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Original article

Analysis of various economic production aspects in high and low density walnut orchards. Case study

Análisis de diversos aspectos económicos de la producción en huertas de nogales de alta y baja densidad. Estudio de caso

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ABSTRACT: The cultivation of pecan nuts is one of the most important economic activities in Chihuahua, Mexico. In recent years, the price of the walnut has increased, causing a high profitability of the walnut, this has motivated several producers to establish new orchards, with high densities (204 trees per hectare). However, to date there is no reliable economic information to support that high densities are better than low ones. For this reason, the objective of this research was to economically analyze the production of high and low density walnut orchards. In this study, a quantitative research approach was used. The required information was collected through 66 surveys (three for each year of the 11 years analyzed of low and high density plantations) carried out to walnut producers with high and low density plantations (6 producers per year). From the information from the surveys, the production costs were determined by considering all the activities carried out in the high and low density plantations and the income from harvest sales. The results obtained indicate that production costs in the first four years were higher at low densities than at high densities. The yield per nut per walnut from the eighth year was higher at low densities than at high densities and the yield per hectare was higher at high densities due to the greater number of walnut trees per hectare that were planted at high densities. The cost benefit ratio was higher at low densities than at high densities. To date there is no information on the production of walnut in low and high density, so this study is important for farmers, especially in Mexico.

Key words: Cost, yield, income, profit, walnut.

RESUMEN: El cultivo de nuez pecana, es una de las actividades económicas más importantes en Chihuahua, México. En los últimos años, el precio de la nuez ha aumentado originando una alta rentabilidad, lo que ha motivado al establecimiento de nuevos huertos, con altas densidades (204 árboles por hectárea). Sin embargo, hasta la fecha, no existe información económica confiable que respalde que el cultivo en altas densidades es mejor que en las bajas. Por esta razón, el objetivo de esta investigación fue analizar económicamente la producción de huertos de nuez cultivadas en alta y baja densidad. En este estudio, se utilizó un enfoque de investigación cuantitativa y la información requerida fue recolectada por medio de 66 encuestas (tres por cada año de los 11 analizados de plantaciones de baja y alta densidad) realizadas a los productores de nuez con plantaciones de alta y baja densidad (seis productores por año). De la información de las encuestas, se determinaron los costos de producción y los ingresos por venta de cosecha. Los resultados obtenidos indican que los costos de producción en los primeros cuatro años fueron mayores en las bajas densidades, que en las altas densidades. El rendimiento por nuez, por nogal, a partir del octavo año, fue mayor en bajas densidades que en altas densidades y el rendimiento por hectárea fue mayor en altas densidades, por el mayor número de nogales (nueces por hectárea) que se plantan en altas densidades. La relación costo beneficio fue mayor en bajas densidades que en altas densidades. Hasta la fecha no hay información sobre la producción de nuez en baja y alta densidad, por lo que este estudio es importante para los agricultores, especialmente en México.

Palabras clave: costo, ganancias, ingresos, nuez, rendimiento.

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INTRODUCTION

The walnut cultivation (*Carya illinoensis* Koch) is one of the most important in the agricultural region of Delicias city, Chihuahua. The pecan walnut is native to the southeastern United States of America and northern Mexico. The cultivation of the walnut began in Chihuahua State about 400 years ago in the Allende valley, with Creole trees (1). Nuts are a perishable product, since they contain a high percentage of oils (70-75 %), 12-15 % of carbohydrates, 9-10 % of proteins, 1.5 % of minerals and 5 % of water (2).

In relation to world walnut production, Mexico produces about 38 % (3) and in Mexico this has increased by around 80 % in the last 30 years (2003 to 2015), currently reaching around 110 thousand tons (4), from which Chihuahua produces 65 % (5). COMENUEZ, a Mexican entity of nut producers backed by SAGARPA, considers that Mexico's nut production could reach 149,685 tons by 2025 (6).

In Chihuahua state, walnut plantations predominate with different distances between them (6x6m to 30X30m) (7,8), however, the high densities favor high yields in first years, but also increase production costs and a decrease in yield per ha-1 after 10 years of establishment.

The pecan walnut requires large amounts of light to have a high photosynthetic efficiency, therefore, shading significantly reduces the seasonal growth of the shoot and has a negative effect on production, stability and quality of the walnut (9). In this regard some author mention that high densities of walnut causes little light reception due to tree shading since there is intertwining of branches, reducing the amount of photosynthetically active light received per area of walnut leaf (10). Therefore, sugars do not accumulate, growth is affected, causing the percentage of almonds to decrease. Finally, there is a considerable reduction in the walnut production per tree, obtaining low yields per ha-1 and a low quality of the walnut (10). Similarly other researchers mention that establishing high walnut densities will produce high yields per ha-1 in the first years of production (11), which will allow to considerably increase an economic benefit to walnut producers.

However, what has not been reported, perhaps due to ignorance that in orchards with high densities (204 walnut trees per ha or more) there will be shading problems after 10 years or more of establishment, decreasing the yield.

In recent years the walnut price has increased considerably, causing high profitability of walnut orchards. This has motivated several producers to establish new orchards. Some of these are being established at high densities (204 walnut trees per hectare), that is, at distances between walnut trees and rows of seven meters. However, producers are faced with the reality that there is no reliable economic information that allows them to decide best density of walnut in the new plantations, all this permitting to obtain the best income in the future. Therefore, the objective of this study was to analyze some economic aspects in high and low density walnut orchards.

MATERIALS AND METHODS

In the present case study a comprehensive qualitative-quantitative research approach was used, since it refers to systematic and empirical investigations of the different types of walnut plantations, their management and productivity. The type of research was conclusive, descriptive, since they describe the plantation systems used and the cultivation of alfalfa interspersed between walnut trees (at low densities).

Walnut trees in Delicias city, Chihuahua are planted in a wide variety of soils, the most widely used being clay-sandy loam with a slightly alkaline pH, deep with good drainage and with a low content of organic matter. The climate in the region is extreme, semi-arid, with little rainfall, very high temperatures in the summer (40-41 ℃) and low temperatures in the winter (-5 to -6 ℃) (12).

The analytical review technique was used for which the information was obtained through 66 surveys, of variables such as: initial Investment, variable costs (application of fertilizers, agrochemicals and foliar, pruning and irrigation), fixed costs (number of trees planted) and income from the sale of pecan walnut in production, and from the alfalfa harvest among the walnut trees. The above from one-year orchards, up to 11 years old, in low and high density.

The plantation frame of 10m x 10m (100 trees ha^{-1}) and high density, the plantation frame of 7m x 7m (204 trees ha^{-1}) was established as low density.

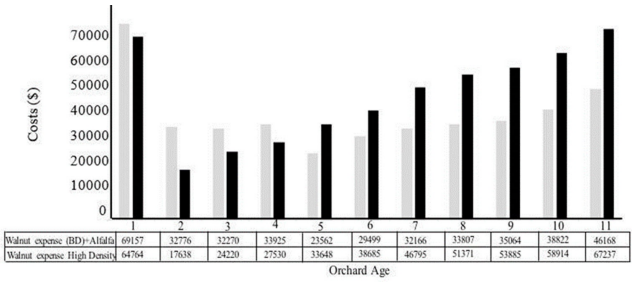
As an indicator to determine the best plantation economically in the first 11 years after its establishment, the Benefit-Cost (B/C) relationship was used, this relationship is obtained by dividing the walnut income per ha between the walnut production cost per ha and investment payback period for the two production systems studied.

To determine the production costs of walnut, the cost of the establishment work the first year, irrigation, fertilization, control of pests, diseases, elimination of weeds and harvest was considered. For the above, the methodology proposed by Trusts Instituted in Relation to Agriculture (13) was used, which is a system for determining production costs in agricultural and fruit crops. Alfalfa production cost was determined considering all the tasks carried out in said crop (14). The information gathering process was carried out through 66 surveys (three for each year of the 11 years analyzed of the orchards, low and high density) and interviews with walnut producers (6 per year). The population considered in the study was of producers who, in 2018, had an established orchard with high or low density from one to 11 years of plantation, in the municipalities of Saucillo, Delicias, Rosales, Meoquí and Julimes, in Chihuahua State, Mexico.

The analysis unit for the research was to determine economically which is the best walnut plantation, for this reason the costs of establishment, management or labor and income for the production of high and walnut low densities were analyzed to compare economic income of both systems (13) to obtain walnut yield per ha. The walnut yield per walnut reported by each surveyed producer was used, later it was multiplied by the number of walnut trees according to the plantation framework, to obtain the yield per ha. The orchards that met the characteristics of both densities, years of orchard planting and alfalfa establishment as the second crop among the rows of walnut trees (in low-density plantations) were selected.

The information collection was carried out between the months of October-December 2018 through surveys of walnut producers with orchards established in both densities.

Once the information was obtained, it was organized, analyzed and the production and income costs per year were determined. The graphs and tables required to explain the information were made, using the Excel program, the investment recovery time was determined in both densities studied, as well as the Benefit-Cost relationship per year and the one obtained from costs and income totals at 11 eleven years after its establishment. For the statistical analysis, the data were subjected to a simple variance analysis. The differences between treatment means were compared using the Tukey test ($p < 0.05$). The statistical package Statgraphics 5.1 (2001) was used for the analysis.



	1	2	3	4	5	6	7	8	9	10	11
Walnut expense (BD)+Alfalfa	69157	32776	32270	33925	23562	29499	32166	33807	35064	38822	46168
Walnut expense High Density	64764	17638	24220	27530	33648	38685	46795	51371	53885	58914	67237

Source: FCAyF-UACH, 2019

In each of the years 11 years of study, in the investigation and analysis of the production establishment of high and low density walnut orchards

Figure 1. Costs of establishment and management of high and low density orchards per ha.

RESULTS AND DISCUSSION

Production costs per hectare of low and high density walnut trees

Based on the results of the surveys carried out with the producers, as well as the consultation of information from official sources, on the establishment and management of the orchards, it was possible to determine the cost of establishment and management of both production systems by hectare. (Figure 1).

In the first year of orchard establishment, the highest investment cost was in the low- density plantation plus the cultivation of alfalfa with a cost of $ 69,157.00, whereas in the high-density orchard a cost of $ 64,764.00 was generated. In Figure 1 it can be seen that in the first 4 years the cost of establishment and management in low-density orchards is higher than the cost and management of high-density orchards. From the fifth year on, high-density orchards cause the highest management cost compared to low-density orchards. This result does not coincide with the one obtained (15) where the high-density plantation of fruit trees that last less time than walnut to produce, reached total production in the fourth year and also had the highest proportion (>80 %) of fruits that were better both in terms of quality and price. Another result that does not coincide with that obtained in this research was in plum (*Prunus domestica* L.) where the establishment costs were 1.9 times higher in the high-density orchard (7,729 € ha $^{-1}$) than in the low-density one (€ 4,069.3 ha $^{-1}$), although investment recovered between the second and third year of production (16).

In mango cultivation (*Mangifera indica* L.) is unlikely that productivity will increase through the use of high density plantations without great efforts in plant improvement and crown management (17). In the specific case of walnut, pruning is a basic aspect to take into account to increase yields even more in high-density orchards.

The higher cost generated in the year of establishment and the following three years in the low-density walnut orchards is attributed to the production cost of the intercropped alfalfa crop in the low-density system, since the total expenditure for the first year ($ 69 157.00), the cost of the establishment and management of alfalfa corresponds to $ 39,533.00, this represents 57 % of the total cost of this low-density production system. In contrast, the plantation and management of walnut generates a total cost of $ 29,624.00, which represents 43 % of the total cost of the production system. In the second, third and fourth years, alfalfa management cost was again the one that increased the cost of the low-density system, being 85.7, 75.4 and 71.6 % respectively, while the management of walnut only represented 14.3, 24.6 and 28.4 % of the total cost. The increase in the production cost of walnut from the second year is attributed to the fact that as walnut grows, it requires greater amounts of inputs such as fertilizers, insecticides and spending on pruning.

From the fifth year in the low-density production system, the walnut trees, due to their growth, occupy more space, causing a lot of shade, which does not allow the development of another crop among the walnut trees and from this date the costs were generated only by the management walnut. When making the comparison of the costs generated by high and low densities, it can be seen in figure 1 that the high-density orchards in the fifth year generated a higher cost than those of low densities, in $ 10,086 and gradually increased in the following years of the fruit tree . In the tenth year, the cost of producing high densities was $ 20,092 higher than the cost of producing low-density walnut. This increase in costs was due to a greater amount of fertilizers, insecticides, pruning, harvesting and irrigation, due to the greater number of trees.

According some author the use of high-density plantations in orchards is an innovative concept to increase productivity without altering the quality of the fruits (15), even when these orchards need a greater investment compared to conventional ones, it is useful to apply the concept because they can provide faster and better returns on invested funds.

Walnut yield per tree and hectare in low and high walnut densities

The walnut begins its production from the fifth year. Considering that each producer gives his own management to the garden according to his knowledge, experience or advisor, it can be said that there is a great diversity of management that can produce different yields, however,

there are less than 20 walnuts per walnut that produced in its first year of trial, the number of walnuts increases by the sixth year of age, but its performance is not significant. From the seventh year according to the results of the survey, the walnut tree produces an average of 1.5 kg of walnut per tree and increases its yield according to the management it receives in the orchard, even when the management that is given depends on the producer.

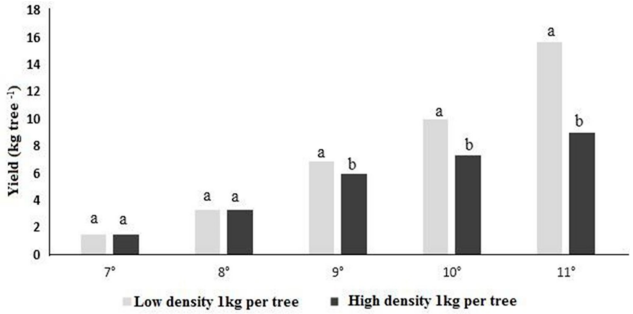
In low-density orchards (100 walnut trees per ha^{-1}), it was found that 8-year-old trees have a production of 3.34 kg, on average, this yield increases to 6.85 kg in the ninth year and to 10 kg in the tenth year. In high-density orchards until the seventh year there is no competition for light between walnut trees, therefore, their yield potential (1.5 kg) is equal to trees established at low densities. However, after the eighth year, the yield per tree tends to decrease, in relation to the trees planted at 10 x 10 meters with a yield of 3.33 kg. The yield at nine years is 6 kg, this yield continues to increase on average to 7.35 kg and 9 kg in the tenth and eleventh year respectively. These yields of the last 3 years are lower than the yields that produce walnut trees of the same age at low densities (Figure 2). This lower yield is attributed to what is mentioned by some researchers (10), that the shading of the leaves causes a lower photosynthetic efficiency of the leaves, which negatively affects the yield, retention of fruits and production of flower buds.

The lower yield obtained from the ninth year in the high-density orchard is attributed to the fact that from this date the branches between neighboring walnut trees intertwine causing less penetration of light to the internal leaves of the walnut. This low amount of light received by the internal leaves of the walnut has a negative effect on the tree photosynthesis and consequently its performance is affected, causing a decrease in it, as reported (10).

When estimating yields per hectare (Figure 3), it was found that from the seventh year to the eleventh year, the yield is higher when there is a density of 204 trees (high density).

The highest performance in high density is obtained because in this there are more than twice as many walnut trees as in low density. It is also appreciated that in the seventh and eighth years the performance at high densities is twice the performance at low densities. In the eleventh year, a higher yield is obtained at high densities of 230 kg ha^{-1} with respect to low densities, although there are no significant differences. This is attributed to the fact that from the ninth year the yield per tree at high densities tends to decrease due to shading effects, which causes less photosynthesis, decreased emission of flower buds, and walnut fall (10).

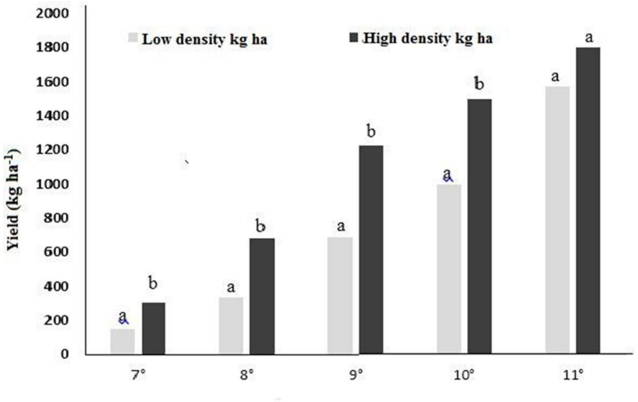
In another investigation, three varieties of almonds were studied in low and high density and the authors found that the yield per nut tree was higher in low density, but the yield per ha was higher in high density (18), this due to the existence of a greater number of trees per hectare. This result coincides with that of this research where the highest yield per hectare was also obtained at high densities. This is very important in the first years of walnut production and one of the producers' objectives is to obtain higher yields per hectare, in order to achieve higher income.



Source: FCAyF-UACH, 2019

In the research, analysis of the production establishment of high and low density walnut orchards

Figure 2. Walnut yield per tree and economic analysis of the establishment and production of high and low density walnut orchards.



Source: FCAyF-UACH.2019

In the research, analysis of the production establishment of high and low density walnut orchards

Figure 3. Walnut yield per hectare and economic analysis of the establishment and production of high and low density walnut orchards.

In relation to the higher yield per tree in low densities than in high ones, this is attributed to the fact that in low densities the tree has a greater space, receives more light, which causes greater photosynthesis and higher yield. On this subject, some authors established that growth increases according to greater accessibility, that is, at low densities (19).

Benefit-cost ratio per hectare in low and high densities of walnut

The Benefit-Cost Ratio (B/C) is always desired to be greater than one, being this way it indicates that a greater profit is being generated than the investment made in the activity that is being practiced. In the production of walnut with low and high densities, the B / C ratio began to be analyzed from the first year in the low-density orchards. The first year, despite the fact that the alfalfa generated an income of $ 51,408.00 pesos, the B/C ratio was 0.74, a negative relationship because the cost of establishing the orchard and the alfalfa was considered. From the second year onwards,

the B/C ratio was greater than one until the fourth year, while in the high-density orchards, as they did not generate income, a B/C ratio was not obtained. The good B/C ratio obtained in the first years in low-density orchards is attributed to the income generated by the cultivation of alfalfa since in these years the walnut does not produce. As of the seventh year, which is when the walnut tree begins to have commercial production, the B/C ratio generated by income is analyzed. The production in both densities is low and the management cost is higher than the income obtained, which generates a B/C ratio of less than one, being much lower from the seventh to the ninth year in orchards with low density. The higher B/C ratio obtained in these years in the high-density orchards is attributed to a higher production of walnut caused by the greater number of trees per hectare than in the low-density orchards (Table 1).

To date, there is no information on this subject in walnut, this being the first investigation of this type from here on the importance of the results that are presented. The relevance of interspersing the alfalfa with walnut in low densities in the first four years after the orchard is established is highlighted, since it allows generating income that helps the maintenance of the walnut orchard, not being possible in the orchards of high densities, which are not generate income in these years. However, it is important to note that, in the first years of walnut production, orchards with high densities, despite having higher production costs than orchards with low densities, generate a better B/C ratio. The above, due to the greater number of walnut trees in high densities. In both walnut densities studied, the tenth and eleventh year after establishment, a B/C ratio greater than two is generated. This indicates that in these years and in the following years, due to the high yield and sale price of the walnut, the income per hectare will be very beneficial for the producers, who will be able to recoup the investment in the first years and obtain profits. Similar results to those of this research were reported that in a mango plantation where the B/C ratio was 1.49 and 2.00 in traditional and high density respectively and the internal rate of return was higher in high density plantations than in the traditional (20). A similar result, but referring to income, was obtained in palm cultivation, where the analysis indicated that the maximum income could be obtained in high density compared to conventional (21). In walnut there is no information on studies of the B/C ratio, this being the first investigation to compare high and low density plantations.

CONCLUSIONS

- The results obtained indicate the importance of establishing low densities of walnut intercropped with alfalfa, to obtain income that helps to cover the costs of managing walnut orchards. Considering the walnut yield per tree, orchards with low densities (100 walnut trees per ha.) Are better than those with high densities (204 walnut trees per ha.). In low-density orchards, each tree from the eighth year produces a higher yield than trees in high-density orchards.
- The highest overall B/C ratio was achieved in low density compared to high density plantations. The payback period was first in low-density orchards (11 years), compared to high-density orchards where there is no payback during this same period analyzed. In low density orchards in the eleventh year, a profit of $ 74,590.00 was obtained, while the high densities had a deficit of $ 45,325.00.

BIBLIOGRAPHY

1. Ojeda Barrios DL, Arras Vota AM, Hernandez Rodriguez OA, Lopez Diaz JC, Aguilar Valdes A, Denogean Ballesteros FG. Análisis FODA y perspectivas del cultivo del nogal pecanero en Chihuahua. Revista Mexicana de Agronegocios. 2010;27(1345-2016-104334):348-59.
2. Chávez González CH. Almacenamiento refrigerado de nuez pecanera *Carya illinoensis*. Revista informativa y de interés para el sector nogalero de México. 2019;13(54):18-21.

Table 1. Benefit-Cost Ratio per year in low and high walnut densities

Low density				High density			
Year	**Walnut Cost (BD) + Alfalfa**	**Profit in pesos**	**B/C ratio**		**Walnut Cost High Density**	**Profit in pesos**	**B/C ratio**
Inv	$ 34 930.00			Inv	$ 47 000,00		
1°	$ 34 227.00	$ 51.408.00	0.74	1°	$ 17 764.00	$ -	0.00
2°	$ 32 776.00	$ 51.408.00	1.57	2°	$ 17 638.00	$ -	0.00
3°	$ 32 270.00	$ 43 885.00	1.36	3°	$ 24 220.00	$ -	0.00
4°	$ 33 925.00	$ 35.985.00	1.06	4°	$ 27 530.00	$ -	0.00
5°	$ 23 562.00	$ -	0.00	5°	$ 33 648.00	$ -	0.00
6°	$ 29 499.00	$ -	0.00	6°	$ 38 685.00	$ -	0.00
7°	$ 32 166.00	$ 12 000.00	0.37	7°	$ 46 795.00	$ 24 000.00	0.51
8°	$ 33 807.00	$ 26 720.00	0.79	8°	$ 51 371.00	$ 53 440.00	1.04
9°	$ 35 064.00	$ 54 800.00	1.56	9°	$ 53 885.00	$ 97 920.00	1.82
10°	$ 38 822.00	$ 80 000.00	2.06	10°	$ 58 914.00	$ 120 000.00	2.04
11°	$ 46 168.00	$ 125 600.00	2.72	11°	$ 67 237.00	$ 144 000.00	2.14
Total	$ 407 226.00	$ 481 806.00	1.18	Total	$ 484 687.00	$ 439 360.00	0.91
	Gain	$74 590.00			Deficit	-$ 45 327.00	

Source: FCAyF-UACH.2019
In the investigation and analysis of the establishment of production of orchards of high and low density of walnut

3. INC (International Nut & Dried Fruit). Global Statistical Review 2014-2015. 2015. 76 p.
4. Orona Castillo I, Sangerman-Jarquín DM, Cervantes-Vázquez MG, Espinoza- Arellano J de J, Núñez-Moreno JH. La producción y comercialización de nuez pecanera en México. Revista mexicana de ciencias agrícolas. 2019;10(8):1797-808.
5. Herrera Aguirre E. Producción de nuez pecanera a nivel mundial. Revista informativa y de interés para el sector nogalero de México. 2019;13(54):24-9.
6. COMENUEZ. Comité Mexicano del Sistema Producto Nuez. 'Internet". 2017 'cited 03/03/2021". Available from: https://www.encuentren.me/es/chihuahua/empresa/comenuez/perfil/60381/
7. Wells L, Conner P. Southeastern pecan growers' handbook. University of Georgia. 2007;236.
8. Madero ER, Trabichet FC, Pepé F, Wright ER. Manual de manejo del huerto de nogal pecán. Ediciones INTA; Estación Experimental Agropecuaria Delta del Paraná; 2016.
9. Hernández de Santiago J, Arreola Avila J, Trejo Calzada R, Flores Hernandez A. Distribución de luz en nogal pecanero *Caryaillinoensis*después del aclareo de huertas con problemas de sombreo. Revista Chapingo Serie Zonas Áridas. 2006;(2):185-90.
10. Arreola-Avila J, Hernández-Martínez M, Trejo-Calzada R, Flores-Hernández A. Condiciones de luz y actividad fotosintética en árboles en producción de nogal pecanero *Caryaillinoensis* (Wangenh.) K. Koch). Revista Chapingo Serie Zonas Áridas. 2007;6(2):219-22.
11. Fronza D, Janner J, Vanderlei B, de Oliveira RA, Alcir EM. Pecan cultivation: general aspects. Ciência Rural. 2018;48(2):1-9.
12. Tarango R. Paquete Tecnológico para Nogal pecanero. Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias; 2015 p. 1-9.
13. FIRA. Agrocostos, Sistema de Costos Agrícola 'Internet". 2019. Available from: https://www.fira.gob.mx/InfEspDtoXML/TemasUsuario.jsp
14. Hernández RP, Cuellar J. Agenda Técnica Agrícola - Coahuila by Senasica - issuu 'Internet". 2015 'cited 03/03/2021". Available from: https://issuu.com/senasica/docs/07_coahuila_2015_sin
15. Majid I, Khalil A, Nazir N. Economic Analysis of High Density Orchards. International Journal of Advance Research in Science & Engineering. 2018;7(4):821-9.
16. Milosevic T, Zornic B, Glisic I. A comparison of low-density and high-density plum plantings for differences in establishment and management costs, and in returns over the first three growing seasons-a mini-review. The Journal of Horticultural Science and Biotechnology. 2008;83(5):539-42.
17. Menzel CM, Le Lagadec MD. Can the productivity of mango orchards be increased by using high-density plantings? Scientia Horticulturae. 2017;219:222-63.
18. Kumar D, Ahmed N, Verma MK. Studies on high density planting in almond in Kashmir valley. Indian Journal of Horticulture. 2012;69(3):328-32.
19. Zimmerman RH, Steffens GL. Cultivar, planting density, and plant growth regulator effects on growth and fruiting of tissue-cultured apple trees. Journal of the American Society for Horticultural Science. 1995;120(2):183-93.
20. Kerutagi MG, Deshetti MB, Abhilash K. Comparative economics of traditional Viz high density mango cultivation in Karnataka. Asian Journal of Agricultural Extension, Economics & Sociology. 2017;1-12.
21. Latif J, Mohd NM, Tayeb DM, Kushairi DA. Economics of higher planting density in oil palm plantations. Oil palm industry economic journal. 2003;3(2):32-9.