EFFECTS OF DEFICIENT IRRIGATION ON THE YIELD OF CELERY (Apium graveolens) crops, KELVIN RZ F1 VARIETY IN LA MOLINA

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Summary
The objective of this study was to evaluate the effect of four levels of deficit irrigation (100%, 80%, 70% and 60% of evapotranspirative demand) on yield and water productivity in the cultivation of celery (*Apium graveolens*), Kelvin RZ F1 variety, using a drip irrigation system. The research was carried out at the Center for Research and Extension of Irrigation (CIER) of the National Agrarian University La Molina.
The irrigation time was calculated daily based on the crop evapotranspiration (ETc), estimated using the class "A" evaporometer tank, using crop coefficients (Kc) adjusted to the phases of phenological development of celery. The experimental design was completely randomized (DCA) with four treatments and three replications, resulting in a total of 12 experimental units. The agronomic variables evaluated were plant height, stem diameter, fresh weight and yield, in addition to the quantification of the volume of water applied and water productivity.
The results showed that the T1 treatment (100% of the demand) obtained the best values in the evaluated variables, with an average height of 79.0 cm, a stem diameter of 99.6 mm and a fresh weight of 1.54 kg, reaching a maximum yield of 85.4 t/ha. However, the T2 (80%), T3 (70%) and T4 (60%) treatments achieved water savings of 19.58%, 26.12% and 13.06%, respectively, compared to T1. Despite the reduction in the irrigation sheet, the yields obtained were 74.2 t/ha (T2), 68.0 t/ha (T3) and 79.6 t/ha (T4), demonstrating that moderate levels of deficit irrigation can maintain an acceptable production.
Water productivity was higher in the T2 and T3 treatments, with values of 39.1 kg/m³, compared to 36.4 kg/m³ in T1. These results suggest that the application of a deficit irrigation of 70% of the evapotranspirative demand can be an efficient strategy to optimize water use without significantly affecting crop production. The implementation of these practices can contribute to sustainable water resource management in agriculture, especially in regions with limited water availability.
Keywords: Deficit irrigation, drip irrigation, *Apium graveolens*, water productivity, efficient irrigation management.

1. Introduction

The cultivation of celery (*Apium graveolens*) has an outstanding nutritional and medicinal value, being recognized for its anti-inflammatory properties and its use in the treatment of conditions such as rheumatoid arthritis, cystitis and urethritis. In addition, its frequent consumption contributes to the well-being of the urinary tract and joints, which makes it a functional food appreciated in various cultures (Vigliola, 1992). However, celery cultivation, like other vegetables, faces significant challenges in terms of sustainability, especially when it comes to the efficient use of water, an essential and increasingly limited resource.
Globally, agriculture consumes approximately 70% of available freshwater, and in developing countries, this figure can reach up to 90% (FAO, 2002). With the global population projected to reach 9,700 million people by 2050, it is estimated that food production will need to increase by at least 60% (FAO, 2021). This scenario raises the urgent need to implement strategies to maximize agricultural productivity with a more efficient use of water resources, especially in regions affected by water scarcity.
In Peru, agriculture represents a fundamental pillar of the economy, especially in rural areas where vegetable cultivation predominates. The drip irrigation system has established itself as a key technology to improve water efficiency, by supplying water accurately and minimizing losses due to evaporation and runoff. Within this context, controlled deficit irrigation (CDR) emerges as a promising strategy to optimize water use in agricultural crops. This technique, developed since the 1980s, consists of applying reduced volumes of water

during phenological periods that are less sensitive to water stress, maintaining acceptable yields and reducing total water consumption (Chalmers et al., 1985; Sánchez &Torrecillas, 1995).
The present study focuses on evaluating the impact of deficit irrigation on yield and water productivity in the cultivation of celery, Kelvin RZ F1 variety, under controlled conditions at the National Agrarian University La Molina. This work seeks not only to contribute to the technical-scientific knowledge on irrigation management in horticultural crops, but also to offer practical alternatives that can be implemented by farmers in regions where water availability is limited.
The choice of celery as the object of study responds to its economic importance in the Peruvian agricultural sector and the growing demand in national and international markets. In addition, its water-intensive cultivation nature makes it an ideal model for evaluating efficient irrigation strategies. Through this study, it is expected to generate valuable information that will allow balancing environmental sustainability with agricultural profitability, promoting more responsible practices in the management of water resources.

2. Objectives

2.1 General objective

To evaluate the yield in the cultivation of celery (Apium graveolens), Kelvin RZ F1 variety, using deficit irrigation (100%, 80%, 70% and 60% of demand), which was carried out at the Center for Research and Extension of Irrigation of the National Agrarian University La Molina.

2.2 Specificobjectives

- ✓ Determine the volume of water using 4 different sheets, by means of deficit irrigation.
- ✓ Determine the yield of celery (Apium graveolens) production with different irrigation sheets.
- ✓ To determine the water productivity in the cultivation of celery (Apium graveolens) by applying deficit irrigation with 4 different sheets.

3. Methodology

The methodology of the study was experimental, designed to evaluate the effects of deficit irrigation (100%, 80%, 70% and 60% of evapotranspirative demand) on the yield and productivity of the celery (*Apium graveolens*) crop, Kelvin RZ F1 variety. The following are the key aspects of the methodology applied:

3.1 Location of the Experimental Area

3.1.1 Location of the study area

This research was carried out at the facilities of the Center for Research and Extension of Irrigation (CIER) of the Academic Department of Water Resources of the National Agrarian University La Molina, located in the district of La Molina, province and department of Lima.
Altitude: 233 meters above sea level.
Longitude: 76°56'56"W
Latitude: 12° 5'1.45"S
Temperature: 15 – 28 °C

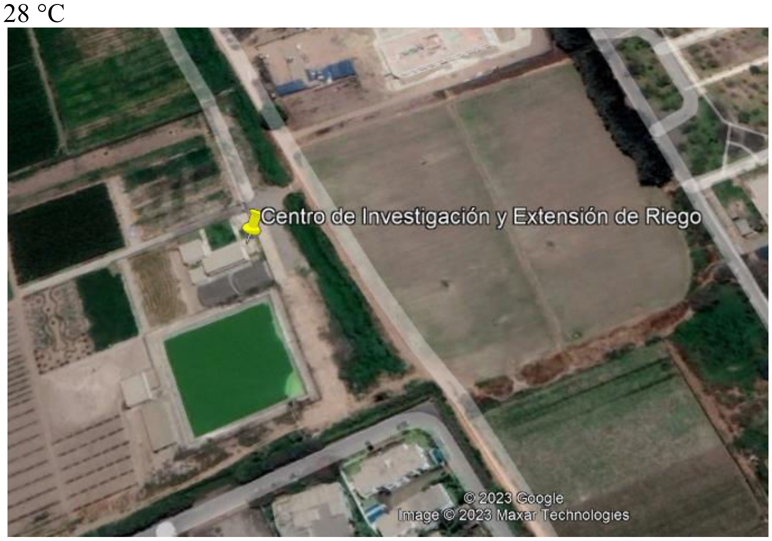

Figure 5: Location of the Research Center

Source: Google Earth, 2023.

3.1.2 Weather conditions

The meteorological information on the climate in the district of La Molina was obtained through the Water Resources station, located at UNALM, belonging to the Faculty of Agricultural Engineering (FIA), taking into account the record of the duration of this research, which was carried out from March 2023 to June of the same year. Where the average maximum temperature was 32.9°C recorded in April, and the average minimum temperature was 16.9°C on June 4.

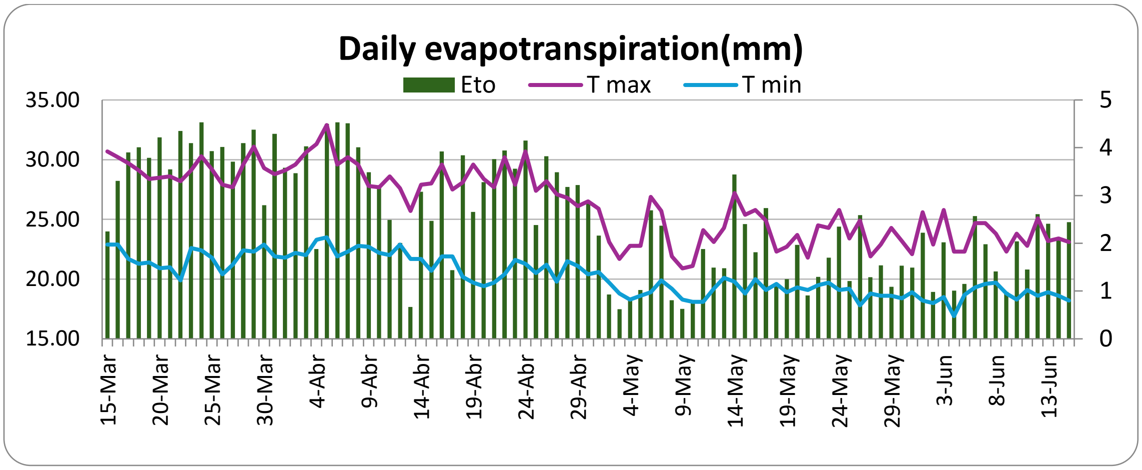

Figure 2: Average temperatures and evapotranspiration

3.1.3 Duration of the study

The study began on March 15, 2023 and ended on June 15 of the same year, in this period of time, first there was a uniform irrigation until 28 days after transplanting (DDT), and then 4 treatments were applied with different irrigation sheets (100%, 80%, 70% and 60% of evapotranspiration). according to the phenology of the crop in which it was found. Finally, the samples were evaluated and analyzed as indicated in the specific objectives.

3.1.4 Laboratory analysis

3.1.4.1 Soil characterization

The physicochemical characterization of the soil of the study area was carried out in the agricultural chemistry laboratory - Valle Grande, located in Huaral. The analysis was of two representative samples taken at depths of 40 cm and 20 cm. According to the results of the characterization analysis, the soil has a sandy clay loam texture at a depth of 20 cm and a sandy-loam texture at a depth of 40 cm, a PH of 7.76 and 7.61 was also obtained, being slightly alkaline and the organic matter of 1.03 % and 1.21% (considered low), at 40 and 20 cm, respectively.

3.1.4.2 Characterization of water for irrigation

The water used to irrigate the celery crop was extracted from the reservoir located in the irrigation extension research center (CIER), belonging to the Faculty of Agricultural Engineering, at UNALM. For its evaluation, a sample of water was taken from the reservoir, which was analyzed in the Laboratory of Analysis of Soils, Plants, Water and Fertilizers (LASPAF) of the Faculty of Agronomy, in table 4 the results of the analysis are presented, which when compared with the Water Quality Standards (ECA), category 3 Irrigation of low-stemmed and high-stemmed vegetables (D.S. No. 002-2008-MINAM). they show that their quality is suitable for vegetable irrigation. Thus, as a result of the electrical conductivity (EC) the value of 0.99 dS/m, being less than 2 dS/m, the ECAS indicated that there is no risk of salinity. Italsohad a slightlyalkaline pH.

Parameter	Unit	Value
pH	-	8.6
CE	dS/m	0.99
Calcium	meq/L	5.75
Magnesium	meq/L	1.35
Potassium	meq/L	0.33
Sodium	meq/L	2.78
Sum of cations	-	10.21
Nitrates	meq/L	0.0
Carbonates	meq/L	0.0
Bicarbonates	meq/L	1.95
Sulphates	meq/L	1.51
Chlorides	meq/L	6.90
Sum of Anions	-	10.30
Sodium	%	27.24
EVENNESS	-	1.48
Boron	Ppm	0.51
Classification	-	C3 - S1
Phosphate	Ppm	1.77
Alkalinity	Ppm	118.80

Table 1. Water analysis results

3.2 Materials and Equipment

3.2.1 Plant material

- ✓ Celery seedlings, Kelvin RZ F1 variety from RIJK ZWAAN

3.2.2 Irrigationsystems and inputs

- ✓ High frequency pressurized irrigation head
- ✓ Drip irrigation system
- ✓ Venturi type injection fertigation equipment
- ✓ Reservoir with water for irrigation

3.2.3 Equipment

- ✓ 20 l backpack sprayer
- ✓ Digital Scale
- ✓ Sample drying oven
- ✓ Tape Measure
- ✓ Humidity Sensor (TDR-150)
- ✓ Vernier Caliper
- ✓ Class A evaporimeter tank

3.2.4 Fertilisers and phytosanitary inputs

- ✓ Humic acids
- ✓ Potassium chloride
- ✓ Potassium Sulfate
- ✓ Potassium nitrate
- ✓ Ammonium nitrate
- ✓ Calcium nitrate
- ✓ Magnesium nitrate
- ✓ Monoammonium phosphate
- ✓ Nutrisorb
- ✓ Gel Tec K

- ✓ Fruit XL
- ✓ Medal
- ✓ Embark 90 SC
- ✓ Kohinor 350 SC

3.2.5 Others

- ✓ Rake
- ✓ Hoes
- ✓ Shovels
- ✓ Jump ropes
- ✓ Agro-industrial glue
- ✓ Containers
- ✓ Field notebook
- ✓ Pen
- ✓ Laptop
- ✓ Reed
- ✓ Colored plastic
- ✓ Leaves

3.3 Research methodology

The methodology was experimental, where the procedure was as follows:

4.3.1 Preparation of the land

In the preparation of the land, agricultural machinery was used which carried out the leveling and ploughing work, in order to soften the soil, later, the furrower traced a total of 15 furrows in the land. A day before planting, a crush irrigation was carried out for 3 hours, in order to moisten the surface layers of the soil, and facilitate the transplanting of celery seedlings, as well as avoid the appearance of any pest. On March 15, 2023, 3975 celery seedlings were transplanted, respecting the planting density, with a distance of 0.2 m between plants and 0.9 m between rows.

3.3.2 Using the Evaporimeter Tank

For the management of daily evapotranspiration, the class "A" evaporimeter tank, belonging to the FIA, was used as meteorological equipment, as well as climatic records of the station belonging to Water Resources, to carry out the irrigation programming corresponding to the 4 different sheets.

3.3.3 Irrigation System Installation

A surface drip irrigation system was installed, with drip tapes corresponding to the aries 16150 model of the Netafim brand, with an emitting flow of 0.95 l/h at 1 bar of operation, with a distance between drippers of 0.20 m. The tape was installed 0.2 meters from the planting bed, a row of celery was transplanted per row.

The research center has an automated irrigation booth, where the primary network is connected to the secondary networks, and they join the tertiary network. The system has an automated irrigation shed, with pressure regulating valves, check valves, pressure gauges, filter system with rings, pumps, Venturi-type fertilization equipment, flow meters, etc. Finally, there was an irrigation arch where the distribution of irrigation could be regulated, and in turn the tapes had stopcocks, where the passage of water was opened and closed.

3.3.4 Experimental design and layout

The research was based on a Completely Randomized Design, with 4 treatments and 3 replications, where the treatments were different percentages of irrigation sheets.

Treatment	Etc (mm/day) (%)
T1 (Witness)	100
S2	70
S3	60
S4	80

Table 2. Treatments according to percentage of Etc

4. Results and discussions

4.1 5.1 Uniformity Coefficient Test

The test was carried out in the experimental field, with 5 repetitions distributed in the 15 grooves, at different pressure levels. Data collection was at the beginning of the furrow, then at 15m from the start, 30m, and at 50m. Thefollowingequationwas used:

$$CU_g = 100 * (\frac{Q_{25}}{Q_n})$$

Where:

- ✓ Q25: Average of the values of the lowest 25% of the expenditure recorded in the issuer
- ✓ Qn: Average of total spending values

The uniformity coefficient of the Aries Netafim dripper is 92%, which indicated a fairly even distribution of water in the irrigation area. This parameter was essential to ensure optimal plant growth and avoid over- or under-irrigation.

Pressure (m)	Repetitions	0m (ml)	15m (ml)	30m (ml)	50m (ml)	Prom (ml)	Conversion (l/hr)	Prom (l/hr)
5	Take 1	20.00	19.00	16.00	17.50	18.13	1.09	1.08
	Take 2	19.00	19.00	17.00	17.00	18.00	1.08	
17	Take 1	17.00	17.50	17.00	16.00	16.88	1.01	1.02
	Take 2	17.50	17.00	17.00	17.00	17.13	1.03	
17	Take 1	17.00	17.50	18.00	18.00	17.63	1.06	1.07
	Take 2	18.00	18.00	18.00	18.50	18.13	1.09	
5	Take 1	18.00	18.00	18.00	19.00	18.25	1.10	1.06
	Take 2	17.00	17.00	18.50	16.00	17.13	1.03	
17	Take 1	19.00	19.00	18.00	17.00	18.25	1.10	1.11
	Take 2	19.00	19.00	19.00	18.00	18.75	1.13	

Table 3: Data taken for the CU

PartialProm (l/hr)	Minimum (ml)	MinimumProm (l/hr)	Partial total prom (l/hr)	Coef. Uniformity (%)
1.08	16.00			
1.02	16.00			
1.07	17.00	0.984	1.07	92.01
1.06	16.00			
1.11	17.00			

Table 4: UC calculation

4.2 Calculated Irrigation Sheets

The gross sheets shown in Table 5 are slightly lower than the net sheets, since the coefficient of uniformity is 0.92. In terms of total quantities, T1 had a total of 211.06mm of foil, while T2, 169.78mm, T3, 156.01mm and T4 a total of 183.53mm.

Table 6 shows the values of the net irrigation sheets calculated for each treatment throughout the vegetative period of the crop; Until day 28 after transplanting, the sheets remained the same for the four treatments, that is, equal irrigation was applied, after that date the water deficit began with the four treatments (100%, 80%,

70% and 60% of the demand), varying the kC for day 28 and 76, thus having a water deficit that was maintained until harvest.
It is important to clarify that the values set out in tables 6. They are the ones that were calculated to send the irrigation time through the shed. Because irrigation management was quantified in the applied time, the reduction of these times calculated for the water deficit was taken as a strategy, and when the times were low and some plants manifested themselves, they ended up being given a few more minutes of irrigation.

DDT	Lnb1 (mm)	Lnb4 (mm)	Lnb2 (mm)	Lnb3 (mm)	DDT	Lnb1 (mm)	Lnb4 (mm)	Lnb2 (mm)	Lnb3 (mm)	DDT	Lnb1 (mm)	Lnb4 (mm)	Lnb2 (mm)	Lnb3 (mm)
0	1.712	1.712	1.712	1.712	31	4.474	3.579	3.132	2.684	62	3.127	2.502	2.189	1.876
1	2.518	2.518	2.518	2.518	32	1.643	1.315	1.150	0.986	63	1.278	1.023	0.895	0.767
2	2.967	2.967	2.967	2.967	33	4.383	3.506	3.068	2.630	64	1.427	1.141	0.999	0.856
3	3.051	3.051	3.051	3.051	34	3.036	2.429	2.125	1.822	65	2.248	1.799	1.574	1.349
4	2.884	2.884	2.884	2.884	35	3.743	2.995	2.620	2.246	66	1.039	0.831	0.727	0.623
5	3.211	3.211	3.211	3.211	36	4.291	3.433	3.004	2.575	67	1.484	1.187	1.039	0.890
6	2.701	2.701	2.701	2.701	37	4.497	3.597	3.148	2.698	68	1.940	1.552	1.358	1.164
7	3.310	3.310	3.310	3.310	38	4.063	3.250	2.844	2.438	69	2.682	2.146	1.877	1.609
8	3.120	3.120	3.120	3.120	39	4.736	3.789	3.315	2.842	70	1.381	1.105	0.967	0.829
9	3.447	3.447	3.447	3.447	40	2.716	2.173	1.901	1.630	71	2.956	2.365	2.069	1.774
10	2.990	2.990	2.990	2.990	41	4.360	3.488	3.052	2.616	72	1.472	1.178	1.031	0.883
11	3.059	3.059	3.059	3.059	42	3.983	3.187	2.788	2.390	73	1.758	1.406	1.230	1.055
12	2.823	2.823	2.823	2.823	43	3.629	2.903	2.541	2.178	74	1.244	0.995	0.871	0.746
13	3.120	3.120	3.120	3.120	44	3.675	2.940	2.573	2.205	75	1.663	1.330	1.164	0.998
14	3.333	3.333	3.333	3.333	45	3.287	2.630	2.301	1.972	76	1.620	1.296	1.134	0.972
15	2.130	2.130	2.130	2.130	46	2.465	1.972	1.726	1.479	77	2.413	1.930	1.689	1.448
16	3.264	3.264	3.264	3.264	47	1.061	0.849	0.743	0.637	78	1.065	0.852	0.746	0.639
17	2.724	2.724	2.724	2.724	48	0.708	0.566	0.495	0.425	79	2.196	1.757	1.537	1.317
18	2.640	2.640	2.640	2.640	49	0.936	0.749	0.655	0.562	80	1.098	0.878	0.768	0.659
19	3.066	3.066	3.066	3.066	50	1.164	0.931	0.815	0.698	81	1.250	1.000	0.875	0.750
20	1.430	1.430	1.430	1.430	51	3.070	2.456	2.149	1.842	82	2.793	2.235	1.955	1.676
21	3.424	3.424	3.424	3.424	52	2.705	2.164	1.893	1.623	83	2.152	1.722	1.507	1.291
22	3.447	3.447	3.447	3.447	53	0.924	0.740	0.647	0.555	84	1.533	1.226	1.073	0.920
23	3.432	3.432	3.432	3.432	54	0.719	0.575	0.503	0.431	85	1.065	0.852	0.746	0.639
24	3.051	3.051	3.051	3.051	55	0.890	0.712	0.623	0.534	86	2.217	1.774	1.552	1.330
25	2.655	2.655	2.655	2.655	56	2.146	1.717	1.502	1.287	87	1.576	1.261	1.103	0.946
26	2.427	2.427	2.427	2.427	57	1.701	1.360	1.190	1.020	88	2.837	2.270	1.986	1.702
27	1.895	1.895	1.895	1.895	58	1.689	1.351	1.182	1.013	89	2.620	2.096	1.834	1.572
28	0.765	0.612	0.535	0.459	59	3.926	3.141	2.748	2.356	90	2.272	1.817	1.590	1.363
29	3.515	2.812	2.461	2.109	60	2.739	2.191	1.917	1.643	91	2.652	2.122	1.857	1.591
30	2.819	2.255	1.973	1.691	61	2.066	1.653	1.446	1.239	92	2.652	2.122	1.857	1.591

Table 5. Raw irrigation sheets per treatment

DDT	Lnb1 (mm)	Lnb4 (mm)	Lnb2 (mm)	Lnb3 (mm)	DDT	Lnb1 (mm)	Lnb4 (mm)	Lnb2 (mm)	Lnb3 (mm)	DDT	Lnb1 (mm)	Lnb4 (mm)	Lnb2 (mm)	Lnb3 (mm)
0	1.712	1.712	1.712	1.712	31	4.474	3.579	3.132	2.684	62	3.127	2.502	2.189	1.876
1	2.518	2.518	2.518	2.518	32	1.643	1.315	1.150	0.986	63	1.278	1.023	0.895	0.767
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27	1.895	1.895	1.895	1.895	58	1.689	1.351	1.182	1.013	89	2.620	2.096	1.834	1.572
28	0.765	0.612	0.535	0.459	59	3.926	3.141	2.748	2.356	90	2.272	1.817	1.590	1.363
29	3.515	2.812	2.461	2.109	60	2.739	2.191	1.917	1.643	91	2.652	2.122	1.857	1.591
30	2.819	2.255	1.973	1.691	61	2.066	1.653	1.446	1.239	92	2.652	2.122	1.857	1.591

Table 6: Net sheet of irrigation by treatments

4.2.1 Irrigation film applied by Kc values

As can be seen in the figures, treatments had the same irrigation supply during the first stage with the Kc of 0.7, with a total net sheet of 81.94mm, while from the change of the Kc to 1.05 the deficit irrigation began, taking advantage of the use of the highest Kc, after an analysis after 2 weeks. of the width of the diameter and the heights of the plants, their application was considered, with a total of 121.36 mm of sheet for T1 (100%), 84.95 mm for T2 (70%), 72.52 mm for T3 (60%) and finally, 97.09 mm for T4 (80%). From day 76 onwards, the third phase was considered where the Kc was reduced to 1, where the total sheets applied in these periods were lower, since the celery crop matured after exactly 3 months, due to the weather and high temperatures. The irrigation consumption for T1 was 32.78 mm, and for treatments T4, T2 and T3, they were 26.22 mm, 22.94 mm, and 19.67 mm respectively. Table 12 shows the calculated net sheets corresponding to the treatments during the vegetative cycle, however, the ones shown in Figure 8 are the sheets applied in reality, since, for reasons of management of irrigation times, and especially fertigation, they ended up being provided for a few more minutes for their application. This is because at the time of fertigation, the system takes between 10 to 15 minutes to provide the field with fertilizer, so they were given a few more minutes when the time they had was less than or equal to 10 minutes.

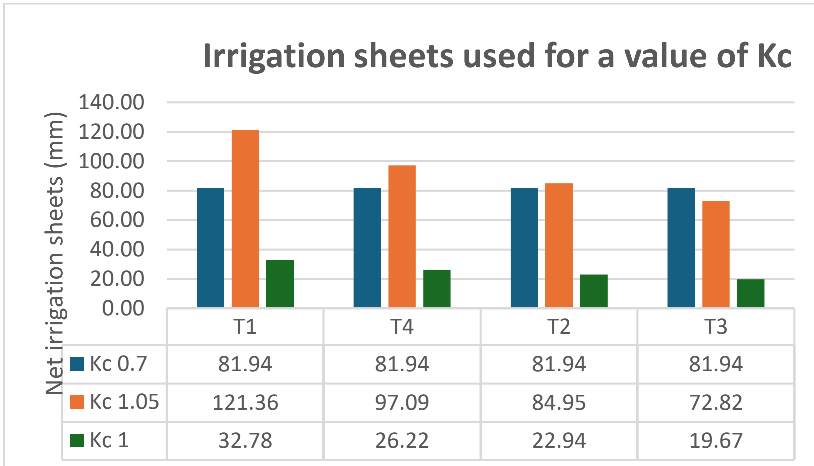

Figure 3: Bar graph of irrigation sheets by Kc

4.2.2 Relationship between irrigation sheets and yield

In the Figure, the net irrigation sheet applied (mm) in relation to the yield (ton/ha) in the cultivation of celery variety "Kelvin KZ F1" is observed, for each of its deficit irrigation treatments (100%, 80%, 70% and 60% of the demand), under drip irrigation. With respect to the T1 control treatment, the irrigation sheet applied was 236.08 mm and a yield of 85.04 ton/ha was obtained; for the T2 treatment, the applied sheet is 189.83 mm and its yield is 73.25 ton/ha, for the T3 treatment, the applied sheet is 174.42 mm, with a yield of 68 ton/ha, and for the T4 the applied sheet was 205.25mm, with a yield of 79.21 ton/ha. As can be seen in the four treatments, the higher the water applied the higher the yield. Vergara (2001) mentions that irrigation is the safest regulator in production, and that, the higher the irrigation sheet, an increase in crop yields is achieved, that is; There is a directly proportional relationship between the amount of water applied and the yield.

It is important to mention that the irrigation sheets shown in the figure are those found to program the irrigation time in minutes that is sent to the CIER irrigation booth.

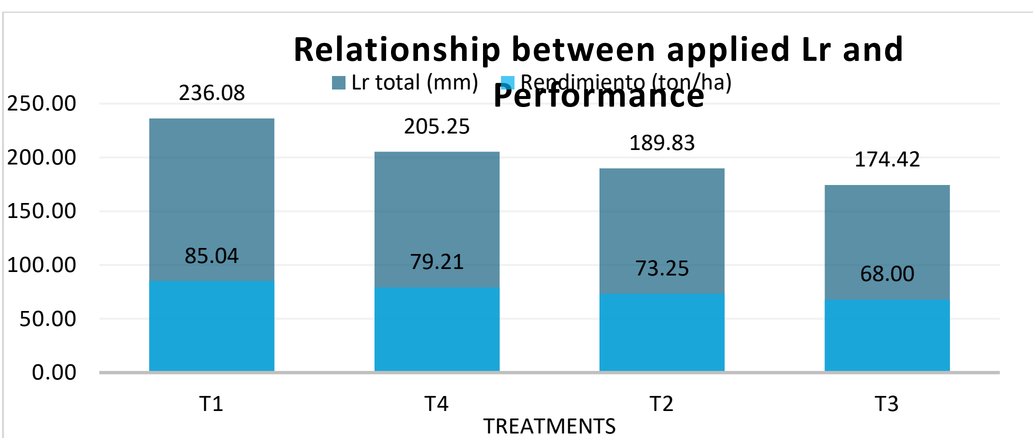

Figure 4. Bar graph between applied irrigation sheet and yield.In original language Spanish

4.3 Harvest production

4.3.1 Trunk diameter

Table 7 shows the results obtained through Tukey's test, on the effect that the 4 irrigation sheets have on the diameter of the celery trunk measured in cm with the caliper's foot, evaluated for T1 (100%) was 99.6 mm, in T2 (70%) 92.1 mm, T3 (60%) of 87.6 mm, and T4 (80%) of 94.2 mm. According to the analysis of variance performed, there were very significant differences between the treatments when obtaining a p value equal to 0.1, where T3 (60% sheet) has different results than T1, while the other treatments are statistically similar. Likewise, the coefficient of variation obtained is 6.9%, being a very low one, which means that the data recorded by treatment have been homogeneous, as can be seen in the statistical graphs. The results in the four treatments exceed the values obtained by Sarli, A. (1980), so it is understood that in all treatments there was good crop management.

Treatment	Diameter (mm)	CV	Analysis of variance
T1	99.6 ± 5.67a	6.90%	**
S4	94.2 ± 4.56ab		
S2	92.1 ±6.62ab		
S3	87.6 ± 4.79b		

Table 7. Average diameter per treatment

****:** Very significant differences
Cv: Coefficientofvariation

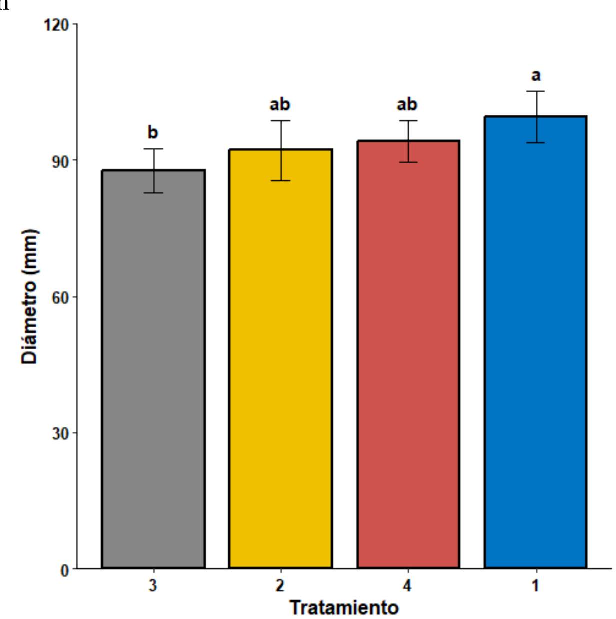

Figure 5: Diameter (mm) variance analysis graph.In original language Spanish

4.3.2 Height

Table 8 and Figure 5 show the average height values for the 4 treatments obtained in the Tukey test, after having been evaluated at harvest with 100 cm rulers and tape measurers. It is observed that the highest value is given to T1 (100%) with 79 cm, followed by T4 (80%) with 78.1 cm, T2 (70%) with 77.4 cm and the lowest average belonging to T3 (60%) with 74.8 cm, where no significant differences were found, that is, the effect on height for the 4 treatments had statistically equal results. However, the 4 average heights are numerically higher than the values found by TISCORNIA, J; (1983), which are around 60 cm, likewise, the FAO (1990) mention maximum values of celery height at 60 cm.
The coefficient of variation obtained for the variable height (cm) is considered very good, since it demonstrates the reliability of the results, as the treatments evaluated are homogeneous among themselves.

Treatment	Height (cm)	CV	Analysis of variance
T1	79 ± 2.22a	3.88%	ns
S2	77.4 ± 2.80a		
S3	74.8 ± 3.65a		
S4	78.1 ± 1.84a		

Table 8: Average height per treatment

Ns: there are no significant differences
Cv: Coefficientofvariation

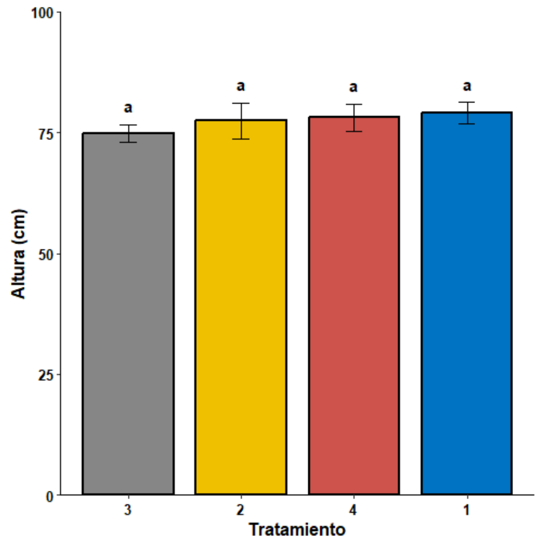

Figure 5. Height (cm) Analysis Graph of Variance.In original language Spanish

4.3.3 Fresh Weight

Table 9 shows the results of the ANOVA and Tukey test performed on the weights obtained at harvest, measured with a calibrated scale. For T1 an average weight of 1.54 kg was found, for T2 an average weight of 1.33 kg was found, T3 obtained 1.23 kg, this being the lowest on average, finally, T4 had an average weight of 1.43 kg. Likewise, in the analysis of variance, a $p<0.05$ is obtained, with the p-value being equal to 0.0121, with a result of significant treatments, where mainly T1 and T3 show these differences at the weight level, while between T1, T2 and T4 they show statistically similar values.
The statistical graphs for the weights, it can be seen that there was an outlier within the box diagram, for the 4 treatments, the highest being for T1, a plant with a weight of 2.35 kg was found.

Treatment	Weight (Kg)	CV	Analysis of variance
T1	1.54 ± 0.218a		
S2	1.33 ± 0.0936ab	13.19%	*
S3	1.23 ± 0.164b		
S4	1.43 ± 0.0978ab		

Table 9. Average weight per treatment

*: Significant differences
Cv: Coefficientofvariation

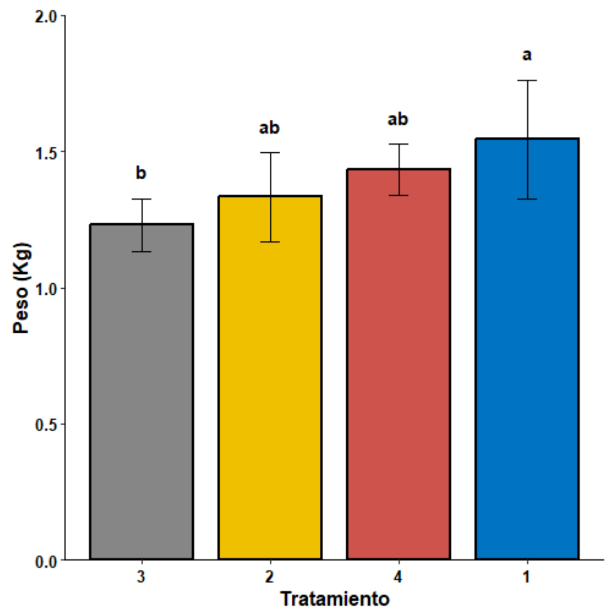

Figure 6. Weight (kg) Analysis Graph of Variance.In original language Spanish

4.3.4 Performance

The yield obtained in T1 (100%) was 85.04 ton/ha, T2 (70%) was 73.25 ton/ha, T3 (60%) was 68 ton/ha, and T4 (80%) was 79.21 ton/ha. As shown in Figure 7.

Mainly within the T1 and T2 treatments, outliers were obtained, for T1 an experimental unit was evaluated that had 110 tons/ha of yield, while for T2 90 tons/ha were found, the other values being normal, as also indicated by the value of the cv, and shown in the density graph.

The analysis of variance obtained a p of 0.0111, complying with $p<0.05$, which indicates that the quantities evaluated are significant, where the results of T1 differ significantly from T3, while T1, T2, and T4 are similar to each other, as well as T2, T3 and T4 are also similar.

The yields achieved in the 4 treatments are well above the yield of the celery crop, which ranges from 5 to 22.6 tons/ha according to Minagri (2018).

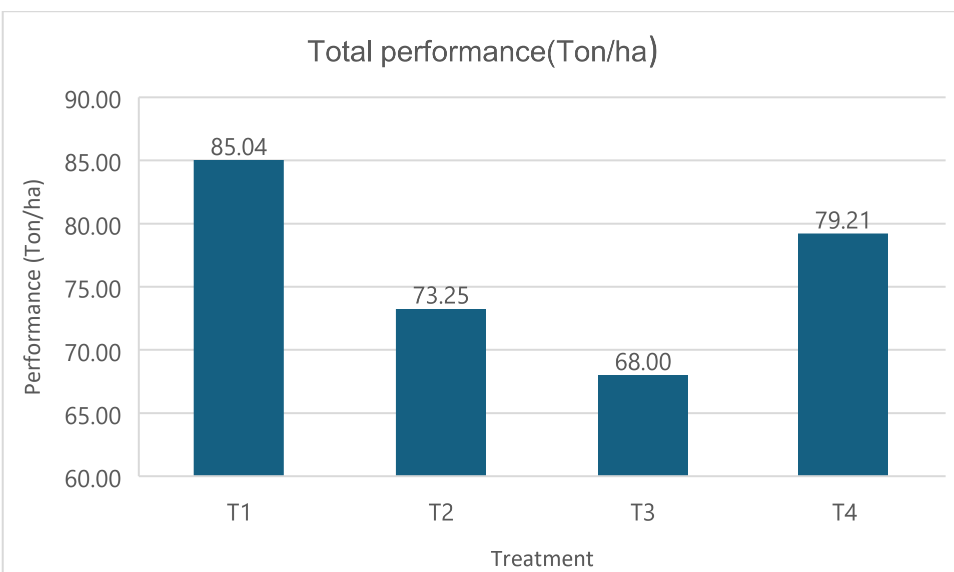

Figure 7. Harvest performance T1, T2, T3 and T4

Treatment	Yield (Ton/ha)	CV	Analysis of variance
T1	85.9 ± 12.1a	13.20%	*
S4	79.6 ± 5.09ab		
S2	74.2 ± 9.03ab		
S3	68.2 ± 5.48b		

Table 10. Average yield in Ton/ha

*: Significant differences
Cv: Coefficient of variation

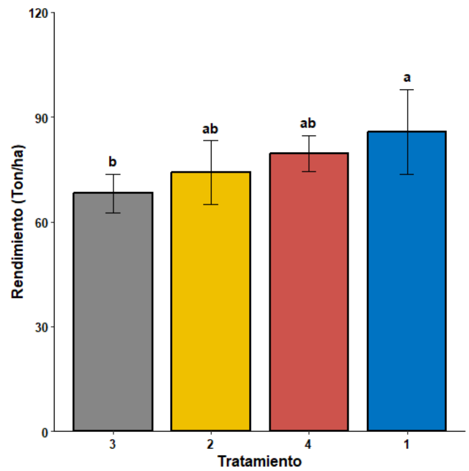

Figure 8: Yield variance analysis graph (Ton/ha).In original language Spanish

4.4 Water quantification

The total volume of water applied in the cultivation of celery variety Kelvin KZ F1 for the control treatment T1 (100%) was 2360.75 m3/ha, for treatments T2 (70%), T3 (60%) and T4 (80%), was 1898.34, 1744.2 and 2052.48 m3/ha respectively. These values are shown in Figure 9.

In the total volume of water applied to the treatments in m3/ha we observe that there is a water saving equivalent to 462.41, 616.55 and 308.28 m3/ha for the T2, T3 and T4 treatments, respectively, and in percentage the water savings they represent is 19.58, 26.11 and 13.06 percent, in the drip irrigation system of the T2 treatments, T3 and T4 with respect to the T1 control treatment.

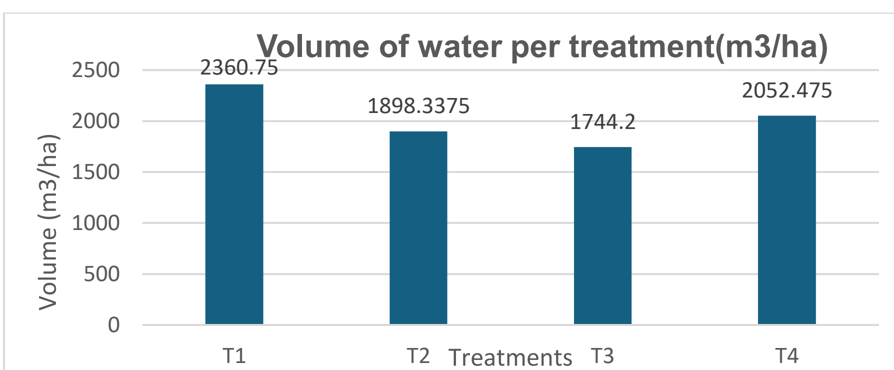

Figure 9. Volume of water applied (m3/ha) per treatment

Figure 10 shows the total volume of irrigation water used (m3/ha) with respect to the yield (Ton/ha.) obtained in the treatments applied. In T1, a yield of 85.04 Ton/ha was obtained with a water volume of 2360.75 m3/ha applied during the evaluation period; with T2 a yield of 73.25 Ton/ha was obtained with a water volume of 1898.34 m3/ha, for T3, 68 Ton/ha of yield with a water volume of 1744.2 m3/ha, and T4 obtained a yield of 79.21 Ton/ha, with a volume supply of 2052.48 m3/ha. So it can be seen that the difference in water volumes in percentage is 19.58, 26.11 and 13.06 for T2, T3 and T4 respectively, as indicated above, with respect to treatment one or control. In the case of yields, there is a percentage of 13.8, 20.03 and 6.85, for T2, T3 and T4, respectively, compared to T1, with greater water savings and yield difference in the case of T3, in second T2 had a water saving greater than its yield difference, and finally T4.

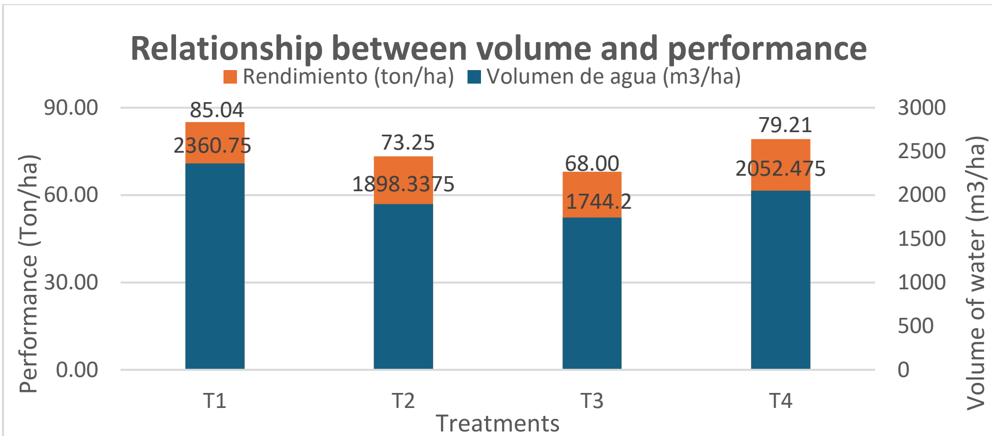

Figure 10. Ratio of applied water (m3/ha) and yield (Ton/ha).In original language Spanish

4.5 Water productivity (kg/m3)

Water productivity (kg/m3) was evaluated using yield (kg/m3), and the volume of water applied in m3/ha for each treatment, where it is shown that for T2 (70%) and T4 (80%), the water productivity value is 38.6 kg/m3 and T3 (60%) 39 kg/m3, differentiating by approximately 0.4 kg/m3. while T1 (100%) has a value of 36 kg/m3. In proportion to what was stated by Sánchez et al. (2006), the amount of water that is applied to an irrigation system is more efficient when this volume is lower, and the production is higher, it is inferred that T2, T3 and T4 are more efficient compared to T1, the quantities have been evaluated in kg/m3, having a high performance in treatments. Regarding the application of irrigation sheets, T1 with a sheet of 236.08 mm has a water productivity of 36 kg/m3, while for T2 the sheet of 189.83 mm corresponds to 38.6 kg/m3, for T3 with 174.42 mm and 205.25 mm of T4, 39 and 38.6 kg/m3 are also obtained, respectively. This would be reduced to the fact that in the treatments there has been a good use of water for the production of celery crops, since the differences between them are minimal.

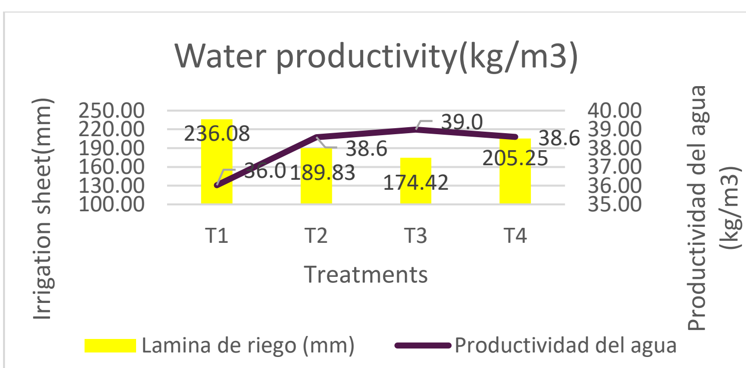

Figure 11. Water productivity (kg/m3).In original language Spanish

The ANOVA analysis performed on the water productivity for the 4 treatments shows that there are no significant differences between the values of the treatments. While the TUKEY test between treatments shown in table 11, have an average of 39.1 kg/m3 for T3 and T2, for T4 a value of 38.8 kg/m3 and the lowest value is for T1 with 36.4 kg/m3, with its respective standard variation per treatment.

Treatment	USA (kg/m3)	CV	Analysis of variance
S3	39.1 ± 3.14a	10.53%	Ns
S2	39.1 ± 4.76th		
S4	38.8 ± 2.48th		
T1	36.4 ± 5.48b		

Table 11. Average EUA (kg/m3)

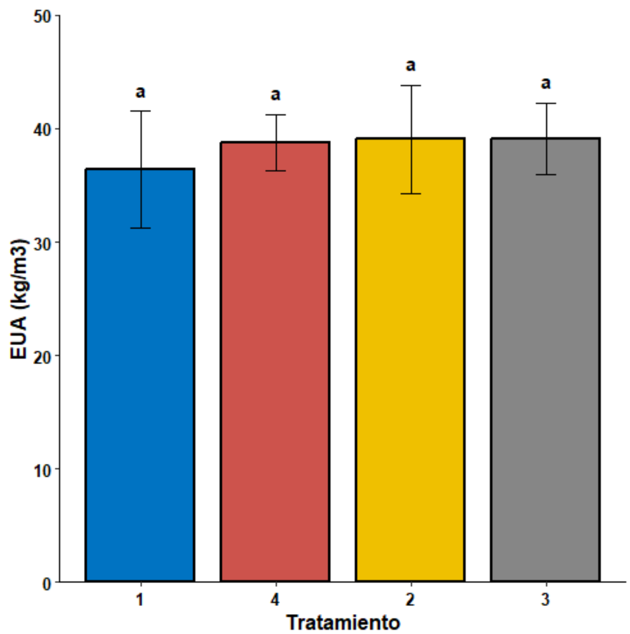

Figure 12. EUA Graph of Variance (kg/m3).In original language Spanish

5. Conclusions

The results of the study showed that the application of deficit irrigation significantly affects yield and water use efficiency in the cultivation of celery (*Apium graveolens*), Kelvin RZ F1 variety. The T1 treatment, with an irrigation sheet at 100% of the evapotranspirative demand, achieved the highest yield (85.4 t/ha) and the highest values in the agronomic variables evaluated: plant height (79.0 cm), stem diameter (99.6 mm) and fresh weight (1.54 kg). However, the deficit treatments T2 (80%), T3 (70%) and T4 (60%) achieved significant water savings compared to T1, with reductions of 19.58%, 26.12% and 13.06%, respectively. This highlights the viability of deficit irrigation as an efficient strategy to optimize the use of water resources.

In terms of water productivity, the deficient treatments showed higher values than those of the control treatment. T2 and T3 presented the highest efficiency, with 39.1 kg/m³, while T4 reached 38.8 kg/m³ and T1 was at 36.4 kg/m³. These results suggest that a deficit irrigation at 70% of evapotranspirative demand can balance water savings with acceptable yields, being a sustainable option for areas of limited water availability.

On a practical level, the use of controlled deficit irrigation allows to maintain competitive production, significantly reducing water consumption and associated costs. This is particularly relevant in the current context of increasing demand for food and water resources that are becoming increasingly scarce. In addition, the results show that, although deficit sheets impact certain agronomic variables, these differences do not considerably compromise the commercial quality of the crop.

Finally, it is concluded that the implementation of strategies such as 70% deficit irrigation represents a viable and sustainable alternative to optimize the use of water in celery cultivation, maximizing water efficiency and promoting responsible agricultural practices. It is recommended to conduct further research considering product quality, commercial value, and broader economic analyses to validate the applicability of this technique in different agroclimatic contexts and production systems.

6. Recommendations

- ✓ To evaluate the treatment of deficit irrigation during dates other than the one chosen by this work, to observe the effect of the deficit on the quantity and quality of production, and to compare the volumes of irrigation water applied.
- ✓ Carry out research on irrigation and yield sheets for other varieties of celery cultivation, on the coast and in the mountains, which is where celery production is greatest.
- ✓ It is recommended to replicate the research by considering evaluating the quality of the product required by the market, applying deficit irrigation.
- ✓ Replicate the research under appropriate conditions of fertilization doses, so that differences within celery production can be better visualized, and in turn nutritional deficiencies that may be exacerbated by the deficit irrigation applied can be avoided.
- ✓ It is recommended to carry out an economic analysis that involves the cost of fertilizers, seeds or seedlings, water applied for crop irrigation, and other products for agricultural use. With the intention of knowing the feasibility of its application according to the economic budget.
- ✓ Finally, it is recommended to the farmer to use a homemade evaporimeter tank, with the intention of measuring evapotranspiration and thus the water requirement of the crops, and thus avoid the excessive application of irrigation, and obtain water savings in agriculture.

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