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Effect of the application of several irrigation sheets, through the study of the phenological and physiological behavior of strawberry cultivation (*Fragaria sp* "Albión Californiana"), supported by the use of geographic information systems (GIS).

[1]Cristian Santiago Tapia Ramírez, [2]Edmundo Danilo Guilcapi Pacheco, [3]Susana Monserrat Zurita Polo [4]Vicente Javier Parra León, [5]David Santiago León Armijos

Ingeniero Agrónomo, Master en Riego y Drenaje, Escuela Superior Politécnica de Chimborazo, Riobamba-Ecuador. cristians.tapia@espoch.edu.ec, http://orcid.org/0000-0003-2104-5972

[2]Ingeniero Agrónomo, Magister en Biodiversidad y Recursos Genéticos, Escuela Superior Politécnica de Chimborazo, Riobamba-Ecuador. eguilcapi@espoch.edu.ec, https://orcid.org/0000-0001-5072-1437

3 Ingeniera en Sistemas Informáticos, Master Universitario en Ingeniería de Software y Sistemas Informáticos, Escuela Superior Politécnica de Chimborazo, Riobamba-Ecuador. mailto: susana.zurita@espoch.edu.ec, https://orcid.org/0000-0002-5325-486X

[4]Ingeniero Agrónomo, Master en Agroecosistemas con Mención en Agroecología, Escuela Superior Politécnica de Chimborazo, Riobamba-Ecuador. vicente.parra@espoch.edu.ec, https://orcid.org/0000-0002-7632-2474

[5]Ingeniero Agrónomo, Master en Riego y Drenaje, Investigador independiente, Riobamba-Ecuador. dleon1684@gmail.com, https://orcid.org/0009-0000-9600-3836

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SUMMARY

Strawberries are a new crop introduced recently that has gained its space mainly in the central and northern part of the province of Chimborazo. However, given the lack of knowledge of producers about the proper management of irrigation in strawberry cultivation that has resulted in the irrational use of water, the research was carried out in the Pungal El Quinche sector, belonging to the Guano canton, in a soil with a sandy loam texture. The objective was to evaluate the effect of four irrigation sheets on strawberry cultivation (*Fragaria sp* "Albión Californiana"), using a drip irrigation system. A randomized whole block experimental (DBCA) design was used with four treatments and five replications. The treatments were made up of four irrigation sheets that corresponded to a percentage of 80%, 90%, 100% and 110% of the crop evapotranspiration (ETc) that was calculated through the PETP V 2.0.0 software, which uses the Hargreaves formula based on temperature based on climatic parameters obtained from nearby meteorological stations and spatially interpolated with a digital elevation model (altitudinal gradient) by means of the IDW method (Inverse Distance Weighted) of the GIS. The irrigation sheet of 110% of the crop evapotranspiration presented the highest plant height and the best results at 172 and 179 days after transplanting for the variables corresponding to fruit length, fruit weight per plant, individual fruit weight and with a yield of 7530.54 kg/ha and 8264.22 kg/ha respectively; which confirms that the application of a high irrigation layer in a sandy soil is essential to obtain good vigor and development of the plants, which allows obtaining high productivitys and an excellent quality of the harvested fruit.

Keywords: Treatments; crop evapotranspiration; irrigation sheet; drip irrigation; yield.

INTRODUCTION

The strawberry is a crop that has more than 20 known species, its fruit is currently consumed in several countries worldwide either in fresh or processed state, due to the high nutritional content it presents especially in vitamin C and anticancer. (Bianchi, 2018)

Despite the significant increase in yield in the province of Chimborazo corresponding to 3.66 tons, it is still lower if compared to the province of Tungurahua, which obtains an average of 10 tons per year and an excellent quality of the fruit, classifying most of the production in commercial categories 1 and 2 of the five that currently exist. (Honorable Provincial Government of Tungurahua, 2015)

For several years, strawberry cultivation has been promoted, mainly attracted by its profitability, resistance and recovery to low temperatures (frost); however, when the farmer is faced with the production of a new agricultural item, a series of questions arise regarding water needs, nutrition, pest and disease control, among others. (Álvarez, 2017)

It is known that the yield of strawberries is a function of the contribution of water to the soil since higher humidity in the root zone facilitates the availability of nutrients, which allows the plant to develop properly and the fruits to reach the size and quality required for marketing. (Bohórquez, Contreras, & Gavilán, 2015)

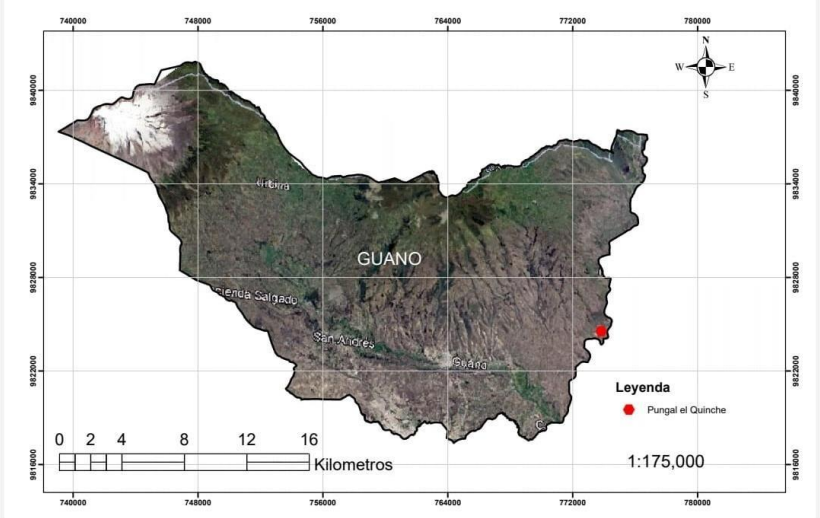
Faced with the needs of the producer and the question of whether this fruit can be grown in areas with scarce water availability, the idea arises for the establishment of tests that allow determining the differences in terms of phenology and physiology based on the amounts of water that are applied to the plant and that is where the need to know with scientific data arises if the application of a larger sheet of water is water allows to obtain plants with the best agronomic indicators.

The development of the research allowed to evaluate the directly proportional relationship between the different phenological characteristics with the application of an irrigation sheet, the information generated will guide the strawberry producer located in the different areas with little water availability in the province of Chimborazo.

METHODOLOGY

Trial Location

This research was carried out in the parish of La Providencia, belonging to the Guano canton in the province of Chimborazo; the same that is located in the central part of Ecuador, in the property located in the Pungal El Quinche sector; at UTM coordinates (WGS 84 zone 17 South) N 9824557.77 and E 773837.51 at an altitude of 2520 meters above sea level.



Graph No. 1. Map of study area location.
Prepared by: Authors, 2023. In original language Spanish

Characteristics of the experimental site

The research was carried out in a locality that presents the following climatic conditions corresponding to an average temperature of 13 ˚C, a precipitation of 574 mm and a relative humidity of 85%. (Alternative Energy and Environment Research Center, 2019)

The life zone corresponds to the Lower Montane Dry Forest (bs-MB), with a predominance of alfalfa (*Medicago sativa*), corn (*Zea mays*) and pastures for cattle feed for dairy production. (Holdridge, 2000),

Edaphic, the topography is slightly inclined with a sandy loam textural class, in order to determine exactly the physical-chemical characteristics of the soil, a sample taken from the surface of the test was sent to the Soils, Foliars and Water Laboratory of the Ecuadorian Agency for Agricultural Quality Assurance (AGROCALIDAD) accredited by the Ecuadorian Accreditation Service (SAE); considering parameters such as macroelements, microelement, pH, electrical conductivity, cation exchange capacity and organic matter for crop fertility and for irrigation management, bulk density, equivalent moisture, field capacity, wilting point, usable water and textural class.

The water for irrigation comes from the Chingazo Pungales irrigation canal, which was analyzed in the laboratory of the Center for Technical Services and Environmental Technology Transfer (CESTTA), considering parameters corresponding to pH, electrical conductivity, total dissolved solids, suspended solids, sedimentable solids, anions and cations.

Vegetative material and variables under study

Mother strawberry plants of the Albion variety YCD 11-19-19 (*Fragaria sp*) were used, from the SHLS-2ª field at the SHASTINA farm in the state of California (USA).

The research analyzed two types of variables: The independent variable made up of the applied irrigation sheet corresponding to crop evapotranspiration (ETc), established as a function of the water requirements of the strawberry (*Fragaria sp* "Albión Californiana") and the dependent variable that includes the physiological behavior of the strawberry crop (*Fragaria sp* "Albión Californiana") against the application of the different irrigation sheets.

The indicators of the dependent variable analysed are: I) plant height at flowering (cm), II) number of fruits harvested per plant, III) fruit weight per plant (g/plant), IV) fruit length (cm), V) individual fruit weight (g/fruit) and VI) yield (kg/ha).

Population and Sample

The trial consisted of a total of 5081 strawberry plants (*Fragaria sp* "Albión Californiana") and each experimental unit had a population of 254 plants that through the systematic random sampling method twenty plants were selected, where from a plant located at the beginning of the useful area of the experimental unit the next one was chosen by means of a calculated interval or elevation coefficient (k). (Lind, Marchal, & Wathen, 2012)

Descriptive and Inferential Statistics

The data of the variables under study were submitted to the analysis of variance (ADEVA) and with the existence of statistical significance, the separation of means was proceeded through the Tukey test at 5% probability of statistical error, the analysis of the data was carried out with the INDROPAT computer software. (Di Rienzo et al., 2020) (Table No. 1).

Table No. 1. Scheme of the analysis of variance (ADEVA).

SOURCE OF VARIATION	FORMULA	DEGREES OF FREEDOM
Repetitions	R-1	4
Treatments	T-1	3
Experimental error	t(r-1)	12
Total	(t x r)-1	19

Prepared by: Authors, 2023

For the present research, an experimental design corresponding to randomized complete blocks (DBCA) was used, which included 4 treatments with 5 repetitions (4x5) (Condo & Pazmiño, 2015).

The treatments are made up of the different irrigation sheets that were applied to the strawberry crop (*Fragaria sp* "Albión Californiana"), which are detailed in (Table No. 2) below:

Table No. 2. Treatments under study.

TREATMENT	NOMENCLATURE	DESCRIPTION	Raw sheet (mm/year)
T1	L1	80% of crop evapotranspiration	472,55
S2	L2	90% of crop evapotranspiration	531,62
S3	L3	100% of crop evapotranspiration	590,68

S4	L4	110% of crop evapotranspiration	649,75

Prepared by: Authors, 2023

Specifications of the experimental field.

Each treatment is made up of five beds (replications), with dimensions corresponding to 22.0 m long and 0.40 m wide, and in each bed in its middle part an irrigation belt was located, for a total of 20 experimental units. In the experimental units, strawberry plants (*Fragaria sp* "Albión Californiana") were planted, with a separation between them of 0.20 m and between rows at a distance of 0.90 m in a double row for each irrigation line. The beds had a density of 254 plants, the useful area for each experimental unit corresponds to 7.20 m2, the net and total area of the trial was 144 m2 and 425.5 m2 respectively.

Experimental variables

Of the usable area of each experimental unit, the height of twenty randomly taken plants was first evaluated, when 75% of the plot was in flowering. At 158-165-172 and 179 days after transplantation (DDT), the number of fruits harvested was counted, expressing the results in number of fruits per plant; Then, using a precision scale, all the fruits were weighed, expressing the results in grams per plant.

The length of the fruits was evaluated, measuring them from the base to their apex with the help of a caliper (accuracy of 0.1 mm (1/128"), expressing the results in average fruit length; then the fruits were individually weighed using a precision scale (1 g/0.1 oz) where the results were expressed in grams per fruit and finally all the useful surfaces of each one were harvested of the experimental plots, proceeding to weigh it to transfer it and subsequently express it at kilograms per hectare (kg/ha) to determine the expected yield.

Assay management

Soil Preparation and Cultivation

Initially, the soil was prepared by performing two passes of disc ploughing and one pass of the harrow to proceed with the preparation of the beds by lifting and tamping layer by layer the previously moistened soil to form a ridge with a height of 0.40 m, 0.40 m wide and 22 m long. leaving a slight slope of close to 1% to facilitate irrigation by longitudinally placing drip irrigation tapes. All the beds were then covered with a perforated black plastic at a separation of 0.20 m corresponding to the planting density of the strawberry crop.

The strawberry transplant was carried out manually, placing the plant in each hole with an arrangement in the beds corresponding to double rows of three bobbins with a distance of 0.20 m between plants. A month and a half after transplanting, the stolons, diseased leaves and the buds of the first flowers were manually removed. The weeding only eliminated the weeds that proliferated on the roads and those that protruded from the places where the plants are located due to the effect of the plastic that was placed in each of the beds.

The fertilization of the experimental units was carried out based on the nutritional demand of the strawberry crop (*Fragaria sp*) Var. Californian Albion for each phenological stage and depending on the results of the soil and water analysis carried out; where fertilizers dissolved in the water (nutrient solution) were applied in each irrigation and injected through the irrigation system to guarantee a uniform distribution and rapid use by the crop.

For the control of diseases causing root rot during transplantation (*Fusarium sp* and *Phytophthora sp*), the active ingredient Carbendazim and the ingredients Chlorpyrifos + Cypermethrin were used to eliminate the chopworms (*Agrotis sp*) present. During the crop production cycle, foliar applications of the active products Azoxystrobin, copper hydroxide, copper sulfate pentahydrate and Citrex were made every 15 days for the control of soft rots (*Botrytis cinerea*) and powdery mildew (*Oidium fragarie*), for mites (*Tetranychus urticae*) the active molecule Acequinocyl was used.

The harvest was carried out manually from 158 days after transplanting, when 75% of the fruit surface of the experimental units that made up the treatments presented a red coloration and a firm consistency.

Irrigation programming and design

Weather information

The climatological information used to estimate potential or reference evapotranspiration was obtained from the automatic meteorological stations of Matus and Quimiag, installed by the Center for Research on Alternative Energies and Environment (CEAA) and from the conventional station of the National Institute of Meteorology and Hydrology (INAMHI), located at the Polytechnic School of Chimborazo (Table No. 3).

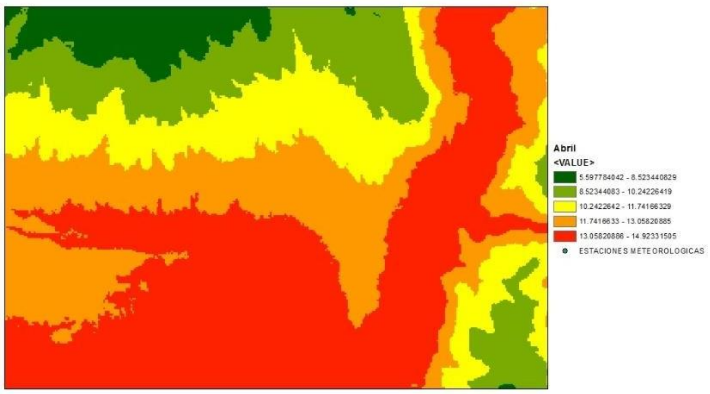
Table No. 3. Meteorological stations used for the estimation of ETo.

SEASON	GUY	PARISH	CANTON	NORTH	THIS	ALTITUDE
KILL	Automatic	Matus	Penny	9827892	777564	2471
CHEM	Automatic	Chem	Riobamba	9816406	770082	2718
ESPOCH	Conventional	Lizarzaburu	Riobamba	9816965	758398	2740

Source: CEAA (2020), INAMHI (2020). Prepared by: Authors, 2023

In order to generate more accurate meteorological data in accordance with the area where the test was located, isothermal maps were created considering altitudinal gradients based on the methodology described by (Fries et al., 2012), which spatially interpolates the climatic variables of the three stations based on a digital elevation model (altitudinal gradient) by means of the IDW (Weighted Inverse Distance) method of the ArcGis software (ArcGis Desktop, 2019), with an output resolution of 30 meters (Graph N^{or} 2).

The procedure described above can be applicable only for temperature and relative humidity, which are climatic parameters that vary depending on altitude.



Graph No. 2. Map of isotherms for the month of April, considering the altitudinal gradient.
Prepared by: Authors, 2023. In original language Spanish

For the estimation of potential or reference evapotranspiration (ETo), the Hargreaves method or formula based on temperature was used for areas that do not have sufficient meteorological information through the use of the PETP V 2.0.0 software (Gutiérrez, C, 2018); which assesses potential evapotranspiration by means of empirical formulas used on a global scale (Table No. 4).

Table No. 4. Calculated potential evapotranspiration of the assay implementation area.

Month	d (Days)	Tm (°C)	FMT (°F)	HR (%)	MF (mm/month)	CH	CE	ETo (mm/month)	ETo (mm/day)
January	31	13.58	56.44	82.46	2.54	0.70	1.05	104.86	3.38
February	28	13.60	56.48	85.35	2.13	0.64	1.05	80.22	2.86
March	31	13.57	56.43	87.37	2.35	0.59	1.05	82.08	2.65
April	30	13.57	56.43	87.51	2.19	0.59	1.05	76.09	2.54
May	31	13.28	55.90	87.66	2.12	0.58	1.05	72.59	2.34
June	30	12.57	54.63	88.81	1.97	0.56	1.05	62.77	2.09
July	31	11.90	53.42	87.00	2.07	0.60	1.05	69.42	2.24
August	31	12.28	54.10	83.59	2.20	0.67	1.05	84.20	2.72
September	30	12.68	54.82	81.51	2.25	0.71	1.05	92.61	3.09
October	31	13.46	56.23	82.45	2.37	0.70	1.05	97.19	3.14
November	30	13.69	56.64	82.70	2.25	0.69	1.05	92.47	3.08
December	31	13.19	55.74	84.70	2.29	0.65	1.05	86.91	2.80

Source: (Gutiérrez, C, 2018). Prepared by: Authors, 2023

Crop coefficient (kc)

The crop coefficient is a dimensionless value that establishes the degree of physiological development or soil cover by the crop for which its water consumption will be determined. For the calculation of crop evapotranspiration (ETc) of strawberries (Fragaria sp) Var. Californian Albion, the kc values obtained for a semi-arid climate and under mulch (plastic) presented in the following Table No. 5 were used.

Table No. 5. Kc values for strawberries under mulch (plastic) and a semi-arid climate.

Cultivation	Initial Kc	Kc Development	Medium Kc	Kc Final
Strawberry	0.40	0.50	0.70	0.60

Source: Antúnez (2009). Prepared by: Authors, 2023

Net sheet or net demand

(Calvache, 2013), states that the net demand basically corresponds to the corrected evapotranspiration of the crop, which can be calculated based on the following expression:

$$Dn = ETo * kc * Kl * Kvc \quad (2)$$

Where:
Dn = Net demand (mm).
ETo = Potential or reference evapotranspiration (mm/day).
Kc = Crop coefficient (dimensionless).
Kl = Correction coefficient by location (dimensionless).
Kvc = Correction coefficient for climatic variation (1.15 or 1.20 depending on the crop's water needs).

The correction coefficient per location is calculated with the following mathematical equation:

$$Kl = A + 0{,}15\ (1 - A) \quad (3)$$

Where:

Kl = Correction coefficient by location.

A = Fraction of shaded area.

Where A corresponds to the shaded area and what it does is coincide with the projection on the ground of the perimeter of the vegetation cover, it is calculated with the following formula:

$$A = \frac{\frac{\pi \times D^2}{4}}{Ep \times Eh} \quad (4)$$

Where:
A = Fraction of shaded area (m2).
D = Diameter of the crop's leaf area (m)
Ep = Plant Spacing (m)
Eh = Spacing between rows of plants m)

Gross sheet or gross demand

(CONGOPE, 2016), cites that the gross lamina is the amount of water that must be applied in each irrigation to the soil to ensure that moisture enters sufficiently and allows the value of the net lamina to be retained in the root zone. Basically, the gross sheet is equal to the net demand on the application efficiency, in drip irrigation this efficiency refers to the additional contribution of water that must occur due to the effect of losses caused by deep percolation, salinity and lack of uniformity of irrigation.

(Calvache, 2013), mentions that for the calculation of gross demand, the net demands, the washing requirement or fraction and the uniformity of the emission of the drippers must be considered. The following equation is used for the calculation:

$$Db = \frac{Dn}{(1 - RL)Cu} \quad (5)$$

Where:
Db = Gross demand (mm).
Dn = Net demand (mm).
RL = Washing requirement.
CU = Coefficient of uniformity.

Salt Washing

(Monge, 2018), states that the need for washing or salt washing fraction is the amount of additional water that is required to dissolve the salts and displace them from the root zone. The amount of water required for the washing of salts depends on the type of crop, the type of irrigation and the salinity of the soil; that is, for a high salt content in the soil solution, the greater the amount of water that must be applied to wash the salts. This activity becomes relevant in localized irrigation.

The calculation of the washing fraction depends on the type of irrigation that is being used, for localized irrigation the following formula will be used:

$$NL = \frac{CE_a}{2 * CE_{ex\ max}} * 100 \quad (6)$$

Where:

NL = Washing requirements in percentage.

CEa = Electrical conductivity of irrigation water (dS/m).

CEex max = Maximum electrical conductivity of the soil saturation extract for an expected crop yield in dS/m.

Dripper watering foil

The irrigation sheet of the drippers was determined according to the design characteristics of the irrigation system (dripper flow) and by the arrangement of the crop in the field (planting frame), using the following equation. (Ortiz, 2008)

$$Lr = \frac{Qn \times NL}{Sl \times Se} \quad (7)$$

Where:

Lr = Irrigation sheet provided by the drippers (mm/h or l/m2).

Qn = Nominal dripper flow rate (l/h).

NL = Number of irrigation laterals per row of crops.

Sl = Separation between irrigation laterals (m).

Se = Separation between drippers (m).

Watering frequency

(García, 2015), mentions that the frequency of watering is the interval in days between two successive waterings for the same subunit. The frequency is calculated with the following expression (p. 235):

$$F' = \frac{DPH}{Et} \quad (8)$$

Where:

F' = Frequency in days.

DHP = Net sheet of water to be applied (mm).

Et = Adjusted evapotranspiration under drip irrigation conditions.

The net sheet of water to be applied is calculated with the following formula:

$$DPH = 10 * (CC - PMP) * d_a * ZR * f * P \quad (9)$$

Where:

DHP = Net sheet of water to be applied (mm).

CC = Moisture content at field capacity (%).

PMP = Moisture content at the point of permanent wilting (%).

da = Bulk soil density (g/cm3).

ZR = Effective depth of root exploration in meters.

f = Abatement factor (values of 0.2 and 0.3 for crops sensitive to water deficit and 0.4 to 0.5 for those crops that resist a higher degree of water deficit).

P = Fraction of field area that is moistened under drip irrigation conditions

Watering Time

The irrigation time required for the application of a sheet of water to the strawberry crop (Fragaria sp) Var. Californian Albion to meet its water needs was determined by the following mathematical expression. (NETAFIM, 2015)

$$Tr = \frac{Db}{Lr} \qquad (10)$$

Where:

Db = Gross demand (mm).

Lr = Irrigation sheet provided by the drippers (mm/h).

Total volume of water required for irrigation

(Calvache, 2013), states that the calculation of the volume required for irrigation purposes allows us to assess whether the available volume is capable of satisfying the irrigation demand.

For this calculation, the following formula is applied:

$$V = 10 * A * Db \qquad (11)$$

Where:

V = Volume required for irrigation (m3).

Db = Gross demand (mm).

A = Irrigated area (ha).

Coefficient of Emission Uniformity

For the evaluation of the installed irrigation system, the uniformity coefficient was used, determined from field tests of the discharges of 16 emitters expressed in l/h along four selected irrigation laterals: The first reading was made at the beginning, the second at 1/3, the third at 2/3 and the fourth at the end of each lateral line. using a graduated container to measure the flow rate of each dropper for a period of time corresponding to 5 minutes. With the information collected, the average of 25% of the emitters with the lowest flows was obtained and with the general average the uniformity coefficient was calculated, to later qualify the irrigation system according to its uniformity coefficient based on Table No. 6. (Vidal, 2007)

$$C.U. = 100 * \frac{Q_{25\%}}{Qn} \qquad (12)$$

Where:

CU = Coefficient of Uniformity

Q25% = Average discharge flow rate of 25% of the emitters with the lowest flow.

Qn = Average flow rate of all the emitters evaluated.

Table No. 6. Rating a Facility of localized irrigation, according to the value of the coefficient of uniformity.

Value of the coefficient of uniformity	Qualification
> 95%	Excellent
85 – 95%	Good
80 – 85%	Acceptable
70 – 80%	Poor
< 70	Unacceptable

Source: Bohórquez *et al.,* (2015)

Irrigation design

The application of water to the different experimental units was through an irrigation system, made up of hoses with a diameter of 16 mm that contain a series of drippers inserted with a flow rate of 1.60 l/h; spaced every 0.20 m and operating at a minimum and maximum pressure of 0.5 and 1.5 bar respectively (Mertzer Group, 2019), the distance between rows was 0.90 m and an irrigation line was placed for each row of crops.

The different treatments were made up of the four irrigation sheets, determined by a percentage of 80%, 90%, 100% and 110% of crop evapotranspiration (ETc).

The irrigation sheet to be applied was calculated using equation (2) that establishes the net demand and equation (5) that determines the gross demand (Calvache, 2013), to which the percentage of treatments expressed in decimals (0.8, 0.9, 1.0, 1.10) was multiplied.

RESULTS AND DISCUSSION

Irrigation Programming (Application Sheet)

The calculation of the irrigation schedule corresponding to the strawberry crop (*Fragaria sp* "Albión Californiana"), determined that the highest water requirements in each of the treatments occurred in the month of January, due to a high monthly and daily evapotranspiration of 104.86 mm and 3.38 mm respectively (Table No 7), which determined application sheets, irrigation times and larger volumes of water, which the irrigation system must provide.

For the month of June, which presented the lowest monthly and daily evapotranspiration with 62.77 mm and 2.09 mm respectively; application sheets, irrigation times and lower water volumes were determined, which corresponds to a low water demand of the

strawberry crop (*Fragaria sp* "Albión Californiana") for each of the treatments studied (Table No. 7).

Table No. 7. Irrigation programming for strawberry cultivation (*Fragaria sp* "Albión Californiana"),

									T 1 (80%)				T 2 (90%)				T 3 (100%)				T 4 (110%)			
Mes	Dia	Evapo transpiración (mm/día)	Evapo transpiración (mm/mes)	Coeficiente de cultivo (Kc)	Coeficiente corrector por localización (Kl)	Coeficiente corrector por variación climática (Ka)	Requerimiento de lavado (RL)	Coeficiente de uniformidad (CUC)	Lámina de aplicación (mm /mes)	Lámina de aplicación (mm /día)	Tiempo de riego (minutos)	Volumen (m3/ha)	Lámina de aplicación (mm /mes)	Lámina de aplicación (mm /día)	Tiempo de riego (minutos)	Volumen (m3/ha)	Lámina de aplicación (mm /mes)	Lámina de aplicación (mm /día)	Tiempo de riego (minutos)	Volumen (m3/ha)	Lámina de aplicación (mm /mes)	Lámina de aplicación (mm /día)	Tiempo de riego (minutos)	Volumen (m3/ha)
Octubre	22	3.14	68.97	0.48	0.41	1.20	0.39	0.91	23.08	1.05	7.08	0.45	25.96	1.18	7.97	0.50	28.85	1.31	8.85	0.56	31.73	1.44	9.74	0.61
Noviembre	30	3.08	92.47	0.58	0.41	1.20	0.39	0.91	37.75	1.26	8.49	0.54	42.47	1.42	9.56	0.60	47.19	1.57	10.62	0.67	51.91	1.73	11.68	0.74
Diciembre	31	2.80	86.91	0.69	0.41	1.20	0.39	0.91	42.10	1.36	9.17	0.58	47.36	1.53	10.31	0.65	52.62	1.70	11.46	0.72	57.88	1.87	12.60	0.79
Enero	31	3.38	104.86	0.70	0.41	1.20	0.39	0.91	51.49	1.66	11.21	0.71	57.92	1.87	12.61	0.80	64.36	2.08	14.01	0.88	70.80	2.28	15.42	0.97
Febrero	29	2.86	83.08	0.70	0.41	1.20	0.39	0.91	40.79	1.41	9.50	0.60	45.89	1.58	10.68	0.67	50.99	1.76	11.87	0.75	56.09	1.93	13.06	0.82
Marzo	31	2.65	82.08	0.70	0.41	1.20	0.39	0.91	40.30	1.30	8.78	0.55	45.34	1.46	9.87	0.62	50.38	1.63	10.97	0.69	55.42	1.79	12.07	0.76
Abril	30	2.54	76.09	0.70	0.41	1.20	0.39	0.91	37.36	1.25	8.41	0.53	42.03	1.40	9.46	0.60	46.70	1.56	10.51	0.66	51.37	1.71	11.56	0.73
Mayo	31	2.34	72.59	0.70	0.41	1.20	0.39	0.91	35.64	1.15	7.76	0.49	40.10	1.29	8.73	0.55	44.56	1.44	9.70	0.61	49.01	1.58	10.67	0.67
Junio	30	2.09	62.77	0.70	0.41	1.20	0.39	0.91	30.82	1.03	6.93	0.44	34.67	1.16	7.80	0.49	38.53	1.28	8.67	0.55	42.38	1.41	9.54	0.60
Julio	31	2.24	69.42	0.70	0.41	1.20	0.39	0.91	34.09	1.10	7.42	0.47	38.35	1.24	8.35	0.53	42.61	1.37	9.28	0.58	46.87	1.51	10.21	0.64
Agosto	31	2.72	84.20	0.70	0.41	1.20	0.39	0.91	41.34	1.33	9.00	0.57	46.51	1.50	10.13	0.64	51.68	1.67	11.25	0.71	56.84	1.83	12.38	0.78
Septiembre	30	3.09	92.61	0.70	0.41	1.20	0.39	0.91	45.47	1.52	10.23	0.64	51.16	1.71	11.51	0.73	56.84	1.89	12.79	0.81	62.53	2.08	14.07	0.89
Octubre	8	3.14	25.08	0.70	0.41	1.20	0.39	0.91	12.31	1.54	10.39	0.65	13.85	1.73	11.69	0.74	15.39	1.92	12.99	0.82	16.93	2.12	14.29	0.90
			1001						**472.55**			**7.21**	**531.62**				**590.68**			**9.01**	**649.75**			**9.91**

Prepared by: Authors, 2023. In original language Spanish

Height from plant to flowering.

The analysis of variance for the height of the plant (cm) measured at the beginning of flowering (Table No. 8), determined that there are highly significant statistical differences in the treatments corresponding to the application of the different irrigation sheets to the strawberry crop (*Fragaria sp* "Albión Californiana")), with a coefficient of variation of 9.81% and a general mean of 18.33 cm.

Table No. 8. ADEVA Plant height (cm) at flowering.

F.V.	Gl	S.C	C.M	F.C	P-VALUE
TREATMENTS	3	229,58	76,53	23.70 **	0,00002
REPETITIONS	4	4,17	1,04	0,32	0,8573
Error	12	38,76	3,23		
Total	19	272,51			
CV (%)	9.81				

****:** Highly significant

Prepared by: Authors, 2023

The Tukey Test at 5% for the height of the plant at flowering (Table No. 9), establishes the existence of two ranges; in the "A" range are T4 (L4) and T3 (L3) with averages of 22.33 cm and 21.13 cm respectively, while in the "B" range are T2 (L2) and T1 (L1) with averages of 15.38 cm and 14.56 cm.

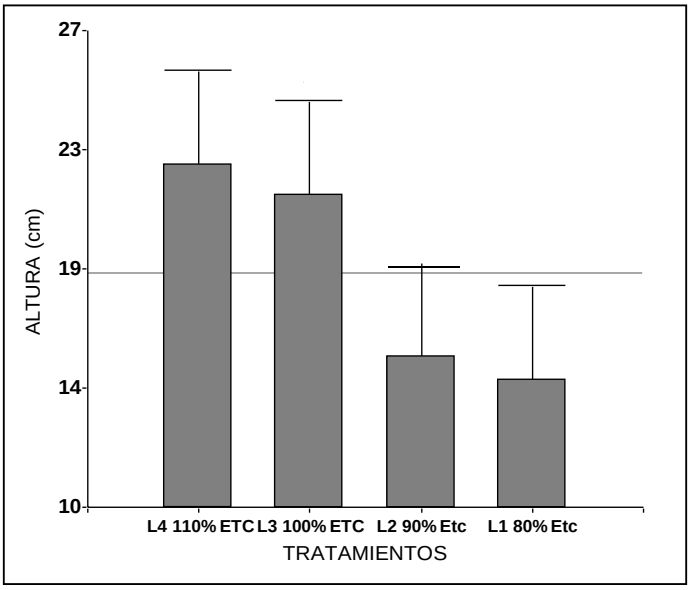
Table No. 9. Tukey 5% test for plant height (cm) to flowering.

TREATMENTS (IRRIGATION SHEETS)	HALF	RANK

T4 110% ETC	22,23	To	
T3 100% ETC	21,13	To	
T2 90% ETC	15,38		B
T1 80% ETC	14,56		B

Prepared by: Authors, 2023

In Graph No. 3, the influence of the application of the four irrigation sheets on the strawberry crop (*Fragaria sp* "Albión Californiana") on the height of the plant (cm) at flowering is directly appreciated, with T4 (L4) presenting the highest average with 22.23 cm, statistically surpassing T1 (L1) with 14.56 cm.



Graph No. 3. Average plant height (cm) at flowering.
Prepared by: Authors, 2023. In original language Spanish

Number of fruits harvested per plant.

The analysis of variance for the number of fruits harvested per plant at 158, 165, 172 and 179 days after transplanting, did not show significant statistical differences in the treatments corresponding to the application of the different irrigation sheets to the strawberry crop (*Fragaria sp* "Albión Californiana"), with coefficients of variation of 9.34%. 12.05%, 14.01% and 11.24% respectively.

Fruit weight per plant (g/plant)

Fruit weight per plant (g/plant) at 158 and 165 days after transplanting.

The analysis of variance for the weight of the fruits per plant (g/plant) at 158 and 165 days after transplanting, did not show significant statistical differences in the treatments corresponding to the irrigation sheets applied to the strawberry crop (*Fragaria sp* "Albión Californiana"), with coefficients of variation of 17.49% and 15.60% respectively.

Fruit weight per plant (g/plant) at 172 days after transplanting.

The analysis of variance for the weight of the fruits per plant (g/plant) at 172 days after transplanting (Table No. 10), showed statistically significant differences between the treatments corresponding to the irrigation sheets applied to the strawberry crop (*Fragaria sp* "Albión Californiana")), with a coefficient of variation of 13.93% and a general mean of 48.14 g.

Table No. 10. ADEVA Fruit weight per plant (g/plant) at 172 days after transplanting.

F.V.	Gl	S.C	C.M	F	P-VALUE
TREATMENTS	3	737,86	245,95	5.47 *	0,0133
REPETITIONS	4	264,44	66,11	1,47	0,2715
Error	12	539,40	44,95		
Total	19	1541,70			
CV (%)	13.93				

*: Significant

Prepared by: Authors, 2020

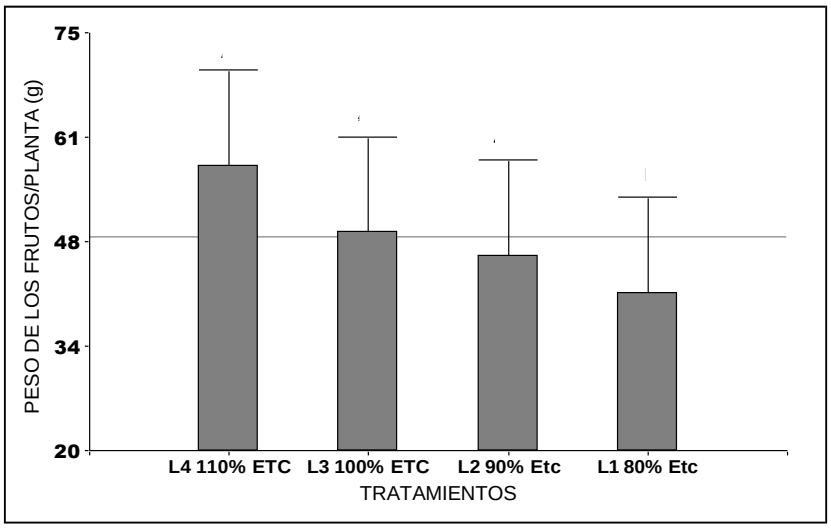
Tukey's test at 5% for fruit weight per plant (g/plant) at 172 days after transplanting (Table No. 11); establishes the existence of two ranges, in the "A" range is T4 with an average value of 57.45 g, while in the "B" range is T1 with an average of 40.78 g.

Table No. 11. Tukey's 5% test for fruit weight per plant (g/plant) at 172 days after transplanting.

TREATMENTS (IRRIGATION SHEETS)	HALF	RANK	
T4 110% ETC	57,45	To	
T3 100% ETC	48,71	To	B
T2 90% ETC	45,61	To	B
T1 80% ETC	40,78		B

Prepared by: Authors, 2023

In Graph No. 4, the influence of the application of the four irrigation sheets on the strawberry crop (*Fragaria sp* "Albión Californiana") on the weight of the fruits per plant (g/plant) at 172 days after transplanting can be seen, with T4 (L4) presenting the highest average. statistically surpassing T1 (L1).



Graph No. 4. Average fruit weight per plant (g/plant) at 172 DDT. Prepared by: Authors, 2023. In original language Spanish

Fruit weight per plant (g/plant) at 179 days after transplanting.

The analysis of variance for fruit weight per plant (g/plant) at 179 days after transplanting (Table No. 12) showed highly significant statistical differences between the treatments corresponding to the irrigation sheets applied to strawberry cultivation (*Fragaria sp* "Albión Californiana"), with a coefficient of variation of 10.45% and a general mean of 54.33 g.

Table No. 12. ADEVA Fruit weight per plant (g/plant) at 179 days after transplanting.

F.V.	Gl	S.C	C.M	F	P-VALUE
TREATMENTS	3	1130,82	376,94	11.70 **	0,0007
REPETITIONS	4	422,26	105,57	3,28	0,0492
Error	12	386,47	32,21		
Total	19	1939,55			
CV (%)	10,45				

**: Highly significant

Prepared by: Authors, 2023

Tukey's 5% test for fruit weight per plant (g/plant) at 179 days after transplanting (Table No. 13); establishes the existence of two ranges, in the "A" range is T4 with an average value of 64.43 g and T3 with a mean of 58.71 g, while in the "B" range is T2 and T1 with means of 47.35 g and 46.83 g respectively.

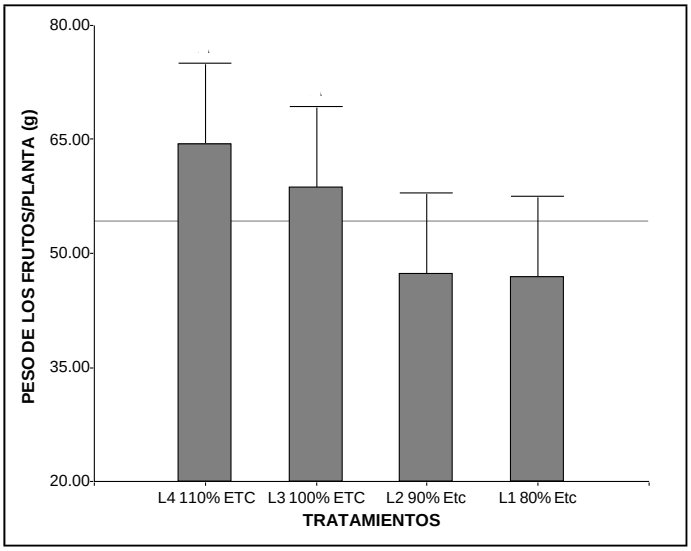
Table No. 13. Tukey's 5% test for fruit weight per plant (g/plant) at 179 days after transplantation.

TREATMENTS (IRRIGATION SHEETS)	HALF	RANK
T4 110% ETC	64,43	To
T3 100% ETC	58,71	To

T2 90% ETC	47,35	B
T1 80% ETC	46,83	B

Prepared by: Authors, 2023

In Graph No. 5, the influence of the application of the four irrigation sheets on the strawberry crop (*Fragaria sp* "Albión Californiana") on the weight of the fruits per plant (g/plant) at 179 days after transplanting is directly appreciated, with T4 (L4) presenting the highest average with 64.43 g, statistically surpassing T1 (L1) with 46.83 g.



Graph No. 5. Average fruit weight per plant (g/plant) at 179 DDT.

Prepared by: Authors, 2023. In original language Spanish

Fruit length (cm).

Fruit length (cm) at 158 and 165 days after transplanting.

The analysis of variance for fruit length (cm) at 158 and 165 days after transplanting shows no statistically significant differences between the treatments corresponding to the irrigation sheets applied to the strawberry crop (*Fragaria sp* "Albión Californiana"), with coefficients of variation of 5.21% and 3.71% respectively.

Fruit length (cm) at 172 days after transplantation.

The analysis of variance for fruit length (cm) at 172 days after transplanting (Table No. 14), showed highly significant statistical differences between the treatments corresponding to the irrigation sheets applied to the strawberry crop (*Fragaria sp* "Albión Californiana"), with a coefficient of variation of 3.47% and a general mean of 4.05 cm.

Table No. 14. ADEVA Fruit length (cm) at 172 days after transplantation.

F.V.	Gl	S.C	C.M	F	P-VALUE
TREATMENTS	3	0,49	0,16	8.38 **	0,0028
REPETITIONS	4	0,06	0,02	0,76	0,5689
Error	12	0,24	0,02		

Total	19	0,79
CV (%)	3,47	

**: Highly significant

Prepared by: Authors, 2023

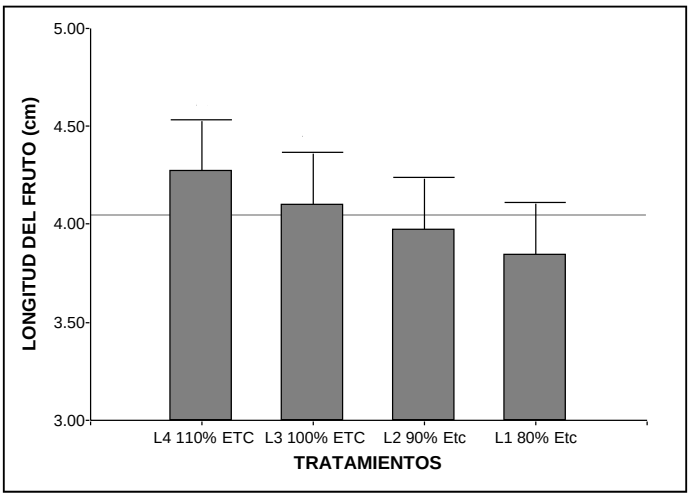
Tukey's 5% test for fruit length (cm) at 172 days after transplantation (Table No. 15); establishes the existence of two ranges, in the "A" range is T4 with an average value of 4.27 cm, while in the "B" range is T2 and T1 with means of 3.97 cm and 3.85 cm respectively.

Table No. 15. Tukey's 5% test for fruit length (cm) at 172 days after transplant.

TREATMENTS (IRRIGATION SHEETS)	HALF	RANK	
T4 110% ETC	4,27	To	
T3 100% ETC	4,10	To	B
T2 90% ETC	3,97		B
T1 80% ETC	3,85		B

Prepared by: Authors, 2023

In Graph No. 6. The influence of the application of the four irrigation sheets on the strawberry crop (*Fragaria sp* "Albión Californiana") on the fruit length (cm) at 172 days after transplanting is directly appreciated, with T4 (L4) presenting the highest average with 4.27 cm, statistically surpassing T1 (L1) with 3.85 cm.



Graph No 6. Average fruit length (cm) at 172 DDT.

Prepared by: Authors, 2023. In original language Spanish

Fruit length (cm) at 179 DDT.

The analysis of variance for fruit length (cm) at 179 days after transplanting (Table No. 16), showed statistically significant differences between the treatments corresponding to the irrigation sheets applied to the crop of (*Fragaria sp* "Albión Californiana"), with a coefficient of variation of 5.78% and a general mean of 4.12 cm.

Table No. 16. ADEVA Fruit length (cm) at 179 DDT.

F.V.	Gl	S.C	C.M	F	P-VALUE

TREATMENTS	3	0,71	0,24	4.16 *	0,0309
REPETITIONS	4	0,55	0,14	2,44	0,1037
Error	12	0,68	0,06		
Total	19	1,94			
CV (%)	5,78				

*: Significant

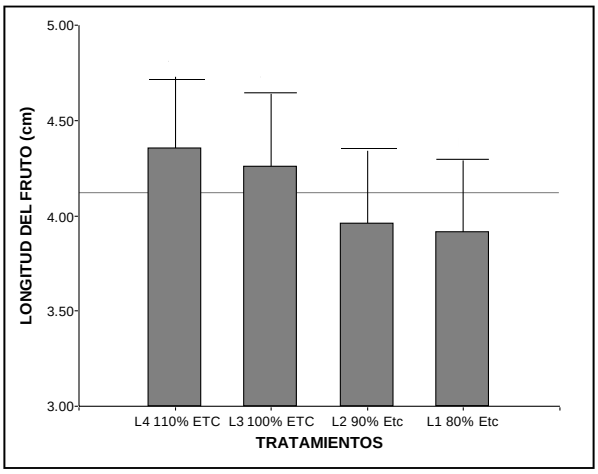
Prepared by: Authors, 2023.

The 5% Tukey test for fruit length at 179 days after transplantation (Table 17 and Graph 7) places T4 in the "A" range with a mean of 4.35 cm, statistically surpassing the "B" range that places T2 and T1 with averages of 3.96 cm and 3.91 cm, respectively.

Table No. 17. Tukey's 5% test for fruit length (cm) at 179 DDT.

TREATMENTS (IRRIGATION SHEETS)	HALF	RANK	
T4 110% ETC	4,35	To	
T3 100% ETC	4,26	To	B
T2 90% ETC	3,96		B
T1 80% ETC	3,91		B

Prepared by: Authors, 2023



Graph No 7. Average fruit length (cm) at 179 DDT.
Prepared by: Authors, 2023. In original language Spanish

Fruit weight (g/fruit).

Fruit weight (g/fruit) at 158 and 165 days DDT.

The analysis of variance for fruit weight (g/fruit) at 158 and 165 days after transplantation did not show statistically significant differences between the treatments corresponding to the irrigation sheets applied to the strawberry crop (*Fragaria sp* "Albión Californiana"), with coefficients of variation of 11.41% and 8.58%.

Fruit weight (g/fruit) at 172 DDT.

The analysis of variance for fruit weight (g/fruit) at 172 days after transplanting (Table No. 18), showed highly significant statistical differences between the treatments

corresponding to the irrigation sheets applied to the strawberry crop (*Fragaria sp* "Albión Californiana"), with a coefficient of variation of 8.31% and a general mean of 18.00 g.

Table No. 18. ADEVA Fruit weight (g/fruit) at 172 DDT.

F.V.	Gl	S.C	C.M	F	P-VALUE
TREATMENTS	3	62,91	20,97	9.38 **	0,0018
REPETITIONS	4	12,18	3,05	1,36	0,3038
Error	12	26,82	2,24		
Total	19	101,91			
CV (%)	8,31				

**: Highly significant

Prepared by: Authors, 2023

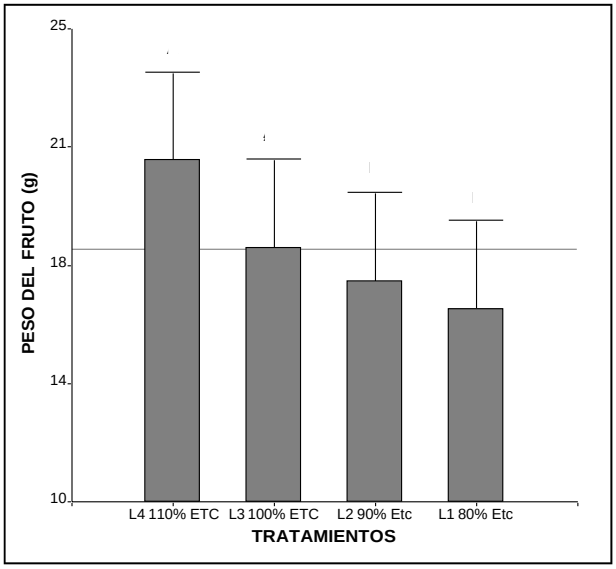
Tukey's 5% test for fruit weight (g/fruit) at 172 days after transplantation (Table No. 19); establishes the existence of two ranges, in the "A" range is T4 with an average value of 20.83 g and the "B" range where T2 and T1 are located with means of 16.99 g and 16.12 g respectively.

Table No. 19. Tukey's 5% test for fruit weight (g/fruit) to 172 DDT.

TREATMENTS (IRRIGATION SHEETS)	HALF	RANK	
T4 110% ETC	20,83	To	
T3 100% ETC	18,05	To	B
T2 90% ETC	16,99		B
T1 80% ETC	16,12		B

Prepared by: Authors, 2023

In Graph No. 8, the influence of the application of the four irrigation sheets on the strawberry crop (*Fragaria sp* "Albión Californiana") on the weight of the fruit (g/fruit) at 172 days after transplantation can be seen, with T4 presenting the highest average with 20.83 g, statistically surpassing T1 with 16.12 g.



Graph No. 8**. Average fruit weight (g/fruit) at 172 DDT.**
Prepared by: Authors, 2023. In original language Spanish

Fruit weight (g/fruit) at 179 days after transplantation.

The analysis of variance for fruit weight (g/fruit) at 179 days after transplanting (Table No. 20), showed statistically significant differences between the treatments corresponding to the irrigation sheets applied to strawberry cultivation (*Fragaria sp* "Albión Californiana")), with a coefficient of variation of 14.54% and a general mean of 18.84 g.

Table No. 20. ADEVA Fruit weight (g/fruit) at 179 DDT.

F.V.	Gl	S.C	C.M	F	P-VALUE
TREATMENTS	3	104,95	34,98	4.66 *	0,0221
REPETITIONS	4	54,07	13,52	1,80	0,1937
Error	12	90,10	7,51		
Total	19	249,11			
CV (%)	14,54				

*: Significant

Prepared by: Authors, 2023

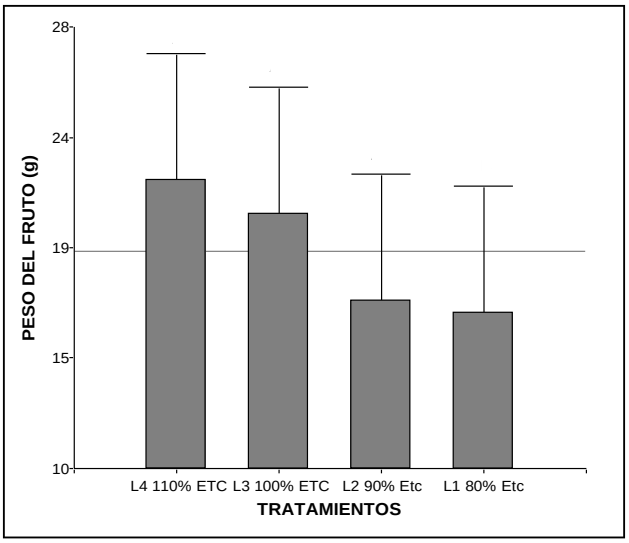
Tukey's 5% test for fruit weight (g/fruit) at 179 days after transplantation (Table 21 and Graph 9); establishes the existence of two ranges, in the "A" range is T4 with an average value of 21.76 g and in the "B" range is T1 with an average of 16.36 g respectively.

Table No. 21. Tukey's 5% test for fruit weight (g/fruit) at 179 DDT.

TREATMENTS (IRRIGATION SHEETS)	HALF	RANK
T4 110% ETC	21,76	To
T3 100% ETC	20,39	To B
T2 90% ETC	16,85	To B

T1 80% ETC	16,36	B

Prepared by: Authors, 2023



Graph No 9**. Average fruit weight (g/fruit) at 179 DDT.**
Prepared by: Authors, 2023. In original language Spanish

Yield

Yield (kg/ha) at 158 and 165 DDT.

The analysis of variance for yield (kg/ha) at 158 and 165 DDT, did not present statistically significant differences between the treatments corresponding to the irrigation sheets applied to the strawberry crop (*Fragaria sp* "Albión Californiana"), with coefficients of variation of 14.26% and 12.37%.

Yield (kg/ha) at 172 DDT.

The analysis of variance for yield (kg/ha) at 172 DDT (Table No. 22), showed statistically significant differences between the treatments corresponding to the irrigation sheets applied to the strawberry crop (*Fragaria sp* "Albión Californiana")), with a coefficient of variation of 10.70% and a general mean of 6174.44 kg/ha.

Table No. 22. ADEVA Yield (kg/ha) at 172 DDT.

F.V.	Gl	S.C	C.M	F	P-VALUE
TREATMENTS	3	12139478,77	4046492,92	5.47 *	0,0133
REPETITIONS	4	4350615,07	1087653,77	1,47	0,2715
Error	12	8874465,03	739538,75		
Total	19	25364558,87			
CV (%)	10,70				

*: Significant

Prepared by: Authors, 2023

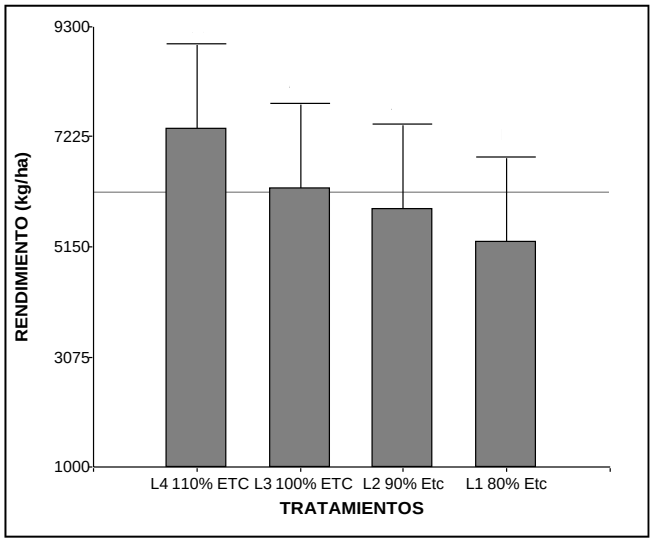
Tukey's 5% yield test (kg/ha) at 172 days after transplantation (Table No. 23); establishes the existence of two ranges, in the "A" range is T4 with an average value of 7 368.92 kg/ha and in the "B" range is T1 with an average of 5 230.71 kg/ha respectively.

Table No. 23. Tukey's 5% test for yield (kg/ha) at 172 DDT.

TREATMENTS (IRRIGATION SHEETS)	HALF	RANK	
T4 110% ETC	7368,92	To	
T3 100% ETC	6247,87	To	B
T2 90% ETC	5850,24	To	B
T1 80% ETC	5230,71		B

Prepared by: Authors, 2023

Graph No. 10 shows the direct influence of the application of the four irrigation sheets on the strawberry crop (*Fragaria sp* "Albión Californiana") on the yield (kg/ha) at 172 days after transplanting, with T4 presenting the highest average with 7368.92 kg/ha, statistically surpassing the rest of the treatments under study.



Graph No 10**. Average yield (kg/ha) at 172 DDT.**
Prepared by: Authors, 2023. In original language Spanish

Yield (kg/ha) at 179 DDT.

The analysis of variance for yield (kg/ha) at 179 days after transplanting (Table No. 24), showed highly significant statistical differences between the treatments corresponding to the irrigation sheets applied to the strawberry crop (*Fragaria sp* "Albión Californiana")), with a coefficient of variation of 7.22% and a general mean of 6968.73 kg/ha.

Table No. 24**. ADEVA Yield (kg/ha) at 179 DDT.**

F.V.	Gl	S.C	C.M	F	P-VALUE
TREATMENTS	3	18604698,42	6201566,14	11.70 **	0,0007
REPETITIONS	4	6947197,05	1736799,26	3,28	0,0492
Error	12	6358269,17	529855,76		
Total	19	31910164,64			
CV (%)	7,22				

******: Highly significant

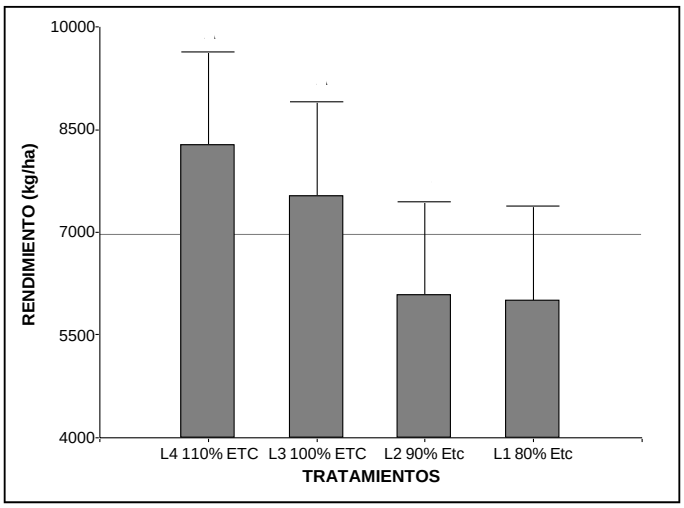
Prepared by: Authors, 2023

Tukey's 5% test for yield (kg/ha) at 179 DDT (Table No. 25); establishes the existence of two ranges, in the "A" range is T4 with an average value of 8264.22 kg/ha and T3 with an average of 7530.54 kg/ha, while in the "B" range is T2 and T1 with averages of 6073.43 kg/ha and 6006.73 kg/ha respectively.

Table No. 25**. Tukey's 5% test for yield (kg/ha) at 179 DDT.**

TREATMENTS (IRRIGATION SHEETS)	HALF	RANK
T4 110% ETC	8264,22	To
T3 100% ETC	7530,54	To
T2 90% ETC	6073,43	B
T1 80% ETC	6006,73	B

Prepared by: Authors, 2023



Graph No. 11**. Average yield (kg/ha) at 179 DDT.**
Prepared by: Authors, 2020. In original language Spanish

Graph No. 11 shows the direct influence of the application of the four irrigation sheets on the cultivation of (*Fragaria sp* "Albion Californiana") on the yield (kg/ha) at 179 DDT, with T4 presenting the highest average with 8264.22 kg/ha, statistically surpassing T1 with 6006.73 kg/ha.

DISCUSSIONS

The methodology (Fries et al., 2012) is important to obtain specific and accurate climatic information for the Pungal El Quinche sector, belonging to the Guano canton in the province of Chimborazo, where there are no meteorological data available.

Through geographic information systems (GIS) it is possible to create isothermal maps, by considering the altitudinal gradient through the spatial interpolation of the climatic variables of relative humidity and average temperature of the Matus, Quimiag and ESPOCH stations, based on a digital elevation modelby means of the IDW (Weighted Inverse Distance) method present in the ArcGis software, with an output resolution of 30

meters and in this way there are georeferenced digital databases that when updated allow obtaining climate data for that particular area and that can be used in subsequent research work regarding the use and management of water resources in agriculture.

The best results in terms of the phenological and physiological response of the strawberry crop (*Fragaria sp* "Albión Californiana") were obtained with an irrigation sheet corresponding to 110% of the crop evapotranspiration (ETc), with an average fruit weight of 20.83 g at 172 days after transplanting and 21.76 g at 179 days after transplanting. likewise with a mean fruit length of 4.27 cm (42.70 mm) at 172 days after transplantation and 4.35 cm (43.5 mm) at 179 days after transplantation; which are similar to what was reported by (Chávez et al., 2013), in a research carried out at the Botana Experimental Farm of the University of Nariño in Colombia, where the high blades delivered to the cultivation of the strawberry variety Camino Real, the highest values are obtained regarding the weight of the fruit per plant with an average of 29.86 g and a fruit length of 44.90 mm, which corroborates that the high sheets delivered to the strawberry crop increase the water content in the fruits and significantly increase their size and weight. As stated by (Deaquiz et al., 2014), in a research carried out under a greenhouse in the city of Tunja (Boyacá) in Colombia, "He evaluated the effect of different irrigation sheets on the production and quality of the strawberry Ventana variety'' and determined that the application of high amounts of water evidences a greater development of the plant with a larger leaf surface; on the contrary, if the water supply is insufficient, a stomatal closure occurs that causes a decrease in photosynthesis that has the immediate effect of limiting the growth of the stem and leaves, likewise a greater water supply allows the nutrients in the soil to be easily available and can be directed towards the fruits through more efficient processes of assimilation and translocation, which finally increases their weight.

The maximum yield was obtained with treatment 4 (110% of crop evapotranspiration) with averages of 7368.92 kg/ha at 172 days after transplanting and 8264.22 kg/ha at 179 days after transplanting; results similar to those reported by (Chávez et al., 2013), where the application of a high irrigation sheet on the cultivation of the Camino Real variety strawberry presents the highest yield with 22.12 T/ha, as a result of the high amount of water present in the soil that increases the production of dry matter causing a greater extraction of nutrients and high yields of fresh fruit. (García et al., 2018), in a research carried out in the province of Tungurahua on a sandy loam soil similar to that of the trial area, determined that the application of 125% of the raw sheet in the cultivation of strawberry (Fragaria vesca) Var. Diamante produced the highest yield with an average of 812 kg/ha/week of fruit; confirming the directly proportional relationship between the water content provided to the crop and the relative yield, a statement that is evidenced by treatments 1 and 2 that showed the lowest yields when receiving lower amounts of water.

CONCLUSIONS

The effects of the four irrigation sheets evaluated on the cultivation of strawberries (Fragaria sp) Var. Californian Albion under the agroclimatic and edaphic conditions of the Pungal el Quinche sector in the Guano canton in the province of Chimborazo, determined that the application or replacement of a sheet of 649.75 mm/year (2.28 mm/day) corresponding to 110% of the crop evapotranspiration (ETc), presented the plants with a good development and with the greater weight and length of the harvested fruits in relation to the rest of the treatments.

In the cultivation of strawberries (Fragaria sp) Var. Californian Albion, the directly proportional relationship between the application of a high irrigation sheet (110% of the evapotranspiration of the ETc crop) and the highest yields obtained corresponding to 7368.92 kg/ha at 172 days after transplanting and 8264.22 kg/ha at 179 days after transplanting respectively is confirmed.

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