Article

Organic fertilization with three levels of chicken manure in four potato cultivars

Josué Peñaloza Monroy[1]
Ana Karen Reyes Ramírez[1]
Andrés González Huerta[1]
Delfina de Jesús Pérez López[1§]
Dora Ma. Sangerman-Jarquín[2]

[1]Faculty of Agricultural Sciences-Autonomous University of the State of Mexico-University *Campus* 'El Cerrillo'. El Cerrillo Piedras Blancas, Toluca, Mexico. CP. 50200. Tel. 722 2965518, ext. 148 (agonzalezh@uaemex.mx; josuepm-30@hotmail.com; anakaren-reyes26@hotmail.com). [2]Experimental Field Valle de México-INIFAP. Los Reyes-Texcoco Highway km 13.5, Coatlinchán, Texcoco, State of Mexico. CP. 56250. Tel. 01 800 0882222, ext. 85353. (sangernan.dora@inifap.gob.mx).

[§]Corresponding author: djperezl@uaemex. mx.

Abstract

The present work was carried out in the spring-summer cycle of 2017 in Ojo de Agua, municipality of Zinacantepec, State of Mexico, to evaluate the response of three levels of chicken manure and a chemical fertilization treatment in four potato cultivars. The 16 treatments were evaluated in a randomized complete block design in a 4x4 factorial arrangement with three replications. The size of the experimental plot was integrated with three furrows 4 m long and 0.90 m wide. The registered variables were plant height, number of stems and tubers per plant, tuber weights per plant, fresh foliage, harvest index, yield per hectare, diameter (DT) and tuber length (LT). The results showed that the cv. Rosita (24.38 t ha^{-1}) and Ágata (23.85 t ha^{-1}), in 4 t ha^{-1} of chicken manure, produced the highest tuber yields. Major components 1 and 2 explained 69.19% of the original total variation. In 4 t ha^{-1} of chicken manure there were more stems and greater weights of tuber, foliage in fresh and tuber production. The cv. Rosita and Ágata excelled in stems per plant, as well as tuber weights and fresh foliage; the first had more tubers per plant. In the cv. Fianna, Ágata and Lucero recorded the highest harvest rates.

Keywords: *Solanum tuberosum* L., High Valleys of Central Mexico, organic fertilizers, principal component analysis.

Reception date: June 2019
Acceptance date: August 2019

Introduction

Potato (*Solanum tuberosum* L.) is one of the main sources of human nutrition (Gopal and Khurana, 2006), after wheat (*Triticum aestivum* L.), corn (*Zea mays* L.) and rice (*Oriza sativa* L.) (FAO, 2012). Worldwide, more than 18 million hectares are planted, and the potato occupies the fourth place in economic importance (FAOSTAT, 2016). In Mexico, 53 107.24 ha are planted annually, with a production of 1 590 075.89 million tons and 32.52 t ha^{-1}. The main producing states are Sonora, Sinaloa, Mexico, Veracruz, Baja California, Guanajuato, Coahuila, Nuevo Leon and Tamaulipas, among others. The State of Mexico produces 175 325 t with 29.28 t ha^{-1} (SIAP, 2016).

The use and application of organic matter has experienced a reduction in its use, probably due to the introduction of chemical fertilizers that produce higher yields at a lower cost. However, in recent years there has been greater interest in organic fertilizers (Terralia, 1998) for the contribution of nutrients to crops in the form of organic matter (Romero *et al*., 2000), as it promotes better development of the plant and increases yield and product quality (Navarro, 2009). It also improves the physical and chemical properties of the soil since the use of chemical fertilizers over time has generated loss of fertility and productive capacity (Trinidad, 1987).

The chicken manure is a concentrated organic fertilizer and quick action, contains all the essential nutrients essential for plants (Arzola *et al*., 1981; Yagodin *et al*., 1986). Several studies have shown that with chicken manure, higher production and tuber quality were obtained (Romero *et al*., 2000; Luna *et al*., 2016) and corn yield was increased by increasing the available phosphorus in the soil (Pool *et al*., 2000). The characteristics of the plant, fruit and production of the zucchini showed that the fertilization with processed chicken manure, the mycorrhizal inoculation or its combination, gave similar results to those caused by inorganic fertilization (Díaz *et al*., 2016). In *Vicia faba* the chicken manure and the mushroom compost in 3 t ha^{-1} had the best phenotypic expression in floral knots, plant height, green index, pods per plant, pod weight per plant, clean seeds, weight of clean seeds , weight of 100 seeds and grain yield (Orozco *et al*., 2016).

At present, the dilemma of producers is related to the weighting between sustainability and economy; that is, obtain a quality production with higher performance. In the previous context, the main objective in this study was to evaluate the response of three levels of chicken manure and an inorganic fertilization treatment in four potato cultivars in the community of Ojo de Agua, belonging to the municipality of Zinacantepec, State of Mexico.

Materials and methods

Description of the study area

The present study was developed in 2017 under rainfed conditions in the community of Ojo de Agua, in the municipality of Zinacantepec, State of Mexico, located at 99° 46’ 13’’ north latitude and 19° 12’ 58’’ west longitude, to 3 037 masl. In this region the temperate sub-humid climate predominates, with an average temperature of 28 °C in summer and 5 °C in winter. The Andosol soil is a migajon type, with clay-sandy to silty texture, dark gray-brown in color and with a depth of 4 to 9 m, very fertile (IGECEM, 2014).

Genetic material

The potato cultivars Fianna, Ágata, Rosita and Lucero, provided by producers from the Toluca-Zinacantepec region (Table 1) were used.

Table 1. Agronomic characteristics of the four potato varieties.

Varieties	Description
Fianna	Green plant of intermediate cycle, white flower, oval tubercle, cream cuticle and white pulp, has moderate resistance to dry rot and scab.
Lucero	Intermediate cycle green plant, white flower, oval tuber, skin and light-yellow flesh.
Ágata	Short plant of intermediate cycle, extended stems, large to medium leaves, green to light green, tubercle oval, yellow skin, susceptible to *Phytophthora* spp.
Rosita	Short plant of late cycle, tubercle oval, red skin with deep eyes, cream pulp, tolerant to late bligh.

Source: Potato Council (2011); Nivap Holland (2007).

Design and size of the experimental plot

The 16 treatments that were formed by combining the levels of four cultivars and four types of fertilization (Table 2) were evaluated in the field in a randomized complete block design in a 4x4 factorial arrangement, with three replications. The experimental plot had three rows of 4 m long and 0.9 m wide, a tuber was deposited every 20 cm. The useful experimental unit was the central row.

Table 2. Structure of the treatments.

Study factors	Levels
Cultivars	V1= Fianna
	V2= Ágata
	V3= Rosita
	V4= Lucero
Inorganic fertilization	F1= 154 N-356 P-60 K
Organic fertilization with chicken manure	F2= 2 t ha^{-1} + F1
	F3 = 3 t ha^{-1} + F1
	F4= 4 t ha^{-1} + F1

T1=Fianna + F1; T2=Fianna +F2; T3=Fianna + F3; ,…, ; F16=Lucero + F4.

Physical-chemical analysis of the soil where the experiment was made

The soils that predominate in the community of Ojo de Agua, in the municipality of Zinacantepec, State of Mexico have the characteristics shown in Table 3.

Table 3. Physicochemical soil analysis.

Characteristic	Unit	Value	Classification
pH		5.29	Moderately acidic
Cation exchange capacity	($Cmol^+ kg^{-1}$)	48.75	Very high
Organic carbon	(%)	3.96	Low
Organic material	(%)	6.86	Medium
Electric conductivity	($dS m^{-1}$)	0.26	Normal
Total nitrogen	(%)	0.22	High
Phosphorus	(ppm)	28.69	Medium
Potassium	(ppm)	60.25	Low
Carbon/nitrogen ratio	(%)	17.99	Deficient
Calcium	(ppm)	65.39	Very low
Magnesium	(ppm)	-	Traces
Sodium	(ppm)	16.38	Very low
Apparent density	($g cm^{-3}$)	0.9	Low
	(%) sand	69.2	
Textural class	(%) clay	5.2	Sandy loam
	(%) silt	25.6	

Soil Laboratory of the Faculty of Agricultural Sciences. Data 2017.

Composition of chicken manure

His physical and chemical analysis was carried out in a laboratory of the Faculty of Agricultural Sciences (Table 4).

Table 4. Physical and chemical composition of the chicken manure.

Characteristic	Unit	Value
pH		6.5
Cation exchange capacity	($Cmol^+ kg^{-1}$)	37.5
Organic carbon	(%)	31.2
Organic material	(%)	53.8
Electric conductivity	($dS m^{-1}$)	2.83
Total nitrogen	(%)	1.39
Phosphorus	(ppm)	207.1
Potassium	(ppm)	860.3
Carbon/nitrogen ratio	(%)	22.5
Calcium	(ppm)	3531
Magnesium	(ppm)	773.4
Sodium	(ppm)	66.4
Apparent density	($g cm^{-3}$)	0.51
Textural class	(%) sand	-
	(%) clay	-
	(%) silt	-

Soil Laboratory of the Faculty of Agricultural Sciences. Data 2017.

Development of the field experiment

A fallow and a harrow pass were made on June 21, 2017. The 90 cm wide furrows were formed with a yoke of horses. On June 1st the tubers were immersed for five minutes in water+Celeste (fludioxanil, control of *Rizoctonia solani*)+Bactrol (streptomycin, control of *Erwinia carotovora*) and Tecto 60 (Thiabendazole, control of *Fusarium* spp.). The manual seeding was carried out on July 1st and consisted of depositing the tubers at a depth of 15 cm and at a distance between them of 20 cm, then covered using the yoke. Fertilization was carried out in two stages: when planted, 2, 3 and 4 t ha^{-1} of chicken manure and 154 N-356 P-60 K were applied, in the latter they were used for 600 kg ha^{-1} of diammonium phosphate (18 N-46 P- 00 K), 100 kg of urea, 400 kg of simple calcium phosphate superphosphate and 100 kg of potassium chloride.

On September 2, 200 kg ha^{-1} of urea, 200 kg of potassium chloride and 400 kg of simple calcium phosphate were applied per ha. Post-emergence weed control was done on July 20 with Titus CE (Rimsulfurom), applying in a band of 75 to 100 g ha^{-1}. The two hives were carried out on August 12 and September 2, to control weeds and prevent pests such as blind hen (*Phyllophaga* sp.). To prevent damage by nematodes (*Globodera rostochiensis* and *Meloidogyne* sp.) CYREN 5% G (Chlorpyrifos ethyl) was applied, mixed with fertilizers.

To combat whitefly (*Bemisia tobacco* and *Trialeurodes vaporariorum*), Paratrioza (*Bactericera cockerelli*) and cutworms (*Agrotis* sp., *Trichoplusia ni*, *Spodeptera* sp.), alternate sprays of insecticides were carried out. To prevent and control diseases such as late blight (*Phytophthora infestans*), early blight (*Alternaria solani*) and black crust (Rizoctonia *solani*), 12 applications were made with different systemic and contact fungicides. The foliage was cut 100 days after sowing and the harvest was made 20 days after the foliage was removed.

In 10 plants of the useful plot plant height was recorded (AP, in cm, from the base of the main stem to the apex), stems per plant, tubers per plant (NT), tuber weight per plant (PT, in g), foliage weight in fresh (PFF, in g), harvest index (IC, quotient between agronomic and biological performance), tuber length and diameter (LT and DT, in cm), and yield per hectare (Rha, in t ha^{-1}).

Statistical analysis

An analysis of variance was performed and when the F values were significant, a comparison of treatment means was made with the Tukey test (p= 0.01). Both techniques were described by Martínez (1988). The analysis of principal components, also called biplot treatment x variable, was described by Sánchez (1995); Pérez *et al*. (2010).

Results and discussion

Variance analysis

In the present work it was observed that the experimental area was homogeneous (Table 5), because the effects between repetitions were only significant in fresh foliage weight (PFF) and harvest index (IC). The effects caused by chicken manure (factor A) were only detected in tuber weights per plant (PT), PFF and yield per hectare (Rha), which coincides with that published by Seminario *et al*.

(2017). Among cultivars (factor B) in plant height (AP), stems per plant (NTP), number of tubers (NT), PT, PFF, IC and tuber length (LT), there were significant effects (p= 0.01). The AxB interaction was significant in tuber weight (p= 0.01) and PFF (p= 0.05). These results are similar to those reported by Pérez *et al*. (2009); Pérez *et al*. (2010); Seminario *et al*. (2017). The coefficients of variation changed from 6.7 (LT) to 31.48% (Rha).

Table 5. Mean squares and statistical significance of the values of F

FV	GL	AP	NTP	NT	PT	PFF	IC	Rha	DT	LT
Repetitions	2	56.29ns	0.028ns	3.214ns	19.090ns	19595.68*	0.0127**	1.071ns	0.227ns	1.359ns
Treatments	(15)	113.43**	0.191**	60.256**	41036.06**	70917.93**	0.0152**	36.103**	0.382ns	2.284**
Chicken manure (A)	3	16.31ns	0.016ns	4.753ns	88221.44**	32038.85**	0.0023ns	165.242**	0.251ns	0.404ns
Cultivars (B)	3	452.08**	0.529**	286.8**	49637.1**	277566.35**	0.0635**	2.184ns	0.457ns	10.099**
AxB interaction	9	32.92ns	0.137ns	3.242ns	22440.59**	14994.81*	0.0034ns	4.364ns	0.4ns	0.306ns
Error	30	20.74	0.068	1.764	7039.4	4961.52	0.00198	2.476	0.469	0.523
Total	47									
Average		34.4	1.72	9.85	605.64	330.72	0.657	17.21	5.33	7.9
CV (%)		13.34	15.26	13.48	13.85	21.29	6.77	9.1	12.84	9.15

*= significant at 0.05; **= significant at 0.01; ns= not significant; FV= source of variation; GL= degrees of freedom; CV= coefficient of variation; AP= plant height; NTP= no. of stems per plant; NT= no. tubers per plant; PT= tuber weight per plant; PFF= fresh foliage weight; IC= harvest index; Rha= yield per ha; DT= tuber diameter; LT= tuber length (LT).

Comparison of chicken stockings (factor A)

The effect of the chicken manure was not significant in plant height (AP), stems per plant (NTP), tubers per plant (NT), harvest index (IC), diameter (DT) and tuber length (LT) (Table 6).

For tuber weight per plant (734.1 g, PT), fresh weight of the foliage (400.71g, PFF) and yield per hectare (22.61 t ha^{-1}, Rha) there was better response when applying 4 t ha^{-1} of chicken manure and this dose differed statistically from minor and chemical fertilization. The latter and the highest dose differed by 8.38 t ha^{-1} (Table 6). Carter *et al*. (2004) noted that the increase in yield is due to a higher production of tubers, which is favored by a higher content of organic matter, phosphorus and cation exchange available in chicken manure.

Table 6. Comparison of means between fertilizers (factor A).

Fertilization	AP	NTP	NT	PT	PFF	IC	Rha	DT	LT
F_1	35 a	1.7 a	10.17 a	563.21 b	278.89 b	0.67 a	14.23 c	5.17 a	7.97 a
F_2	34.84 a	1.68 a	9.08 a	567.86 b	333.06 ab	0.63 a	15.44 bc	5.28 a	7.79 a
F_3	35.1 a	1.73 a	9.62 a	557.42 b	310.23 b	0.65 a	16.84 b	5.52 a	7.71 a
F_4	32.65 a	1.76 a	10.51 a	734.10 a	400.71 a	0.66 a	22.61 a	5.34 a	8.13 a
DMSH	5.05	0.29	1.47	93.13	78.19	0.04	1.74	0.76	0.8

The means with the same letter within each column is statistically equal (Tukey, p= 0.01). AP= plant height. NTP= number of stems per plant; NT= number of tubers per plant; PT= tuber weight per plant; PFF= fresh foliage weight; IC= harvest index; Rha= yield per hectare; DT= tuber diameter; LT= tuber length.

Lima *et al*. (2000) when evaluating organic fertilizers and chemical fertilizers reported that for each ton of chicken manure applied there was an increase in tuber yield of 1.468 t over 40.752 t. Zamora and Rodríguez (2008) estimated 32 t ha^{-1} when fertilizing with organic fertilizers and Rodríguez and Ortuño (2007) recorded from 11.53 to 15.93 t ha^{-1} with application of arbuscular mycorrhizae in interaction with organic fertilizers. Corzo and Moreno (2003) mentioned that the main element responsible for the mobilization of the starch from the leaves towards the tuber is potassium, in such a way that a good availability of this nutrient is decisive for obtaining a high yield and better quality.

Comparison of means between cultivars (Factor B)

In Fianna, the highest plant height (41.89 cm) was recorded. These results are contrasting with those of Zamora and Rodríguez (2008) and Buchanan (1993) (Table 7). Rosita, Creole variety and Ágata, improved variety, produced two stems per plant and differed statistically from Fianna and Lucero. These results are similar to those of Devaux *et al*. (1997). Number of stems is closely related to tuber size and population density (Van der Zaag *et al*., 1990; Masarirambi *et al*., 2012). Rosita produced 17.15 tubers per plant. This characteristic is genetically controlled and depends on the number of stems per plant (Estrada, 2000), in this study this variety obtained more stems per plant, but shorter tuber length. The results are contrasting with those of Luna *et al*. (2015), who reported 5.91 for Rosita and 9.35 for Libertad. Pérez *et al*. (2009) reported quantified from 3.75 to 5.23 in 17 potato genotypes (Table 7).

Table 7. Comparison of means between cultivars (factor B).

Cultivars	AP (cm)	NTP	NT	PT (g)	PFF (g)	IC	Rha (t)	DT (cm)	LT (cm)
Fianna	41.89a	1.61b	7.21b	598.84 a	305.26b	0.66 a	16.92a	5.49a	8.83a
Ágata	36.26b	1.78ab	8.05b	655.04 a	271bc	0.71a	17.88a	5.49a	8.5a
Rosa	32.15bc	1.98a	17.15a	651.49ab	548.74a	0.55b	17.29a	5.1a	6.87b
Lucero	27.27c	1.5b	6.97b	517.21b	197.89c	0.70 a	17.04a	5.24a	7.41b
DMSH	5.05	0.29	1.47	93.13	78.19	0.04	1.74	0.76	0.8

The means with the same letter within each column is statistically equal (Tukey, p= 0.01). AP= plant height. NTP= number of stems per plant; NT= number of tubers per plant; PT= tuber weight per plant; PFF= fresh foliage weight; IC= harvest index; Rha= yield per hectare; DT= tuber diameter; LT= tuber length.

The tuber weight per plant (PT) in Ágata and Rosita was 655.04 and 651.49 g, respectively, and both differed statistically from Lucero and Fianna. This behavior could be explained by the genetic differences between cultivars, especially those related to their biological cycle; Rosita is late and the other three are precocious. Pérez *et al*. (2010) reported values of 627.38 to 204.13 g and Seminario *et al*. (2017) from 68.3 to 987.3 g (Table 7). Rosita had the highest fresh weight of foliage (548.74 g) and statistically differed from the rest. These results contrast with those of Pérez *et al*. (2009), who registered from 111 to 280.2 g.

Fianna, Lucero and Ágata had harvest rates (66, 70 and 71%) statistically higher than Rosita (50%). These results are similar to those obtained by Rojas and Seminario (2014, between 53 and 77%). Currently, plant breeders have given greater importance to the increase of the harvest index since a greater partition of biomass to the tubers will contribute to a higher yield per hectare. Pérez *et al*. (2009) reported values of 38 to 72.22%.

The previous results show that potatoes are very efficient in the transformation of inputs, water and light to green or dry matter and specifically, to the production of tubers per plant and per hectare. In yield per hectare the four cultivars showed a similar behavior. These yields were obtained under temporary conditions but were lower than the national average (24.40 t ha^{-1}) and the state average (29.71 t ha^{-1}). In the High Sierras and Valleys of Mexico, the yield potential is lower in relation to those obtained in the North of the country and in the Bajio region (Table 7).

The four cultivars were statistically equal in tuber diameter, results similar to those reported by Luna Ágata, (2015). Fianna (8.83 cm) had a longer tuber length, but it was similar to that of Ágata (8.50 cm) and both differed statistically from Rosita (6.87 cm) and Lucero (7.1 cm). This characteristic is very important for the fresh market and for the agroindustry; in the first, dimensions between 4.5 and 5 cm are required and for fried foods they must be greater than 6.5 cm. These values agree with those obtained in the present work and Ágata and Lucero are recommended for industrial use, Fianna is dual purpose and Rosita is preferred for fresh consumption. With the application of the scale proposed by Macías *et al*. (2006), the tubers obtained in the present study were classified in first category.

Principal component analysis

Major components 1 (43.21%) and 2 (25.98) explained 69.19% of the original total variability (Figure 1). These percentages are desirable to reliably interpret the approximate correlations observed in the biplot, as suggested by Sánchez (1995); Pérez *et al*. (2014), among others, the closest approximation between cultivars and variables indicates a close relationship between them.

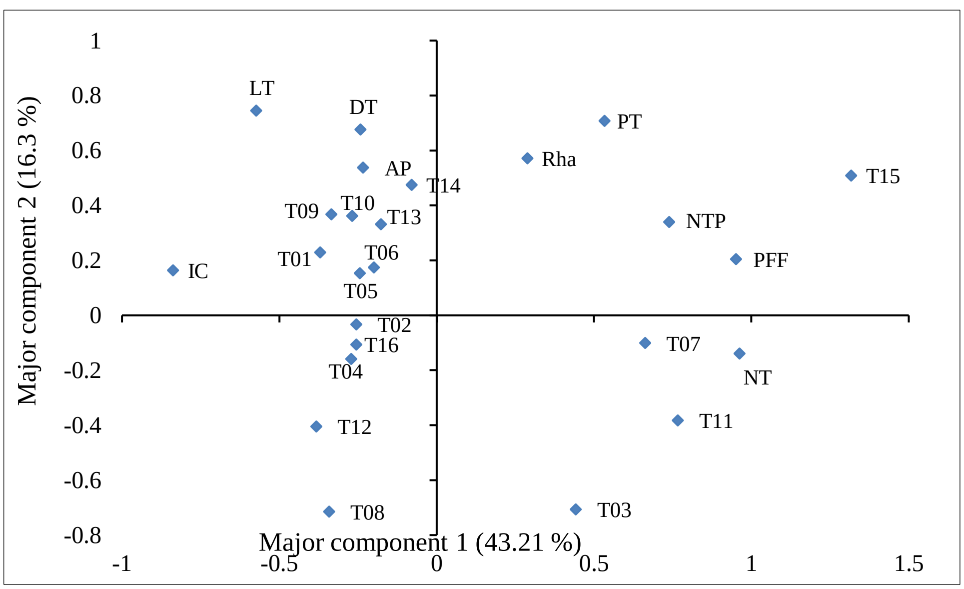

Figure 1. Biplot between treatments (cultivar + fertilizer in number) and agronomic variables (in letter) based on components 1 and 2.

Tuber yield correlated positively and significantly with most of the variables. CP1 was determined mainly by tuber weight (PT), stems per plant (NTP), fresh foliage weight (PFF), tuber yield (Rha) and tubers per plant (NTP). In other studies, similar results have been observed (Rousselle *et al*., 1999; Estrada, 2000; Caceres, 1971). In Quadrant 1 it was observed that treatment 15 (cv. Rosita in 4 t ha^{-1} of chicken manure) showed a positive association with yield and with its main performance components (Romero *et al*., 2000). This fact partially corroborated the results that were previously shown when their arithmetic averages were compared with the Tukey test. The chicken manure is one of the organic fertilizers that help to improve the biological properties of the soil (Estrada *et al*., 2004; Orozco and Thienhaus, 1997), but also contributes to the increase in the acidity of the soils, particularly those of volcanic origin, as those that predominate in the study area. The adaptation of the potatoes to the High Valleys of Central Mexico has made this species an important alternative for producers.

Conclusions

The cv. Rosita (24.38 t ha^{-1}) and Ágata (23.85 t ha^{-1}), both in 4 t ha^{-1} of chicken manure, were the best. In 4 t ha^{-1} of chicken manure there were more stems and greater tuber weight, fresh weight of the foliage and yield of tuber. The cv. Rosita and Ágata expressed the best characteristics in stems per plant, weight of tuber, and fresh weight of the foliage; the first had the highest number of tubers per plant. The cultivars Fianna, Ágata and Lucero excelled in harvest index. The taller plants also produced tubers of longer length and diameter. Major components 1 and 2 explained 69.19% of the original total variation.

Cited literature

Arzola, P. N.; Fundadora, H. O. y Machado, A. J. 1981. Suelo, planta y abonado. Editorial Pueblo Educación. La Habana, Cuba. 461 p.

Buchanan, M. 1993. Study examines efficient use of compost. Cultivar-Santa Cruz. 11(1):9-10.

Cáceres, E. H. 1971. Producción de hortalizas. Herrero Hermanos, Sucesores. México, DF. 310 p.

Cadena, H. M. A. V; López, D. H.; Zabala, Q. T. E.; Flores, L. R.; Villareal, G. M.; Rivera, P. A.; Rubio, C. O.; Rocha, R. R.; Azpiroz. R. H. S.; Rodríguez, de la O. J. L.; Manzo, G. A. y Barrales, D. S. 1999. Evaluación de variedades de papa para producción de tubérculo-semilla en los estados de México y Tlaxcala. Agric. Téc. Méx. 25(25):97-105.

Carter, M.; Sanderson, R. and Macleod, J. 2004. Influence of compost on the physical properties and organic matter fractions of a fine sandy loam throughout the cycle of a potato rotation. Canadian J. Soil Sci. 84(2):211-218.

Corzo, P. y Moreno, J. 2003. Manual de papa para productores. Corporación Colombiana de Investigación Agropecuaria, CI. Tibaitatá, Mosquera, Colombia. 101 p.

Devaux, A.; Vallejos, J.; Hijmans, R. y Ramos, J. 1997. Respuesta agronómica de dos variedades de papa (*tuberosum* y *andigenum*) a diferentes niveles de fertilización mineral. Rev. Latinoam. Papa. 9/10(1):123-139.

Díaz, F. A.; Alvarado, C. M.; Alejandro, A. F. y Ortiz, C. F. E. 2016. Crecimiento, nutrición y rendimiento de calabacita con fertilización biológica y mineral. Rev. Int. Contam. Ambie. 32(4):445-453.

Díaz, F. A.; Alvarado, C. M.; Alejandro, A. F. y Ortiz, C. F. E. 2017. Uso de abonos orgánicos y micorriza arbuscular en la producción de repollo. Rev. Chapingo Ser. Zonas Áridas. 16(1):15-21.

Estrada, G.; Eugenio, M.; Peralta, C. y Ramón, J. 2004. Evaluación de dos tipos de fertilizantes orgánicos (gallinaza y estiércol vacuno) y un mineral en el crecimiento y rendimiento del cultivo de frijol común (*Phaseolus vulgaris* L.) variedad Dor-364, Postrera 2001. Tesis de Diploma. 1(55):11-30.

Estrada, N. 2000. La biodiversidad en el mejoramiento genético de la papa. PROINPA, CIP, CID. La Paz, Bolivia, 372 p.

FAO. 2012. Food and Agricultural Organization of the United Nations. Statistical yearbook. 366 p.

FAOSTAT. 2016. Base de datos estadísticos de la FAO. http://faostat.fao.org/site/336/default.aspx.

IGECEM. 2014. Investigación Geográfica, Estadística y Catastral del Estado de México. Comisión de Límites del Gobierno del Estado de México. 52 p.

Lima, M. D. R.; Santos, A. T.; Espinosa, R. G. y Cerrato, R. F. 2000. Producción de papa y biomasa microbiana en suelo con abonos orgánicos y minerales. Agrociencia. 34:261-269.

Luna, M. R.; Espinosa, C. K.; Trávez, T. R.; Ulloa, M. C.; Espinoza, C. A. y Bejarano, A. A. 2015. Respuesta de variedades de papa (*Solanum tuberosum*, L.) a la aplicación de abonos orgánicos y fertilización química. Publicado como nota técnica en Ciencia y Tecnología. 9(1):11-16.

Macías, V. L. M.; Reyes, M. L. y Robles, E. F. J. 2006. Guía para cultivar papa en Aguascalientes. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP)-Campo Experimental Pabellón. Aguascalientes, México. Folleto técnico núm.13. 16 p.

Martínez, G. A. 1988. diseños experimentales. métodos y elementos de Teoría. Editorial Trillas, 1ra Ed. México, DF. 756 p.

Masarirambi, M. T.; Mandisoza, F. C.; Mashingaidze, A. B. and Bhebhe, E. 2012. Influence of plant population and seed tuber size on growth and yield components of potato (*Solanum tuberosum*). Inter. J. Agric. Biol. 14(4):545-549.

Navarro, G. H. 2009. Agricultura orgánica y alternativa. Editorial. Universidad Autónoma Chapingo (UACH). Texcoco, Estado de México. 271 p.

NIVAP. 2007. Instituto holandés para el fomento de ventas de patatas de siembra (por sus siglas en holandés). Catálogo de Variedades Holandesas de Papa. 286 p.

Orozco, H. L. A.; Pérez, L. D. J.; González, H. A.; Franco, M. O.; Rubí, A. M. y Aguilera, G. L. I. 2016. Efecto de *Glomus fasciculatum* y su relación con tres abonos orgánicos en dos cultivares de haba. Rev. Mex. Cienc. Agríc. 7(6):1423-1437.

Orozco, M. y Thienhaus, S. 1997. Efecto de la gallinaza en plantaciones de cacao (*Theobroma cacao* L.) en desarrollo: Agron. Mesoam. 8(1):81-92.

Pérez, L. D. J.; González, H. A.; Franco, M. O.; Díaz, H. C.; Rivera, P. A. y Ramón, G. C. 2009. Análisis de rendimiento y sus componentes en diecisiete genotipos de papa (*Solanum tuberosum* L.). Rev. Cienc. Agríc. Informa. 18(1):27-36.

Pérez, L. D. J.; González, H. A.; Franco, M. O.; Rivera, P. A.; Sahagun, C. J.; Balbuena, M. A.; Rubí, A. M. y Gutiérrez, R. F. 2010. Variabilidad genética, diversidad fenotípica e identificación de genotipos sobresalientes de papa. Rev. Mex. Cienc. Agríc. 1(4):579-592.

Pérez, L. D. J.; González, H. A.; Franco, M. O.; Rubí A. M.; Ramírez, D. J. R. A.; Castañeda, V. A. y Aquino, M. J. G. 2014. Aplicación de métodos multivariados para identificar cultivares sobresalientes de haba para el estado de México, México. Rev. Mex. Cienc. Agríc. 5(2):264-279.

Pool, N. L.; Trinidad, S. A.; Etchevers, B. J. D.; Pérez, M. J. y Martínez, G. A. 2000. Mejoradores de la fertilidad del suelo en la agricultura de ladera de los Altos de Chiapas, México. Agrociencia. 34(3):251-259.

Potato Council. 2011. Manual de variedades de patatas británicas. Base de datos de variedades de patatas británicas. 255 p.

Rodríguez, K. y Ortuño, N. 2007. Evaluación de micorrizas arbusculares en interacción con abonos orgánicos como coadyuvantes del crecimiento en la producción hortícola del Valle Alto de Cochabamba, Bolivia. Rev. Boliviana. 1(5):26-51.

Rojas, M. L. P. y Seminario, C. J. F. 2014. Productividad de diez cultivares promisorios de papa chaucha (*Solanum tuberosum*, grupo Phureja) de la región Cajamarca. Scientia Agropecuaria. 5(4):165-175.

Romero, L. M. R.; Trinidad, S. A.; García, E. R. y Ferrera, C. R. 2000. Producción de papa y biomasa microbiana en suelo con abonos orgánicos y minerales. Agrociencia. 34(3):261-269.

Rousselle, P.; Robert, Y. y Crosnier, J. C. 1999. La patata: producción, mejorada, plagas enfermedades y utilización. Ediciones Mundi-Prensa. Madrid, España. 607 p.

Sánchez, G. J. J. 1995. El análisis biplot en clasificación. Rev. Fitotec. Mex. 18(2):188-203.

Seminario, C. J. F.; Seminario, C. A.; Domínguez, P. A. y Escalante, Z. B. 2017. Rendimiento de cosecha de diecisiete cultivares de papa (*Solanum tuberosum* L.) del grupo Phureja. Sci. Agrop. 8(3):181-191.

SIAP. 2016. Sistema de Información Agroalimentaria y Pesquera. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. www.siap.gob.mx/cierre-de-la-produccion-agricola-por-cultivo.

Trinidad, S. A. 1987. El uso de abonos orgánicos en la producción agrícola. Serie Cuadernos de Edafología 10. Centro de Edafología, Colegio de Postgraduados, México. 129 p.

Van der Zaag, P.; Demagante, A. and Ewing, E. 1990. Influence of plant spacing on potato (*Solaumn tuberosum* L.) morphology, growth and yield under two contrasting environments. Potato Res. 33(3):313-323.

Yagodin, B. A.; Simirnov, P. and Peterburgs, K. A. 1986. Agroquímica, Tomo I y II. (Ed.). Mir Moscú. 787 p.

Zamora, F.; Tua, D. y Rodríguez, D. T. 2008. Evaluación de cinco fuentes orgánicas sobre el desarrollo vegetativo y rendimiento del cultivo de papa. Agron. Trop. 58(3):233-239.