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Artículos Científicos

Estudio preliminar del fertirriego en el cultivo de la sandía (Citrullus lanatus, thumb) en Tolimán, Jalisco

Preliminary Study of the Fertirriego in the Culture of the Watermelon (Citrullus Lanatus, Thumb) in Tolimán, Jalisco

Estudo preliminar da fertirrigação no cultivo de melancia (Citrullus lanatus, thumb) em Tolimán, Jalisco

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Resumen

El cultivo de la sandía (*Citrullus lanatus, thumb*) es de los que más requiere del factor hídrico, por lo que la implementación de una adecuada nutrición, aunado al uso eficiente del agua, puede ser una buena alternativa de manejo para los productores de este fruto en la región de Tolimán, Jalisco, y en otras regiones del país. Se realizaron muestreos de suelo y de agua para determinar su calidad para riego, así como del estado nutrimental del cultivo de la sandía mediante las metodologías del índice de balance de Kenworthy (IBK) y la desviación del óptimo porcentual (DOP). Los resultados muestran que el IBK es útil para los casos de muestras pequeñas y en estudios a nivel local (por valles y/o municipios). Asimismo, este estudio preliminar sugiere que el número de observaciones sea cuando menos de 48, porque así se tendrán tres rangos nutrimentales: alto, medio y bajo. Bajo este esquema se repartirían las observaciones en una población normal: 48 / 3 = 16 observaciones por rango, lo que es suficiente para determinar los valores reales, sin tener que hacer uso de la desviación estándar.

Palabras clave: dosis, fertilizante, fertirriego, sandía.

Abstract

The cultivation of watermelon (*Citrullus lanatus, thumb*) is one that most requires the water factor, so the implementation of adequate nutrition, coupled with the efficient use of water, can be a good alternative management for watermelon producers from the Tolimán, Jalisco region, and from other regions of the country. Soil and water samples were taken to determine their quality for irrigation, as well as the nutrient status of the watermelon crop using the Kenworthy balance index (IBK) and the optimal percentage deviation (DOP) methodologies. The results show how the IBK is useful for small sample cases and in local studies (by valleys and/or municipalities). Likewise, this preliminary study suggests that the number of observations be at least 48, because this way there will be three nutrimental ranges: high, medium and low. Under this scheme, the observations would be distributed in a normal population 48 / 3 = 16 observations per range, enough to determine the real values, without having to make use of the standard deviation.

Keywords: dosage, fertilizer, fertigation, watermelon.

Resumo

O cultivo de melancia (Citrullus lanatus, polegar) é o que mais requer o fator água, portanto a implementação de uma nutrição adequada, aliada ao uso eficiente da água, pode ser uma boa alternativa de manejo para os produtores deste tipo. frutas na região de Tolimán, Jalisco, e em outras regiões do país. Amostras de solo e água foram conduzidas para determinar a qualidade da irrigação, assim como o estado nutricional da cultura da melancia, utilizando as metodologias do Índice de Equilíbrio de Kenworthy (IBK) e o desvio percentual ótimo (PDO). Os resultados mostram que o IBK é útil para pequenos casos de amostra e em estudos no nível local (por vales e / ou municípios). Da mesma forma, este estudo preliminar sugere que o número de observações seja de pelo menos 48, pois haverá três faixas nutricionais: alta, média e baixa. Sob este esquema, as observações seriam distribuídas em uma população normal: 48/3 = 16 observações por intervalo, o que é suficiente para determinar os valores reais, sem ter que fazer uso do desvio padrão.

Palavras-chave: dose, fertilizante, fertirrigação, melancia.

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Introduction

Modern drip irrigation had its origins in the arid zone of Israel. There, the Israeli engineer Simcha Blass, after an extensive period of drip irrigation research, in 1966, creates the first emitter for drip irrigation. In 1969, the issuer is patented in the United States of America by Ischajahu Blass and Simcha Blass. The concept of surface drip irrigation extended in the 60s from Israel to Australia, North America and South Africa and eventually worldwide. During the period of 1981-2000, microirrigation increased from 0.4 million to 3.2 million hectares. The United States was the first country to implement this technology with 1,050,000 hectares; Mexico ranked eighth in the world with 105,000 hectares (Lamm, Ayars and Nakayama, 2007).

Watermelon is one of the most important vegetables for Mexico due to the high volumes that are exported. These exports reached 283 million pesos in its accumulated of July 2016, which makes this fruit one of the most commercialized products by Mexico to the world (Ministry of Agriculture and Rural Development [Sagarpa] -Service of Agrifood

Information and Pesquera [SIAP], 2016). Likewise, this same source indicates that between 2015 and 2016, exports of this cucúrbita increased in terms of value 41 million dollars: a production in the country of 753 817 tons was reached, produced mainly in ten states of the Mexican Republic. Among this dozen entities, Jalisco ranked second nationally, only behind the state of Sonora, which contributed 23% of national production.

For the autumn-winter cycle of 2018, the intention of planting watermelon was 788,246 tons, which in a way maintained a good amount for export. Such production would be set at 23,785 ha, with an average of 33.14 ton / ha (SIAP, 2018).

With regard to the study region, where there is a low production of watermelon, Sepúlveda (2009) points out that this low yield is due to three main factors limiting production: fertilization, water rationing and disease damping off (early fungal wilt caused by invasion of host fungus before seedling emergence). This production for the municipality of Tolimán was 8,000 tons with an economic spill of 11,200,000 pesos and for Tuxcacuesco it was 9900 tons with a profit of 17,820,000 pesos.

Since this area of Jalisco is purely agricultural and livestock, the economic spill of this crop means a great root of the locals for their region, since the cultivation of watermelon requires a number of significant wages. In addition, indirectly, there is an extra entrance to the inhabitants for the transport, movement of agricultural machinery, purchase of inputs and consumption of automotive fuel.

Background

Fertigation is understood as the application of fertilizers dissolved in irrigation water, in a continuous or intermittent manner. Fertigation cannot be done with all irrigation systems, since the main requirement is to obtain maximum uniformity in the distribution of fertilizers. Therefore, this practice is basically associated with high frequency localized irrigation systems, that is, drip irrigation and micro sprinkler systems, although it can also be applied through sprinkler irrigation (Fuentes, 2003).

This same author, Fuentes (2003), points out that to achieve high levels of productivity in crops requires the external application of fertilizers. This application should be carried out considering the nutrient extractions required by each crop, taking into account the physical-chemical characteristics of the soil, crop management and the phenological behavior of the species. Foliar analysis is an important tool to know the nutritional status of cash crops (Marín and Pérez de Roberti, 1992). In fact, Marín and Pérez de Roberti (1992) also point out that foliar analysis can be interpreted by different mathematical methodologies or by qualitative comparison of these analyzes and also by the response of crops to fertilizers.

The most used methodologies, according to Schulte and Kelling (2010), Cadahía (2005) and Campbell and Plank (2000), are the following:

a) Critical levels (NC). For most diagnostic purposes, plant analyzes are interpreted based on a "critical level" for each of the nutrients, which is defined as "the content of an element in a certain indicator tissue below which expect a significant response to the application of this element "(Howeler, 1993: 6). For many nutrients, the yield decreases just before a symptom of deficiency is observed visually. For some researchers, the critical level is the concentration of the nutrient at 90% or 95% of maximum yield. This critical level is defined for each species and at a specific stage of growth or maturity. Nutrient intervals in some cases are represented as deficient, low, sufficient, high and excessive.

b) Sufficiency ranges (RS). In general, when a nutrient is deficient, adding this results in an increase in crop growth and usually a higher concentration of the element in the plant and also causes better yield. Not always adding fertilizer to the soil is a guarantee that the crop will benefit, since it may not be available to the plant, which is why physiologists have done studies on nutrient interactions and so, after several plant analyzes , discovered several among some elements.

c) Kenworthy Index (IK). It has also been proposed to interpret the foliar analysis of the Kenworthy Balance Index (IBK), by means of which the standard value is defined as the average of the nutritional concentration of sampled leaves in a particular state of trees of a plant species with a development desirable horticultural. To generate said standard value, 10% or more of a population that exhibits a desired attribute (for example, high yields) and a coefficient of variation (CV) of less than 34% is selected. Nutrient concentrations in a sample are expressed as a percentage of the standard value and are adjusted using the CV of the standard (Salazar y Lazcano, 1999; Maldonado *et al.* 2008).

d) Deviation from the optimal percentage (PDO). This index of interpretation of the foliar analysis allows, in addition to the realistic diagnosis of a given nutritional situation, to know the order of limitation both by excess and by deficit of each of the nutrients considered. For the interpretation of the analytical data and to be able to make the correct diagnosis of a given nutritional situation, it is always essential to have reference values that can be the optimal nutritional ones (midpoint of the interval that coincides with the maximum harvest). The PDO index is defined as the percentage deviation of the concentration of an element with respect to the optimum concentration considered reference value. The sign of the PDO for a given element will be negative in case of deficit and positive in case of excess. When the sample content coincides with the reference optimum, it will be equal to zero (Montañés et al. 1990; Montañés et al. 1993).

In addition to the above, PDO is also defined as a statistical method that compares the concentration of the nutrient in the sample with respect to the norm, which is based on an optimal nutritional level in which the crop expresses its maximum potential yield. The PDO method quantifies the value at which a nutrient deviates from the individual norm. An optimal nutritional situation, for any element, is defined by the PDO index equal to zero, which gives the order of limitation both by excess and by deficit of each of the nutrients under study (Ventura et al., 2012).

e) Diagnosis of nutrient composition (CND). The corresponding ratios of the highest yields of the population (norms) are compared with the ratio present in the sampling being analyzed; A concentration ratio by itself cannot be used to diagnose problems in the plant, but combination combinations of different nutrients can be combined mathematically to determine which nutrients are most likely to limit yield. The results of such calculations are the indices of the integrated diagnostic and recommendation system (DRIS).

f) DRIS. This methodology detects differences in the availability of the analyzed nutrients and expresses them in a relative way, their breadth of the database can be determinant of the results obtained. Likewise, it must be used as another tool in the diagnosis, within a context that considers the analysis of the soil and other data of the population under evaluation (Landriscini and Galantini, 2018). It is an approach to the interpretation of plant analysis results that involves hundreds of sampling analyzes of a specific crop. Samples are divided into two populations with high and low yields. The analytical result of each population is studied to determine what criteria can be used to distinguish between low and high performance of the same population. Thus, as these yield relationships of the concentration of nutrients in the plant, they offer better results than simple concentrations alone.

Once the DRIS indices for each nutrient have been determined, the nutritional imbalance index (IDN) is calculated and all the indices are added, regardless of the sign. The larger value indicates greater nutritional imbalance and, therefore, a lower yield would be expected (Reis Junior and Monnerat, 2003; Bangroo et al., 2010; Schulte and Kelling, 2010).

For the interpretation of these indices, the following general rules must be taken into account: 1) The absolute numerical value indicates the importance or severity of the anomalous situation. 2) Logically, when the PDO index is zero, the corresponding element is in optimal concentration.

The PDO also allows to know directly the relative order of limitation between the elements considered based on adjusting the fertilization needs with the corresponding PDO indices. But it also allows classifying the nutrient situation by defining three categories: deficit limits, excess limits and those that are at an optimal level. With respect to the elements that have a negative value, it means that the level of nutrition is below optimal nutrition and that, therefore, it will be necessary to increase the fertilization program corresponding to that element. Positive values indicate that the amounts of the element in fertilization should be reduced.

The absolute sum of the PDO indices can be used as a relative measure of the nutritional balance in crop studies and it is concluded that the lower the PDO index is closer to the optimum, the set of elements considered (Montañés et al., 1993; Ventura, 2012; Landriscini and Galantini, 2018). Based on the above, the following objectives are proposed.

Objectives

General

Obtain a dose of fertilizer that is related to the foliar analysis to be used in drip irrigation in the cultivation of watermelon in the municipality of Tolimán, Jalisco.

Specific

a) Determine in the laboratory the analyzes of soil, water quality and foliar analysis of plots with watermelon in Tolimán, Jalisco.

b) Know the nutritional status of watermelon cultivation in Tolimán, Jalisco.

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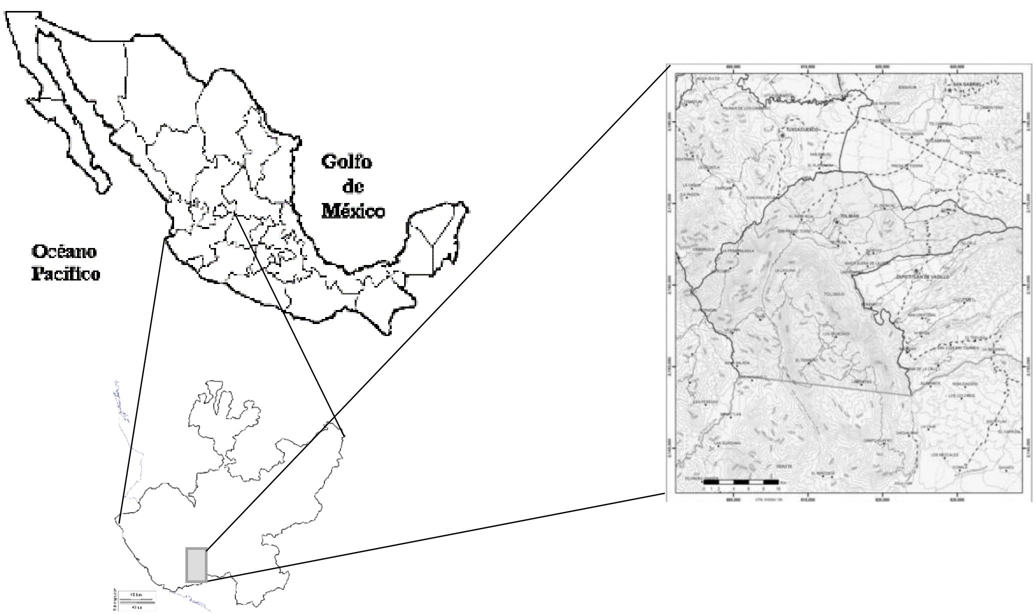
Materials and methods

Description and location of the study area

The municipality of Tolimán is located between coordinates 190 24´ 00¨ N and 1030 44´ 00¨ (figure 1) and is located at 760 m. n. m. (National Institute of Statistics and Geography [Inegi], 1981). Its population is 10 310 inhabitants (Inegi, 2015). Tolimán's climate is BS1 (h´) w (i´´), which means that it is a warm dry climate in the winter and with little temperature oscillation, with a rainfall of 570 mm (García, 1988). The soils belong to the Cenozoic or tertiary age and the rocks are limestone, extrusive igneous, such as rhyolites, andesites, basalt, tuffs and volcanic gaps. Sedimentary rocks are sandstones, conglomerates and alluvial deposits (Inegi, 1981).

Figura 1. Ubicación del municipio de Tolimán, Jalisco



Fuente: Elaboración propia

The height of the plain before going down to the Ayuquila-Armería river is 894 m and the towns of the municipality of Tolimán where watermelon is planted are the Paso Real and San Pedro Toxin, which are at a height of 710 m. n. m. and the river is at a height above sea level of 684 meters (the height was determined with a GPS 12 XL brand Garmin).

According to the National Institute of Statistics, Geography and Informatics [INEGI] (1976) and the Food and Agriculture Organization of the United Nations [FAO] (2006), the six plots under study are located in three types of soil : Calcium regosol, haplic castañozem and calcic feozem. The type of regosol soil falls in class 4, which are mineral soils influenced by its topography and physiography. These belong to lowlands associated with recurrent flooding or prolonged humidity and in high or rugged terrain where soil formation has been prevented by erosion. For the particular case of regosol, this occurs in unconsolidated material and only has a developed surface profile. In class 8, steppe soils are found between dry climates and the humid temperate zone. This transition zone has a pasture vegetation and dry forest. These locations have a leaching process. The castañozem are located in the shallowest parts, with a brown surface and accumulation of carbonate or plaster; They arise in the driest part of the steppe. Feozem are dark reddish soils of prairie regions with high saturation base, but not with visible signs of carbonate accumulation.

Soil preparation and sampling

Soil samples were taken at a depth of between 0 and 40 cm, trying to consider the radical part of the watermelon. They were sent to analyze the Laboratory of Multiple Uses of the University Center of the South Coast of the University of Guadalajara.

Once the soil sampling was done, the plot was plowed and left 10 days under this condition. Subsequently, two dredge steps were performed and allowed to rest for four days. Next, the 2-meter-wide planting beds were installed, padded and conditioned for irrigation. It was sown immediately at a distance of one meter between plant and plant. That same day the weather shelter was installed on the farmer's plot.

Water sampling for irrigation

Water samples were conducted in order to analyze their quality for irrigation. These were carried out in the Ayuquila-Armería river, one of the main tributaries of the area, as well as in the area of springs known as the Autlán aquifer, water sources used for irrigation by watermelon producers and other crops for this and others municipalities.

Fertilization

The fertirriego was carried out by means of a tensiometer and with a reading of 13 cb, that is, to prevent the soil from being saturated. Reading shots were taken daily. A tensiometer was 30 cm deep and 30 cm away from the neck of the plant. This served to irrigate the crop when it was 1 day to 20 days after transplantation (ddt); and another tensiometer was placed at 50 cm depth, which served to water the plant when it began to release guide.

The nutrient solution was prepared in drums with 150 liters. All fertilizers were added except the calcium nitrate that was in another tambo and was applied half an hour after the first solution was applied.

In each irrigation the nutritive solution was acidified with 97% sulfuric acid; and the solution was left at a pH of 5.5. The fertirriegos were made according to table 1, while the management of the health of the plant according to table 2.

Tabla 1. Fertirriego en kg/ha/riego

Ddt	**N como fosfonitrato**	**P_2O_5 como fosfato monoamónico**	**K_2O como KNO_3**	**Ca como $CaNO_3$**	**Mg como $MgSO_4$**	**S como $MgSO_4$**
0-15 4 riegos	11.360	11.880	16.300	7.500	12.500	Al aplicar $MgSO_4$
16-30 8 riegos	3.787	3.960	8.150	3.750	6.250	
31-45 16 riegos	1.893	1.980	6.112	2.812	3.125	
46-60 16 riegos	2.840	2.970	6.112	2.812	3.125	
Total	150	95	150	30	30	26

Fuente: Elaboración propia

Foliar sampling

Foliar or plant tissue analysis is an essential tool for the nutritional diagnosis of crops. It consists in measuring the total content of the nutrients present in the leaves or in another part of the plant through specific chemical procedures (Martínez and Soriano, 2014).

For the sampling, it was tried not to take them on plants located near roads, buildings, etc., or on those that had accumulation of waste by some type of spray treatment, since it was understood that the analyzes would not be representative.

For this study, in addition to the above, leaf sampling was done at 50 ddt, taking 12 leaves of the main guide, the tenth leaf from the apex to the stem, one leaf per plant. Irrigation water sampling was carried out by determining water hardness, and the presence of nitrates, nitrites, chlorine with the Hach spectrophotometer was mainly obtained. This sampling was done three times for three months; the foliar analysis and the chemical analysis of the water were made in the Laboratory of Multiple Uses of the University Center of the South Coast of the University of Guadalajara.

Tabla 2. Enfermedad y/o plaga, producto y dosis a aplicar en kg/ha

Enfermedad	Producto	Dosis kg/ha
Mildiu	Mancozeb 80	1.5 l
Pseudoperonospora	Tattoo c	2.0 lt
cubensis	Ridomil bravo	1.0 kg
Cenicilla polvorienta	Zineb micro 80	1.5 kg
Erysiphe	Blindaje 50	0.5 kg
chicoracearum		
Nemátodos	Nemacur	4-8 l
Pulgón	Aflix	l
	Actara	0.4 kg
	Thiodan	1.5 lt
	Methan	1.5 lt
Diabrótica	Parathion metilico	20.0 kg
	Confidor 350	1.0 l
	Sevin 80 %	1.0 kg
Mosquita blanca	Diazinon	0.8 lt
	Folimat	1.0 l
	Ambush	0.4 l
Minador de la hoja	Diazinon	0.8 l
	Lorsban 480 EM	1.5 l
	Endocoral 50	1.0 l
Gusano del fruto	Lannate 90	0.4 kg
	Ambush 50	0.4 lt

Fuente: Elaboración propia

Watermelon nutritional status

To determine the nutritional status of the watermelon crop, the IBK and PDO were used. The calculations for the IBK were:

If X is > than the standard value:

$$P = \frac{X}{X}\ 100 \qquad I = (P - 100)\left(\frac{CV}{100}\right) \qquad B = P - I$$

If X is < than the standard value:

$$P = \frac{X}{X}100 \qquad I = (100 - P)\left(\frac{CV}{100}\right) \qquad B = P + I$$

As:

P = percentage of standard value.

I = adjustment of the standard value using the coefficient of variation.

X = sample nutrient concentration.

CV = coefficient of variation.

$\dot{X}$ = population average.

B = balance index.

In addition, with the IBKs the diagnosis was made in only three ranges: low (83-93), medium (94-104) and high (105-115), although some researchers use five ranges (Maldonado et al., 2008; Maldonado , Etchevers, Rodríguez and Colinas, 2001).

The PDO index was calculated with the following formula:

$$DOP = C\frac{100}{Cref} - 100$$

As:

C: It is the foliar concentration of the element in the analyzed sample.

$C\ ref.$: It is the reference optimum of the same element, with the same characteristics in which the problem sample was taken.

The following point shows the results generated based on the objectives set:

Results and Discussion

Soil analysis

Tabla 3. Análisis físico-químico de suelos antes de la siembra de los poblados Paso Real y San Pedro Toxin del municipio de Tolimán, Jalisco. Profundidad de 0-25 cm y 25-50 cm, respectivamente

	Parcela 1*	Parcela 2	Parcela 3	Parcela 4	Parcela 5	Parcela 6
Textura	F-A	F-A	A-F	F-A	A-F	A-F
pH	8.27	8.05	8.28	7.73	7.69	7.89
CE	0.2	0.02	0.05	0.02	0.02	0.07
MO	0.69	0.26	0.13	0.76	0.69	0.17
N	13.45	12.71	12.65	13.67	13.47	12.26
P	50.7	48	47.7	51.4	51.6	46.6
K	480	476	461	506	506	453
Ca	4571	4200	4631	3615	3701	3667
Mg	476	461	450	461	453	461
Textura	F-A	F-A	A-F	F-A	A-F	A-F
pH	8.13	8.30	8.28	7.53	7.82	7.66
CE	0.2	0.1	0.08	0.02	0.01	0.08
MO	0.07	0.07	0.07	0.58	0.47	0.07
N	12.20	12.46	12.21	13.54	13.43	12.20
P	46.6	47.4	46.3	51.3	51.9	47.0
K	446	446	450	491	495	450
Ca	4162	4646	4612	3506	4125	3611
Mg	438	438	438	453	450	446

F-A = Franco Arenoso; A-F = Areno Francoso; *N* = kg/ha. Los demás elementos en ppm
*En la parcela uno se instaló la parcela demostrativa y también estaba el cultivo de un agricultor, por lo que aquí estaba la parcela uno y dos de los siguientes cuadros.

Fuente: Elaboración propia

Table 3 shows the following results:

For cultivated soils of subtropical or temperate climate, Castellanos, Uvalle and Aguilar (2000) classify sandy soils as normal if they have an amount of organic matter (MO) between 1.21% and 1.60% and if the soils are straightforward they must contain 1.81 -2.30% of MO to be considered normal, so the soils under study are classified as very poor soils.

Regarding the pH three soils varied from 7.64 to 7.89, so they can be classified as slightly alkaline; and three other soils ranged from 8.05 to 8.28, which are moderately alkaline (Troe and Thompson, 2005).

Electrical conductivity (EC) is not a salinity problem nor does it affect growth due to the osmotic pressure of the soil solution, since it is at a concentration less than 2.0 mmhos per cm (Richards, 1977).

The N of the soil in the 6 plots varied from 12.26 to 13.67 kg / ha, so they can be classified as very low soils, since Castellanos et al. (2000) indicate that an average soil in nitrogen has 101-150 kg / ha.

The nutrients P, K, Ca and Mg are classified, according to Castellanos et al. (2000), as tall, moderately tall, tall and moderately tall, respectively (table 3). The above results are for the depth of 0-25 cm; the depth of 25 to 50 cm is not commented since mathematically there is a difference that is not significant both in nutrients and in the other soil variables.

Irrigation water analysis

The pH of the river and the spring varied from 7.4 to 8.6 (see table 4). The Official Mexican Ecology Standard (1996) says that 5 to 10 pH units are allowed; although Ayers and Westcot (1994) comment that there should be slight restrictions with pH above 8.4, because production can be reduced for some crops.

The EC of the river water varied from 0.40 to 0.98 siemens per meter (SI) and that of the spring from 0.36 to 0.80 (table 4). In this regard, Ayers and Westcot (1994) comment that when the EC is between 0.7 and 3.0 mmhos / cm, there should be slight restrictions, which is why in this study the EC is considered as normal. These same authors say that the alkalinity measured as bicarbonates (HCO3) should be in a range of 0 to 10 meq / l, so, by dividing the mg / l of bicarbonates by 61.01, which is the molecular weight of the bicarbonate, only the plots that were irrigated with the spring water were above what was allowed in the month of January.

Calcium varied from 12-103.2 and Mg from 102 to 1415.2 mg / l (see table 4). In this regard, Motsara and Roy (2008) comment that in the analysis of water Ca and Mg do not behave identically in the soil system, since Mg deteriorates the soil structure, particularly in the waters where Na or where the waters are slightly saline. A high level of Mg usually promotes higher development of exchangeable sodium in irrigated soils. That is why, according to the three categories based on the Mg / Ca ratio, the waters are classified as: <1.5 safe; 1.5-3.0 moderate, and> 3.0 dangerous. Ayers and Westcot (1994) point out that for calcium and magnesium the allowed range is 20 and 5 meq / l, respectively (400 y 60 mg/l).

Rincón (2005) comments that all the waters that have a solution of at least 1.5 meq / l of Ca (30 mg / l) and 1 meq / l of Mg (12.16 mg / l) provide sufficient Ca and Mg for crops that do not require very large quantities high. However, due to the high degree of washing and the deficiency of Ca that watermelon presents when it is in the phase of development of the fruit, it is advisable to make preventive contributions of Ca and Mg during this phase to avoid possible deficiencies: the recommended amounts to replenish are 50% of the total extractions during the crop cycle.

The amount of chlorides varied from 86 to 109 mg / l in the river and in the spring from 56 to 118 mg / l (table 4), so this element does not represent damage to crops in the region, since the ecological criterion on the quality of water that has the National Institute of Ecology (1989) recommends that chlorides should not be greater than the amount of 147.5 mg / l.

Regarding the element Na, Ayers and Westcot (1994) recommend that water has no restriction if its value does not exceed the value of 3 meq / l (69 mg / l). This reinforces what has been said in relation to the EC, that the salts are not harmful to crops in the area of the municipality of Tolimán (see table 4).

Tabla 4. Análisis del agua del río y del nacimiento durante el cultivo de la sandía

	8/I/2010		3/11/2010		5/III/2010	
	Río	Manantial	Río	Manantial	Río	Manantial
pH	8.6	8.5	7.5	7.5	7.5	7.4
CE	0.98	0.80	0.40	0.80	0.69	0.36
Alcalinidad (HCO_3)	368.7	1425.9	305.5	323.9	103.1	200.9
NO_3	16	16	14	15	15	14
PO_4	0.06	0.02	0.06	0.02	0.06	0.02
K	21	21	22	23	22	22
Ca	12	84.8	103.2	151.2	92	50
Mg	488	1415.2	272.8	270.8	102	190
SO_4	14	15	16	13	17	12
Cl	86.8	84	105	118	109	56
Na	22	20	24	25	22	21

Fuente: Elaboración propia

Foliar analysis

In table 5, the IBK indicates that in plot 4 and 7 the element that is restricting production is N, since this results in soil analyzes as very low, and in plot 4 only 56 kg of soil was applied. N (table 6) and were not sufficient to feed at 46.6 ton / ha (table 7). In plot 7, only 22 kg of N were applied, which caused this element to limit the yield with a production of only 25 ton / ha.

In plot six it turned out that phosphorus is the main limitation of production; This same plot confirms it, since it has the least phosphorus in the soil.

Also, in plot three, K was the one that limited production and this could be due to the fact that the more K is needed in the development of the fruit, the depth of the soil is where the most alkaline pH is and this limits the absorption of the same, as it is also reflected in the data in table 7; there it is observed that the average size of the fruit for export is the lowest in yields above 30 kg / ha.

Ca limits production in plot two and this could be due to the fact that this is where more phosphorus was applied; and Foth (1990) comments that when the soil pH is above 7.2, the phosphate anion reacts with Ca and forms the insoluble calcium phosphate compound.

The S is the element that most limits production in plots one and five. While plot 1, which is the demonstration plot, indicates that if we want to obtain yields above 45 tons, more than 26 kg of S must be applied to the soil. On the other hand, in plot five the soils are very poor in MO. In this regard, Thompson (1974) and Fassbender and Bornemisza (1987) point out that there is a direct relationship between the amount of soil MO and the amount of sulfur available for crops. It is also true that this plot had poor water management, so the lowest yield was given with only 18.9 ton / ha.

Tabla 5. Diagnóstico nutrimental para los siete sitios en el cultivo de la sandía en Tolimán, Jalisco, por los métodos IBK y DOP

		Composición Nutrimental de la hoja al inicio del fruto						
		N	**P**	**K**	**Ca**	**Mg**	**S**	**IBN**
1	CNF	3.9	0.41	3.9	1.9	0.67	0.51	
	IBK	100	102	96	100	100	92	590
	ORN	S > K > N = Ca= Mg > P						
	DOP	+10	0	+11	-20	+18	+70	129
	ORN	Ca > P > N > K > Mg > S						
2	CNF	3.6	0.39	4.1	1.7	0.61	0.53	
	IBK	93	98	101	90	92	95	569
	ORN	Ca > Mg > N > S > P > K						
	DOP	+2	-5	+17	-29	+7	+77	137
	ORN	Ca > P > N > Mg > K > S						
3	CNF	4.1	0.44	3.9	1.9	0.71	0.65	
	IBK	105	109	96	100	106	114	630
	ORN	K > Ca > N >Mg > P > S						
	DOP	+16	+7	+11	-20	+25	+117	196
	ORN	Ca > P > K > N > Mg > S						
4	CNF	3.9	0.46	4.3	2.1	0.68	0.6	
	IBK	100	114	105	110	101	106	636
	ORN	N > Mg > K > S > Ca > P						
	DOP	+10	+12	+23	-12	+19	+100	+176
	ORN	Ca > N > P > Mg > K > S						
5	CNF	3.6	0.34	4.1	1.8	0.63	0.46	
	IBK	93	86	101	95	94	84	553
	ORN	S > P > N > Mg > Ca > K						
	DOP	+2	-17	+17	-24	+11	+53	124
	ORN	Ca > P > N > Mg > K > S						
6	CNF	4.3	0.38	4	1.9	0.74	0.61	

	IBK	110	95	98	100	110	108	621
	ORN	P > K > Ca > S > N > Mg						
	DOP	+21	-7	+14	-20	+30	+103	195
	ORN	Ca > P > K > N > Mg > S						
7	CNF	3.8	0.4	4.2	2	0.67	0.58	
	IBK	98	100	103	105	100	103	609
	ORN	N > P > Mg > K > S > Ca						
	DOP	+8	-2	+20	-16	+18	+93	157
	ORN	Ca > P > N > Mg > K >S						

IBN= Índice de balance nutrimental. CNF= Concentración nutrimental foliar. ORN= Orden de requerimiento nutrimental.

Fuente: Elaboración propia

Tabla 6. Dosis de fertilizante aplicada durante el cultivo por medio de la fertirrigación en kg/ha

Núm. de parcela	**N**	**P**	**K**	**Ca**	**Mg**	**S**
1	150	95	150	30	30	26
2	53	50	63	7	1	0.7
3	67	14	69	12		
4	**56**	33	31			
5	48	5	90	13		
6	58	26	48			
7	22	3	14	3	2	1

Fuente: Elaboración propia

Tabla 7. Rendimiento, peso promedio de fruta de exportación y pachanga en el cultivo de la sandía

Núm. de parcela	Rendimiento (Kg/ha)	Peso promedio del fruto (Kg)	Pachanga* (% total)
1	45.1	9.05	3.62
2	36.0	9.06	5.8
3	32.8	8.63	10.48
4	46.6	8.73	11.43
5	18.9	8.03	24.47
6	27.4	8.47	5.81
7	25.0	7.62	7.18

*Fruta no comercial y de consumo local

Fuente: Elaboración propia

Regarding the PDO methodology, it indicates that calcium is the main element that limits production in total plots (table 9). These results suggest that there was something not related to either the amount of calcium in the soil or the applied dose of fertilization; and it was thus that the order of nutritional requirement by the PDO is more in line with the averages of the ranks of sufficiency that are used. Table 5 shows that all values are below the reference average used (2.38), and that is why Ca appears as the most limiting element.

Likewise, when analyzing the element S in table 5, in the order of nutritional requirement it is the one that least limits the production in the total of the plots, but this is also due to the fact that all the values obtained in the study are above the average reference value (0.3).

Since fertigation is the fractional application of fertilizer in water, it was measured in the number of irrigations and hours during irrigation for each of the weeks during the watermelon crop development cycle (this action was in each one of the plots). In the following table you can see how to plot number five at the beginning of the plantation, that is, in the first weeks, it needed water; Similarly, plot seven was poorly managed, because when the fruit was growing it was not provided with the right amount. Thus, together with the above causes, water influenced so that in these two plots the fruit yield was lower than the others (see table 8).

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Tabla 8. Número de riegos por semana y horas, total de riegos y metros cúbicos de agua gastados en el ciclo del cultivo de la sandía en Tolimán, Jalisco

	Núm. de parcela						
Semanas	1	2	3	4	5	6	7
1.ª	1		4.5	1	0.5	1	6
2.ª			1		0.5		
3.ª				1	0.5-1		
4.ª			1	2	1	1	
5.ª	1 1	1 1	1	2	1 1	1	1
6.ª	1 1	1	1	4R: 1.5	1 1	1	
7.ª	4R: 1	1	2	4R: 1.5	4R: 1	1 1	1
8.ª	4R: 1	1	1.5		1 1	1	1
9.ª	4R: 1	1 1 1	2	7R: 1.5	1 1	3R: 1.5	1
10.ª	7R: 1	2 2	1 1	7R: 1.5	4R: 2	3R: 1.5	1 1
11.ª	7R: 1	5R: 1.5	4R: 2	7R: 2	6R: 1.5	7R: 2	1 1
12.ª	7R: 1	7R: 1.5	7R: 2	7R: 2.5	7R: 2	7R: 3	5R: 1.5
13.ª	7R: 1	7R: 2.5	7R: 2.5	7R: 2.5	7R: 1.5	7R: 3	6R: 2
14.ª	7R: 1	6R: 2.5	7R: 2.5		7R: 2		7R: 2.5
Total (hrs)	51	52.5	73	88	57	72	51
M3/ciclo	1104.9	1137.4	1581.5	1906.5	1234.9	1559.8	1104.9

Fuente: Elaboración propia

Conclusions and recommendations

Under this study and conditions, the Kenworthy Balance Index (IBK) methodology is considered to be useful for small sample cases and in very local studies (studies in complete valleys). The current work is only a preliminary study and it is suggested that the number of observations be at least 48, because there will be three nutritional ranges: high, medium and low, where the observations would be distributed in a normal population: 48/3 = 16 observations per range, which is enough to determine the range of sufficiency with real values, without having to make use of the standard deviation.

Likewise, the determination of the PDO is a methodology that could be used to evaluate the nutritional status of different regions and with high observations and so that in the order of nutritional requirement the nutritional status of the study in question is really reflected. It is clear that in this study the demonstration plot should not have been fertilized with magnesium because of the excessive amount of this nutrient that the irrigation water contained. The order of nutritional requirement indicates that to obtain high yields the dose of S. must be increased. Based on the results of production in the plots, the dose applied to the soil and the order of nutritional requirement, it is suggested to reduce the dose of P to 60 kg / ha. In addition and according to the same results, the fertilization formula for this valley is suggested to be applied as follows:

N	P	K	Ca	Mg	S
150	60	150	30	00	40

According to the IBK, the following foliar ranges are proposed:

N	P	K	Ca	Mg	S
3.8-3.9	0.38-0.41	4.1-4.3	1.78-2.02	0.67-0.68	0.53-0.58

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