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Effect of Potassium Iodide and Salicylic Acid in the Cultivation of Hydroponic Strawberries (*Fragaria* L)

Efecto del Ioduro de Potasio y Ácido Salicílico en el Cultivo de Fresas Hidropónicas *(Fragaria* L*)*

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Abstract

The fortification of essential foods that the majority of the population consumes has a very great advantage in nutrition; Since it is one of the most effective ways to fill some deficiencies, the objective of this work is to increase the nutritional value of strawberry cultivation under hydroponic conditions, the methodology started with the disinfection with 10% chlorine of the hydroponic system, it was located In the basket, to place the seedlings, the nutrition was implemented with the initial Steiner's solution at 50% and later at 100%, three salicylic acid (AS) treatments were carried out: 0.0012 g / L, 0.0030 g / L, 0.0070 g / L and control (0 salicylic acid) and Potassium Iodide (KI) with treatments of 0.0014g / L, 0.0016g / L and 0.0018g / L and control (0 iodine). In soluble solids, a total of three fruits were selected per treatment, it was shown that (T3), repetition 1 (0.0014 g / L) with KI, obtained an average of 8 fruits, the (T1), repetition 2 (0.0030 g / L) with AS (Salicylic Acid) with an average of 23.3 g of fruit weight, repetition 1 (0.0014 g / L) with IK, obtained an average of 8.8000 ºBrix, the ANOVA analysis shows in AS a P value of 0.034, in the control has a P value of 0.054 and in IK a P value of 0.040, which tells us that there is a positive significance in relation to the control towards the weight of the fruits, for which treatment number three is suggested for subsequent work . Keywords: Salicylic acid, potassium iodide, strawberry, NFT system and refractometer.

Salicylic acid, Iodine, Strawberry, NFT system, Refractometer

Resumen

La fortificación de alimentos esenciales que consume la mayoría de la población, tiene una ventaja muy grande en la nutrición; ya que es una de las maneras más eficaces de suplir algunas deficiencias, el objetivo del presente trabajo es incrementar el valor nutricional del cultivo de la fresa bajo condiciones hidropónicas, la metodología inicio con la desinfección con cloro al 10% del sistema hidropónico, se ubicó en la canastilla, para colocar las plántulas, la nutrición se implementó la solución de Steiner inicial al 50% y posteriormente al 100%, se realizaron tres tratamientos ácido salicílico (AS) fueron: 0.0012 g/L, 0.0030 g/L, 0.0070 g/L y testigo (0 ácido salicílico) y el Ioduro de Potasio (KI) con tratamientos de 0.0014g/L, 0.0016g/L y 0.0018g/L y testigo (0 yodo). En solidos solubles se seleccionó un total de tres frutos por tratamiento, se demostró que el (T3), repetición 1 (0.0014 g/L) con KI, obtuvo una media de 8 frutos, el (T1), repetición 2 (0.0030 g/L) con AS (Ácido Salicílico) con media de 23.3 g de peso en frutos, repetición 1 (0.0014 g/L) con IK, obtuvo una media de 8.8000 ºBrix, el análisis ANOVA arroja en AS un valor de P de 0.034, en el testigo un valor de P de 0.054 y en IK un valor de P de 0.040, lo cual nos dice que hay una significancia positiva en relación al testigo hacia el peso de los frutos, por lo cual se sugiere el tratamiento número tres para posteriores trabajos.

Ácido salicílico, Yoduro de Potasio, Fresa, Sistema NFT, Refractómetro.

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Introduction

The *Fragaria* x *ananassa* Duch. Strawberry is a fruit appreciated worldwide for its aroma, bright red color and juicy texture (Khoshnevisan *et al*., 2013). The incorporation of this crop in the municipality of Rodeo, Dgo, may be developed under two protected conditions; one is the greenhouse for better pest control and the hydroponic system that helps control the application of nutrient solutions in a safe and efficient way.

Seedling development under NFT conditions and under greenhouse conditions is a great tool for the control of pests that affect the development of fruits, flowers and plants. On the other hand, the introduction of soilless crops or hydroponic crops are techniques used for the optimal development of the crop in which its root system develops without soil (Nieto, 2013).

This process is generated without soil, giving the plants the appropriate conditions (oxygenation and the assimilation of nutrients in an ionic way), in addition, according to Ruíz (2012), he estimated the amount of fruit of the first and second qualities are the most commercialized. So more production is generated in less space by using production tools properly.

Theoretical Foundation

Strawberry in Mexico

Strawberry cultivation was confined until 1990 in the regions of Irapuato, Gto.; Zamora, Michoacán; and neighboring municipalities (central Mexico). Starting in 1991, it spread to the San Quintin, Baja California area. The expansion of the crop occurred in 1994, with the entry into force of the North American Free Trade Agreement. In 2009, a sown area of 6,131 ha was reported, located in Michoacán, 3,561 ha in Baja California and 1,543 in Guanajuato, which covered 92% of the total area (SADER-SIAP, 2019).

Today Michoacán and Guanajuato concentrate 4,588 ha, which represents 69% of the cultivated area in the country (Cruz, 2014).

Strawberry cultivation

Strawberry is a perennial type vegetable that can live for several years, however, it lasts two years in economic production, in older plantations they are weaker, with low yield and lower quality fruits (Cruz, 2014).

Strawberry reproduction

The plants are propagated by stolons, and are generally distributed by bare roots. The crop follows one or two models, annual plasticulture, or a perennial system of rows or mounds (Sánchez, 2017).

Strawberry marketing

In national terms, strawberry production is important due to the generation of foreign exchange for exportation since Mexico is the main strawberry exporter to the US market (Villegas, 2017).

Nutritive solution

The concentration at which the different ions are found can be expressed in different ways, being millimole / L or meq / L in soilless cultivation systems, the most common in the case of ppm macro elements, and micro elements. To arrive at the formulation of the nutrient solution, it is important to take into account factors such as the hydrogen potential (pH), electrical conductivity (EC), which lead to good plant nutrition (Steiner, 1984).

NFT hydroponic system

This system forms a crop layer along the channels with a slope, where plants, especially vegetables, keep their roots moist and necessary nutrients. The greenhouse strawberry production with this system is used in temperate zones; since with excess temperature stress is caused in the plant, which requires greater care and nutritional treatment (González, 2008).

Iodine in agriculture

In the programs fortification of table salt with iodine, and with the purpose of ensuring the recommended daily intake of 150-300 μg of iodine day-1 (Risher and Keith, 2009).

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Various efforts are carried out to add iodine to terrestrial plants (especially medicinal plants and vegetables) to give them greater therapeutic or nutritional value (Cui *et al*., 2003).

Salicylic acid (AS) applied in agriculture Recent research indicates that AS stimulates the biosynthesis of phenolic compounds and the antioxidant capacity in fruits that, when consumed, improve public health (Khalili *et al*., 2010; Khandaker *et al*., 2011).

Methodology to be developed

Description of the study area

The present work was developed within the facilities of the Technological University of Rodeo in the municipality of Rodeo, Dgo, (Figure 1). It is located in the center of the state of Durango. It borders to the north with the municipality of San Pedro del Gallo; to the northeast with San Luis del Cordero; to the east with Nazas; to the south San Juan del Río. Its municipal seat is located at the coordinates 25º11 'of north latitude and 104º34' of west longitude, at an altitude of 1,340 meters above sea level.

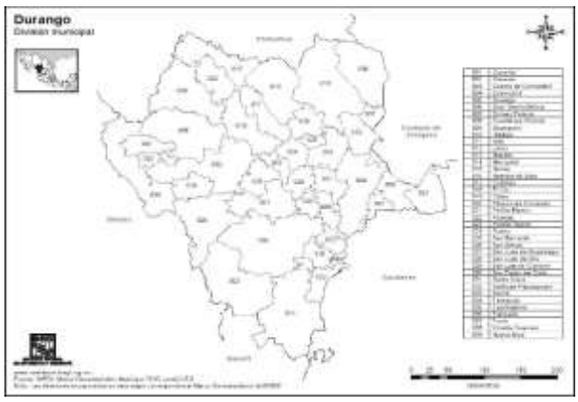

Figure 1 Location of study area
Source: Silva, 2020

Washing and disinfecting the NFT system

To wash the NFT system, the equipment was uninstalled for greater efficiency when cleaning, in addition to having a better reach in and out of the tubes with the help of a wire or cable that is flexible enough to place a sponge. or rag to push back and forth.

Chlorine was used for disinfection, in a concentration of 1 ppm

Water circulation in the NFT system

For the water circulation a submersible pump of 19 L / hour is used to give fluidity to the system, in order to oxygenate the roots and plants as much as possible, as well as to promote fertilization.

Strawberry seedling transplant

To place the seedlings in the NFT system, the baskets that hold the plants over the tube hole are disinfected with the same dosage with which the system and the pump were disinfected.

Sponge placement in baskets

A sponge was placed around the root and placed in the basket to prevent light rays from penetrating the root, leaving out the propagation of pests inside the tubes, preventing good oxygenation.

Vegetal Nutricion

In the nutrition process, it was carried out with a Steiner solution at 50% and later at 100%, with fertilizers being represented (Table 1).

Agrochemicals	Amount of g for 50 L of water
Nitric acid (HNO_3)	2.2 mL
Phosphoric acid	6.15 mL
Calcium nitrate (CaNO3)	22 g
Potassium nitrate (KNO3)	13.65 g
Potassium sulfate (K2SO4)	10 g
Magnesium MgSO47H2O	17.2 g
Micros	2 g

Table 1 Amount of fertilizers applied for the 100% Steiner solution in 50 L of water

Application of micro-nutrients in water

A quantity of 2 g of microphones was applied, which has iron as an essential element. Once the strawberry plant was observed, the leaves turned green-brown; this in order that the plant does not absorb the alkaline from the recirculating water.

Foliar application of iodine

The first foliar application of potassium iodide was carried out 15 days after transplantation, with 4 foliar applications being made throughout its cycle, with 15-day intervals. The treatments were iodine in quantities of 0.0014 g / L, 0.0016 g / L and 0.0018 g / L, as well as a control (0 iodine) with the same applications as the previous treatments.

The foliar sprays were carried out with one atomizer per plant to reduce the danger of contamination in the other treatments. The concentrations being represented in the following Table 2.

Treatment	Weight in mg	Division by 1000	Weight in g / L
0 UM	0	/1000	Witness
5 UM	1.40 mg/L	/1000	0.0014 g/L
10 UM	1.60 mg/L	/1000	0.0016 g/L
15 UM	1.80 mg/L	/1000	0.0018 g/L
*UM= Millimolar units			

Table 2 Concentration of each of the iodine applications by treatment

Foliar application with salicylic acid

The first foliar application of salicylic acid was carried out 15 days after transplantation, with 4 foliar applications being made throughout its cycle, with 15-day intervals. The treatments were 0.0012 g / L, 0.0030 g / L, 0.0070 g / L, and a control (0 salicylic acid) with the same applications as the previous treatments. The foliar sprays were carried out with the help of a one-liter atomizer to facilitate the application per plant and reduce the danger of contamination in the other treatments than in subset, as expressed by Sariñana-Aldaco (2019), in an investigation that I performed with Salicylic Acid, which showed a good response of the tomato crop, the application was directly in the nutrient solution, in the present experiment the concentrations were represented in the following Table 3.

Treatment	Weight in mg	Division by 1000	Weight in g / L
0 UM	0	/1000	Witness
5 UM	1.20 mg/L	/1000	0.0012 g/L
10 UM	3.07 mg/L	/1000	0.0030 g/L
15 UM	7.05 mg/L	/1000	0.0070 g/L
*UM= Millimolar units			

Table 3 Concentration of each of the salicylic acid applications per treatment

Determination of total soluble solids in fruit

For the determination of soluble solids, a total of 3 fruits were selected per treatment, gloves made of latex material were used in order not to contaminate the samples, which consisted in the extraction of the aliquot of the fruit in order to deposit it in the orifice of the manual refractometer (Master Refractometer Automatic Atago), for later the values were expressed in degrees brix and temperature taken.

Fruit weight

In this activity, 3 fruits per treatment were taken as a reference in order to compare the weight in grams, for this a gramera scale with a capacity of 1000 g was used.

Number of sheets

For the number of leaves, it was completely at random observing the new leaves per plant of each treatment; this in order to relate the fruits with the other applications of potassium iodide and salicylic acid.

Experimental design

A completely randomized experimental design was used with five treatments and six repetitions per treatment, with a total of 30 experimental units (each plant is considered an experimental unit), this was carried out a statistical analysis using SPSS Version 15.0 software, with an analysis variance (ANOVA) and mean comparison using the single-sample test ($P \leq 0.05$).

Results and Discussion

Analysis of variance and comparison of mean using the test of a single sample ($P \leq 0.05$), for number of fruits. For the analysis of variance, it was determined in the SPSS version 15.0 program, with a single sample test ($P \leq 0.05$), which showed that treatment 3 (T3), repetition 3 with KI (Potassium Iodide), with addition of 0.0070 g / L obtained an average of 8 fruits. In an investigation with strawberry plants, cultivar Camarosa, the foliar application of gibberellic acid in a range of 0 to 40 mg / L increased the production of fruits per plant (Pérez de Camacaro *et al*., 2013).

These data do not agree in the present investigation; Since it was handled in units of g / L, in the case of the other treatments (salicylic acid and Control) the treatments are statistically equal in comparison of means, the same results were obtained (Table 4 and 5).

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Treatments	Number	Mean	Standard deviation	Typ. Error of the average
AS	3	6.6667	2.08167	1.20185
TES	3	6.0000	1.00000	0.57735
KI	3	8.6667	4.16333	2.40370
* AS = Salicylic Acid, KI = Potassium Iodide, TES = Control				

Table 4 Comparison of means using the test of a single sample (P≤0.05), in numbers of fruits

Treatments	gL	Sig. (Bilateral)	Difference of means	95% Confidence interval for the difference	gL	Sig. (Bilateral)
	Lower	Higher	Lower	Higher	Lower	Higher
AS	5.50	2	0.031	6.6166	1.4455	11.7878
TES	10.3	2	0.009	5.9500	3.4659	8.4341
KI	3.58	2	0.070	8.6166	-1.7256	18.9590
* AS = Salicylic Acid, KI = Potassium Iodide, TES = Control						

Table 5 Statistics for a sample analysis of variance (ANOVA), for numbers of fruits

Analysis of variance and comparison of mean using the single sample test (P≤0.05), for fruit weight

For the fruit weight variable, the analysis of variance and with a single sample test (P≤0.05), it was shown that treatment 1 (T1), repetition 2 with AS (Salicylic Acid) with the addition of 0.0030 g / L obtained An average of 23.3 g with fruit weight, in an investigation by Domínguez-Morales (2012), evaluated the variety 'Aguedilla' of strawberry cultivation presented the highest average fruit weight throughout the campaign, with average values of 29.5 g fruit -1, these results do not agree in the present investigation (Table 6).

Treatments	Number	Mean	Standard deviation	Typ. Error of the average
AS	3	23.3333	7.63763	4.40959
TES	3	18.3333	7.63763	4.40959
KI	3	22.6667	8.08290	4.66667
* AS = Salicylic Acid, KI = Potassium Iodide, TES = Control				

Table 6 Comparison of mean using single sample test (P≤0.05), fruit weight

On the other hand, in the case of the other treatments (salicylic acid and potassium iodide), the ANOVA analysis shows a P value of 0.034 in AS, (salicylic acid), a P value of 0.054 in the control and in IK (Potassium iodide) a P value of 0.040, which tells us that there is a positive significance in relation to the control towards the weight of the fruits (Table 6 and 7).

Treatments	gL		Sig. (Bilateral)	Difference of means	95% Confidence interval for the difference	gL
	Lower	Higher	Lower	Higher	Lower	Higher
AS	5.280	2	0.034	23.28333	4.3104	42.2562
TES	4.146	2	0.054	18.28333	-.6896	37.2562
IK	4.846	2	0.040	22.61667	2.5376	42.6957
* AS = Salicylic Acid, KI = Potassium Iodide, TES = Control						

Table 7 Statistics for a sample analysis of variance (ANOVA), for fruit weight

Analysis of variance and mean comparison using the single sample test (P≤0.05), for total soluble solids

For the variable total soluble solids, the analysis of variance and with a single sample test (P≤0.05), which showed that treatment 3 (T3), repetition 1 with IK (Potassium Iodide), with the addition of 0.0014 g / L obtained an average of 8.8000 ºBrix, in the case of the other treatments (salicylic acid and Control), they are statistically equal in comparison of means, the same results were obtained, in an investigation by Casierra-Posada *et al*. (2011b), who mention that under the transparent cover, the strawberry plants showed a Net Assimilation Rate, higher than that presented by the strawberry plants grown under covers of other colors and obtained a higher content of TSS (Total soluble solids) , (Table 8 and 9). On the other hand, Petran *et al*. (2017), reported a difference in the SST values in fruits of different harvests. Likewise, it is mentioned that climatic conditions influence the total concentration of soluble solids.

Pokhrel *et al*. (2015), found that at higher temperatures the concentration of sugars increased in strawberry fruits.

Treatments	Number	Mean	Standard deviation	Typ. Error of the average	Treatments
AS		3	7.4333	0.51316	0.29627
TES		3	7.7000	0.36056	0.20817
IK		3	8.8000	0.69282	0.40000
*AS=Ácido Salicílico, KI=Ioduro de Potasio, TES=Testigo					

Table 8 Comparison of mean using the single sample test (P≤0.05), for total soluble solids (Brix degrees)

Treatments	Lower s	Degrees of freedom	Sig. (Bilateral)	Difference of means	95% Confidence interval for the difference	
	Inferior	Superior	Inferior	Superior	Lower	Higher
AS	24.921	2	0.002	7.38333	6.1086	8.6581
TES	36.749	2	0.001	7.65000	6.7543	8.5457
IK	21.875	2	0.002	8.75000	7.0289	10.4711
* AS = Salicylic Acid, KI = Potassium Iodide, TES = Control						

Table 9 Estadísticos para una muestra análisis de varianza (ANOVA), para solidos solubles totales (Grados brix)

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Conclusions

Based on the results, it was shown that potassium iodide surpassed in at least 2 variables with number of fruits and in total soluble solids with the addition of 0.0014 g / L, between the two variables evaluated. In the case of AS, (Salicylic acid), in variable fruit weight stood out with the addition of 0.0030 g / L.

Recomendations

Perform quantification of total flavonoids, antioxidant capacity and phenolic compounds with this to perform a more in-depth investigation.

Treatment number three is suggested for further work.

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