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Original Article

Yield, Quality and Phytochemicals of Organic and Conventional Raspberry Cultivated in Chihuahua, Mexico

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Abstract

Raspberry production represents an alternative for farmers in the temperate zones of Mexico. Due to the environmental impact caused by conventional agriculture, there is currently greater demand for organic food in the national and international market. To achieve this need, new fertilization techniques based on organic amendments are being tested. In the present study, yields and quality were evaluated over a 3-year period (2015, 2016 and 2017) as well as the phytochemical compounds of the production in 2017, with management of organic versus conventional fertilization of raspberry crop in open field in Cuauhtémoc, Chihuahua, Mexico. During the three years of study, the conventional fertilization system obtained higher yields, compared to the organic one, with values of 2,698 and 2,351 g per linear meter in 2015, 2,423 and 1,301 g per linear meter in 2016 and the data for 2017 were 3,077 and 2,550 g per linear meter, respectively. Regarding quality, the results showed no statistical differences between the two systems of production about colour, firmness, total soluble solids, titratable acidity and pH of the fruit. Differently the composition of phytochemicals, phenols, flavonoids, total anthocyanins and antioxidant capacity was better under the organic management. In conclusion, the conventional system showed higher yields, the quality of the fruits was not different between the two systems, while the levels of phytochemicals were higher with the organic farming. Therefore, it is important to continue the research in order to improve soil fertility and achieve higher yields under the organic management.

Keywords: antioxidants; farming; organic amendments; *Rubus idaeus* L; systems

Introduction

In recent years, production of small fruit like raspberry is being promoted in the State of Chihuahua, Mexico, due to the need to diversify fruit production and expand export markets. The rapid development of raspberry crop in these new temperate zones of the country resulted in the addition to agrochemicals to increase yields in production. However, the organic farming (Conti *et al.*, 2015) is advisable as an alternative to the conventional management in order to reduce the excessive use of pesticides, which have serious effects on the environment and cause immediate and long-term damage to ecosystems (Rivera-Becerril *et al.*, 2017). Recent studies indicate that the excessive use of pesticides cause harmful effects to the microbiology of the soil, which leads to the degradation of the natural fertility of it (Aktar *et al.*, 2009; Prashar and Shah, 2016).

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Organic agriculture, as an alternative to the conventional system, has developed rapidly, driven by the demand for pesticide-free and healthy foods (Gomiero, 2017). Indeed organic agricultural systems are reportedly able of producing food with high quality standards (Lairon, 2011) and high concentrations of phytochemicals (Olsson *et al*., 2006; Jin *et al*., 2011; Vinha *et al.,* 2014; Cuevas *et al.,* 2015).

Raspberries are a good source of phytochemicals, which provide protection against human diseases caused by oxidative stress, since they contain high levels of phenols, flavonoids such as anthocyanins and antioxidant capacity (Skrovankova *et al*., 2015). Raspberries have shown greater antioxidant capacity with organic fertilization management (Jin *et al*., 2012). Similarly, other investigations with fruits such as strawberry, blueberry and plum showed higher levels of anthocyanins, phenolic compounds and higher antioxidant capacity in organically produced crops (Olsson *et al.,* 2006; Jin *et al*., 2011; Crecente-Campo *et al*., 2012; Cuevas *et al*., 2015).

However, some researchers state that there is not enough evidence about the higher quality and physicochemical composition of organic food compared to the conventional one (Lairon, 2010; Lima and Vianello, 2011; Oliveira *et al*., 2013). Therefore, further investigations are needed, even concerning the improvement of technologies and long-term sustainability of organic systems. The purpose of the present study was to asset yields, quality and total phytochemical compounds of red raspberry with organic and conventional fertilization cultivated in open field in the northwest side of Chihuahua State, Mexico.

Materials and Methods

This work was carried out during 2015 to 2017 at the Faculty of Agrotechnology Sciences, Autonomous University of Chihuahua, Cuauhtémoc Campus, located at 28° 24' 45.1 "N, 106° 52' 54.9" W and at 2060. The soil had a clay-loam (clay 23.1%, silt 39.2%, and sand 37.5%). Information about annual rainfall, minimum and maximum temperatures were obtained from the three years of study on a UNIFRUT meteorological station located in Cuauhtémoc, Chihuahua, Mexico (Table 1).

Establishment of the experiment

Plantation was established with the cultivar 'Heritage' in February 2015. The experiment was composed of 6 rows of 20 m each, each experimental unit was 4 linear m, a distance of 2 meters between rows and 1 m between each experimental unit, with a density between 30 y 35 canes per linear m.

The experimental protocol was based on the comparison between organic and conventional management. The completely randomized experimental design was used, with 12 repetitions. Distribution following the soil preparation, 10 kg of compost per experimental unit (12.5 t ha^{-1}) was applied to the organic treatment and was incorporated before planting. In the conventional treatment, no fertilizer was applied until the plants were established and the emergence of new shoots was observed. To obtain the vegetative material, the complete root system of dormant raspberry was extracted from a commercial orchard and was handled with bare roots. Once the plantation was established, the drip irrigation system was designed and installed, with emitters embedded every 60 cm, with a flow of 1.6 L per hour. With this system, watering was carried out three times per week, with five-hour length. Weed control was carried out manually or mechanically along or between the rows respectively.

Crop management

The supplying company of organic and conventional fertilizers was Union Agricola Regional de Fruticultores del Estado de Chihuahua (UNIFRUT). Organic treatment consisted of applying vermicompost, leachate of vermicompost and commercial organic fertilizer ("GreenBackS11" with 3-4-4 of N-P-K), whose physicochemical properties are indicated in Table 2. These organic fertilizers were dissolved in water and applied manually by experimental unit as described below.

Table 1. Monthly values of minimum and maximum temperatures (average) and rainfall (sum) in the three years of research

Months	2015			2016			2017		
	Min (°C)	Max (°C)	Pres (mm)	Min (°C)	Max (°C)	Pres (mm)	Min (°C)	Max (°C)	Pres (mm)
January	-0.7	27.0	18.1	-3.4	14.2	0.7	-0.8	16.9	2.5
February	1.7	22.4	17.3	-0.5	19.6	0.4	0.2	19.8	0.4
March	9.7	25.1	29.4	2.9	21.1	4.3	4.0	23.0	0.6
April	12.2	26.2	13.2	4.8	23.1	1.1	6.3	25.6	1.9
May	12.6	29.6	0.8	8.3	26.9	1.6	7.6	27.3	4.5
June	14.7	32.2	39.5	12.0	28.9	38.8	12.4	31.0	11.1
July	15.0	29.4	108.7	13.5	27.8	90.0	13.5	25.6	288.0
August	12.6	27.4	77.6	12.9	23.8	277.6	13.2	24.5	184.8
September	11.0	26.8	76.6	11.6	24.7	32.1	10.3	25.0	38.7
October	7.0	21.9	42.4	6.9	24.4	17.9	7.5	24.5	7.0
November	1.9	20.2	38.9	2.1	19.2	6.3	4.5	24.2	0.0
December	-1.9	15.9	3.3	1.2	18.0	10.5	2.3	20.3	0.0
Annual average temperatures and total rainfall	8.0	25.3	465.8	6.0	22.6	481.3	7.1	24.3	539.5

The compost was applied at the rate of 10 t ha^{-1} the first and second year of study; for the third year it was 15 t ha^{-1}. Leachate vermicompost in 2015 and 2017 was applied at 24000 L ha^{-1}, in 2016, the dose was lowered to 18000 L ha^{-1}. It is worth mentioning that before applying the vermicompost leachate, the pH was lowered from 8.2 to 7, with organic apple vinegar. In the 2017 production cycle, a 7.5 t ha^{-1} commercial organic fertilizer was also applied (Table 3). The organic fertilizer applications started in June, and continued weekly until August 2015 (12 applications). In 2016 and 2017, the applications started in May, and were concluded at the end of September (16 applications); they were applied weekly until the raspberry plants bloomed and finished production. In the conventional handling treatment, commercial (synthetic) fertilizers of nitrogen, phosphorus and potassium (NPK) were applied, which were based on ammonium nitrate, triple 17 and potassium sulphate (Table 4). These conventional fertilizers are applied on the row in granular composition. The inorganic nitrogenous fertilizer was applied at a rate of 150 kg ha^{-1} from May to August in 2015, from May to September in 2016 and May to October in 2017. Nitrogen rates remained the same for the three years to promote the reproductive growth. Inorganic P fertilizer was also added at a rate of 40 kg ha^{-1} and 190 kg ha^{-1} of K. In 2016 the dose of K was lowered to 130 kg ha^{-1}.

Soil analysis

Soil analysis was performed on a composite sample obtained in the different repetitions of the treatments applied (conventional and organic), at a depth of 0-30 cm. Soil chemical analysis were made according to the Brucina methodology for nitrates ($N\text{-}NO_3$) (APHA, 1992), Olsen and Bray method for phosphorus (P) (Olsen, 1954; Bray and Kurtz, 1945), reaction HCl visual method for organic matter and calcium carbonate ($CaCO_3$).

Foliar analysis

The foliar analysis was carried out in August by sampling leaves from the middle part of the shoot without fruiting in the phenological stage of full production. For the quantification of nutrients, a wet digestion was carried out with a mixture of nitric and perchloric acids. The concentration of N in the plant was determined by the analysis of plant tissue by the method of Micro-Kjeldahl proposed by Muller (1961). The determination of K, P, Ca, Mg, Fe, Mn, Zn and B was performed by coupled plasma atomic emission spectrometry (ICP-AES) (Gastelum-Osorio *et al*., 2013).

Harvest and yield

The harvest in 2015 began in the first week of August, while the next two years (2016 and 2017) in mid-June. The raspberries were harvested when they could be detached from the receptacle and had an intense red colour; which corresponds to a brightness of 27 ± 1 on the scale of ° Hue. There were 4 to 5 partial harvests per week, in the morning and in the afternoon, when the fruit had less heat in the field. Later, they were weighed on an OHAUS precision scale and reported in g per experimental unit. The accumulated yield was obtained by adding all the partial harvests. The average weight of the fruit was calculated by dividing the yield (g) by the number of fruits harvested per experimental unit, in each partial harvest.

Physicochemical composition (colour, firmness, titratable acidity, °Brix and pH)

The fruits were harvested at the intense red colour stage, and analysed for their physicochemical characteristics such as weight, colour, firmness, °Brix, titratable acidity and pH. The average weight of fruits was obtained by dividing the yield (g) by the number of fruits harvested per experimental unit.

Table 2. Chemical and physical characteristics of vermicompost, vermicompost leachate, and commercial organic fertilizer

Properties	Vermicompost	Vermicompost leachate	Commercial organic fertilizer
pH	6.0	8.2	6.7
Organic material (%)	85	40	45
Total organic carbon (%)	18.57	-	-
N total (%)	2.24	2.30	3
P total (%)	0.12	0.300	4
K total (%)	0. 0.01	0.37	4
Ca total (%)	1.33	0.01	16
Mg total (%)	1.21	1.00	1.6

Table 3. Organic fertilizers applied in each production season

Organic Fertilizers	2015	2016	2017
Vermicompost ($t{\cdot}ha^{-1}$)	10	10	15
Vermicompost leachate ($L{\cdot}ha^{-1}$)	24000	18000	24000
Commercial organic fertilizer ($t{\cdot}ha^{-1}$)	----	----	7.5

Table 4. Fertilizer as conventional ($kg{\cdot}ha^{-1}$) in each production season.

Conventional Fertilizers	2015	2016	2017
NH_4NO_3	315	315	315
TRIPLE 17 (NPK)	40	40	40
K_2 SO_4	284	170	284

The colour was determined using a CR-400 Chroma Meter (Konica Minolta Sensing Americas, Inc., Ramsey, NJ, USA), where values of L*, a* and b* were obtained for the CIELAB scale, the values were expressed in ° hue. Firmness was measured using a texture analyzer (CT3-1000; Brookfield) fitted with a 2 mm flat probe. Each drupelet was compressed 2 mm at a speed of 0.5 mm s-1, and the maximum force developed during the test was recorded (Vicente *et al*., 2007). Soluble solids, titratable acidity and pH were determined by macerating 10 fruits per variety to obtain juice. The total soluble solids (TSS) were determined using digital refractometer (ATAGO, Japan, Model: DR-A1) (Forney *et al*., 2015). The titratable acid percentage (TA) was determined by diluting 5 ml of raspberry juice in 100 ml of distilled water, and then titrating to pH 8.2 using 0.1 N NaOH, and the result was expressed as mg of citric acid / 100 ml of juice. The pH was measured with an OHAUS potentiometer (Starter 3100). For the physicochemical parameters mentioned above, 10 fruits were used per each repetition with a total of four repetitions per each treatment studied.

Phytochemical composition (total phenols, total flavonoids, total anthocyanins and antioxidant capacity)

The total phenolics content in raspberry extracts were measured with the Folin - Ciocalteu reagent according to the method of Slinkard and Singleton (1977) using gallic acid as a standard. The results were expressed in mg of gallic acid equivalent (GAE) / 100 g of fresh weight (fw). The total flavonoids content was measured using a colorimetric assay in accordance with the method of (Zhishen *et al*., 1999). Flavonoids were extracted 5% $NaNO_2$ 10% $AlCl_3$ and 1 mol L^{-1} NaOH and measured spectrophotometrically at 510 nm using quercetin as standard. The results were expressed as mg of quercetin equivalents (QE)/100 g of fresh weight. Total anthocyanin content was determined using the pH differential method (Lee *et al*., 2005). According to this method, 25 mM potassium chloride and 0.4 M sodium acetate were used as buffer solutions with a pH of 1.0 and 4.5, respectively. The bokbunja extract, stomach digestion mixture and small intestine digestion mixture were diluted using the buffer solutions described above. Absorbance was measured at 530 nm and 700 nm using a UV-visible spectrophotometer (Biochrom Libra S22, Santa Barbara, CA, USA). Anthocyanin content was expressed as cyanidin-3-glucoside equivalents:

Anthocyanin content (cyanidin 3 glucoside equivalents, mg/L) =

$$\frac{AXMW \times DF \times 10^3}{\varepsilon\ 1}$$

Where A = pH 1.0 ($A_{530\ nm}$ - $A_{700\ nm}$) - pH 4.5 ($A_{530\ nm}$ - $A_{700\ nm}$); MW = molecular weight of cyanidin-3-glucoside (449.2 g/mol); DF = dilution factor and ε = molar extinction coefficient of cyanidin-3- glucoside (26,900 L/mol × cm). The antioxidant capacity was evaluated by radical elimination activity using DPPH (2-diphenyl-1-picryhydrazyl) as detailed by Velderrain-Rodríguez *et al.* (2018), expressed mg of trolox equivalent (TE) / 100 g of fresh weight (fw).

Statistical analysis

A completely randomized analysis was used, with a factorial arrangement, where the factor A was the three years of evaluation (2015, 2016 and 2017) and the factor B the fertilization systems (organic and conventional). The data were analysed with the SAS package by ANOVA and the separation of means was performed using the Tukey´s test ($P \leq 0.05$).

Results and Discussion

Soil properties

The treatment with conventional fertilization showed a pH of 6.84, whereas the pH was 7.65 with the organic one. The application of ammonia fertilizers reduces the pH of the soil by causing a high rate of proton release due to the processes of nitrification and absorption by ammonium (Francioli *et al*., 2016). Attention must be paid to the chemical composition of organic fertilizers, since the application method can make a difference. This is mentioned because in this study we worked by lowering the pH of the leachate to 7.0, a management that favored the absorption of available elements of the soil, which was reflected in growth and yield. The application of vermicompost increased the content of organic matter in the organic treatment to 3.1%, compared to the conventional with 2.0%. Nitrogen content was 34.2 NO3 kg ha^{-1} for conventional and 19.7 NO3 kg ha^{-1} organic. P, K, Ca, Mg, Fe and Zn in both fertilization systems was found to be sufficient, while N deficiencies were recorded (Table 5). In this regard Malvi (2011) found total nitrogen applied was used to ensure optimum absorption of potassium, as well as phosphorus, magnesium, iron, manganese and zinc. According to the results, the content of organic matter and fertilization improve the physical, chemical and nutritional properties of the soil, and accordingly the yield of the crops (Ibrahim and Fadni, 2013). The soil transfers the nutrients to the system of the plant by some biosynthetic and natural chelates, simultaneously; the pesticides that were used in the same surface of the soil could act as possible competitors to chelate the metal ions (Kumar *et al*., 2015). Nutrients from organic repeated application of composted materials enhances soil organic nitrogen content by up to 90%, storing it for mineralization in future cropping seasons, often without inducing nitrate leaching to groundwater (Diacono and Montemurro, 2011).

Table 5. Nutrient content of soil in conventional and organic treatments (August 2017)

Treatments	NO_3 (kg ha^{-1})	Organic material (%)	pH (H_2O)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	Fe (ppm)	Zn (ppm)
Conventional	34.2	2.0	6.8	90.3	474.5	2712	354	187	29.6	5.8
Organic	19.7	3.1	7.6	51.3	388.0	3408	444	182	21.0	6.4

Leaf nutrients concentration

Raspberry leaf analysis showed deficiencies of P and K in both treatments, as well as enough levels of N, Ca, Mg, B, Zn, Cu and Mn (Table 6) compared with Jones *et al.* (1991). Plant analysis shows the nutrients that were absorbed by the plant, reflecting the availability of nutrients in the soil, indicating that such applications were enough for both fertilization systems. Results reported by Hernandez *et al.* (2014) affirm that organic fertilizers lead to lower concentrations of N in leaves and fruits than conventional inorganic fertilization. However, according to this study, the concentrations are very similar, which proves the efficiency of organic fertilizers.

Cumulative yield

The results highlight the potential of chemical fertilization to obtain higher raspberry yields, compared to the organic production system (Fig. 1). In the three years of production, statistically significant differences were found between the organic and conventional fertilization system. The highest yield was obtained in 2017 with 2,550 g / m linear, which corresponds to 12. 4 t ha^{-1} for organic and 3,077 g / m linear, with 15.2 t ha^{-1} for conventional. The lower productivity of organic crops can be attributed to a lower effectiveness of organic fertilizers compared to conventional mineral fertilizer (Conti *et al.*, 2014). In organic farming, nutrients are provided more slowly, making them available to the plant in periods that vary from days to months (Lima *et al.*, 2017). Therefore, it becomes clear that with conventional fertilization there is greater availability of nutrients in the soil, compared with the organic, which is slower but more efficient; that is why in the foliar analyses of this study they are similar in both fertility systems.

Regarding the organic production of raspberries, Pedreros *et al.* (2008) reported a yield of 9.07 t ha^{-1} where they evaluated different mulches, obtaining higher yields with the pine sawdust treatment. Another study reports that the organic production of red raspberry, under tunnel conditions, improved the yield with 14.8 t ha^{-1} and minimized the incidence of fungal diseases, compared to productions in open fields (Hanson *et al.*, 2016). Regarding conventional yield, based on statistics from the Servicio de Información Agroalimentaria y Pesquera (Agri-Food and Fisheries Information Service) (SIAP), SAGARPA indicated an average yield of 15.8 t ha^{-1} for 2015, with conventional handling in high tunnels. This information is similar to the results found in this study, considering that in the tropics and subtropics of Mexico, two harvests per year are obtained with high tunnels. Considering that organic crops, in general, can produce 5 to 50% less than conventional crops (Quirós *et al.*, 2014), it is possible that these crops experience some level of stress that could be responsible for the low yield. Suge *et al.* (2011) state that organic fertilizers are enough to improve plant capacity, produce high yields and improve the composition of the fruit, compared to plants treated with inorganic fertilizers. Ibrahim and Fadni (2013) reported that organic fertilizers are efficient amendments to improve the physical, chemical and nutritional properties of the soil, thus promoting increases in crop yields. This could be attributed to the fact that the nutrients in the organic fertilizer are released gradually through the mineralization process, maintaining optimum levels in the soil during prolonged period of time. Studies have shown that continuous use of chemical fertilizers may lead to a decrease in soil quality and productivity (Tao *et al.*, 2015; Chen *et al.*, 2018).

Dorais and Alsanius (2015) reported that an average yield reduction of 11% was observed in organic horticultural cultivation, mainly due to the scarcity of adapted genotypes for this system, as well as the effects associated with stress, which can affect organic crops more than conventional crops (eg. presence of pests and nutritional imbalances). Taking into account that organic agriculture is an expanding market (Noriega-Cantu *et al.*, 2012), the generation of suitable varieties for organic management should be considered, through genetic engineering (Orsini *et al.*, 2016). More than 95% of the varieties grown under organic agriculture have been selected for conventional high input agriculture (van Bueren *et al.*, 2011). Several scientists began to look for ancient and local varieties, with a trait of adaptation and rusticity, relevant to organic conditions, because their genetics can improve crop yield in unfavourable environmental conditions (Cortés-Olmos *et al.*, 2014). In addition, native varieties and local ecotypes may also present interesting quality traits, since they were selected before the massive use of chemical inputs (Dawson *et al.*, 2011). However, these organic systems are in function of achieving preferential prices in the market and above all a sustainable production by using non-polluting products to the environment and the consumer (Noriega-Cantu *et al.*, 2012).

Number and fruit weight

Regarding the average fruit weight, no significant differences were recorded between the treatments, as they are in the Table 7. Significant interaction was detected between years and fertilization systems with the top value in 2017 of 1024.2 fruits per linear meter while the 2016 organic management caused the lowest with 574 fruits per meter line. The number and weight of the fruits are components of the yield, therefore the smaller values gave a reduction of yields. Pacheco *et al.* (2017) evaluated the size of the passion fruit pulp and no differences were found in

Table 6. Nutrition leaf status of 'Heritage' raspberry in full production (August 2017)

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	B (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
Conventional	3.4	0.1	1.1	0.7	0.2	32.2	11.5	66.0	3.1	535.5
Organic	3.2	0.1	1.2	0.9	0.2	44.3	12.5	75.0	3.8	316.0
Reference for sufficient level in raspberry crops (Jones *et al.*, 1991)	2.5-4.0	0.3-0.5	1.5-3.0	0.8-1.5	>0.3	25-75	3-5	30-150	3-50	50-250

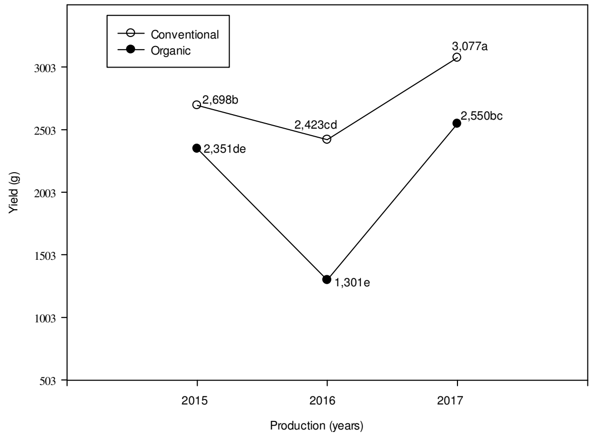

Fig. 1. Yield (g per linear meter) of 'Heritage' raspberry grown with the organic and conventional fertilization systems. Values followed by different letters are significantly different according to the Tukey test ($P < 0.05$)

the number and weight of the fruits between conventional and organic fertilizers. However, in another study Maggio *et al.* (2013) reported that in the organic system a significant reduction in the height and diameter of the cauliflower corymbs was determined, with the consequent decrease in fresh weight (-20%) compared to the conventional system, in cauliflower. The small size of the vegetative and reproductive organs in organic agriculture could have been caused by a lower availability of nutrients in coincidence with sensitive stages of development. Zarabi and Jalai (2012) reported that the nutrient release pattern of organic fertilizers may not coincide optimally with the requirements of the plant.

Physicochemical composition (colour, firmness, soluble solids, titratable acidity and pH)

For the physicochemical attributes of the fruit there were no statistical differences between the years of production and the treatments such as: colour, firmness, soluble solids, titratable acidity and pH (Table 8). The above confirms what was mentioned by Lairon (2011) where organic systems have proven capable of producing food with high quality standards. Other studies also confirm that the different types of organic fertilizers did not affect the quality parameters in oranges (Rapisarda *et al.*, 2010), likewise in apples, where Roussos and Gasparatos (2009) found that the quality of the fruit is similar in terms of total soluble solids, pH of the juice, titratable acidity and colour indexes. The results obtained in this study coincide with the results reported by Hargreaves *et al.* (2008), who studied the quality of raspberries, with no effect of the application of organic amendments. This has been confirmed by several studies showing that the management of organic and conventional fertilization does not impact on the organoleptic quality of the fruit (Polat *et al.*, 2010), but there are residues of inorganic inputs applied during the production process.

Phytochemical composition (total phenols, total flavonoids, total anthocyanins and antioxidant capacity)

In the present study, the total phenols achieved the values of 343.9 mg 100 g^{-1} fw, and 196.6 mg 100 g^{-1} fw with the organic or the conventional fertilization respectively. Previously published reports identified results similar to those found here with values between 360 and 380 mg 100 g^{-1} fw (Jin *et al.*, 2012). With the conventional Jin *et al.* (2012) reported values between 300 and 320 mg 100 g^{-1} fw, with the current study data being lower. Presumably the chemical fertilization which was based on NPK 5-3-4 caused an imbalance causing stress damage to the plants, which benefited the accumulation of these compounds that is why the results of total phenols were higher than those of the present work where it was fertilized with lower doses of NPK at ratio 3-1-5. Moreover other results of total phenols in cranberries are similar to those found in this research for organic and conventional with 319.3 and 190.3 mg 100 g^{-1} of fw respectively (Wang *et al.*, 2008).

Table 7. Number and average weight of the fruit in the years of research with the systems of organic vs conventional fertilization

Year of production	Fertilization system	Number of fruits per linear meter	Average fruit weight (g)
2015	Conventional	913.0 a	2.9 a
	Organic	787.8 b	3.0 a
2016	Conventional	840.6 a	2.8 a
	Organic	574.0 b	2.2 a
2017	Conventional	1024.2 a	3.0 a
	Organic	873.2 b	2.9 a

Different letters within the same column indicate significant differences (Tukey test, $p < 0.05$).

Table 8. Physicochemical composition of the fruit produced with organic and conventional fertilization systems in the years from 2015 to 2017

Year of production	Fertilization system	Colour (°hue)	Firmness (g of force)	Soluble solids (°brix)	Titratable acidity (%citric acid)	pH
2015	Organic	27.4	68.5	11.0	1.8	3.0
	Conventional	27.0	67.9	10.9	1.8	3.0
2016	Organic	27.2	68.4	11.0	1.7	3.0
	Conventional	27.8	67.8	11.0	1.8	3.0
2017	Organic	27.9	68.4	11.3	1.7	3.1
	Conventional	27.4	68.5	11.0	1.9	3.0
	ns. not statistically significant	ns	ns	ns	ns	ns

Table 9. Phytochemical composition of the fruit produced with organic and conventional fertilization systems in the period of 2017

Fertilization system	Total phenols mg GAE/100 g^{-1} fw	Total flavonoids mg QE/100 g^{-1} fw	Total anthocyanins mg C3G/100 g^{-1} fw	Antioxidant capacity (DPPH) mg TE/ 100 g^{-1} fw
Organic	343.9 a	87.9 a	34.0 a	451.5 a
Conventional	196.6 b	16.6 b	15.0 b	351.6 b

Different letters within the same column indicate significant differences (Tukey test, $p<0.05$). GAE = Gallic acid equivalent; QE = Quercetin equivalent; C3G = Cyanidin-3-glucoside; TE = Trolox equivalent.

The results of total flavonoids were also higher in the organic fertilization system with values of 87.9 mg 100 g^{-1} fw versus 16.6 mg 100 g^{-1} fw for the conventional one. There is a gap in the literature regarding total flavonoids under organic fertilization in raspberry fruits. Research on strawberry fruits and broccoli with organic management have reported significantly higher flavonoid content in comparison to conventional crops (Jin *et al*., 2011, Lima *et al*., 2014). Other data reported in tomato fruits also show higher flavonoid levels, with 21% higher in organic (Vinha *et al*., 2014). Reports of another study with conventional agriculture system in the variety of raspberry 'Heritage' found results of 103.4 mg 100 g^{-1} fw (Liu *et al*., 2002). The superiority of fruits with organic management could be due to the flavonoid compounds, which are produced in plants as secondary metabolites through shikimic acid. Shikimic acid is the precursor of phenylalanine ammonia, the main enzyme in the biosynthesis of aromatic amino acids and, therefore, the precursor of the biosynthesis of phenylpropanoids (Robbins, 2003). The activity of phenylalanine ammonia (PAL) is greatly influenced by factors such as nutrient levels, which could explain the increase of these compounds in plants produced in an organic farming system. Due to the lack or limited use of synthetic chemicals in organic production (Conti *et al*., 2015), plants need to use their own defence mechanisms against exogenous agents, increasing their content. In other words, there is a greater exposure of the plant to a stressful environment, such as an attack by insects or fungi, which can induce the production of natural defense substances such as phenolic compounds (Winter and Davis, 2006).

In the same way, the total anthocyanins were higher in the organic fertilization system compared to the conventional one with 34.0 and 15.0 mg 100 g^{-1} fw respectively. Total anthocyanin data for organic management are within the ranges previously reported by Jin *et al*. (2012) who published 34 mg 100 g^{-1} fw, while for conventional 30 mg 100 g^{-1} fw. Similarly, Crecente-Campo *et al*. (2012) found significantly higher anthocyanin content in organically grown strawberry fruits. Finally, the results of antioxidant capacity indicate that the management of organic fertilization also stands out in the comparison with the conventional with values of 451.5 and 351.6 mg 100 g^{-1} fw. With respect to the previously described results of the antioxidant capacity, current investigations coincide with what was found in the present study, suggesting greater antioxidant capacity in organically grown strawberry and cranberry fruits (Olsson *et al*., 2006; Jin *et al*., 2011). This is because in organic agriculture, nutrients are provided more slowly to the plant, making them available in periods that vary from days to months. Therefore, the low availability of mineral nutrients, mainly soil nitrogen (Table 5) can cause stress to plants, directing more resources to the synthesis of their own chemical defense mechanisms. On the other hand, in conventional agriculture, fertilizers that are applied as inorganic nutrients are readily available to plants that direct plant resources to their growth, which results in a reduction of secondary metabolites production (Picchi *et al*., 2012).

The leaves can have a good level of nutrients; however the transport of the leaf to the fruit is slow. There are studies that show that nutrients are not concentrated in the same way in leaves as in fruits (Nachtigall and Dechen, 2006; Romero-Dominguez *et al*., 2017). In this study what could happen that the fruits were stressed by the slow transport of nutrients. Since according to the results of the foliar analyses there are no differences between organic and conventional. However, in this study it was not necessary to explore the content of nutrients in fruits, since this was the organ where the phytochemicals were evaluated.

Conclusions

Red raspberry crop can be a viable alternative to the common horticultural crops in Chihuahua, México. The results of the present study showed higher yields with conventional fertilization, but the fruit quality was not influenced by the fertilization system (organic or conventional). However, raspberries produced with organic management contained higher levels of phytochemicals and antioxidant capacity than conventionally produced fruits.

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