| 1 gr per plant / Nathalie Hybrid | 6416.000588 | 4560.05 | 1855.95 | 1.41 |
| 2 gr per plant / Martha R Hybrid | 7721.004407 | 4560.05 | 3160.96 | 1.69 |
| 2 gr per plant / Nathalie Hybrid | 7114.362681 | 4560.05 | 2554.31 | 1.56 |

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Below, Table 11 details the economic analysis of the payback period for using hydrogel in pepper cultivation. According to the Ministry of Agriculture and Livestock (MAGAP, 2021), the interest rate for irrigation and plant breeding is 6.79%.

**Table 9. Economic analysis of amortization with application of hydrogel in pepper cultivation.**

**1st year 2ndyear**

| | First cycle | Second cycle | Third cycle | Fourth cycle | Fifth cycle | Sixth cycle | Seventh cycle | Eighth cycle |
|---|---|---|---|---|---|---|---|---|
| **Cash flow** | -5054.90 | 980.00 | 980.00 | 980.00 | 980.00 | 980.00 | 980.00 | 980.00 |
| **Updated balanceat 6.79%** | -5054.90 | 911.60 | 847.97 | 788.78 | 733.72 | 682.51 | 634.87 | 590.56 |
| **Accumulated balance** | -5054.90 | -4143.30 | -3295.33 | -2506.55 | -1772.83 | -1090.32 | -455.46 | 135.09 |

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**RATE:**6.79% NPV: $11,153.24 IRR: 12%

**PRI:**1 year and 8 months

**DISCUSSION**

According to the results obtained, it is stipulated that the pepper hybrids Nathalie and Martha R plus

the different doses of hydrogel (1 gram and 2 grams) were adapted in the experimental field, the test data showed that the different doses of hydrogel influenced the production, optimizing the agronomic variables of the fruit and growth in the plant, which qualified the T5 treatment of two grams of hydrogel with the Martha R hybrid as the one with the highest statistical average; in the measurement of plant height at 15 days it exposed data of 14.18 in height after transplantation, followed by 30 days with 33.58, and in the last evaluation of 45 days with 35.10, in days to flowering it presented a statistical amount of 63.50 days, in number of fruit per plant an average of 8.23 number of fruits, and 479.83 grams in fruit weight. Ortega (2020) explains that the use of hydrogel in pepper cultivation influences the agronomic response of the pepper crop, which shows that in the research carried out, relatively high averages were obtained with the application.

According to the second objective, it was detailed which of the treatments through the application of hydrogel yields positively in the production kg / ha of the pepper crop. Treatment T5 represented by two grams of hydrogel together with the Martha R pepper hybrid obtained the highest average yield 7485.37 kg / ha. According to Rivera and Moreira (2019) they show that the cultivation of pepper with the application of hydrogel generates fruits where if its weight is feasible, a higher yield per unit of area increases. The research work shows that the best and highest yield was with two grams of hydrogel at 16 days of irrigation of 19845 kg / ha.

Finally, in the third objective, an economic analysis of the study treatments was projected in relation to cost benefit and economic analysis of amortization, where in the initial cycle of benefits-costs the control treatments presented higher values of $ 1.29 and $ 1.30 in the dry season, for this in the following vegetative cycle it is agreed that the treatments with hydrogel begin with higher incomes, being treatment 5 (2 grams of hydrogel with the Martha R hybrid) the highest profitability both in dry and rainy seasons, followed by treatment 6 (2 grams of hydrogel with the Nathalie hybrid). In the amortized economic analysis, an NPV of $ 11,153.24 is presented, the IRR of 12% and the recovery period of the investment occurs in 1 year and 8 months. According to Ortega, Guevara, and Ramón (2020), the hydrogel provides monetary benefits to the farmer, lasting 3 to 5 years, allowing it to adapt to any type of crop, optimizing development and growth, helping to save water resources, and being an environmentally friendly substance, among other qualities.

## CONCLUSIONS

Hydrogel doses agronomically influence the growth and development of the pepper crop in the Nathalie and Martha R. hybrids, allowing for the optimization of water resources with 15-day irrigation during the dry season using a gravity-fed irrigation system.

The Martha R and Nathalie hybrids used in this research performed well in terms of plant development and weight, which demonstrates their ability to adapt to the area and their lower incidence of disease.

The T5 treatment of two grams of hydrogel with the Martha R hybrid obtained a higher average yield of 7485.37 kg/ha, and the T6 treatment with the Nathalie hybrid yielded 6897.15 kg/ha. This was followed by the T4 treatment of one gram of hydrogel with the Martha R hybrid, which also presented a higher numerical value of 6558.63 kg/ha, and the T3 treatment with the Nathalie hybrid yielded 6220.11 kg/ha.

The use of hydrogel obtained good results in productivity by extending the irrigation frequency in pepper crops, but it is argued that the commercial value of the product and the dosage applied per plant increases its cost benefit in its initial cycle. This is due to the purchase of the product, but in the amortization carried out in this research it is estimated that the investment recovery site begins at one year and eight months and the cost benefit begins after the second vegetative cycle, showing treatment 5 (Two grams of hydrogel with the Martha R hybrid) as the most profitable since no expenses are made again followed by irrigation only at times determined by the application of hydrogel having a durability of 3 to 5 years.

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