Acta Agron. (2017) 66 (4) p 566-573 ISSN 0120-2812 | e-ISSN 2323-0118 *https://doi.org/10.15446/acag.v66n4.62257*

Integrated system for recommending fertilization rates in pineapple (*Ananas comosus* (L.) Merr.) crop

Sistema integrado para recomendar dosis de fertilización en el cultivo de la piña (*Ananas comosus* (L.) Merr.)

Sergio Salgado García[1], David Jesús Palma López[1], Joel Zavala Cruz[1], Carlos Fredy Ortiz García[1], Luz del Carmen Lagunés Espinoza[1], Mepivoseth Castelán Estrada[1], Armando Guerrero Peña[1], Ángel Isauro Ortiz Ceballos[2] and Samuel Córdova Sánchez[3*]

[1]Colegio de Postgraduados-Campus Tabasco, Grupo SIRDF. Km. 3.5 Periférico Carlos A. Molina S/N. H. Cárdenas, Tabasco. CP 86500. México. [2]Universidad Veracruzana, Instituto de Biotecnología y Ecología Aplicada (INBIOTECA), Xalapa, México. [3]Universidad Popular de la Chontalpa, División de Ciencias Básicas e Ingenierías. CA-QVDS. Carr. Cárdenas - Huimanguillo, Km. 2.0, Cárdenas, Tabasco. CP 86500. México. Author for correspondence: sacorsa_1976@hotmail.com

Rec.:30.01.2017 Accep.:08.04.2017

Abstract

In recent years much attention has focused on the impacts of agriculture on climate change, due to this stage specialists in plant nutrition and soil fertility have achieved the task of generating adequate fertilization doses for pineapple to reduce effects on environment. A methodology for Integrated System for Recommending Fertilizer Dose (ISRFD) was used. As a result, seven Thiessen polygons of the average annual rainfall, where rainfall ranged from 1640 to 2841 mm was correlated. Therefore, three major soil groups were defined and classified as subunit level. Likewise, eight doses of fertilizers were generated as follows: N, P_2O_5 and K_2O, with a fertilizer dose, a map is generated according to the cultivar: 230-138-300 for Creole pineapple in Acrisol Cutanic (Chromic, Ferric); 460-161-480 for Cayenne and MD2 in Acrisol Cutanic (Endoclayic, Ferric); 345-161-450 for Cayenne and MD2, 253-138-450 for Creole in Acrisol Cutanic (Endoclayic, Hyperdystric, Ferric); 391-161-450 for Cayenne and MD2 in Acrisol Umbric Cutanic (Endoclayic, Hyperdystric) and Acrisol Umbric Cutanic (Endoclayic, Hyperdystric, Ferric); 207-138-300 for Creole in Acrisol Umbric Cutanic (Endoclayic, Hyperdystric); 253-138-300 for Creole in Acrisol Umbric Cutanic (Endoclayic,Hyperdystric, Ferric); 253-138-360 for Creole in Acrisol Umbric Gleyic (Hyperdystric, Ferric); and 391-161-360 in Cambisol Endogleyic (Clayic, Eutric). These fertilizer doses were supplemented with micronutrients to obtain the expected results.

Keywords: Acrisol, fertilizer formulations, fertilization map, micronutrients, nutrient availability (soil), plant nutrition, soil fertility.

Resumen

En los últimos años se ha puesto mucha atención en los impactos de la agricultura por el cambio climático, debido a este escenario, los especialistas en nutrición vegetal y fertilidad de suelos se han dado la tarea de generar dosis óptimas de fertilizante para el cultivo de piña a fin de minimizar los efectos en el ambiente. Se utilizó la metodología del Sistema Integrado para Recomendar Dosis de Fertilizantes (SIRDF). Como resultados se encontraron siete polígonos de Thiessen de la precipitación media anual, se definieron tres grupos mayores de suelos y se clasificaron a nivel de subunidad; así mismo, se generaron ocho dosis de fertilizantes de N, P_2O_5 y K_2O, con las que se generó un mapa de dosis de fertilizantes según el cultivar: 230-138-300 para piña Criolla en Acrisol Cutánico (Crómico, Férrico); 460-161-480 para Cayena y MD2 en Acrisol Cutánico (Endoarcíllico, Férrico); 345-161-450 para Cayena y MD2, y 253-138-450 para Criolla en Acrisol Cutánico (Endoarcíllico, Hiperdístrico, Férrico); 391-161-450 para Cayena y MD2 en Acrisol Úmbrico Cutánico (Endoarcíllico, Hiperdístrico) y Acrisol Úmbrico Cutánico (Endoarcíllico, Hiperdístrico, Férrico); 207-138-300 para Criolla en Acrisol Úmbrico Cutánico (Endoarcíllico, Hiperdístrico); 253-138-300 para Criolla en Acrisol Úmbrico Cutánico (Endoarcíllico, Hiperdístrico, Férrico); 253-138-360 para Criolla en Acrisol Úmbrico Gléyico (Hiperdístrico, Férrico); y 391-161-360 en Cambisol Endogléyico (Arcíillico, Éutrico). Estas dosis de fertilizantes fueron complementadas con micronutrimentos para obtener los resultados esperados.

Palabras clave: Acrisol, disponibilidad de nutrientes (suelo), formulaciones de fertilizantes, mapa de fertilización, micronutrientes, nutrición de plantas, fertilidad del suelo.

Introduction

The commercial production of pineapple in Mexico is carried out with the cultivars Cayena lisa, MD2 and the creole 'Cabezona'. It is known that production system is nomadic due to the poor phytosanitary management of the vegetative material for new plantings and this contributes to disperse the plant diseases, which causes for the following crop cycle, a new site is used. Approximately 1600 ha of pineapple are cultivated in the Sabana de Huimanguillo, Tabasco-Mexico, from which were obtained 42,621t of fresh fruit (SIAP, 2016). Potential yields of pineapple are as follows: 70 $t.ha^{-1}$ in Hawaii, Philippines, Thailand and Costa Rica, those that do contrast with the reported 42.48 $t.ha^{-1}$ for Mexico. Therefore, in Tabasco-Mexico is difficult to estimate yields due the fruit is sold per piece for fresh consumption. In this sense, the factors that most affect fruit yield are as follows: pests and diseases, weeds, nutritional imbalance, low plant population density, soil erosion and acidification, poor flowering control and fruit ripening, water deficit, genetic de-uniformity and poor quality of vegetative material (Teixeira *et al.*, 2011).

Likewise, due to the acid soils low fertility where pineapple plantations are cultivated in Mexico, which are characterized by high phosphorus fixation, boron deficiencies, calcium, magnesium, potassium and zinc, low rate of ammonium formation and nitrates, in addition to a high percentage of aluminum saturation (Salgado *et al.*, 2013; Zavala *et al.*, 2014). These restrictive fertility conditions are manifested in foliar deficiencies, which affect the pineapple yield and quality. With the above mentioned, it is difficult to develop management practices that improve a long-term soil fertility. Given these concerns, in order to address the nutritional problem of pineapple cultivation, a sustainable fertilization program was developed to increase pineapple yields in soils of the Savannah of Huimanguillo on Tabasco, Mexico.

Materials and methods

The study area is located to the center-southeast of the municipality of Huimanguillo, Tabasco-Mexico inside the area of pineapple plantations. Specifically, extreme geographical coordinates are as follows: 17° 35´ 25´´ and 17° 56´ 41´´ N, and 93° 26´ 08´´ and 93° 56´ 31´´ W. This area occupies an extension of 106,499 ha, performs a humid warm *Af(m)* rainy season throughout year, with an average temperature of 26.1°C and annual rainfall of 2290.3 mm. For the study, a proposed methodology implied in an Integrated System for Recommending Fertilizer Doses (ISRFD) was used, which consisted of seven phases (Salgado *et al.*, 2013) as follows:

Climatic characterization

To facilitate a more precise estimation, consisted of two processes. In the first one, an average monthly records from 1971 to 2000 of the maximum and minimum temperatures (°C), rainfall (mm) and evaporation (mm) from the *Mosquitero* (00027033) meteorological station (CONAGUA, 2009), were analyzed. With this information, a climatogram was generated. For the second, data from nine meteorological stations close to Huimanguillo pineapple zone, Tabasco-Mexico, were used to calculate the average annual rainfall from 1971 to 2000, each rainfall cell was georreferenced on the generated soil map to define Thiessen polygons of the average annual rainfall, using ArcGIS 9® software (ESRI, 2008).

Soil survey to define the major groups and/or soil subunits

Twenty-seven soil profiles from a previous study in the same study area were properly selected (Salgado *et al.*, 2016) and 14 pedological wells were excavated in each identified soil map unit. In fact, soil samples were collected from each evaluated soil horizons to carry out the physical and chemical determinations for their soil classification, according to the official Mexican standard (SEMARNAT, 2002). Laboratory analysis results were used to classify the soils according to the World Reference Base of the Soil Resource (IUSS Working Group WRB, 2006). The cartographic units were labeled with the subunit name, according to the WRB classification. The soil map was drawn at scale 1: 50000 using ArcGIS 9® software (ESRI, 2008).

Soil sampling to characterize soil fertility and calculate N, P and K supplying from each soil subunits

50 pineapple plantations were selected from the subunit map. In each pineapple cultivation, six soil subsamples were collected from 0 to 30 cm soil depth, three in the row and three among plants, following a zig-zag path within the plantation to obtain composite samples (Salgado *et al.*, 2013). Conversely, chemical analyzes were carried out in accordance with the official Mexican standard (SEMARNAT, 2002).

Potential yield estimation to determine the nutrient demand for pineapple crop

Three complete pineapple plants were harvested at each site where soil samples were taken. The biomass was obtained from the plant weight, fruit weight and crown weight (kg), crown and plant biomass were separately grounded and fruits were cut into slices. Each sample was homogenized and 300 g were taken to dry into the oven at 70°C until constant weight was reached. Fertilizer doses were determined using the modified conceptual model, DF = (DEM)/EF (Silva & Rodríguez, 1993). It is important to note that supply was eliminated due to a low fertility of Acrisol soils. The fertilizers efficiency values were considered as follows: N 50%, P 30% and K 60%, respectively. Fertilizer management recommendations were generated taking into consideration soil unit, pH and fertilizer sources (Salgado & Núñez, 2012).

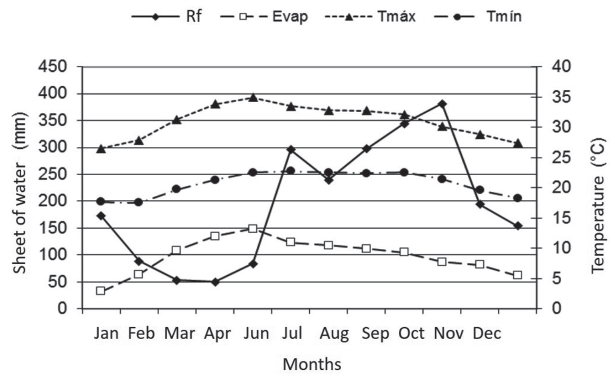

Figure 1. Average behavior for some weather elements in the *Mosquitero* meteorological station, Tabasco-Mexico. Rainfall (Rf), evaporation (Evap), maximum temperature (Tmax), minimum temperature (Tmin).

Results

Climatic characterization

For pineapple cultivation, the required rainfall ranges from 1000 to 1500 mm annually. In the *Mosquitero* station, the average rainfall is 2356 mm, which satisfies the water requirements for pineapple crop (Figure 1).

Seven Thiessen polygons were generated for the study area, annual rainfall ranges from 1640 to 2841 mm (Figure 2). Minor rainfall occurs in the lower-elevation Northeast, coinciding with the *Af* climate. In the soils ACumct(ncehdfr), ACct(ncehdfr), ACumgl(hdfr), ACumct(ncect) and CMngl(ceue), is frequent to observe excessive moisture, which reduces the pineapple growth and crop yields.

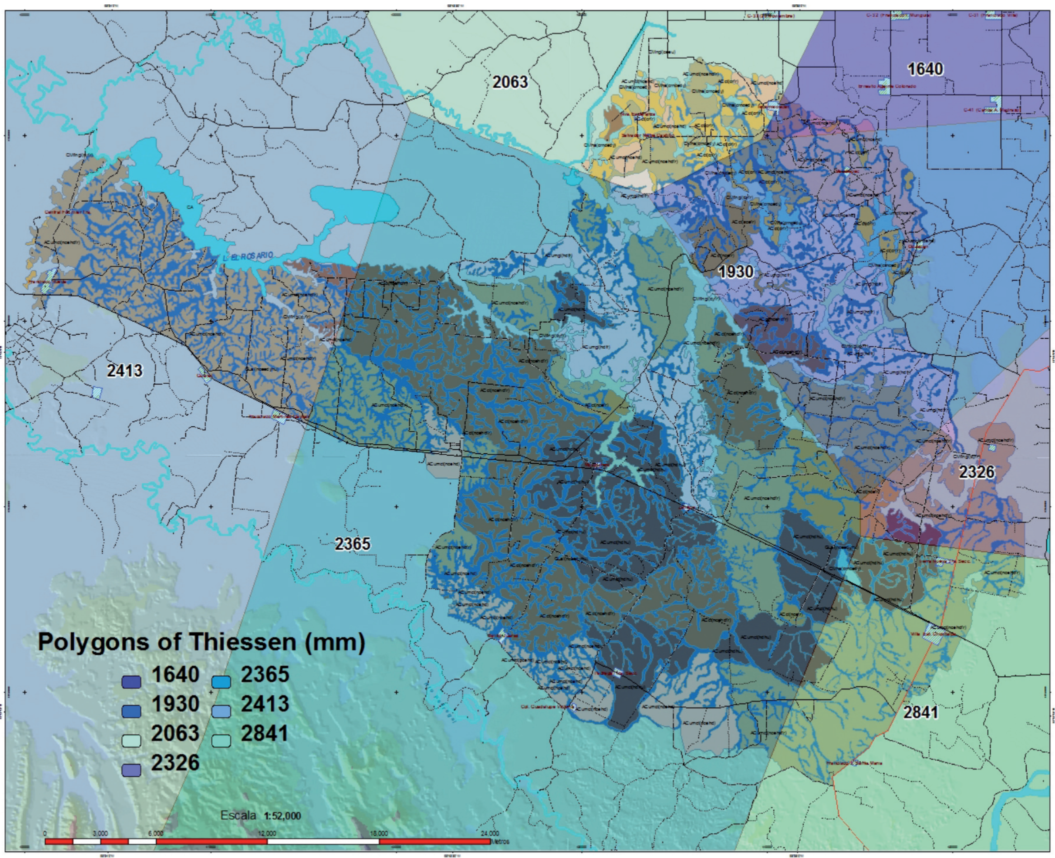

Figure 2. Thiessen polygons of the average annual rainfall for study area cultivated with pineapple crop in Huimanguillo, Tabasco, México.

Soil study

Eleven soil units corresponding to the Acrisol (AC), Cambisol (CM) and Gleysol (GL) groups were identified and soil map was generated at 1: 50000 scale, covering an area of 106,499 ha (Figure 3).

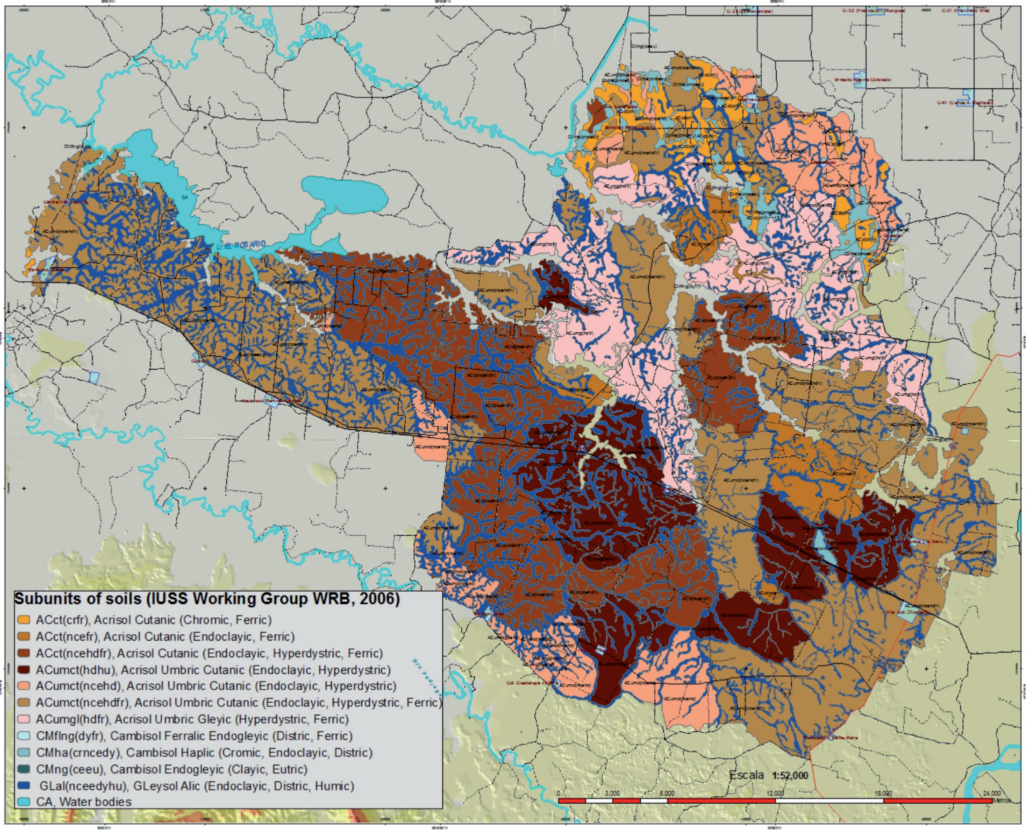

Figure 3. Soil subunits of the cultivated area with pineapple crop in Huimanguillo, Tabasco-Mexico.

The pineapple crop is established in the study area on eight soil subunits as follows: Acrisol Cuatanic (Endoclayic, Ferric), Acrisol Cuatanic (Chromic, Ferric), Acrisol Cuatanic (Endoclayic, Hyperdystric, Ferric), Acrisol Umbric Cuatanic (Endoclayic, Hyperdystric), Acrisol Umbric Cuatanic (Endoclayic, Hyperdystric, Ferric), Acrisol Umbric Cuatanic (Hyperdystric, Humic), Acrisol Umbric Gleyic (Hyperdystric, Ferric), and Cambisol Endogleyic (Clayic, Eutric).

Nutritional demand

The soil ability to produce greater fresh weight in pineapple crop was as follows (t.ha^{-1}): ACct(ncefr) > ACumct(ncehdfr) > ACct(ncehdfr) > ACumct(hdhu) >ACumct(ncehd), in pineapple cv. Cayena and MD2, established with 36000 plants.ha^{-1} (Table 1). Conversely, regarding to cv creole 'Cabezona' the type of soils which produced the highest fresh weight were as follows (t.ha^{-1}): CMng(ceeu) > ACumgl(hdfr) > ACumct(ncehdfr) > ACct(ncehdfr) > ACct(crfr). The observed variability on fresh weight is attributable to the dates of planting, management and the existence of pineapple plantations of second harvest, factors that were not possible to control during the sampling period.

Fertilization dose

The fertilizer doses proposed are presented in Table 2, the N doses fluctuate between 209 to 499 kg.ha^{-1}, P_2O_5 between 139 to 273 kg.ha^{-1} and K_2O between 298 to 563 kg.ha^{-1}.

With this methodology, eight doses of fertilizers (N-P-K) were generated (Table 2). The fertilizer doses distribution within the study area is presented in Figure 4. In Table 2, the sources of fertilizers are detailed, in which can be observed the use of option 1, which considers the sources of N, P and K of higher concentration, is more economical than the use of the complex.

Table 1. Total biomass, dry matter yield, N-P-K demand per pineapple plant, fruit and crown, cropped on the savanna of Huimanguillo, Tabasco, México.

Soil Unit	Plant density and cv.	Fresh weight (kg.ha-1)	Dry matter (kg.ha-1)			Nutritional demand (kg.ha-1)			Fruit demand (kg.ha-1)			Fruit Crown demand (kg.ha-1)		
			plant	fruit	crown	N	P	K	N	P	K	N	P	K
ACct(crfr)	26500	89747	6659	3484	1885	51.81	7.14	75.19	36.44	6.75	45.82	26.37	4.34	17.69
SD	Creole	4462	955	1050	94	9.75	1.47	9.63	22.36	2.27	14.18	4.25	0.57	10.83
ACct(ncefr)	36000	170112	12378	5394	3572	140.49	14.65	148.53	55.97	8.71	65.46	53.04	9.01	32.69
SD	Cayenne and MD2	25135	2749	1727	528	34.25	2.00	49.87	20.34	1.62	33.93	5.64	2.25	7.59
ACct(ncehdfr)	36000	159280	11061	6826	3345	86.67	14.50	100.64	45.59	10.48	66.82	48.58	9.72	42.88
SD	Cayenne and MD2	12746	1047	3312	268	44.23	2.39	25.61	7.56	3.65	14.50	2.95	2.49	31.72
	26500	115717	8056	2994	2430	65.85	8.61	105.65	27.65	5.65	50.07	37.06	5.83	24.17
SD	Creole	21412	1993	177	450	19.98	2.21	68.63	4.60	0.61	19.41	8.89	1.25	14.19
ACumct(hdhu)	36000	153600	10469	4513	3226	115.20	17.31	138.93	43.33	8.42	62.52	50.70	9.29	35.35
SD	Cayenne and MD2	15140	1370	1200	318	15.56	4.71	22.66	4.14	1.66	10.85	9.90	2.08	14.15
ACumct(ncehd)	36000	105960	7611	3475	2225	55.05	11.20	85.92	21.13	5.30	55.07	28.09	5.70	7.53
SD	Cayenne	7656	2118	488	161	11.81	2.06	26.64	4.05	0.63	15.11	3.48	1.60	5.97
ACumct(ncehdfr)	36000	164967	11312	5921	3464	102.42	17.91	162.23	46.01	8.51	79.34	50.76	9.31	20.40
SD	Cayenne	52984	3271	2311	1113	39.51	4.22	77.55	20.99	2.77	43.40	20.58	3.38	11.76
	26500	110982	7890	3955	2331	60.8	8.7	73.5	31.6	5.7	47.0	31.69	5.50	33.98
SD	Creole	3965	657	1434	83	14.46	3.68	26.30	15.64	2.00	42.43	2.69	1.44	9.60
ACumgl(hdfr)	26500	133854	8902	3191	2811	71.7	8.8	108.6	25.4	4.9	49.5	39.3	6.4	14.9
SD	Creole	15908	1134	860	334	13.41	1.91	46.36	3.36	0.60	37.20	4.67	0.64	23.93
CMng(ceeu)	26500	134031	9448	5822	2815	92.76	10.94	81.78	73.90	14.19	51.13	46.58	6.66	31.58
SD	Creole	16180	1353	880	340	12.53	4.49	21.50	8.82	2.80	42.90	14.05	1.08	12.09

SD: Standard deviation

Table 2. Pineapple fruits yield, fertilizers doses and cost of fertilizer doses for pineapple crop in Huimanguillo, Tabasco,Mexico.

Unit	Plant density	Fruit yield (kg.ha-1)	Fertilizers dose (kg.ha-1)			Fertilizer Sources Options			
					1 (kg.ha-1)		2 (kg.ha-1)		
			N	P_2O_5	K_2O	Urea	DAP	KCl	Urea+Triple 17+KCl
ACct(crfr)	26500	29616	230	138	300		400-300-500		200-800-250
SD	Creole	1473					$USD 442.37		$USD 462.01
ACct(ncefr)	36000	56137	460	161	480		850-350-800		650-950-500
SD	Cayenne and MD2	8295					$USD 721.70		$USD 756.30
ACct(ncehdfr)	36000	52562	345	161	450		600-350-800		400-950-500
SD	Cayenne and MD2	4206					$USD 651.38		$USD 685.98
	26500	38187	253	138	360		450-300-600		250-800-350
SD	Creole	7066					$USD 501.28		$USD 521.19
ACumct(hdhu)	36000	50688	391	161	450		700-350-800		500-950-500
SD	Cayenne and MD2	4996					$USD 693.57		$USD 714.11
ACumct(ncehd)	36000	34967	207	138	300		350-300-500		150-800-250
SD	Cayenne	2527					$USD 428.31		$USD 447.94
ACumct(ncehdfr)	36000	54439	391	161	450		700-300-600		500-950-500
SD	Cayenne	17485					$USD 693.57		$USD 714.11
	26500	36624	253	138	300		450-300-500		250-800-250
SD	Creole	1308					$USD 456.17		$USD 476.07
ACumgl(hdfr)	26500	44172	253	138	360		450-300-600		250-800-350
SD	Creole	5250					$USD 501.28		$USD 521.19
CMngl(ceeu)	26500	44230	391	161	360		750-350-600		500-950-300
SD	Creole	5339					$USD 603.34		$USD 623.88

SD: Standard deviation

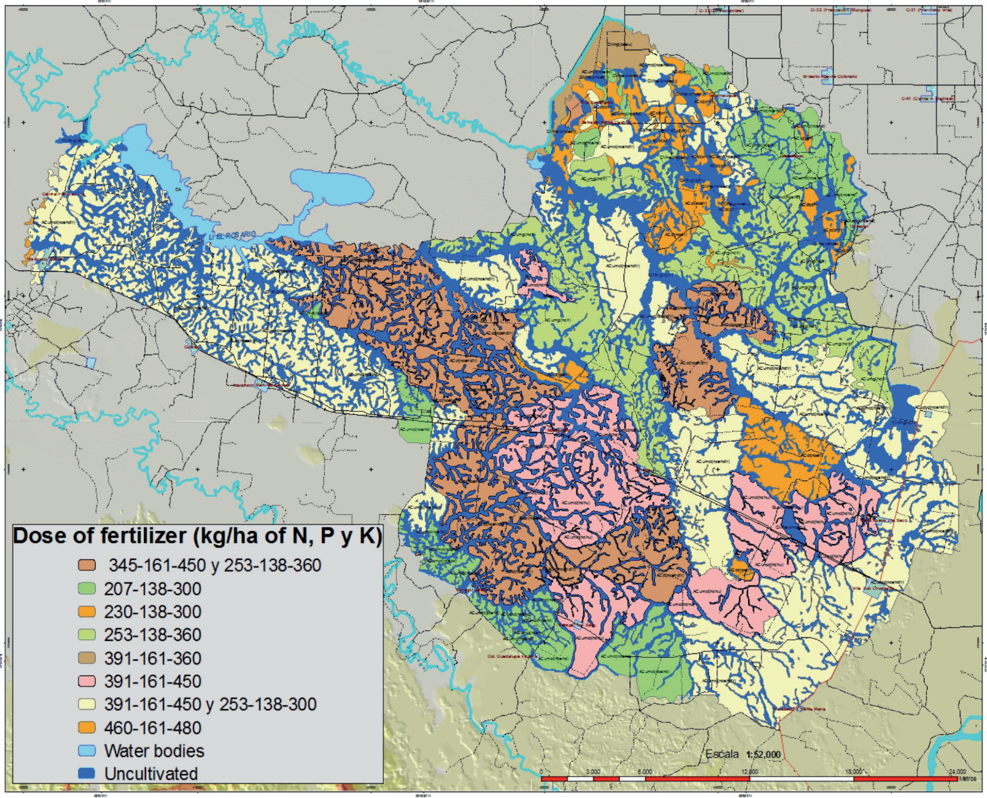

Figure 4. Fertilizer doses recommended for pineapple crop in Huimanguillo, Tabasco-Mexico.

Discussion

Climatic characterization

During the months of February to May, there is a drought season (276 mm), since the evaporation exceeds rainfall. In fact, this limits the pineapple crop yield and is necessary to apply irrigation to favor the fruit filling. On the other hand, from June to January, rainfall of 2080 mm is registered and is related to humidity excess. The temperatures during the plant growth stage are higher than 20°C, which favors the crop growth.

Soil fertility

The chemical properties are similar in all subunits; the differences do not implies any change in the soil classification categories and is necessary to establish a soil fertility description in general. The limiting factors of these soils are acidity, clay and deficiencies of P, K, Ca, Mg, Cu, Zn and Mn, respectively (Zavala *et al.*, 2014).

Soil acidity (pH)

The pH of Acrisol subunits was less than 5.0 and is classified as strongly acid (Salgado *et al.*, 2013), and the CMngl (ceeu) unit was moderately acidic. The cultivation of pineapple develops well in soils with pH of 4.5 to 5.0. However, at these pH values the availability of N, P, K, Ca, Mg, Cu and Zn is reduced, with deficiencies occurring in plants. In contrast, the availability of Fe and Al, increases.

Soil organic matter (SOM)

The SOM contents of the soil units vary between 1.8 and 4.5%, ranging from medium to high (<6.0%, SEMARNAT, 2002). From the point of view of sustainability, it is necessary to maintain a minimum level of 3.4% of SOM (Loveland & Webb, 2003). The value above mentioned can be achieved by providing composting from 5 to 10 $t.ha^{-1}$(Devadas & Kuriakose, 2005). It is advisable to establish a crop rotation based on pineapple-*Mucuna*-pineapple due to the beneficial effects of the fabaceae species to reduce nematodes and weeds (Matos *et al.,* 2009).

Total nitrogen (TN)

The content of N is considered from rich to very rich (0.15 a 0.30% of N, Salgado *et al.*, 2013). There is a relationship between the OM content and N, a medium to low C/N ratio (<15, SEMARNAT, 2002), which indicates that there will be a net mineralization, and therefore an inorganic N available, but insufficient to meet the >250 $kg.ha^{-1}$ of required N for this crop

(Betancourt *et al.*, 2005; Amaral *et al.*, 2014), is necessary to supply N throughout fertilization.

Assimilable phosphorus (P)

In the soil subunits ACct (crfr) and ACct (ncefr), P content is classified as high. Therefore, soil subunits ACumct (hdhu) and ACumct (ncehd), present medium content (5.5-11 mg) (Borges *et al.*, 2008), which shows these pineapple plantations have received usually phosphate fertilizers. The soil subunits ACct (ncehdfr), ACumct (ncehdfr) and ACumgl (hdfr), present a low content of P (< 5 mg of P, Borges *et al.*, 2008), which is necessary to apply a phosphoric fertilizer to improve the quality of pineapple fruits.

Exchangeable potassium (K)

The K content in the soil subunits is classified as low (<0.20 cmol (+) kg^{-1} of soil, Salgado *et al.*, 2013). The K contents are less than 30 $mg.kg^{-1}$, which explains the low sugar content in the fruit if not fertilized with potassium (Halliday & Trenkel, 1992).

Calcium (Ca) and Magnesium (Mg)

The Ca and Mg contents are classified as very low. This reinforces the suggestion of implementing a liming program on these soils (Manica, 1999).

Sodium (Na)

Na is considered a beneficial element for plants, its actual concentration indicates that there are no problems of soil salinity (Salgado *et al.*, 2013).

Cation exchange capacity (CEC)

CEC is classified as low (5 to 15 cmol(+) kg^{-1} of soil, SEMARNAT, 2002) and indicates that the soils had achieved a low fertility and present kaolinite clays 1:1.

Iron (Fe), Copper (Cu), Zinc (Zn) and Manganese (Mn) micronutrients

The concentration of Fe is classified as high (>4.5 $mg.kg^{-1}$ of Fe). Cu and Zn are deficient. In fact, Mn is classified as deficient in the following soil subunits: ACct(ncefr), ACct(ncehdfr) and ACumgl(hdfr).

The moisture percentage in the plant fluctuated from 87 to 91%, higher than those reported by Teixeira *et al.* (2011), and these values served as a basis for calculating the production of dry matter per plant, fruit and fruit crown (Table 2). Therefore, dry matter production showed the same pattern of the fresh weight. The demand for N, P and K, present an order as follows: plant> fruit> crown. All crop components showed the order of requirement K> N> P, as reported by Manica (1999).

Nutritional demand

The N demand for the cultivar Cayenne fluctuated from 124 to 250 $kg.ha^{-1}$; P from 51 to 82 $kg.ha^{-1}$; and K from 192 to 338 $kg.ha^{-1}$, which coincides with that reported by Halliday & Trenkel (1992). Conversely, in the case of the N demand to the creole cultivar 'Cabezona' fluctuate from 115 to 213 $kg.ha^{-1}$; P from 42 to 73 $kg.ha^{-1}$; and K from 179 to 232 $kg.ha^{-1}$ (Table 1).

Therefore, when analyzing the total demand of N, P and K, can be observed that pineapple crop demands a great amount of nutrients, which are supplied by soil and are considered as system losses, due to the system of itinerant cropping, these residues when remaining in the field, mineralize by releasing more than 60% of the nutrients and is necessary to think of using a rotation system to take advantage of these nutrients.

Fertilization doses

The eight fertilizers doses (N-P-K) proposed for the pineapple zone of Huimanguillo, Tabasco, Mexico, agree with the recommendations for other pineapple zones of Mexico and the World (450-100-400, Teixeira *et al.*, 2002; 240-120-240, Devadas & Kuriakose, 2005 and Oliveira *et al.*, 2015; 200-50-200, Betancourt *et al.*, 2005).

The pineapple crop fertilization is manual, applied to the soil, the fertilizer is placed from 5 to 10 cm in soil depth, in the area close to the stem and in the older axillar leaves (Teixeira *et al.*, 2011; Halliday & Trenkel, 1992).

Application timing

We recommend start fertilization at the month of planting. A total dose is divided into four parts, which must be applied at three-month intervals (Spironello *et al.*, 2004).

Fertilizers

In the local market the most common fertilizers sources are urea, triple superphosphate, potassium chloride and/or potassium sulfate (Veloso *et al.*, 2001; Spironello *et al.*, 2004; Amaral *et al.*, 2014) and some complexes. However, the most advisable is to calculate the fertilizer doses cost to make an adequate decision, which are the most economical and consider availability at the local market (Salgado *et al.*, 2013).

Conclusions

Resulting from this study was found seven Thiessen polygons, rainfall varies from 1640 to 2841 mm, being the northeast area the driest one. It is known that rainfall of the area covers the water requirements for the pineapple crop and could cause problems of excess moisture in soils with clay texture. The temperatures have allowed a good plant development.

To acquire a more precise evaluation, 11 soil subunits were identified, which corresponding to soil groups: Acrisol (AC), Cambisol (CM) and Gleysol (GL). Pineapple cultivation is carried out in eight soil subunits. The cultivated area can be grouped into three zones: Estación Chontalpa, Francisco Rueda and Nueva Esperanza. The limiting factors of these soils are as follows: acidity, kind of clay, soil moisture excess and deficiencies of P, K, Ca, Mg, Cu, Zn and Mn.

Given these concerns, eight fertilizer doses (N-P-K) were generated, which are represented in a planning and geodesy map based on a geographic information system of fertilizer doses for pineapple cultivation, which are complemented by applications of copper sulphate, zinc, boron, manganese sulphate in some soil subunits in the influence area grown in pineapple.

Acknowledgements

To the Fundación Produce Tabasco, A.C. and the Consejo Estatal de Productores de Piña de Tabasco, A.C., for their economic and logistical support in carrying out this work.

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