Article

Importance of potassium and ringing in the performance and quality of litchi fruit

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Abstract

The litchi (*Litchi chinensis* Sonn) is an internationally demanded fruit, grown in several states of Mexico with profitable prices, although with low yields. The objective of the research was to determine the effect of potassium and ringing on the yield and quality of the litchi cv Brewster fruit. A completely random block experiment was established, with a 3 x 2 factorial arrangement with 10 repetitions. Factor A consisted of three levels of potassium (300, 600, 900 g tree^{-1}). Factor B in two levels of banding in the branches (absence and presence), so that six resulting treatments were evaluated. The results indicate that the factors A and B, as well as their interaction, are determinant to increase the yield, although they affect little to the quality of the fruit. The levels of factor A and B that have the greatest effect on the yield, are 900 g of potassium and the presence of ringing respectively, so treatment six that combines both factors, records the highest performance. Low doses of potassium produce low yields, while ringing alone doubles it. The factors A and B present individual effects for the variables weight loss (PPF) and pH of the fruit, although the effect of the interaction only occurs for the pH. It is concluded that the contribution of 900 g tree^{-1} of potassium and the ringed in litchi trees, individually and combined positively affect the yield and little to the quality of the fruit.

Keywords: cultivate Brewster, alternative crops, crop nutrition, Sapindaceae.

Reception date: December 2017
Acceptance date: January 2018

Introduction

Litchi (*Litchi chinensis* Sonn.) Is a fruit tree native to China (Kumar *et al*., 2014). The crop has gained interest among Mexican agricultural producers due to its increasing demand nationally and internationally, particularly in the United States of America, Canada and the European Community (Osuna *et al*., 2008) this has motivated Mexican producers to adopted as an alternative crop. However, the research around this fruit is still insufficient, so the technical information on agronomic management is scarce. According to figures from the SIAP (2015), in Mexico the litchi is cultivated in an area of 3 738.19 ha, from which a production of 18 271 t is obtained, with yields of 5.27 t ha^{-1}. The main producing states are Veracruz, San Luis Potosi, Oaxaca, Puebla and Nayarit, with areas of 1.72, 0.73, 0.46, 0.3 and 0.16 thousand hectares, respectively; production volumes of 9.22, 1.96, 1.9, 3.52 and 0.46 thousand tons respectively and yields of 5.87, 2.7, 4.66, 11.71 and 3.79 t ha^{-1} respectively.

Despite the attractiveness of the cultivation of this fruit, there are factors associated with low yields, including: low flowering, alternating production, fruit fall, incidence of pests and diseases, as well as the definition of a fertilization program that allows for adequate nutrition (Alejo-Santiago *et al*., 2015). In order to face the problem of low production, an adequate agronomic management is proposed that contemplates an adequate nutrition of the crop. A widespread practice to face the fall of the yields in some fruit trees such as rambutan and citrus fruit is the ringed, practice that consists of making an incision in the branches of the tree, to interrupt the phloem, which causes an accumulation of carbohydrates and a decrease in the contents of gibberellins in shoots and leaves.

This allows the anticipated induction of flowering and increase of floral differentiation (Gaete, 2007). Likewise, it has been documented that the practice of banding increases the number of bunches and fruit size, in addition to partially correcting the late maturation of the fruits and the alternation of production in litchi and other fruit crops (Deep *et al*., 2010). However, the effects of this practice have not been fully clarified, since according to Joo-Pérez *et al*. (2017) are very variable depending on other factors such as the water regime of the soil.

Another aspect that has been explored to improve yields in the cultivation of fruit trees is the balanced supply of nutrients, particularly potassium (K), since this nutrient has an important role in the opening and closing of stomata, cell turgor, transport of carbohydrates and activation of multiple enzymes, processes that affect yield and fruit quality (Liu *et al*., 2017). Currently there is knowledge about the importance of K in litchi physiology (Singh *et al*., 2012). However, worldwide literature offers a wide variety of doses of potassium fertilization for litchi culture. However, the approach proposed by Volke *et al*. (1998) to determine optimal fertilization doses, points out that it is necessary to know the quantity of nutrients that the soil is capable of supplying, the demand of the crop, as well as the efficiency of recovery of the selected fertilizer as a source.

Adequate nutrition in litchi trees has an effect on higher yields, as well as better fruit quality, which is expressed in both external and internal characteristics of the fruit (Alejo-Santiago *et al*., 2015). According to Sivakumar and Korsten (2006), the external consider size, weight, shape, mechanical damage, decay, cracking, as well as the bright red color of the fruit peel. On the other hand, the internal ones include the size of the seed, the total soluble solids (SST), the titratable acidity (AT) and the SST/TA ratio (Aguas *et al*., 2014).

Although there has been progress in the research on the definition of an adequate agronomic management in litchi culture, information on the effect of K on the nutrition of this fruit is still scarce, while the effect of the practice of banding is reported as variable depending on the climatic conditions of each region (Rajwanshi *et al*., 2017). Therefore, the objective of the research was to evaluate the individual and combined effect of potassium fertilization and the practice of banding, on the yield and fruit quality of litchi culture.

Materials and methods

Description of the study site

The experiment was carried out in an 8-year-old litchi cv "Brewster" plantation, located in the common "Cerro of Tigre", which is located at coordinates 21° 36' 04" north latitude, 104º 56' 47.5" longitude west, at an altitude of 700 m. The topological arrangement of the plantation is in real frame with distance of 6 x 6 m. According to the climate classification of Köppen modified by García (1981), the climate is a (A) e (W2) a (i), which corresponds to a semi-warm (subtropical sub-humid), which is the warmest of the tempered (c); the average annual precipitation is greater than ≥1 300 mm. The plantation has drip irrigation infrastructure.

Initial diagnosis of soil and plants to define fertilization dose

Within the plantation, seven tree lines were randomly selected, in each of them 10 trees were randomly selected, which resulted in a total of 70 trees. To define the doses that would be evaluated, prior to the establishment of the experiment, composite samples were taken, both soil and foliar component. The procedures of the collection are detailed below:

Soil sampling

Soil samples were taken at the four cardinal points of the base of each of the 10 trees of the selected lines, at a distance of 0.5 m and at -40 cm depth. Each of these samples was mixed homogeneously to obtain a single sample for each selected tree. This exercise was replicated in the 10 trees of each line. The 10 samples were mixed to obtain a composite sample for each line. In all the surface of the experimental area seven composite samples were obtained. Once collected, they were taken to the soil, plant tissue and water analysis laboratory of the Agricultural Academic Unit of the Autonomous University of Nayarit.

The analyzes contemplated to diagnose the state of soil fertility were: pH, MO, N, P, K, CIC, CE and interchangeable bases, which were developed by the methods recommended by the Official Mexican Standard PROY-NOM-021- RECNAT-2000 (DOF, 2000).

Diagnosis of edaphic fertility

The soil of the orchard under study has the following characteristics: clay texture, bulk density (g cm^3) of 1.2, P Bray (22.22 mg kg^{-1}), interchangeable K (300 mg kg^{-1}), interchangeable Ca (2 300 mg kg^{-1}), exchangeable Mg (300 mg kg^{-1}), pH 6.4 and CE (dS m^{-1}) of 0.14. The foliar nutritional concentration in the trees was N (1.43%), P (0.14%), K (0.86%), Ca (1.91) and Mg (0.26%), these concentrations are within the optimum range indicated by Menzel and Simpson (1987), for the litchi culture, with the exception of potassium that are in a lower level, these authors indicate 1.2% as optimal.

Sampling of the foliar component

In each tree of each line, two pairs of complete leaflets of the fourth leaf were identified and collected at each cardinal point, according to the methodology of Menzel and Simpson (1987). The samples were placed in paper bags and taken to the laboratory, where they were washed with running water and later with distilled water; they were dried in a forced air oven at 60 °C for 48 h until constant weight was obtained, and ground in a stainless-steel mill. To determine the initial contents of nutrients, an extraction was made in wet digestion following the procedures established by Alcantar and Sandoval (1999). For the case of N, a mixture of sulfuric acid with salicylic acid was used for Ca, Mg, P and K, this mixture was with nitric acid and perchloric acid.

Estimation of fertilization dose

Based on the results of the soil analysis, equation 1 was developed, proposed by Volke *et al*. (1998) by which it is possible to determine the optimal dose of each nutrient.

$$\text{DON} = \frac{Demand - Supply}{ERF} \quad 1)$$

Where: DON= optimum nutrimental dose; demand= is the quantity of the nutrient that the crop requires to complete its physiological processes and to reach to produce a certain production goal; supply= is the quantity of the nutrient that the soil is capable of supplying to the crop; ERF= fertilizer recovery efficiency (ERF). With the application of the equation the optimum doses of N. P, K. were calculated.

Estimation of N dose

To estimate the demand for this nutrient, a production goal of 50 kg of fruit per tree^{-1} was set. With the results of the fertility diagnosis that was made, the supply of N was set at 31 g tree^{-1}, said value results from considering a content of organic matter in the soil (MOS) of 3.7%, an annual mineralization rate of 2%, an N content of 5% in the MOS and a root exploration area at a distance of 75 cm from the base of the tree and a depth of 40 cm, as well as an apparent density of 1.2 Mg m^{-3}. If it is taken into account that for the production of fruit per tree per year^{-1}, 110 g are extracted for the fruit component and for leaf 282 g (calculated from a dry matter production in the foliar component of 23.5 kg year^{-1}, determined through preliminary evaluations), the demand of N per tree per year^{-1} is 392 g of N. The recovery efficiency of nitrogen fertilizer (ERFN) is 60%. Therefore, the N annual dose was 600 g tree^{-1}.

Phosphorus dose estimation

The nutritional extraction for the fruit is estimated at 2.2 kg of P_2O_5 per ton of fruit (Galan, 1987). Therefore, for a production of 50 kg of fruit (yield goal) the demand is 48.4 g of P. As for the case of N, at this value the nutrient extraction of the foliar component was added, which considers a concentration of P of 0.18%, which results in a demand of 42.3 g of P in said component. From the sum of these two values resulted a demand of 90.7 g of P (tree annual^{-1}). The results of the diagnosis of soil fertility indicated that the supply of P was 18.66 g per tree. While the efficiency of phosphate fertilizer recovery was 30%, so the annual dose of P was 240 g tree^{-1}.

Potassium dose estimation

The nutritional extraction for the fruit is estimated at 5.5 kg of K per ton of fruit (Galán, 1987), what the demand for a yield goal of 50 kg of fruit tree^{-1} is 275 g of K, at this value the extracted K per leaf was added, which was 282 g, so the demand for K per tree was calculated at 557 g. The soil analysis reported 300 mg kg^{-1} of exchangeable K, so the supply of K was estimated at 252 g tree^{-1}. If a recovery efficiency of 50% potassium fertilizer is considered. The dose of K was 600 g tree^{-1} year^{-1}. The resulting NPK dose expressed in g tree^{-1} year^{-1} was 600-240-600.

Experimental design/treatments

The experiment was established as completely random blocks, with factorial arrangement 3 x 2, where the factor A consisted of three levels of K, the B factor in two levels of banding. Six treatments emerged from this arrangement. The intermediate dose was considered calculated from equation 1. The levels of N and P remained fixed. The details of the treatments are presented in Table 1.

Table 1. Treatments evaluated in litchi culture

Treatments	Factor A (doses of K)	Factor B (ringing)	N	P	K
			(g plant^{-1} year^{-1})		
1	Low, and	without ringed	600	240	300
2	Medium		600	240	600
3	High		600	240	900
4	Low	with ringed	600	240	300
5	Medium		600	240	600
6	High		600	240	900

The resulting treatments were evaluated with 10 repetitions. As an experimental unit, it was considered a tree. Nutrient sources were potassium nitrate, MAP, potassium sulfate and urea.

Establishment and management of the experiment

Once the designation of the treatments in the field was made, the corresponding trees were annealed, this practice consisted of making a ring-shaped incision of approximately 0.8 cm in width in 70% of tree branches. At the same time, 30% of the fertilization dose was applied, while the remaining 70% was dosed by fertigation to the emission of the reproductive shoots, which occurredsix months after the first fertilization. During the whole production cycle, the crop was watered twice a week, applying 100 liters of water per tree, suspending said irrigation 20 days before harvesting.

Response variables

Variables determined in fruit

For each variable, 25 fruits of each treatment were randomly selected. The variables and methods are indicated in Table 2.

Table 2. Evaluated variables that determine the yield and quality of the litchi fruit.

Variable	Metod
Width (equatorial diameter) and length of fruit (cm)	Vernier digital
Shell, seed and pulp ratio (%)	Gravimetry
Degree of acidity (pH)	Digital potentiometer brand Cornig 720®
Total soluble solids (°Brix)	Digital refractometer brand Atago®
Titratable acidity (%)	(AOAC, 2005)
Color	Colorimeter (BakingMeter BC-10) Konita Minolta® (McGuire, 1992)
Loss of fruit weight (%)	$PPF = (\frac{\text{initial weight}-\text{final weight}}{\textit{initial}\text{ weight}}) * 100$ 2)

Performance (t ha^{-1})

The harvest was made when the fruits had a reddish coloration. The harvested fruits were classified as commercial and damaged by birds. Those damaged by birds were counted and multiplied by the average weight of 10 commercial fruits; the weights of damaged and commercial fruits per tree were added to estimate the yield expressed in t h^{-1}, for this a population density of 277 trees ha^{-1} was considered.

Analysis of results

The data were analyzed by means of analysis of variance and correlation, as well as tests of comparison of Tukey means ($p< 0.05$) through the statistical package SAS for Windows version 6.12 (SAS, 1999).

Results and discussion

Determining variables of performance

The results show an individual effect of factor A (potassium levels), factor B (banding levels), as well as their interaction, on the variables total yield (RT). It can be seen that the B factor plays a more important role on the variables fruit width (AF), fruit length (LF) and fruit production per tree (PFA), with respect to the factor A. Therefore, treatment six which combines a higher dose of K (900 g tree^{-1}) with the presence of ringing was the one with the highest fruit yield (Table 3).

Table 3. Effect of potassium and ringed fertilization on the performance determinants of litchi cv Brewster.

Treatment	PTF	Peel	Seed	Pulp	AF	LF	PFA	RT
	(g)				(cm)		(kg tree^{-1})	(t ha^{-1})
1	13.6	2.7	2.3	8.5	2.8 bc	3.2 a	8.8 de	2.4 de
2	15.4	3.3	3.2	8.9	2.6 c	3.4 a	8.3 e	2.3 e
3	15.8	2.8	2.7	10.6	3.2 ab	2.5 b	8.5 e	2.4 e
4	14.9	2.9	3.2	8.8	2.9 abc	3.3 a	19.9 cb	5.5 cb
5	16.1	3.3	2.9	9.9	3.2 a	3.4 a	21.7 b	6 b
6	14.5	3	3	8.6	2.8 abc	3.3 a	44.2 a	12.2 a
P>F	0.76^{ns}	0.72^{ns}	0.53^{ns}	0.38^{ns}	0.0001*	0.0001*	0.0001*	0.0001*
DMS	2.88	1.38	1.53	3.48	0.42	0.5	9.01	2.49
	Factor A							
300	14.2	2.8	2.7	8.7	2.8 ab	3.2 a	14.3 b	4 b
600	15.8	3.3	3.1	9.4	2.9ab	3.4 a	15 b	4.1 b
900	15.2	2.9	2.9	9.6	3 a	2.9 b	26.4 a	7.3 a
P>F	0.61^{ns}	0.34^{ns}	0.78^{ns}	0.49^{ns}	0.15*	0.003*	0.0001*	0.001*
DMS	3.64	0.94	1.04	2.36	0.28	0.34	3.97	3
	Factor B							
Without ringing	14.8	3	2.7	9.1	2.8 b	3.1 b	10 b	2.8 b
With ringing	15.2	3.1	3	9.1	3 a	3.3 a	28.6 a	7.9 a
P>F	0.80^{ns}	0.62^{ns}	0.31^{ns}	0.73^{ns}	0.13*	0.005*	0.0001*	0.001*
DMS	1.86	0.48	0.53	1.21	0.14	0.17	2.03	3.5
	A∗B							
P>F	0.52^{ns}	0.97^{ns}	0.27^{ns}	0.13^{ns}	0.0001*	0.0004*	0.001*	0.001*
CV	17.82	22.89	26.64	19.01	7.35	7.85	16.16	16.16

^{ns}= statistical difference not significant; *= statistical difference; DMS = minimum significant difference; Tukey ($p\leq 0.05$). PTF = total weight of the fruit; AF = width of the fruit; LF = length of the fruit; PFA = production of the fruit per tree; RT = total yield.

The effect of factor A and B, as well as their interaction on fruit yield, is due to higher fruit production per tree (PFA), since as can be seen in the same table, both the dimensions of the fruits, as the proportions of husk, pulp and seed between the treatments, do not denote statistically significant differences. Other investigations had already documented similar results. Pathak and Mitra (2010), indicate that the supply of K favorably affects the yields in litchi trees, due to a higher photosynthetic rate activity, stoma conductance as well as greater efficiency in the use of water. Although this increase in yield, it is not necessarily due to a positive modification in the anatomical constitution of the litchi fruit, derived from the application of increasing doses of K (Rai *et al*., 2002).

In spite of the documented evidences, the effect that the K has on the yield and quality of fruit cannot be generalized, since the hydric condition to which the trees are subjected, is an important factor in this answer, mainly because the K has a specific physiological role in the opening and closing of stomata through its influence on the osmotic potential of guard cells (Havlin *et al*., 1999). Due to the variability of this condition, research has been conducted in which the effect of K is equal to or lower than that of other nutrients. Reza *et al*. (2007) and Joo-Pérez *et al*. (2017) indicate that under irrigation conditions, the requirement of K in the litchi culture is lower than those of N and P. Although in the case of this investigation, the above is only congruent in the treatments without banding, since in the treatments that were ringed, there was a response to increasing doses of K (Table 3).

Various investigations have established that ringing in litchi trees and other fruit trees causes an accumulation of carbohydrates (Gaete, 2007), which probably caused an increase in the demand for K, since this nutrient intervenes in the processes of synthesis and transport of sugars and starches (Liu *et al*., 2017), which is why those treatments with rings that received higher levels of K, were those that expressed higher fruit yields.

Determining variables of fruit quality

The analysis of the effects of factors A and B, as well as their interaction on most of the variables related to fruit quality did not show statistically significant differences. Except in the variable pH, which is affected mainly by the factor B. From the above it follows that the fruits of treatments 4, 5 and 6 recorded a higher pH (3.64), with respect to those from trees that they lacked the incision (3.41) (treatment 1, 2 and 3). According to Çolpan *et al*. (2013), the supply of K can cause an increase in the pH of the fruit due to the synergy that this element presents with others such as Ca, which is reflected in an increase in the levels of °Brix, caused by the increase in the amount of total soluble solids (SST) in the juice. However, in the present investigation, these variables were not substantially affected by factors A and B, nor by their interaction (Table 4).

An effect of factor A on the variable fruit weight loss (PPF) is observed. However, this effect is not totally clear and forceful. Although it is necessary to advance in this physiological phenomenon, it is proposed that the dose of 600 g tree^{-1} of K is the most adequate to maintain the turgor of the fruits for longer, since both the low dose (300 g^{-1} of K) as the high dose (900 g^{-1} of K), have a higher PPF, being the low dose of (300 g tree^{-1} of K) where there is a higher

PPF (Table 4). The results obtained in this investigation suggest that the K applied to the litchi trees, improve the water supply to the fruits, which caused a dilution effect in the juice, so the SST: water ratio, as well as the Levels of °Brix did not present significant statistical differences, nor for the individual effects of factors A and B, as well as those of their interaction.

Table 4. Effect of potassium fertilization on the variables determining the quality of the litchi *cv* Brewster fruit.

Treatments	°Brix	Acidity	PPF	Color	pH
		(%)			
1	20	0.6	38.6 a	42.4	3.5 ab
2	19.6	0.5	31.2 b	39.7	3.5 ab
3	18.2	0.6	36.1 ab	41.3	3.6 a
4	20.7	0.5	38.6 a	42	3.7 a
5	20.7	0.7	33.1 ab	41.2	3.7 a
6	19.8	0.5	37.8 ab	41.5	3.5 ab
P> F	0.43^{ns}	0.41^{ns}	0.02*	42.48	0.01*
DMS	7.12	0.77	7.35	0.49^{ns}	0.29
	Factor A (doses of K)				
300	20.4	0.6	38.6 a	42.4	3.5
600	20.1	0.6	32.2 b	40.4	3.5
900	19	0.5	36.9 ab	41.4	3.6
P> F	0.36^{ns}	0.98^{ns}	0.003*	42.25^{ns}	0.3^{ns}
DMS	4.84	0.52	5	0.2	0.37
	Factor B (ringing)				
Without ringing	19.45	0.7	35.33	3.04	3.41 b
Vith ringing	20.43	0.59	36.52	41.35	3.64 a
P> F	0.78^{ns}	0.21^{ns}	0.37^{ns}	41.73^{ns}	0.02*
DMS	2.48	0.26	2.56	0.37	0.19
	A*B				
P>F	0.95^{ns}	0.64^{ns}	0.81^{ns}	1.55^{ns}	0.01*
CV	7.44	37.07	10.22	0.8	7.84

^{ns}= statistical difference not significant; *= statistical difference; DMS= minimum significant difference; Tukey (p <0.05). PPF= loss of fruit weight.

Conclusions

The individual effects of the factors A (dose of K), B (ringed) and their interaction, favorably affect the yield, and little to the quality of the fruit. These factors and their interaction increase the number of fruits per tree, which is reflected in a higher yield, while the size, as well as the anatomical construction of the fruit (husk, seed and pulp), are little affected. Only a few variables related to fruit quality, such as pH and fruit weight loss (PPF), were affected by K doses and banding.

In the case of pH increase, it is attributed to factor B, while the lower PPF is due to factor A, so an intermediate dose of 600 g tree^{-1} of K with banding produces intermediate yields with better quality fruits. Therefore, to obtain higher fruit yields in litchi cv Brewster trees, a management is recommended that combines the application of 900 g tree^{-1} of K, together with the practice of banding, while an intermediate dose of 600 g tree^{-1} of K with ringed, produces acceptable yields and of better quality. The individual effect of factor A allows to increase the yield 82.5%. The effect of the individual of the factor B allows to increase the yield in 182%, while the combined effect of both factors allows to increase the yield 408%.

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