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CONTRIBUTION OF NUTRIENTS, ORGANIC AMENDMENTS AND MYCORRHIZAE ON THE YIELD COMPONENTS IN PECAN WALNUT (*Carya ilinoinensis*)

Contribución de nutrientes, enmiendas orgánicas y micorrizas, sobre los componentes de rendimiento en nogal pecanero (*Carya ilinoinensis*)

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ABSTRACT. The average national yield of pecan walnut is 1,5 t ha^{-1} which can be increased with proper management of nutrition and decrease the rate of alternation. A Taguchi L25 structure was used with six factors and five levels for each factor in kg ha^{-1}: N 0; 16; 80; 160 and 320; P_2O_5 0; 7; 35; 70 and 140; K_2O 0; 7,5; 37,5; 75 and 150; Composting 0; 250; 1250; 2500 and 5000; vermicompost 0; 100; 500; 1000 and 2000; mycorrhizae 0; 3,81; 19,05; 38,00 and 76,20 g per cm of trunk diameter. Commercial carriers: Ammonium sulfate (20,5 % N, 24 % S), phosphoric acid (49 % P_2O_5, density 1,61 kg L^{-1}), potassium thiosulfate (12,6 % K_2O, density 1,46 kg L^{-1}); compost vermicompost and mycorrhizae, evaluating the production and quality of the nut. For a production of 1,94 t ha^{-1},149 nuts kg^{-1} and 59 % of edible nut were used kg ha^{-1} 226 of N, 121 of P_2O_5, 94 of K_2O, 3111 of Compost, 1905 vermicompost and 33,02 g cm dt of mycorrhizae; of those doses, the requirements for production were 30 % of N and organic amendments, 50 % of P and K; mycorrhizae they contributed 95 % in quality of the walnut. Fertilizer costs accounted for 40,8 % of revenues, which were distributed 50 % for current year quality, 25 % for maintenance of potential production and 25 % for next year's production.

Key words: seed quality, fertilization, mycorrhizae, production

RESUMEN. El rendimiento nacional promedio de nuez pecanera es de 1,5 t ha^{-1} el cual se puede incrementar con un manejo adecuado de la nutrición y disminuir el índice de alternancia. Se utilizó una estructura Taguchi L25 con seis factores y cinco niveles para cada factor en kg ha^{-1}: N 0; 16; 80; 160 y 320; P_2O_5 0; 7; 35; 70 y 140; K_2O 0; 7,5; 37,5; 75 y 150; composta 0; 250; 1250; 2500 y 5000; humus de lombriz 0; 100; 500; 1000 y 2000; micorrizas 0; 3,81; 19,05; 38,00 y 76,20 g por cm de diámetro de tronco. Portadores comerciales: sulfato de amonio (20,5 % N, 24 % S), ácido fosfórico (49 % P_2O_5, densidad 1,61 kg L^{-1}), tiosulfato de potasio (12,6 % K_2O, densidad 1,46 kg L^{-1}); composta, humus de lombriz y micorrizas, evaluándose la producción y calidad de la nuez. Para una producción de 1,94 t ha^{-1}, con 149 nueces kg^{-1} y 59 % de nuez comestible se utilizaron en kg ha^{-1} 226 de N, 121 de P_2O_5, 94 de K_2O, 3111 de Composta, 1905 de Humus de Lombriz y 33,02 g cm dt de micorrizas. De esas dosis, las necesidades para producción fueron 30 % de N y enmiendas orgánicas, 50 % de P y K; las micorrizas aportaron un 95 % en calidad de la nuez. Los costos de fertilización representaron 40,8 % de los ingresos, los cuales se distribuyeron 50 % para calidad del año actual, 25 % para mantenimiento de la producción potencial y 25 % para asegurar la producción del próximo año.

Palabras clave: calidad de la semilla, fertilización, micorrizas, producción

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INTRODUCTION

The pecan tree (*Carya illinoinensis* (Wangenh) K. Koch) is a highly profitable fruit species, annually increasing the area of this crop. In 2015, the established area of pecan tree in Mexico was 113 thousand ha, with a production of 123 000 t, and an economic income of

8620 million of pesos. Likewise, the Chihuahua state has an area of 70,5 % of the national total, producing about 80 000 t, with a spill of 6076 million pesos (1). Therefore, the high profitability of the walnut cultivation requires a growing increase in the area planted, with a greater reinvestment in the production units that improve the production process and encourage the expansion of the crop in the international market, as well as compete with emerging countries, since 70 % of national production is exported mainly to the United States, and in the last five years to China (2). However, there are several limitations for its production, such as nutritional deficiencies and imbalances derived from the edaphic characteristics, which affect the yield since they are a reflection of the soil conditions, management and health of the walnut tree (3). Faced with this situation, it is essential to have a nutritional program that increases production per hectare, improves the quality of the nut and decreases the alternating index (4). An alternative is the use of compost, earthworm humus and mycorrhizae, which acquires special relevance to the national average yield, which is 1,5 t ha^{-1} (5-7).

The use of mycorrhizae increases the surface of the root system of the walnut, which is relevant for the absorption of water and nutrients (8). Although in most soils the organic matter content is low, its effects on soil function are important (9), since it exerts a dominant influence on diverse physical, chemical and biological properties of it (10). Certain components of organic matter are responsible for the formation and stabilization of soil aggregates (11), acting as a storehouse of slow release, especially for N (10,12). When the organic material added to the soil exceeds a C:N ratio of 25:1, the microorganisms will deteriorate the soil to obtain sufficient N, and support the microbial development (9). Therefore, to obtain the maximum economic value and minimize the potential for contamination by NO3-N, N management practices must be adjusted according to the expected mineralization process of the amendments (10,12).

The actual estimate of N availability in manures is highly variable (13), in cattle it is 51 % of OM; 1,42 of N; 1,17 of P; 3,41 of K; 3,68 of Ca; 0,7 of Mg; 0,5 of Na and 5,0 % of soluble salts (10).

On the other hand, the mycorrhizal fungus provides a greater radical surface for the absorption of water, nutrients and transport of carbonated compounds from the plant to the soil, even suppressing the damages caused by attacks of pathogens and activation of the defense mechanisms (14) associated with an increase in antioxidant capacity (15,16). Although P abounds in the soil, often the assimilable form is not enough to satisfy the needs of plants, so strategies have been developed to take advantage of it by producing root exudates and establishing symbiosis with mycorrhizae (17,18). A deficiency of P causes delayed flower initiation decreases the number of flowers and seed formation by phosphate degradation (19).

The objective of the work was to evaluate the contribution of N, P, K, compost, earthworm humus and mycorrhizae on the performance components of pecan tree and its distribution of costs.

MATERIALS AND METHODS

The study was conducted in Aldama municipality, Chihuahua, during the 2013-2014 vegetative cycles from sprouting to defoliation (March-November of each year) in ‘Western Schley’ trees planted in 1982 in a square at 12 x 12 m. The climate determined by Thornthwaite of the locality, it is semiarid extreme, with an annual average temperature of 18,53 °C, and an average pluvial precipitation of 330,6 mm (20).

Irrigation was applied by flooding at the season beginning (from March to the beginning of May) and sprinkling during the rest of the vegetative cycle. The soil was characterized with sand content of 18,1 %, silt 40,6 and clay 41,3 %, pH in 0,01 M $CaCl_2$ was 7,86, organic matter (OM) 0,88 %, the content of carbonates 6,24 % and the electrical conductivity 1,00 dS m^{-1}.

For its part, the main nutrients were estimated at $N\text{-}NO_3$=285,0 kg ha^{-1}, P=21,5 mg kg^{-1}, K=1075,0 kg ha^{-1} Ca=3800 kg ha^{-1}, Mg=300 kg ha^{-1}, Cu=0,46 kg ha^{-1}, Fe=1,80 kg ha^{-1}, Mn=6,92 kg ha^{-1} and Zn=1,46 kg ha^{-1}.

A Taguchi L25 structure was used, through the minitab program, for the generation of treatments, with six factors and five levels for each factor with which 25 treatments were generated (Table 1).

Each treatment consisted of three repetitions, and in turn each repetition, consisted of two trees, with a total of 150 trees. The N was distributed in four applications with the following percentages: 1- feminine flowering 25 % (third week of April); 2- fruit growth 25 % (second week of June); 3- Aqueous state 50 %; (mid-July); 4- Milky state 12,5 % (mid-August); for which the source of N was ammonium sulfate (20,5 % N and 24 % S). The percentages of P application for such dates were equal to those of N and phosphoric acid was used as source (49 % P_2O_5, density 1,61 kg L^{-1}).

Table 1. Factors and levels of application of nutrients, amendments and mycorrhizae in walnut

	kg ha^{-1}					g cm dt^{X}
Concentration	N	P_2O5	K_2O	Compost	Earthworm humus	Mycorrhizae
0*	0,0	0,0	0,0	0,0	0,0	0,0
X	16,0	7,0	7,5	250,0	100,0	3,81
5 X	80,0	35,0	37,5	1250,0	500,0	19,05
10 X	160,0	70,0	75,0	2500,0	1000,0	38,00
20 X	320,0	140,0	150,0	5000,0	2000,0	76,20
Mean^{Y}	160,0	70,0	75,0	2500,0	1000,0	38,10

*Control without application, ^{X}grams per centimeter of trunk diameter (g cm dt), standardized to 40.54 cm that equaled 0, 1656, 8280, 16560 y 33120 g ha^{-1}, respectively. ^{Y}Average of the maximum and minimum value for each factor, since from this value the minimum or maximum response is calculated according to the response variable

The K was applied to the following percentages for the dates mentioned (1) 25 %, (2) 12,5 %, (3) 50 %, (4) 12,5 %; the source of potassium was potassium thiosulfate (12,6 % K_2O, density 1,46 kg L^{-1}). On the other hand, the compost (Nt 1,75; P 0,59; K 2,75; Ca 1,13; Mg 0,82; Na 0,0014; NO_3 84,4; Cu 40,5; Fe 1036; Pd 0,15; Pd 0,15; Pd 0,15; Pd 0,15; Pd 0,15; Pd 0,15; Pd 0,15; Pd 0,15; Pd 0,15; Pd 0,15; Pd 0,15; Pd 0,85; Pd 0,85; Pd 0,157; Pd 0,407; Pd 0,157; Pd 0,407; Pd 0,157; Pd 0,407;Pd 0,407; Pd 0,257; Pd. Zn 107, Moisture 28,7 and pH 1: 2 H_2O 8,74) and earthworm humus (Nt 1,15; P 0,4; K 1,08; Ca 1,62; Mg 0,96; Cu 41,5; Fe 778; Zn 14; pH $CaCl_2$ 8,14; OM 46; C.E 70 ds m^{-1} CIC meq 100 g Humus 190-300, Flora micr 15-20 b CFU g^{-1} C: N 09:13) They were divided into two applications, the first at the beginning of April 50 % (male flower in expansion and buds with pistillate flower) and the second at the beginning of June 50 % (after the fall of nuts that did not tie and start of enlargement of fruit).

Of the mycorrhizae (*Acaluospora scobiculata, Giaspora margarita, Glomus fasciculatum, G. constrictum, G. Tortuosum, G. geosporum* with 20,000 viable spores kg^{-1}) the total amount was applied in mid-May. Fertilizers and organic amendments were applied at a coverage distance of 2 to 4 m around the trunk; for a better distribution under the tree canopy. The mycorrhizae were divided into four application doses for each tree in four holes of 10 to 15 cm deep, spaced from the trunk of the tree two meters and oriented towards each of the cardinal points. Fertilizers and amendments were applied prior to irrigation.

Components of Performance

Production. The trees were vibrated mechanically, the nut was collected and the weight in kg was estimated for each tree. Production was extrapolated in tons per hectare by multiplying the production per tree by the number of trees per hectare, corrected by a factor of 0,95 due to the heterogeneity in the individual production of the trees.

Number of nuts per kilogram. The number of nuts of a 300 g sample was counted and the value was extrapolated to the weight unit (kg).

Percentage of edible nut. For the determination of the edible almond content, 300 g were selected, the shell was separated from the edible part, weighed separately and the percentage of edible almond content was determined, whose value allowed to determine the fraction of edible product with respect to the total.

Distribution of costs

An economic analysis was determined, of the costs inherent to the fertilization program and its impact on each of the performance components.

Statistical analysis

Given the factorial nature of the Taguchi structure used, an average analysis of two years was carried out using a complete quadratic response surface, adjusting the surface to determine the levels of the factors for optimal response (21,22).

This technique is used when each factor is studied for three or more levels; a quadratic response surface is estimated by regression with the least squares method. A summary of the suggested optimal range for the best broad spectrum dose is presented.

RESULTS AND DISCUSSION

In Table 2, production is observed, which fluctuated from 0,84 to 1,94 t ha^{-1} during the 2013 and 2014 cycles. This represented an increase of 131 %, which was associated with an increase-decrease ratio for each of the factors based on the average value of the levels studied; for N^- 60 %, P^+34 %, K -17 %, compost without change, worm humus 25 % and mycorrhizae -15 %. Under this analysis, the critical factors for performance are those that are required in larger quantities; in this case, P: 121 kg P_2O_5 ha^{-1} and earthworm humus; 1245,8 kg ha^{-1}. In a work done in walnut under management with N (ammonium sulfate), values of 1,34 t ha^{-1} were obtained lower than that obtained in this investigation (23).

Table 2. Maximum response surface1 for nut production, 2013 - 2014

		Nutrients, organic amendments and microorganisms kg ha^{-1}					
Regresion		N	P_2O_5	K_2O	Compost	Earthworm humus	Mycorrhizae
		0,0002[2]	0,0743	0,0005	0,0039	0,0110	0,1416
Linear (L)	0,0007[2]	C[3]		L,C			
Quad,(C)	0,0053			Compost			
Product	0,0016						
Model	<,0001						
R^2 0,6163		C.V. 16,25			μ 1,34		
t ha^{-1}	Error Stan	kg ha^{-1}					
0,84	0,41	160,0	70,0	75,0	2500,0	1000,0	38,1
0,94	0,39	157,0	72,5	70,3	2368,2	979,1	36,8
1,02	0,37	152,7	75,9	66,1	2251,2	969,6	35,0
1,09	0,36	144,5	81,3	63,3	2182,9	983,9	33,5
1,17	0,35	132,7	88,0	62,1	2184,1	1020,0	32,7
1,26	0,34	120,5	94,3	61,8	2214,7	1060,0	32,5
1,37	0,32	108,9	100,1	61,7	2253,1	1099,0	32,5
1,49	0,32	97,7	105,6	61,7	2293,9	1136,7	32,5
1,63	0,32	86,8	111,0	61,8	2335,7	1173,7	32,5
1,78	0,33	76,0	116,2	61,9	2377,9	1210,0	32,5
1,94	0,36	65,4	121,3	62,1	2420,3	1245,8	32,5
% Increasing (+) decreasing (-) of the initial average value							
+131,0		-60,0	+34,0	-17,0	-3,0	+25,0	-15,0

[1] Mountain range analysis (Ridge); μ Average general; C.V. Coefficient of variation; R^2 Coefficient of determination;
[2]Probability of F: Pr≥0.05 Not significant, significant 0.05≤ Pr≤0.01; highly significant Pr≤0.013 Significant linear response (Pr>|t|) (L); quadratic (C);
[3] Significant products of that nutrient with the rest

In another study carried out in walnut, where nutritional imbalance and response in yield were studied, no differences were found in the production under fertilization treatments (24).

In the same way, other authors pointed out that the walnut absorbs the same amount of P independently of the one contained in the soil or that provided by an application (25).

The amount of N required for a production of 1,94 t ha^{-1} was 65,4 kg ha^{-1}, which confirms that it is possible to decrease the amount of N with the use of organic amendments, in addition, production can be assured from the previous year, at which time the tree requires more N, which is contributed concomitantly to improve the quality of the nut.

The above confirms that when analyzing the number of nuts per kg (Table 3), the requirements of N they increased from 160 to 226.4 kg ha^{-1} to obtain an interval of 179 to 149 nuts per kg; It is worth mentioning that it was the only nutrient that was increased to increase quality, expressed with fewer nuts per kg^{-1}. This value was the highest of the three components of the yield (production, number of walnuts kg^{-1} and percentage of edible walnuts), which is why it is the critical value. Therefore, if the aim is to improve the quality according to market requirements (less kg^{-1} nuts than those registered here), only the quantity of N would have to be increased.

Also important aspects are the significant contribution of P, which was increased to promote a greater production of 70 to 121 kg P_2O_5 ha^{-1}, similar case for earthworm humus from 1000 to 1246 kg ha^{-1}, in both to have an increase in production of 0,8 to 1,9 t per hectare respectively.

Table 4 shows the percentage of edible nut with a μ of 58,4 %, as well as for production and number of nuts per kg^{-1}. The factors studied had a statistical response; the critical elements were K, compost and earthworm humus. The latter was the one with the greatest impact, since to achieve an 8 % increase in the percentage of edible nut, an increase of 1000 to 1905 kg^{-1} of earthworm humus was required, while the respective percentages for K and compost They were 25 %. The answer as a whole indicates that the nutrients and amendments concur in a complementary way in the performance components of the walnut. In relation to production, the critical factors were P and earthworm humus, for nuts kg^{-1} the critical factor was N, while for percentage of edible nut the critical factors were K, compost and earthworm humus. The most intense response corresponded to production with an increase of 131 %, where N and P showed opposite effects presenting a positive increase in production with a decrease in N and increase in P.

Table 3. Minimum response surface1 for nuts per kilogram, 2013 - 2014

			Nutrients, organic amendments and microorganisms kg ha-1				
Regresion		N	P_2O_5	K_2O	Compost	Earthworm humus	Mycorrhizae
		<,0001[2]	0,6903	0,0230	0,0533	0,0732	0,0379
Linear (L)	<,0001[2]	L[3]					
Cuad, (C)	0,3038	P_2O_5					
Products	0,1605	Compost					
Model	<,0001						
R^2 0,7466		C.V. 3,71			µ 171		
Nuts kg-1	Error Stan	kg ha-1					
179	11,93	160,0	70,0	75,0	2500,0	1000,0	38,1
177	11,20	161,1	67,6	71,5	2410,7	964,9	35,5
175	10,58	164,2	64,7	68,2	2316,2	930,2	33,5
172	10,03	1692	61,2	65,0	2215,7	896,0	31,4
170	9,56	175,8	57,0	62,2	2110,2	862,6	30,2
167	9,14	183,4	52,2	59,6	2002,7	830,7	29,2
164	8,82	191,7	47,1	57,3	1895,7	800,5	28,7
161	8,68	200,3	41,7	55,3	1790,8	771,9	28,7
158	8,84	209,0	36,3	53,4	1688,5	744,8	28,7
154	9,37	217,7	30,9	51,7	1588,7	718,8	28,9
149	10,34	226,4	25,4	50,0	1491,1	693,8	29,2
% Increasing (+) decreasing (-) of the initial average value							
-17,0			-64,0	-33,0	-40,0	-31,0	-23,0

[1] Mountain range analysis (Ridge); µ Average general; C.V. Coefficient of variation; R^2 Coefficient of determination;
[2]Probability of F: Pr≥0.05 Not significant, significant 0.05≤ Pr≤0.01; highly significant Pr≤0.013 Significant linear response (Pr>|t|) (L); quadratic (C);
[3] Significant products of that nutrient with the rest

Table 4. Maximum response surface1 in % of edible nut, 2013, 2014

			Nutrients, organic amendments and microorganisms kg ha-1				
Regresion		N	P_2O_5	K_2O	Compost	Earthworm humus	Mycorrhizae
		<,0001[2]	0,0078	0,0174	0,0002	0,0047	0,0048
Linear (L)	<,0001[2]	C[3]			L, C	L, C	L, C
Quad, (C)	0,0092					P_2O_5	P_2O_5
Products	0,0029					K_2O	
Model	<,0001						
R^2 0,7515		C.V. 1,31			µ 58,4		
% Edible nut	Error Stan	kg ha-1					
54,8	0,97	160,0	70,0	75,0	2500,0	1000,0	38,1
55,1	0,96	161,0	65,9	75,0	2501,6	1063,5	36,3
55,4	1,00	162,7	62,9	76,2	2523,5	1145,7	34,8
55,7	1,09	164,3	61,1	78,3	2566,2	1239,3	33,8
56,0	1,21	165,1	60,1	80,6	2623,9	1336,4	33,0
56,4	1,38	164,9	59,6	83,1	2691,9	1433,9	32,5
56,8	1,57	163,6	59,5	85,5	2767,3	1530,6	32,3
57,2	1,79	161,1	59,7	87,8	2848,1	1626,3	31,8
57,7	2,12	157,5	60,1	89,9	2933,1	1720,6	31,5
58,3	2,26	152,8	60,7	92,1	3021,2	1813,4	31,0
58,9	2,51	147,3	61,5	93,8	3111,4	1904,6	30,7
% Increasing (+) decreasing (-) of the initial average value							
+7,5			-12,1	+25,0	+24,0	+90,0	-19,0

[1] Mountain range analysis (Ridge); µ Average general; C.V. Coefficient of variation; R^2 Coefficient of determination;
[2]Probability of F: Pr≥0.05 Not significant, significant 0.05≤ Pr≤0.01; highly significant Pr≤0.013 Significant linear response (Pr>|t|) (L); quadratic (C);
[3] Significant products of that nutrient with the rest

In production an increase of the initial average value of 34 % of P and a decrease for the initial average value of N of 60 % was required; however, for the number of walnuts kg^{-1} the requirement of N increased by 60 % and that of P decreased by 40 %. Special case was for percentage of edible nut, with an increase of 90 % with the earthworm humus application, being positive because the price of the nut is set based on the percentage of edible nut.

In a study conducted in pecan walnut, the quality of the nut was considered mainly by the percentage of the edible part, the color size and almond damages, presenting ranges above the minimum acceptable, 50 % with the application of compost and in this study, values of 90 % were obtained, data that corroborate that the application of compost benefit the increase of the nut quality (26).

Dose associated with performance components

Table 5 shows the summary of the contribution of each of the factors on production and quality; with respect to production, it was positive in phosphorus and mycorrhizae. Of the 121.3 kg ha^{-1} of P for maximum production, 25,4 kg ha^{-1} with 20,9 %, were for the smallest number of nuts per kilogram.

The differential contribution for percentage of edible walnut once subtracted the 25,4 kg ha^{-1} was of 36,1 kg ha^{-1} (29,8 %). In the dose obtained for P in terms of production, only 50 % were for it, and the remaining 50 % were for quality. Under the same discussion procedure, in the case of mycorrhizae a very high percentage of 95 % was for nut quality.

The nuts per kilogram were only affected by N with a requirement for the lowest number of nuts (highest quality) of 226,0 kg ha^{-1}, with 71 % for nut quality.

Table 5. Contribution of factors for production and quality^{x} in pecanal walnut

			Production					
Factor	Dose kg ha^{-1}	%	Factor	Dose kg ha^{-1}	%			
Phosphorus	121,3 (a)	100,0(b)	Mycorrhizae	12,8	100,0			
Walnut kg^{-1}	25,4 (c)	20,9 (d)	Walnuts kg^{-1}	11,5	89,8			
Edible walnut	61,5 (e)		Edible walnut	12,1				
Differential	36,1 (e-c)	29,8 (f)	Differential	0,6	4,7			
Sum		50,7 (d+f)	Sum		94,5			
Residual	59,8 (a-e)	49,3	Residual	0,7	5,5			
Contribution	Production	49,3 (g)	Contribution	Production	5,5			
	Quality	50,7 (b-g)		Quality	94,5			
			Walnut per kilogram					
Factor	Dose kg ha^{-1}	%						
Nitrogen	226,0	100,0						
Production	65,4	28,9						
Edible walnut	147,7							
Differential	82,3	36,4						
Sum		65,3						
Residual	78,3	34,7						
Contribution	Production	28,9						
	Quality	71,1						
			Percentage edible walnut					
Factor	Dose kg ha^{-1}	%	Factor	Dose kg ha^{-1}	%	Factor	Dose kg ha^{-1}	%
Earthworm humus	1905	100,0	Potasium	93,8	100,0	Compost	3111	100,0
Nuts kg^{-1}	694	36,4	Walnut kg^{-1}	50	53,3	Walnut kg^{-1}	1491	47,9
Production	1246		Production	62		Production	2420	
Differential	552	29,0	Differential	12	12,8	Differential	929	29,9
Sum		65,4	Suma		66,1	Suma		77,7
Residual	659	34,6	Residual	31,8	33,9	Residual	691	22,2
Contribution	Production	29,0	Contribution	Production	12,8	Contribution	Production	29,9
	Quality	71,0		Quality	87,2		Quality	70,1

^{x}Quality represented by number of walnuts kg^{-1} and percentage of edible nut: the letters in parentheses indicate the contribution of each variable to the dose obtained from fertilization (a) and its corresponding percentage (b). Addition and subtraction to determine the value obtained from each response variable in relation to the total dose

The quality of the nut in edible percentage was favored with the application of organic amendments: (earthworm fumes 1905 kg ha^{-1} and compost 3111 kg ha^{-1}) and P with 93,8 kg ha^{-1}. The amendments contributed 70 % and P with 87 % of the specified doses.

From the dose obtained in kilograms ha^{-1}, 121,3 of N, 226,0 of P_2O_5, 93,8 of K_2O, 1905 of earthworm humus, 3111 of compost and 12,8 of mycorrhizae, the highest contribution in production was P with 49 %, while N and organic amendments participated with a 29 % and K with 13 % of the amounts indicated.

In quality, the largest contribution was mycorrhizae with 95 %, N and organic amendments contributed with 71 % of the respective doses, that is, when working this year's quality, production is expected the following year, an inherent quality the fruit exploitation. Some authors mention that the incorporation of compost provides a sufficient amount of nutrients during the critical phases of the development of the walnut, thus obtaining favorable results in walnut, as in this study (3,27,28).

Distribution of costs

On the other hand, the estimated costs were determined through an analysis of economic needs, which are shown in Table 6. If it is considered that the estimated maximum production was 1,94 t ha^{-1} with a sale price of $ 50 000.00, the income amounts to $ 97 000.00, therefore, the costs of fertilization to the soil represented 40,8 % of sales revenue. However, in an objective manner, these fertilization costs are 50 % for the current year's quality, 25 % for the maintenance of the current potential production and the remaining 25 % to ensure production next year. As a result, the current harvest represented 30,6 % of revenues ($ 29,664.80), and the remaining 25 % of fertilization costs ($ 9,888.30) are applied to ensure potential production next year, what in terms of opportunity costs represent about twice their percentage in terms of production, this implies that with 25 % of current production costs 50 % could be insured of next year's production, to a minimum value of 1,94 t ha^{-1}.

Taking into account the above, it is suggested to consider the residual effect of the applications of organic amendments and the use of mycorrhizae to promote greater availability of N, P, K, higher content of organic matter and microelements, which leads to a possible reduction of costs, an increase in production or a combination of both responses, which would strengthen the competitiveness of the crop and generate a greater room for maneuver to adapt to adverse situations.

Table 6. Estimated costs for fertilizer application and organic amendments

Material	UNIT	Price	Total cost per ha
Ammonium sulphate	1 t	3 600,00	4 068,00
Phosphoric acid	75 kg	2 355,00	8 004,00
Potasium	1 t	16,20	12 050,00
Compost	1 t	700,00	2 178,00
Earthworm humus	1 t	2 200,00	4 191,00
Mycorrhizae		300,00	3 900,00
Total			$39 553,00

CONCLUSIONS

- A production of 1,94 t ha^{-1}, unit yield of 149 kg^{-1} nuts and 59 % of percentage of edible nut with contributions was obtained of 226 Kg of N, 121 kg of P_2O_5, 94 kg of K_2O, 3111 kg of compost, 1905 kg of earthworm humus, and 13 kg of mycorrhizae.
- The needs for production fluctuated 30 % (N with organic amendments) to 50 % (P and K) whose respective complements were applied to increase the quality, in the latter, the mycorrhizae covered 95 % of the requirements.
- Fertilization costs represented 40,8 % of sales revenue; their distribution for the yield components were 50 % for the current year's quality, 25 % for the maintenance of the potential production and the remaining 25 % to ensure production next year.

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