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Presentation of the Content

In the first chapter we present, *Estimation of the impact (cost-benefit) of bean production in the South Pacific, Mexico* by VÁZQUEZ-ELORZA, Ariel, GARCÍA-MORALES, Soledad and HERRERA-GARCÍA, Adolfo Federico, with adscription in the Centro de Investigación y Asistencia en Tecnología y Diseño del Estado de Jalisco and Benemérita Universidad Autónoma de Puebla, as a second article we present, *Economic evaluation of solar drying process for washed coffee in mixteca region of Oaxaca state, México* by GARCÍA-MAYORAL, Luis Eduardo, QUINTANAR-OLGUIN, Juan and MARTINEZ-RUIZ, Antonio, with adscription in the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, as the following article we present, *Study of the physicochemical characteristics and viscosity profile of Cucúrbita pepo L.*, by MOJICA-MESINAS, Cuitláhuac, ACOSTA-PINTOR, Dulce Carolina, VIDAL-BECERRA, Eleazar* and LORENZO-MÁRQUEZ, Habacuc, with adscription in the Tecnológico Nacional de México – Campus Ciudad Valles, as the following article we present, *HV-570, New maize (Zea mays L.) varietal prospect hybrid for the humid tropic of México*, by SIERRA-MACIAS, Mauro, RÍOS-ISIDRO Clara, GÓMEZ-MONTIEL, Noel Orlando and ESPINOSA-CALDERÓN, Alejandro, with adscription in the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias.

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Estimation of the impact (cost-benefit) of bean production in the South Pacific, Mexico

Estimación del impacto productivo (costo-beneficio) del frijol en el Pacífico Sur, México

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Abstract

Garcia-Chavez et al. (2020) stipulates that beans represented 3.3% of the total energy intake of the diet of people older than 5 years; 3.7% in adults; In addition, it is considered a very important product in the general population, not only because it represents a food product that they grow, mostly, for self-consumption, but also because of the intrinsic monetary value of not paying out income for the purchase of this product in the market. In recent years, this grain has represented the livelihood of indigenous rural families dedicated to productive activities and, in general, the bean is used for self-consumption. However, its traditional production generates an important economic activity since agricultural families stop paying purchase costs, saving the cost for daily sustenance. The objective of this research work is to estimate the impact of ProAgro on bean producers in the productive sector of the Mexican South Pacific in rural households with the greatest social needs. It is evident that there is a substantial difference between those who receive the Program, self-consumption expenses and those who receive labor income. The latter is greatly reduced in localities with 2,500 inhabitants or less.

Indigenous localities, Economic, Agricultural sector, Bean consumption

Resumen

En el presente trabajo se analiza el impacto del sector productivo del frijol, ya que es fundamental para la alimentación de los mexicanos, como lo menciona García-Chávez et al. (2020) estipula que el frijol representó el 3.3% de la ingesta energética total de la dieta de las personas mayores de 5 años; el 3 7% en adultos; además, se considera un producto muy importante en la población en general, no sólo porque representa un producto alimenticio que cultivan, en su mayoría para autoconsumo, sino también por el valor monetario intrínseco al no tener que pagar ingresos por la compra de este producto en el mercado. En los últimos años, este grano ha representado el sustento de las familias rurales indígenas dedicadas a actividades productivas y, en general, el frijol es utilizado para el autoconsumo. Sin embargo, su producción tradicional genera una actividad económica importante porque las familias campesinas ya no tienen que gastar en la compra, ahorrando así dinero para su sustento diario. El objetivo de esta investigación es estimar el impacto del ProAgro a los productores de frijol del sector productivo del Pacífico Sur mexicano en los hogares rurales con mayores necesidades sociales. Es evidente que existe una diferencia sustancial entre los que reciben el Programa, los gastos de autoconsumo y los que reciben ingresos laborales. Este último se reduce considerablemente en las localidades de 2,500 habitantes o menos.

Localidades indígenas, Económico, Sector agrícola, Consumo de frijol

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Introduction

According to Lépiz-Ildefonso (2007) cited by National Seed Inspection and Certification Service (SNICS, 2016). in Mexico there are 70 bean species of the 150 existing worldwide and they represent more than 95% of the grain consumed in the country. Likewise, the common bean (*Phaseolus vulgaris* L.) is a very important product in food consumption in Mexico. (Lara-Flores, 2015, p. 1; Kaplan & Lynch (1999, p. 269) The results of an accelerator mass spectrometry (AMS) study estimated that the cultivation of common beans in Mexico, *P. vulgaris* L., and tepari, *P. acutifolius* Gray, occurred no earlier than approximately 2500 B.P. in the Valley of Tehuacan"; in Tamaulipas it is about 1300 years, and in the Valley of Oaxaca 2100 years. For their part, Barrera-Sánchez et al. (2020). The changes in climate generate new patterns that affect diversity, including beans; on the other hand, there are varieties that adapt to heterogeneous climatic conditions.

García-Chávez et al. (2020) stipulates that beans represented 3.3% regarding the total energy intake of the diet of people older than 5 years; 3.7% in adults; in addition, it is considered a very important product in the general population, not only because it represents a food product that they grow, for the most part, for self-consumption, but also because of the intrinsic monetary value by ceasing to disburse income for the purchase of this product in the market. This information is strengthened by analyzing the National Public Health Survey (ENSANUT) of the National Institute of Public Health (2019) The frequency of consumption of beans prepared at home (de la olla) among adolescents and adults (12 years and older) was distributed as follows: in localities with less than 2,500 inhabitants, 23.8 million people nationwide; however, in the states of Guerrero, Oaxaca and Chiapas, hereafter referred to as the South Pacific Region (SPR), it represented 21% of this total (5.08 million people).08 million people); localities of 2,500 to 100 thousand inhabitants there are 30.0 million representing frequency of consumption of beans prepared at home (de la olla) where the SPR is 16%, and in localities of 100 thousand inhabitants and more the frequency was 48.4 million with 6% in the SPR.

Of the estimated population that consumes beans in the form of preparations from the pot (at home) in the South Pacific in localities with less than 2500 inhabitants, 58% consumes it once a day, which is the equivalent of one cup, 38% twice and, 2% between three and four times, respectively. In localities with 2,500 to 100,000 inhabitants, an estimated 4.1 million households consume beans; of this total, 71% consume beans once a day, 26% twice and 3% three times. In towns with 100,000 or more inhabitants there are 22 million inhabitants who consume beans; of this total, 62% consume beans once a day, 32% twice and 6% three times (own data generated from ENSANUT (2019) in National Institute of Public Health (2019). This is evidence of the importance of beans in the diet of households in the South Pacific, especially those living in marginalized and rural areas.

However, it is of vital importance to consider that environmental conditions are constantly evolving and changing. According to Padilla et al. (2013, p. 38) According to the National Institute of Forestry, Agricultural and Livestock Research (INIFAP) South Pacific Regional Research Center, "The productive diversity and intensification of cultivated land through associations such as corn and beans generate the system called "milpa", which takes advantage of reduced spaces and difficult to work land". In recent years, this grain has represented the livelihood of indigenous rural families dedicated to productive activities and, in general, beans are used for self-consumption. However, its traditional production generates an important economic activity, since farming families no longer have to spend money on purchases, thus saving money for their daily sustenance. In some major cities of the South Pacific, "farmers' markets" are developed where there is a culture of exchanging food (barter) at various levels of marketing in many small (rural indigenous) producers.

In the RPS, 13,544 lands dedicated to beans in open fields were reported in Chiapas with a total area of 76,208.86 ha; 2,887 lands in Guerrero (33,521.07 ha) and 7,877 lands in Oaxaca (101,285.12 ha) (Marco Censal Agropecuario del National Institute of Statistics and Geography, Agricultural Census - INEGI 2016.). In total, 211,000 ha were dedicated to beans, which represents a significant area dedicated to the activity in the RPS, mainly in localities with very high levels of marginalization (Figure 1).
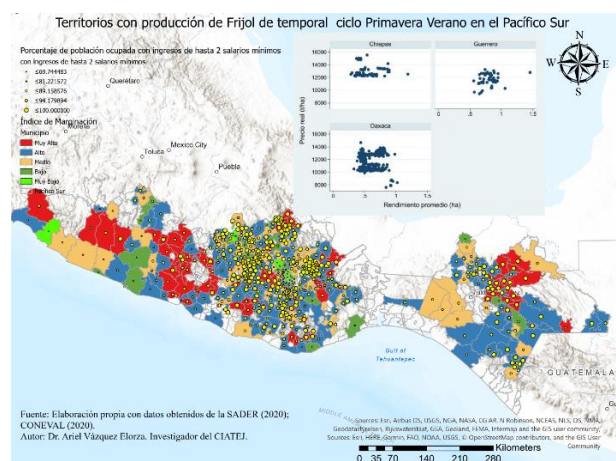
Figure 1 Territories with rainfed bean production in the P-V cycle in the South Pacific
Source: Own elaboration with data from the SADER-SIAP (2020), (CONEVAL, 2020)

The objective of this research is to estimate the impact of the bean production sector in the Mexican South Pacific on rural households with the greatest social needs. It is estimated that direct farm support and subsidy transfers can create distortions in the labor market and, above all, generate some form of dependency in the medium and long term among the beneficiary population. Most of the production is generated under rainfed conditions in the spring-summer production cycle (PV) and, to a lesser extent, in autumn-winter (OI) (Table 1).

Cycle	Production volume (t)	Value (actual)	Area planted	Harvested area	Price (actual)	Yield (t/ha)
O-I	36,203.84	435,000,000	54,066	54,066	12,092	0.89
P-V	72,041.40	913,000,000	115,320	115,299	12,188	0.68

Note: The information is deflated with Base=100 INPC of BANXICO (2022)

Table 1 Production characteristics of beans in the South Pacific (2020)
Source: Own elaboration based on SADER-SIAP (2020)

The bean plant is essentially grown in 23 Rural Development Districts (RDD) classified in the RPS according to SADER-SIAP (2020), totaled 169,387.45 ha planted with beans. During the 2010-2020 period, the area planted has experienced a reduction in the Average Annual Growth Rate (AAGR) of approximately -0.32% (Figure 2).

On the other hand, the RDDs that have mostly reduced the amount of planted area are Altamirano with -10.80%; Comitán (-0.67%), Iguala (-5.46%), Motozintla (-1.13%), Palenque (-0.14%), Selva Lacandona (-0.21%), Tapachula (-4.48%), Tuxtla Gutiérrez (-0.72%), Valles Centrales (-4.00%).

On the other hand, the ratios of real farm-gate prices paid to producers show a reduction with an average annual growth rate ranging from -7.94% to -1.23% in 20 of the RDDs in the region from 2010-2020. The only 3 RDDs with real growth in price received at producers are: Las Vigas (2.70%), Atoyac (1.54%) and Chilpancingo (0.67%).
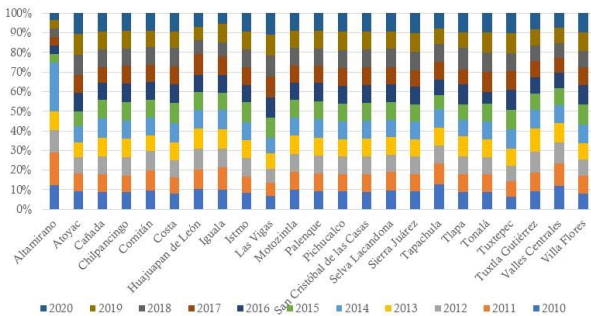
Figure 2 Area planted to P-V/O-I beans in the South Pacific Region (2010-2020)
Source: Own elaboration with data from the SADER-SIAP (2020).

Rural income from bean sales according to dietary conditions

Rural incomes from bean sales according to food insecurity conditions present heterogeneity according to the level of locality size in the South Pacific. Our own results obtained from the evidence that the INEGI-ENIGH (2020) The results themselves obtained from the evidence that the indigenous-speaking population experiences a very interesting pattern; namely, as food insecurity increases, the price per kilogram on average also experiences a very significant increase. On the contrary, in the non-indigenous-speaking population, the opposite effect occurs; as food insecurity increases, the price per kilogram of beans sold is lower. It also highlights the existence of unavailable information, especially when food insecurity increases in the indigenous-speaking population. It is hypothesized that the majority of this population uses beans as a product for self-consumption rather than a product to offer in the market. This positive relationship of self-consumption is in line with the characteristics of the marginalized population where, generally, the production uses beans for food and daily life and as an alternative form of expenditure substitution.

Indigenous language speaker						
Location	Size of locality	Food safety	Mild food insecurity	Moderate food insecurity	Severe food insecurity	Total
100,000 and more inhabitant	Price per kilo			nd	nd	
	Quarterly income	4,223	8,144	nd	nd	7,464
15,000 to 99,999 inhab.	Price per kilo		nd	nd	nd	
	Quarterly income	nd	nd	nd	nd	0
2,500 to 14,999 inhab.	Price per kilo					
	Quarterly income	2,332	2,281	1,695	1,127	2,127
Less than 2,500 inhab.	Price per kilo					
	Quarterly income	1,851	2,225	1,247	831	1,787
Total average	Price per kilo					
	Quarterly income	1,940	2,337	1,303	867	1,889
Non-indigenous language speaker						
Location	Size of locality	Food safety	Mild food insecurity	Moderate food insecurity	Severe food insecurity	Total
100,000 and more inhabitant	Price per kilo	nd		nd		
	Quarterly income	nd	1,057	nd	41,250	31,529
15,000 to 99,999 inhab.	Price per kilo					
	Quarterly income	15,820	2,849	4,244	3,554	8,055
2,500 to 14,999 inhab.	Price per kilo					
	Quarterly income	7,514	4,239	2,382	3,279	5,296
Less than 2,500 inhab.	Price per kilo					
	Quarterly income	3,106	2,109	1,947	2,923	2,423
Total average	Price per kilo					
	Quarterly income	4,305	2,296	2,058	4,579	3,066

Table 2 Production characteristics of beans in the South Pacific (2020)
Source: Own elaboration based on SADER-SIAP (2020).
Note: The information is deflated with Base=100 INPC of BANXICO (2022)

Methodology

Impact assessment model Propensity Score Matching (PSM)

Rosenbaum and Rubin (1983a, p. 41) state that the PMS tool "is the conditional probability of assignment to a particular treatment given a vector of observed covariates." In this study, the analysis is focused on bean producers in the P-V cycle in the South Pacific, including those who are beneficiaries of ProAgro government support considered as the control group and those who did not receive it (treatment group) based on the year 2020. The information base for the analysis comes from the National Survey of Income and Expenditures of Households of the National Institute of Statistics and Geography (INEGI-ENIGH, 2020). Likewise, we include those producers who have or do not have a labor income as a control variable, in order to differentiate the disparities that exist among small indigenous rural producers in the region. Jalan & Ravallion (2003) state that "Anti-poverty programs often require participants to work in order to obtain benefits.

These *workfare* programs have been used in crises [...] in which large numbers of the able-bodied poor have become unemployed". Typically, rural support programs seek to increase the welfare of rural families and, above all, their income, so that they can have better living conditions to face the food crisis. for this reason, it is essential to know the impact of the income distribution of the programs, especially to identify the main incentives they generate in the context of the rural population of the region under study.

Rubin & Thomas (1996, p. 2049) point out that:

"Matched sampling is a methodology for reducing bias due to observed covariates in observational studies of causal effects. The basic situation involves a sample of subjects treated with N_t and a larger sample of control subjects with N_c, where the paired "p" variables $X = (X_1, \ldots, X_p)$ have density f_t, between subjects treated with mean μ_t, and variance-covariance matrix $\sum_t$, and density f_c, among control subjects with mean μ_t, and variance-covariance matrix $\sum_c$."

For their part, Rosenbaum and Rubin (1983a) explain that "the N units are viewed as a simple random sample from some population, and the quantity to be estimated is the average treatment effect", defined as:

$$E(ri) - E(r0), \text{ where } E(.) \text{ denotes} \quad (1)$$
expectation in the population.

Rosenbaum and Rubin 1983a, 1984. cited by Cerulli (2015, p. 78) show that "the propensity score is the conditional probability of receiving the treatment, given the x confounding variables. Interestingly, given D is binary." The support that producers receive from those who receive ProAgro are identified with 1 and, zero otherwise, whose equality is:

$$p(x) = Pr(D = 1|x) = E(D|x) \quad (2)$$

Vargas and Eguiarte (2017, p. 71). suggest that "the mean estimate of a program's results is shown by equation [3], being πi the result of comparisons of causal effects."

$$\pi i = E\left[\frac{Yi(1)}{T(i)} = 1\right] - \left[\frac{Yi(0)}{Ti} = 0\right] \quad (3)$$

A selection of producers was generated including x variables with observable characteristics including age, indigenous language speaker, poverty conditions, quantity of bean sales, price per kilo, standardized quarterly self-consumption, following with the methodology proposed by. Vargas and Eguiarte (2017).. The average effect of labor income is generated, segmenting the base in those who receive the ProAgro, in contrast, with those rural producers who do not receive it. The aim is to compare between the population of the RPS. This is explained by:

$$E[Yi(0) - Yi(1)] = E[Yi(0)|Ti = 0, x] - E[Yi(1)|Ti = 1, x] \quad (4)$$

Vargas and Eguiarte (2017, p. 71). explain "the hypothesis that an individual or family has the same probability of being placed in any of the groups, defined as conditional independence":

$$E[Yi(0), Yi(1)|Ti, X] y E[Yi(0)|Ti = 0, x] = E[Yi(1)|Ti = 1, x] \quad (5)$$

Cerulli (2015, p. 78) denotes that the "Balance of confounding variables, given the propensity score: if p(x) is the propensity score [...] implying that, conditional on p(x), the treatment and the observables are independent," then:

$$D \perp x|p(\mathrm{x}) \quad (6)$$

Vargas and Eguiarte (2017, p. 72) describe that "for each probability estimated for individuals in the treatment group there is a similar probability in the control group."

$$E[Yi(0), Yi(1)|Ti, X] y E[Yi(0)|Ti = 0, x] = E[Yi(1)|Ti = 1, x] \quad (7)$$

Khandker et al. (2009, p. 55) note that "Conditional independence states that, given a set of observable covariates X that are unaffected by treatment, potential outcomes Y are independent of treatment assignment T". Thus, Y_i^T symbolizes the outcomes for those with ProAgro and the outcomes for those without ProAgro. Y_i^C the outcomes for those who do not participate, thus conditional independence implies:

$$(Y_i^T, Y_i^C) \perp T|x_i \quad (8)$$

Equation 8 "shows the average treatment effect obtained by the difference between the average outcome of the treatment group and the control group" (Vargas and Eguiarte, 2017, p. 72).

$$ATE = E\{E[Y(i)1|Ti = 1, p(xi)] - E[Y(i)0|Di = 0, p(xi)|Ti = 1]\} \quad (9)$$

Abadie et al. (2004, p. 301) indicate that the coincidence estimator that is average treatment effect for the inverse variance-treated weighting matrix (SAAT) is represented as follows:

$$\hat{V}^{sample,t} = \frac{1}{N_1^2} \sum_{i=1}^{N} \{W_i - (1 - W_i)K_M(i)\}^2 \hat{\sigma}_{Wi}^2(X_i) \quad (10)$$

Wang et al. (2017, p. 1). suggest that untreated (ATU) and in-treated (ATT) mean treatment effects "are useful when there is interest in: assessing the effects of treatments or interventions on those who received them, the essence of treatment heterogeneity, or projecting potential outcomes in a (sub)target population."

Treatment variable. Binary *dummy* variable where rural producers who have ProAgro Yi(1) and those who do not have the benefit Yi(0).

Explanatory variables. Indigenous status, poverty conditions, quantity of bean sales, price per kilo, standardized quarterly self-consumption.

Response variable. *Quarterly per capita* income as a product of self-employment at work (expressed in real pesos).On the other hand, the Latin American Food Security Scale (ELCSA) constructed by the Food and Agriculture Organization of the United Nations (FAO) was used to generate the food security indicators: mild food insecurity, moderate food insecurity and severe food insecurity. Food and Agriculture Organization of the United Nations (FAO, 2012). to generate food security indicators; mild food insecurity, moderate food insecurity and severe food insecurity.

Results

Characteristics of the bean population in the region

Figure 3 shows the trends in average income and self-consumption of P-V/O-I bean-producing households in the RPS. The variables of analysis are described as follows: a) self-consumption: consumption by the household of goods produced or marketed by some of its members and for which no value has been paid (quarter). B) sales: income from the sale of beans. C) ing_mon: sum of income from wages, salaries or wages; Christmas bonus; household business; benefits from other social programs; financial payments; business with fishing, hunting and trapping activities. D) ing_lab: sum of income from wages, salaries or wages; income from work of persons under 18 years of age; business with fishing, hunting and trapping activities. E) ict: monetary income and non-monetary income (payment in kind, gifts in kind).

It is relevant to highlight that income from self-consumption, which is the "Consumption by the household of goods produced or marketed by some of its members and for which no value has been paid" INEGI-ENIGH (2020)constitutes an important implicit (non-tangible) stimulus to sustain their households. However, the monetary income of women farmers engaged in bean activities is lower than that of men. This is evidenced by the fact that only in 17 RDDs was income from sales recorded when the head of the household is a woman. Among them, the DRDs of Comitán, Las Vigas, San Cristóbal de las Casas, Iguala and Tlapa stand out with higher incomes; in contrast, where women bean producers receive less income are located in Huajuapán de León, Costa, Tuxtla Gutiérrez, Chilpancingo, Cañada, Palenque and Pichucalco. It should be noted that the income is considered on a quarterly basis according to data generated from the INEGI-ENIGH (2020). Undoubtedly, women bean growers living in the Pichucalco RDD have the lowest levels of average income from bean sales in the RPS (Figure 3). In contrast, the DDR of Tuxtepec, Las Vigas and Sierra Juarez achieved the highest levels of quarterly bean sales when the female head of household is considered. As previously mentioned, labor jobs represent an alternative to maintain a certain source of income, in addition to improving the distribution of income.

Barros & Ferreira (2000, p. 43) used the micro-simulation method to analyze the endogenous factors of labor income, labor aspects and education; consequently, they found that the latter has a strong influence on income distribution, and thus tends to reduce poverty. For their part, female heads of household engaged in bean activities that reached the highest levels of household income, in general, are located in Comitán, Iguala, San Cristóbal de las Casas, Las Vigas, Motozintla, Tlapa, among others.
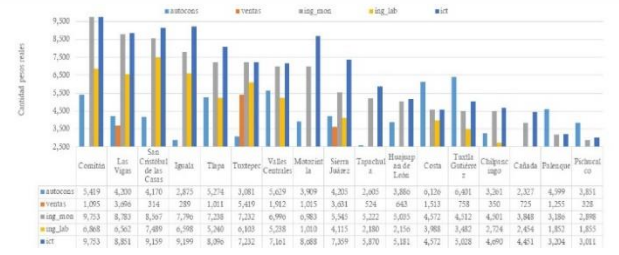
Figure 3 Types of income of rural women P-V/O-I bean producers in the South Pacific Region (2020)
Source: Own elaboration with data from the SADER-SIAP (2020), INEGI-ENIGH (2020)

In the case of men dedicated to bean production activities, the highest levels of monetary income are found mainly in the Isthmus, Coast, Valles Centrales, Altamirano, Tuxtepec and Tapachula (Figure 4).
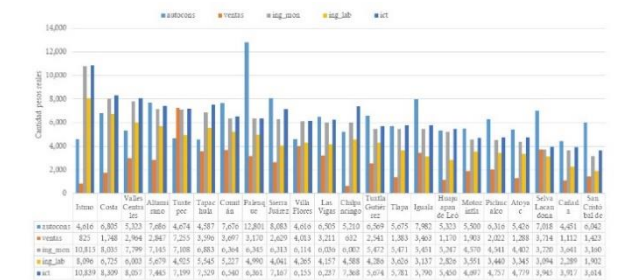
Figure 4 Types of income of rural male P-V/O-I bean producers in the South Pacific Region (2020).
Source: Own elaboration with data from the SADER-SIAP (2020), INEGI-ENIGH (2020)

Socioeconomic vulnerability of bean producers

The bean production sector in the PRS suffers from high levels of vulnerability for multiple structural reasons - land ownership - external reasons - confirms that inflation has a regressive impact on inequality - and internal reasons related to traditional production packages and systems (Morley, 2000, p. 108).

The bean production sector in the PRS suffers from high levels of vulnerability for multiple reasons: structural - land ownership - external - confirms that inflation has a regressive impact on inequality - and internal - related to traditional production packages and systems. Figure 5 shows that bean producers with at least one social deprivation (deprivation) are above 97.5%, with a predominance of people in rural areas; People with deprivation due to access to social security (ic_segsoc) 92.2% in the rural population and 88.1% in urban areas; People in poverty (poverty) 84.8% in rural localities and 87.1% in urban areas, being proportionally higher in urban areas, although in absolute terms it is higher in rural areas; Persons lacking access to basic services in housing (ic_sbv) 83.3% and 57.2%, and Persons in extreme poverty (pobreza_e) 46.3% in rural areas and 38.6% in urban areas, respectively.
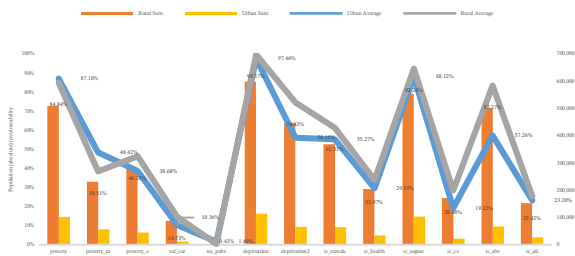
Figure 5 Level of vulnerability of the P-V/O-I bean producer in urban localities of the South Pacific Region (2020)
Source: Own elaboration with data from the SADER-SIAP (2020), CONEVAL (2021), INEGI-ENIGH (2020)

The description of the variables is as follows:

Poverty People in poverty

poverty_mPeople in moderate poverty

poverty_ePeople in extreme poverty

vul_car Vulnerable people due to social deprivation

no_pobvNon-poor and non-vulnerable people

deprivationPopulation with at least one deprivation

deprivations3People with three or more social deprivations

ic_rezeduPeople with educational backwardness

ic_healthPeople lacking access to health services

ic_segsocPeople with lack of access to social security

ic_cv People with housing quality and space deficiency

ic_sbv Persons lacking access to basic services in housing

ic_ali People with food deprivation

In addition to the conditions described above in bean producers, the following conditions are added: People in moderate poverty (pobreza_m) 38.5% rural and 48.4% urban; People deprived by housing quality and spaces (ic_cv) 28.4%, 19.2%; People deprived by access to food (ic_ali) 25.4%, 23.1%; Persons vulnerable due to social deprivation (vul_car) 14.7%, 10.3%; Persons lacking access to health services (ic_asalud) 33.9%, 29.5% , and Non-poor and non-vulnerable persons (no_pobv) 0.43% and 1.69%, respectively (Figure 5).

Figure 6 shows the distribution of the bean farming population for both cycles P-V/O-I in the region by level of marginalization and gender. It can be seen that the majority live in territories with high and very high levels of marginalization, in contrast to those localities with lower levels of marginalization. Consequently, it is confirmed that the population presents the same patterns of inequality and marginalization.

Figure 6 Distribution of bean producers (heads of household plus members) P-V/O-I in the South Pacific Region (2020)
Source: Own elaboration with data from the SADER-SIAP (2020), CONEVAL (2021), INEGI- ENIGH (2020).

Level of food security of the bean population

Based on the indicators included in the INEGI-ENIGH (2020) the Latin American Scale of Food Security (ELCSA) constructed by the United Nations Food and Agriculture Organization (FAO) was used. Food and Agriculture Organization of the United Nations (FAO, 2012).. The classification of food (in)security according to importance is distributed as follows: 28.25% of the bean farming population is in conditions of food security; 43.14% mild food insecurity, followed by the population with moderate food security with 18.57% and severe food insecurity 10.13%. Figure 7 shows the absolute numbers of population in absolute terms - heads of household plus members.

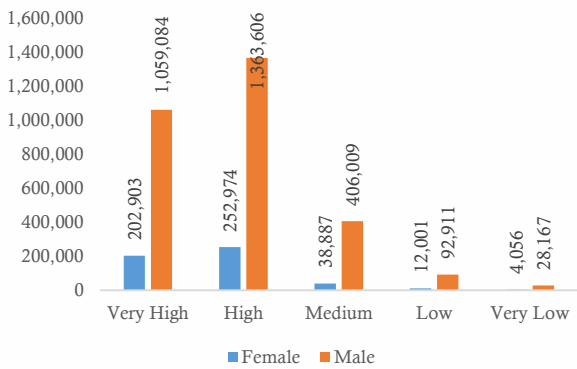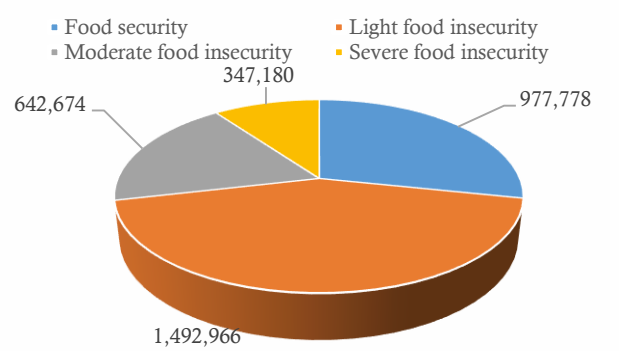**Figure 7** Food security level of the bean population in the South Pacific Region (2010-2019).
Source: Own elaboration with data from the SADER-SIAP (2020), CONEVAL (2021), INEGI-ENIGH (2020).

Food insecurity shows that the majority of the population suffers from very complex conditions in terms of access to food and nutrition. Table 3 shows the main RLDs with heterogeneous food problems.

DDR	Food safety	Mild food insecurity	Moderate food insecurity	Severe food insecurity	Total
Altamirano	6,292	12,304	15,280	8,638	42,514
Atoyac	nd	10,049	1,244	nd	11,293
Cañada	18,726	36,579	31,932	6,372	93,609
Chilpancingo	29,903	57,091	48,784	1,298	137,076
Comitán	144,974	122,035	62,812	37,480	367,301
Costa	17,094	50,221	39,603	7,448	114,366
Huajuapan de Leon	57,874	76,737	69,935	33,989	238,535
Equal	18,338	22,313	9,068	2,380	52,099
Isthmus	1,860	4,780	620	nd	7,260
Las Vigas	36,060	85,374	30,767	21,672	173,873
Motozintla	56,506	113,148	29,406	10,631	209,691
Palenque	120,828	212,237	39,715	35,747	408,527
Pichucalco	39,225	80,324	12,217	6,431	138,197
San Cristobal de las Casas	130,219	127,100	25,896	11,984	295,199
Lacandon Jungle	4,936	nd	1,296	4,536	10,768
Sierra Juarez	18,244	13,658	5,757	nd	37,659
Tapachula	35,568	30,990	5,669	3,080	75,307
Tlapa	52,858	131,723	67,726	28,708	281,015
Tuxtepec	21,269	43,288	25,529	16,776	106,862
Tuxtla Gutierrez	55,269	94,189	21,610	63,988	235,056
Central Valleys	84,685	136,858	83,364	46,022	350,929
Villa Flores	27,050	31,968	14,444	nd	73,462

Table 3 Bean farming population with food (In)security according to DDR
Source: Own elaboration with data from the SADER-SIAP (2020), CONEVAL (2021), INEGI-ENIGH (2020)

Level of education of bean growers

Table 4 shows that 50.2% of the bean population in the South Pacific (1,737,262 heads of household plus members) have incomplete primary education or less. The population with complete primary education represents 26.02% of the total, incomplete secondary education 2.51% and complete secondary education 14.9%. It should also be noted that women have lower levels of educated population, in contrast to men.

Education level	Woman Frequency	Woman Percentage	Man Frequency	Man Percentage	Total Frequency	Total Percentage
Incomplete primary school or less	262,830	7.59	1,474,432	42.61	1,737,262	50.2
Completed elementary school	101,484	2.93	799,035	23.09	900,519	26.02
Incomplete high school	7,989	0.23	78,904	2.28	86,893	2.51
High school completed	97,101	2.81	418,686	12.1	515,787	14.9
Incomplete high school	20,964	0.61	nd	nd	20,964	0.61
Completed high school	21,646	0.63	114,825	3.32	136,471	3.94
Full Normal	3,868	0.11	nd	nd	3,868	0.11
Complete technical career	331	0.01	4236	0.12	4,567	0.13
Incomplete technical career	1,805	0.05	nd	nd	1,805	0.05
Full professional	7,488	0.22	22,695	0.66	30,183	0.87
Professional incomplete	10,147	0.29	12,132	0.35	22,279	0.64
Total	510,821	14.76	2,949,777	85.24	3,460,598	

Table 4 Bean population by level of education.
Source: Own elaboration with data from the SADER-SIAP (2020), CONEVAL (2021), INEGI-ENIGH (2020).

Table 5 shows that the DDRs with the largest bean-producing population in conditions of educational backwardness are: Palenque with approximately 245,250 people; San Cristobal de las Casas (223,499), Valles centrales (208,578), mainly, on the other hand, Atoyac, Istmo and Selva Lacandona have the lowest absolute levels of educational backwardness (own data generated from the INEGI-ENIGH (2020).

DDR	Indicator of educational backwardness		
	No deficiency	Presents deficiency	Total
Altamirano	20,888	21,626	42,514
Atoyac	8,693	2,600	11,293
Cañada	24,536	69,073	93,609
Chilpancingo	48,471	88,605	137,076
Comitán	190,362	176,939	367,301
Costa	20,655	93,711	114,366
Huajuapan de Leon	129,080	109,455	238,535
Equal	19,953	32,146	52,099
Isthmus	3,850	3,410	7,260
Las Vigas	72,583	101,290	173,873
Motozintla	90,866	118,825	209,691
Palenque	163,277	245,250	408,527
Pichucalco	57,858	80,339	138,197
San Cristobal de las Casas	71,700	223,499	295,199
Lacandon Jungle	5,584	5,184	10,768
Sierra Juarez	16,915	20,744	37,659
Tapachula	37,604	37,703	75,307
Tlapa	110,476	170,539	281,015
Tuxtepec	52,070	54,792	106,862
Tuxtla Gutierrez	61,903	173,153	235,056
Central Valleys	142,351	208,578	350,929
Villa Flores	36,241	37,221	73,462
Total	1,385,916	2,074,682	3,460,598

Table 5 Bean population by RDD and level of educational backwardness in the South Pacific
Source: Own elaboration with data from the SADER-SIAP (2020), CONEVAL (2021), INEGI-ENIGH (2020)

Rural and urban bean population

Table 6 shows the pre-pandemic (2018) and early (2020) bean farming population. In principle, there is a larger sample in the last year of almost one million more people engaged in the activity. Consequently, there is an important change in the results: the population with food security in rural areas reached an increase of 78.31%, with mild food insecurity also increased by 29.12%, with moderate food insecurity 9.72% and with severe food insecurity 38.90%. This relationship also shows that approximately 1,721,889 people living in areas with less than 2,500 individuals have some level of food insecurity to a greater extent after the pandemic. In 2020, 61.9% of the producer population reported some level of food insecurity (mild, moderate and severe).

Year	Locations	Food safety	Mild food insecurity	Moderate food insecurity	Severe food insecurity	Total
2018	Urban	90,312	150,942	50,284	50,917	342,455
	Rural	451,185	990,886	519,195	211,808	2,173,074
	Total	541,497	1,141,828	569,479	262,725	2,515,529
2020	Urban	173,256	213,495	73,005	52,969	512,725
	Rural	804,522	1,279,471	569,669	294,211	2,947,873
	Total	977,778	1,492,966	642,674	347,180	3,460,598

Table 6 Bean population in urban and rural localities by food (in)security
Source: Own elaboration with data from the SADER-SIAP (2020), CONEVAL (2021), (INEGI-ENIGH, 2018), INEGI-ENIGH (2020)

Self-consumption and expenditures of bean households by quantile

The second major component of bean growers is their spending and the magnitude according to deciles. On average, a family (head of household) spends $2,344 pesos per quarter. However, this amount changes when examined by deciles. In the first decile the average expenditure is around $146 pesos; second decile $411 pesos, third $630, fourth $769 pesos and successively $1,057; $1,408; $1,862; $2,653; $4,087, until reaching the tenth decile with an average expenditure of $9,209.

Table 7 shows the importance of self-consumption in South Pacific households. The most representative DDR's in average terms are Palenque ($12,534), Sierra Juárez ($8,182), Iguala ($8,176), Altamirano ($7,986) and Costa ($7,025). In contrast, the territories with the lowest levels of self-consumption are: Cañada ($4,420), Tapachula ($4,107) and Istmo ($4,099).

DDR	Average	DDR	Average
Altamirano	7,986.3	Pichucalco	5,835.2
Atoyac	5,221.6	San Cristobal de las Casas	6,621.3
Cañada	4,420.3	Lacandon Jungle	6,928.4
Chilpancingo	4,825.4	Sierra Juarez	8,182.9
Comitán	7,940.4	Tapachula	4,107.8
Costa	7,025.5	Tlapa	5,627.8
Huajuapan de Leon	5,344.1	Tuxtepec	4,576.0
Equal	8,176.7	Tuxtla Gutierrez	6,677.7
Isthmus	4,099.8	Central Valleys	6,168.3
Las Vigas	6,533.3	Villa Flores	5,236.5
Motozintla	5,230.7	Total average	6,912.2
Palenque	12,534.4		

Table 7 Average quarterly expenditure of the bean population according to DDR ($MNN)
Source: Own elaboration with data from the SADER-SIAP (2020), CONEVAL (2021), INEGI-ENIGH (2020).

Cost-benefit impacts

The first quintile of bean producers in the region receive an average per capita labor income of $3,217 and the fourth quintile $6,589 pesos per quarter; agricultural income $4,205 and $5,224 pesos, respectively. It is evident that the agricultural income of primary sector households in Chiapas in the first quantile is slightly higher than in the rest of the states in the region (See Table 8).

Q	Edo.	ictpc	ing_lab	ing_mon	ing_tra	agrope	aexp	age	Members
1		1,322	3,217	4,720	1,498	4,205	36.91	47.2	2.41
2		1,617	4,038	5,684	1,645	4,404	37.96	49.6	2.44
3	Total average	1,493	4,074	5,683	1,568	4,307	40.21	50.4	2.34
4		2,111	6,589	9,241	2,628	5,224	37.68	49.2	2.49
1		1,323	3,438	4,848	1,399	5,969	36.65	47.7	2.45
2	Chiapas	1,679	4,197	5,766	1,569	5,326	38.40	49.6	2.56
3		1,376	4,147	5,320	1,079	5,657	39.16	47.7	2.43
4		1,536	4,174	6,908	2,686	3,916	37.19	46.7	2.57
1		1,334	3,098	4,791	1,693	2,442	36.95	45.4	2.38
2	Guerrero	1,176	3,417	4,750	1,333	2,930	36.60	47.8	2.44
3		1,347	3,791	5,522	1,720	2,273	40.00	49.0	2.46
4		2,437	8,481	11,050	2,568	6,693	36.15	50.5	2.43
1		1,312	2,940	4,720	1,498	4,205	37.29	47.6	2.37
2	Oaxaca	1,868	4,249	5,684	1,645	4,404	38.20	51.1	2.20
3		1,681	4,128	5,683	1,568	4,307	41.55	53.8	2.21
4		2,620	8,233	9,241	2,628	5,224	39.68	51.4	2.45

Note: Q quantile; ing_lab quarterly labor income; ing_mon quarterly monetary income; ing_tra transfer income; ing_tra quarterly cash income; ing_lab quarterly labor income; ing_mon quarterly cash income; ing_tra transfer income

Table 8 Characteristics of real income ($MN), years of experience and age of bean producers in the South Pacific.
Source: Own elaboration based on data from the INEGI-ENIGH (2020)

Impact of ProAgro benefits to bean producers in the region

Table 8 shows the results of the estimates of the average treatment effect in the treated group using nearest neighbor matching for those who are beneficiaries of the ProAgro program considering total per capita autonomous (labor) income, age, indigenous language status, poverty, amount obtained from the sale of beans, quantity sold, price per kilo of the product (in logarithm), autonomous consumption valued by the household, of goods produced or marketed by some of its members and, for which no value has been paid (quarter). The weights for each household were used on the basis of the expansion factor in accordance with the ENIGH-INEGI (2020) in the calculations. With this, the sample can be extrapolated to the whole population with statistical significance. In addition, the income of individuals was classified by quantiles considering the quarterly current income 2020.

As noted in the methodology, the matching method (PSM) sought to match each bean producer with an identical non-participant and then measure the average difference in ProAgro support outcome between the benefited and non-benefited producers, also considering labor income as a control variable. We sought to satisfy the equilibrium property.

Average treatment effect by nearest neighbor matching

Table 9 shows the results of estimating the average treatment effect of female participation in ProAgro support at the 2,500 locations. It is important to note that a female bean producer who receives ProAgro support receives, on average, $2,669 pesos of labor income, in contrast, quarterly valued autonomous consumption reaches $1,388 pesos. In contrast, the female sector without ProAgro receives 4,395 pesos for labor income on average, and the amount for autonomous consumption valued in a quarter is $983 pesos.

Location	Sample	Differences	S.E.	t
Less than 2500 inhab. Woman	ATT[1]	-1,125	866	-1.300
	ATE[2]	-1,012	583	-1.735
	RM[3]	-510	888	-0.575
	ATTK[4]	-1,132	756	-1.498
Less than 2500 inhab. Man	ATT[1]	-517	538	-0.961
	ATE[2]	-134	401	-0.335
	RM[3]	-310	407	-0.762
	ATTK[4]	-72	349	-0.207
Less than 2500 inhab. Female/Male	ATT[1]	-81	440	-0.185
	ATE[2]	-264	356	-0.744
	RM[3]	-107	383	-0.281
	ATTK[4]	-265		-0.758
Largest 2500 inhab. Female/Male	ATT[1]	-1,049	1,641	-6.39
	ATE[2]	-802	.	.
	RM[3]	-2,642	1,908	-1.385
	ATTK[4]	-791	1,124	-704

Table 9 Impact of the ProAgro program on the autonomous income of bean producers by locality.
Source: Own elaboration based on data from the INEGI-ENIGH (2020)
[1]Effect through nearest neighbor matching.
[2]Average treatment effect by stratification matching.
[3]Average treatment effect using radius matching
[4]Average treatment effect using kernel matching

Robustness of the analysis of average treatment effects

The average treatment effect on the outcome of interest is estimated using direct nearest neighbor matching with one match per treatment in the bean production sector (Table 10).

Location	Sample	Differences	S.E.	z	P>|z|	[95% conf. interval]
Less than 2500 inhab. Woman	SATT	-2,398	755	-3.18	0.001	-3,879 -918
	ATE	-1,775		-3.47	0.001	-2,779 -771
Less than 2500 inhab. Man	SATT	-368	385	-0.96	0.340	-1,123 387
	ATE	-419	331	-1.26	0.207	-1,069 231
Less than 2500 inhab. Female/Male	SATT	-709	349	-2.03	0.042	-1,395 -24
	ATE	-487	273	-1.78	0.075	-1,024 49
Largest 2500 inhab. Female/Male	SATT	-2,288	975	-2.35	0.019	-4,200 -376
	ATE	-1,046	851	-1.23	0.219	-2,715 623

Table 10 Robustness of the impact of the ProAgro program on the autonomous income of the bean-producing sector in the region
Source: Own elaboration based on the Propensity Score Matching (PSM) technique with data from the INEGI-ENIGH (2020)
Note: Standard error. S.E. does not take into account that the propensity score is estimated. The contrast analysis variable is the per capita labor income of agricultural households in the region.
SATT = Average treatment effect for the treated.
ATE = Average treatment effect.

Acknowledgment

Conclusions

The outputs show that the ProAgro program targets a population of bean producers with vulnerable characteristics and negative impacts on *per capita* labor income among heads of households in the region. It is evident that there is a substantial difference between those who receive the program and those who receive labor income. The latter is greatly reduced in localities of 2,500 inhabitants or less. The average treatment of treaties (ATT) in per capita autonomous (labor) income is reduced by $1,125 pesos in the female sector, on average, with respect to those who are beneficiaries of the ProAgro program in localities with less than 2,500 inhabitants, compared to the male sector, which decreases to a greater extent with $517 pesos. In contrast, in localities with more than 2,500 inhabitants, there is a reduction in labor income of $2,280 pesos, limiting the incentives to find jobs in the beneficiaries of the program due to the dependency that may be generated (negative externalities and economic-social costs in the beneficiary individuals). Consequently, it is necessary that the design and implementation of public policies present holistic solutions to the problems (innovations, technological packages, food security, jobs, etc.) and that government institutions at all levels establish greater monitoring systems and impact evaluations to focus (scarce) economic resources towards actions that improve living conditions; in addition, public management and administration of the most needy territories require strengthening actions from a social and solidarity economy approach and social impact that really have a positive impact on society.

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Economic evaluation of solar drying process for washed coffee in mixteca region of Oaxaca state, México

Evaluación económica del proceso de secado solar para café lavado en la región mixteca del estado de Oaxaca, México

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Abstract

Solar drying is an alternative innovation to process where product is exposed to direct sunlight and outdoors and where final quality is not always optimal. Solar dryers are installations that require little capital and low maintenance costs, are easy to build and use any locally available material. Objective of this work was to evaluate economic efficiency of drying process of washed coffee beans using a solar dryer built with regional materials. Study was carried out during 2022 coffee harvest, in a passive semi-parabolic greenhouse solar dryer, with an external cover of 36 m² as a collector. Results showed a unit cost of $11.29 MXN on average to dry a kilogram of washed coffee and transform it into parchment coffee; the benefit/cost ratio was 1.40 and the investment recovery period was determined in one months, values that make solar drying unit a highly profitable option.

Resumen

El secado solar es una innovación alternativa al proceso donde se expone el producto a los rayos solares de manera directa y a la intemperie y donde la calidad final no siempre es la óptima. Los secadores solares son instalaciones que requieren de poco capital y bajos costos de mantenimiento, son de fácil construcción y se utiliza cualquier material disponible localmente. El objetivo del presente trabajo fue evaluar la eficiencia económica del proceso de secado de grano de café lavado mediante un secador solar construido con materiales regionales. El estudio se realizó durante la cosecha de café 2022, en un secador solar de invernadero semiparabolico tipo pasivo, con una cubierta externa de 36 m² como colector. Los resultados mostraron un costo unitario de $11.29 MXN en promedio para secar un kilogramo de café lavado y transformarlo en café pergamino; la relación Benéfico/Costo fue de 1.40 y el periodo de recuperación de la inversión fue determinado en un mes, valores que hacen de la unidad de secado solar, una opción altamente rentable.

Unit cost of drying, B/C ratio, Payback period

Costo unitario de secado, Relación B/C, Periodo de recuperación

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Introduction

Sun drying is perhaps one of the oldest methods in which solar radiation is used for food preservation, the traditional way being to extend it under the sun for periods that vary according to the product, but there are serious limitations, as the product in the drying process is affected by rain, dust, insects, rodents or domestic animals.

Drying with the help of solar radiation is a very economical procedure for agricultural products and on the other hand it is very environmentally friendly (Shimpy *et al.*, 2019). However, to increase the efficiency of material drying by solar radiation, a suitable innovation or application is needed (Hii *et al.*, 2019; Upadhyay and Singh, 2017; Yoo *et al.*, 2017).

The alternative innovation to solve this problem has been the development of technology to maximise the use of solar radiation potential in the drying process, referred to as solar drying. There is now a wide variety of designs and sizes of solar dryers that can be used for drying a variety of foods of agricultural origin. They are low capital and low maintenance cost installations, are easy to construct and any locally available material can be used (El-Hage *et al.*, 2018).

The tendency of the designs is towards simplicity, as there is no significant difference in the results obtained with more primitive designs compared to more sophisticated ones (Sharma *et al.*, 2018). They are generally low-capacity equipment, mainly used for drying various foods of agricultural origin, either for family use or for marketing some surplus (Belessiotis and Delyannis, 2011).

In recent years, solar dryers have become popular in the agricultural sector, due to their cost-effectiveness and the use of a clean energy source (Ahmadi *et al.*, 2021), because when the different economic parameters, such as break-even point, net present value, payback period, cost-benefit ratio, annuity and internal rate of return, are calculated, they are highly profitable, so their economic viability is high (Mohana *et al.*, 2020; Singh *et al.*, 2020).

Solar dryers are highly effective devices with low investment to produce good quality dry products (Mathew *et al.*, 2018).

However, factors such as production capacity for drying, drying time, climatic conditions depending on the time of year, cost of dryer components and accessories, labour costs and variable or miscellaneous costs need to be taken into account for economic calculations (Mohana *et al.*, 2020). In all cases, the capital cost of the dryer is used, however, the operating cost of the dryer is not included in the total cost of the solar dryer (ELkhadraoui *et al.*, 2015).

Kesavan *et al* (2019), performed an economic analysis of a solar dryer in a very simple way, determining the cost of the material dried inside the dryer annually, the net profit obtained annually from the dryer, the payback time of the dryer investment. El-Hage *et al.* (2018) conducted an economic study to evaluate the monetary savings due to the application of dryers, they used as parameters the percentage of time the solar dryer is used, the mass of dry feed and the type of feed. Keke *et al.*, (2014) report the economic evaluation of low-cost direct and indirect passive dryers using fixed cost - construction and maintenance cost indicators and a qualitative performance evaluation.

Another approach to economic analysis is the incorporation of cost/benefit analysis. It involves comparing the total expected cost of each option with the total expected benefits, to see if and by how much the benefits outweigh the costs taking into consideration the size, construction materials, efficiency, operation, sophistication and sustainability of the dryers (Dhanushkodi *et al.*, 2015; Desa *et al.*, 2020). To determine the payback period, the capacity of the dryer must be considered and is calculated by dividing the initial investment by the annual cash flows and measures the time period between the investment and its payback (Mohana *et al.*, 2020; Singh and Gaur, 2020; Dhanushkodi *et al.*, 2015).

When performing the economic evaluation of solar drying, drying costs are a function of time and the total investment cost of dryer construction, equipment depreciation, volume of product to be dried, wages per load and administration costs. On the other hand, it is necessary to determine the unit cost of solar drying, which is the ratio between the total annualised cost of the solar dryer and the annual amount of product dried in the solar dryer (Tripathy, 2015).

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The objective of the present work is to determine the economic efficiency of the solar drying process of washed coffee using a solar dryer constructed with regional materials.

Materials and method

The economic evaluation of the drying process was carried out in a dryer classified as a passive type direct semi-parabolic greenhouse, with an external cover of 36 m2 considered as a solar energy collecting surface. It was built with materials from the region: wood and bamboo, covered with greenhouse plastic.

The dryer is located in the following geographical location: 16°40'33" N and 97°47'15" W, at an altitude of 1677 m above sea level, in Zaragoza Itundujia, located in the coffee-growing area of the Oaxacan Mixtec region.

For the economic evaluation, it was determined:

1. The drying cost to obtain a kilogram of parchment coffee (Intawee and Janjai, 2011; Singh and Gaur, 2020), using the following equations:

$$C_{us} = \frac{C_{an}}{P_{sa}}$$

Where:
C_{an} Total annual cost of solar dryer.
P_{sa} Total amount of product dried in the solar dryer solar dryer annually.

To obtain the above, it is necessary to determine the following values:

A.   The annual cost of the solar dryer (Cas) is given as

$$C_{as} = C_{ca} + C_{mt} - V_r + C_{oa}$$

Where:
C_{ca} Annual capital cost, including initial infrastructure initial cost of infrastructure,
C_{mt} Annual maintenance cost of the dryer solar
V_r Recovery value
C_{oa} Annual operating cost of the dryer

B.   The total amount of products dried annually in the solar dryer (Psa) is given by:

$$P_{sa} = \frac{M_{ps}D_u}{D_n}$$

Where:
M_{ps} Mass of product dried per batch in a solar dryer solar dryer,
D_u Number of days during which the dryer is used in the year, D_u dryer is used in the year,
D_n Number of days needed to dry the material per batch material per batch.

2. Payback period (Pr) is the period of time needed to recover the cost of the investment and was calculated using the following formula (Yelmen *et al*., 2019; Krungkaew *et al*., 2020)):

$$\text{Pr} = \frac{I_{ss}}{B_{na}}$$

Where:
C_{an} Investment in the solar dryer,
B_{na} Annual net profit or income.

Results and discussion

The results presented are related to the drying of coffee in a passive semi-parabolic direct greenhouse solar dryer, with an external cover of 36 m2, from a volume of 200 kg (19.5 kg/m2) of coffee beans dried per load.

In relation to the results regarding the cost of drying one kg of material, the initial cost of the dryer was $8,817.00 pesos (Table 1), where 34.2% corresponds to the cost of materials obtained from the region, 25% to the cost of labour to build it and the rest corresponds to complementary materials for its construction. In addition, the annual maintenance cost was $3,000.00 with no recovery cost.

The total amount of coffee dried annually is 1400 kg per season, starting from 200 kg per drying batch, with an average drying time of 10 days, as it depends entirely on the weather, which during the coffee harvesting season is humid and foggy most of the day. Even though the approximate time of use of the dryer is 90 days, which corresponds to the duration of the harvest, it is only feasible to carry out seven loads or drying processes of coffee per season.

Materials	Cost ($)	%
Materials from the region		
Polines, bamboo, wood	3,020.00	34.2
Materials purchased externally		
Greenhouse plastic, metal mesh, screws, staples, nails, hinges, wire, raffia, etc.	3,597.00	40.8
Labour		
12 jornales	2,200.00	25
Total:	8,817.00	100

Table 1 Composition of the total cost of the solar dryer

The results of the economic indicators are presented in Table 2, from evaluating the solar drying process to obtain parchment coffee from washed coffee beans in the coffee-growing area, in the Mixtec region of the state of Oaxaca.

Economic indicator	Value
Annual unit cost of drying	$11.29
B/C ratio	1.40
Payback period	1 mes

Table 2 Economic indicators of the process of solar drying of washed coffee beans

The unit cost of drying one kg of washed coffee into parchment coffee was $11.29 on average for the 2022 harvest season. This result reveals that the solar drying process is quite simple and the unit cost of drying one kg of product depends mainly on the initial investment for construction, the operating cost for labour, maintenance cost, as well as the cost of the volume of product to be dried and the drying time, which ultimately determines the usage time of the dryer (Sharma *et al.*, 2018; Poonia *et al.*, 2019).

On the other hand, the Benefit/Cost ratio was 1.40 for the case study, higher than the value of 1.21 reported by Mohod *et al.* (2011), but lower than the value reported by Dhanushkodi *et al.* (2015) when drying 40 kg of cashew nuts in a solar dryer, which was 5.23. Also lower than the economic indicator value of benefit/cost ratio of 2.09 (Poonia *et al.*, 2019). Results showing the potential of using solar dryers for drying different agricultural products.

With the net income of the harvest season where the dryer was used and applying the equation of the payback period of the investment, we have a value of 0.15, which implies the proportion of time corresponding to the period of use, so the payback period is less than three months and to know in which load it will be, the following operation is performed:

Pri = 0.157*7 = 1.1

This means that the recovery takes place at the end of the second drying run, but as the drying period must be completed, then it is in the second drying run, i.e. in approximately one month.

Thus, the payback period for the dryer studied was determined to be only one month, which is less than that reported by El-Hage et al. (2018), who report a payback period of 10 months when using a dryer with a capacity to dry 120 kg of carrots. Also lower than that reported by Prakash et al. (2016), who determined a recovery period of 1.11 years for a modified greenhouse solar dryer when drying sliced potato, and well below the values reported by Fudholi et al. (2015), who reported an average period of 2.6 years and by Mohod et al. (2011), who reported a recovery period of 2.84 years.

On the other hand, ELkhadraoui et al (2015) mention that a payback period of 1.6 years is very small compared to the lifetime of solar dryers, which on average is 20 years. These low payback period values, which average between 1 to 2 years approximately (Singh and Gaur, 2020), make a solar drying unit very cost-effective (Poonia *et al.*, 2019).

Conclusions

–   The unit cost of drying was $11.29 MNX on average for the 2022 harvest season, and is a good benchmark for comparison for drying processes in different solar dryer designs, as it depends primarily on the initial investment with low maintenance costs.

–   The Benefit/Cost ratio was 1.29 for the case study, which makes it feasible to use solar drying for drying washed coffee.

–   The payback period for the dryer studied was determined to be two months, less than the average values of approximately 1 to 2 years reported in the literature, which makes the solar drying unit very profitable.

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Study of the physicochemical characteristics and viscosity profile of *Cucúrbita pepo* L.

Estudio de las características fisicoquímicas y perfil de viscosidad de la *Cucúrbita pepo* L.

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Abstract

Pumpkin cultivation is an agricultural economic activity that is carried out in several states of Mexico, of which mainly the seed is marketed. The pulp remains in some cases as a by-product and is used for livestock feed (some farmers discard it in the field and incorporate it into the soil, leaving it as an organic fertilizer (SADR, 2020). By having a physicochemical characterization of the different parts of the fruit and a viscosity profile of the seed oil, it is possible to identify its potential future uses in agroindustry. A proximal analysis of the parts and the viscosity profile of the pumpkin seed oil under isobaric conditions was carried out; obtaining the data of shell, pulp, seed (whole and raw), kernel (raw), seed husk, seed (whole and roasted); which serve as points of comparison with other studies carried out and decision making. The following physical properties were analyzed: moisture percentages, bound water, ash, crude fiber, and chemical properties: conductivity, pH, total nitrogen, protein percentage, lipids, organic carbon, C/N ratio, calcium and magnesium. For the oil extracted from the raw seed, viscosity and density were also determined at different temperatures under isobaric conditions.

Peel, Pulp, Seed, Seed oil, Viscosity isobar

Resumen

El cultivo de la calabaza es una actividad económica agrícola, que se realiza en varios estados de México, de éste, se comercializa principalmente la semilla. La pulpa queda en algunos casos como un subproducto y se utiliza para alimento de ganado (algunos agricultores la desechan en el campo y la incorporan al suelo, quedando como un abono orgánico (SADR, 2020). Al tener una caracterización fisicoquímica de las diferentes partes del fruto y un perfil de viscosidad del aceite de la semilla, es posible identificar sus potenciales usos futuros en la agroindustria. Se realizó un análisis proximal de las partes y el perfil de viscosidad del aceite de las semillas de calabaza en condiciones isobáricas; obteniendo los datos de cáscara, pulpa, semilla (entera y cruda), pepita (cruda), cascarilla de semilla, semilla (entera y tostada); que sirvan como puntos de comparación con otros estudios realizados y la toma de decisiones. Se analizaron las siguientes propiedades físicas: porcentajes de humedad, agua ligada, cenizas, fibra cruda, y las propiedades químicas de: conductividad, pH, nitrógeno total, porcentaje de proteínas, lípidos, carbono orgánico, relación C/N, calcio y magnesio. Para el aceite extraído de la semilla cruda, se determinó adicionalmente, la viscosidad y densidad a diversas temperaturas en condiciones isobáricas.

Cáscara, Pulpa, Semilla, Aceite de semilla, Isobara de viscosidad

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Introduction

Pumpkin (*Cucúrbita pepo* L.) is an annual crop of temperate climate very rooted in Mexico, although it can grow from sea level, up to 2700 metres. It has a great diversity of fruit sizes, colours and shapes, as well as ripening periods; it is part of the Mexican diet (Martínez Alvarado, 2000).

Pumpkin is one of the most important crops in Mexico, together with maize and beans, which is why Mexico is ranked 7th in the world in terms of production. The main pumpkin producers in the country are located in the states of Sonora, Sinaloa, Tlaxcala, Nayarit, Hidalgo, Puebla and Morelos (CANABIO, 2019).

Most of the states' production is destined for international markets (Japan, Canada and the United States). It is reported that, in recent years, pumpkin seed production has increased considerably, with more than 8,000 hectares currently under cultivation (IICA, 2018).

Pumpkin has nutritional properties, such as vitamin A, B, C and E. It also contains minerals, being rich in potassium, calcium, magnesium, iron and zinc. In addition, it has a high beta-carotene content (Agrolanzarote, 2012).

Regarding oil concentrations, several studies report 28% for pumpkin seed, 30% for sunflower seed and 15 to 23% for soybean seed (Hernández A. 2010). It is important to highlight that 10% of the weight of the pumpkin is the seed inside, being this the material of greatest interest for producers, which is the reason for this research (Hernández Ángel, 2010).

The pumpkin and its components have various uses, among them are: the production of sweets, soaps, oils, purees, flour, ornamental, snacks, mole de pepita, fodder for livestock, pots, medicinal (anti-inflammatory, laxative, source of fibre, deworming, healing of sores and burns, treatment of haemorrhoids), treatment of wastewater through enzymes (Espinosa, 2018).

The uses of the oil have diversified, for example: in the food industry, in the cosmetics industry, for bioenergy production, aromatherapy, gastronomy, crop protection, medical industry and others (Díaz Gómez, 2010).

The purpose of physicochemical characterisation of the pumpkin components: fruit peel, pulp, seed (whole and raw), kernel (raw), seed husk, seed (whole and roasted); is to determine the physical properties of the pumpkin components: moisture, bound water and ash. For the oil derived from the seed, to analyse viscosity, density at various temperatures, conductivity, and pH. As well as determining the chemical properties of the pumpkin seed components: total nitrogen, proteins, lipids, organic carbon, C/N ratio, crude fibre, calcium and magnesium, with the intention of identifying attributes of potential biotechnological development (Rössel *et al.* 2018).

Methodology to be developed

A sample of pumpkin was obtained from the Colegio de Postgraduados Campus Salinas de Hidalgo, S.L.P., and physicochemical analyses were performed with four replicates on the peel, pulp, seed (whole and raw), kernel (raw), seed hull, seed (whole and roasted).

Moisture determination

To determine the percentage of moisture by gravimetric method, the samples were placed in a drying oven at 65 °C until a constant weight was obtained between three consecutive weighings. For the calculations, the following formula was applied (NMX-F-083-1986, 1986).

$$\% \ Humidity = \frac{(B-A)-(C-A)}{(B-A)} x 100 \qquad (1)$$

Where:
A= Weight of bottle at constant weight [g].
B= Weight of bottle at constant weight with wet sample [g] [g
C= Weight of bottle at constant weight with dry sample [g].

Determination of Total Solids

The Total Solids (St) were obtained by difference, with respect to the percentage of moisture, with the following relation (NMX-F-083-1986, 1986).

$$\% \ St = 100\% - \% \ Humidity \qquad (2)$$

Determination of bound water

The bound water is determined by the oven gravimetric method. Dry samples at 65°C were placed in a drying oven at 135°C until a constant weight was obtained between three consecutive weighings. For the calculations, the following formula was applied (Skoog, West, & Holler, 2015).

$$\%Bonded\ water = \frac{(B-A)-(C-A)}{(B-A)} \quad (3)$$

Where:
A= Weight of bottle at constant weight [g].
B= Weight of bottle at constant weight with dry sample at 65°C [g] [g].
C= Weight of jar at constant weight with dry sample at 135°C [g].

Ash Determination

To determine the ash percentage by gravimetric method, one gram of the materials with moisture determined at 65°C was taken, put into the muffle and subjected to 600°C until a white-greyish residue was obtained; the ash percentages were calculated. This percentage was obtained by difference of weights, using the following formula (NOM-Y-607-NORMEX, 2013).

$$\% Ashes = \frac{[(crucible\ weight\ +Ashes)-(crucible\ weight)]}{sample\ weight} x100 \quad (4)$$

All expressed in grams [g].

Determination of volatile solids

Once the ash percentage was determined (NOM-Y-607-NORMEX, 2013), the percentage of volatile solids was calculated by difference, using the difference of ash percentages, with the following formula.

$$\%Sv = 100\% - \%Ashes \quad (5)$$

Determination of fats

Extractions of each of the pumpkin components were carried out in four replicates. The ethereal extract was determined by the Soxhlet method. The following formula was used: (NMX-F-615-NORMEX-2018, 2018).

$$\%Fats = \frac{(P-p)}{m} x100 \quad (6)$$

Where:
P = Mass of flask with fat [g].
p = Mass of the flask without fat [g]
m = Mass of sample [g]

Figure 1 Fat determination
Own Source

Determination of total nitrogen

Total nitrogen was determined by the Kjeldahl method, based on the destruction of organic matter with concentrated sulphuric acid. Due to chemical reactions ammonia is released, which is recovered by distillation and received in sulphuric acid. Upon reaction, ammonium sulphate is formed, the excess acid is titrated (titrated) with sodium hydroxide, using methyl red as an indicator (NOM-F-68-S-1980, 1980).

Determination of organic carbon

To calculate the percentage of organic carbon from the percentages of organic matter (volatile solids). C/N ratios were calculated for each of the samples, using the following formulas (Skoog, West, & Holler, 2015):

$$\%Organic\ Carbon = \frac{\%\ Organic\ matter}{1.724} \quad (7)$$

Where:
1.724 = conversion factor

Determination of the Carbon/Nitrogen Ratio

From the data obtained for the percentages of organic carbon and nitrogen, the C/N ratio is determined using the following formula:

$$\frac{C}{N} = \frac{\%Organic\ Carbon}{\%Total\ Nitrogen} \quad (8)$$

Determination of Calcium and Magnesium

These minerals were determined by the complex-metric-volumetric method; for the extraction of calcium and magnesium minerals from solid ashes, concentrated hydrochloric acid (HCl) was added to the sample, heated and the crucible where the ashes were obtained was rinsed with distilled water to obtain an aqueous solution (Skoog, West, & Holler, 2015). For Calcium and Magnesium, the standard method for determination of Ca++ in water is used (NMX-AA-072-SCFI-2001, 2001).

Determination of crude fibre

Crude fibre was determined by acid and alkaline digestion of the different samples, obtaining a residue of crude fibre and salts, which with subsequent calcination quantifies the crude fibre for each component of the pumpkin seed (NMX-F-090-S-1978). The methods used for the physicochemical analysis of pumpkin oil were as follows:

Viscosity determination

To measure viscosity, the Oswald viscometer method was used, which is based on the principle of the driving force of gravity to make a substance flow through a capillary tube, where the time required for the oil to travel a known distance was measured (NMX-F-808-SCFI-2018, 2018).


Figure 2 Viscosity determination
Own Source

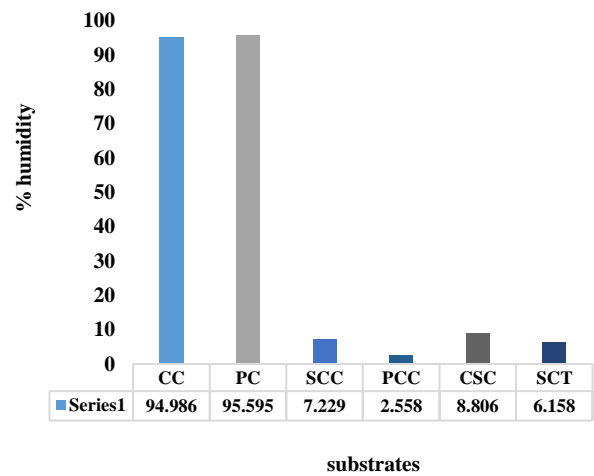## Determination of Conductivity and pH

Conductivity and pH were determined with the multiparametric equipment, brand OAKTON, model PCD650.

Results

The graphs with nested tables abstract the averages of the data determined for pumpkin peel "CC", pumpkin pulp "PC", whole and raw pumpkin seed "SCC", pumpkin seed (raw) "PCC", pumpkin seed hull "CSC", pumpkin seed (whole and roasted) "SCT".


	CC	PC	SCC	PCC	CSC	SCT
■ Series1	4.961	4.359	92.508	97.34	91.149	93.745
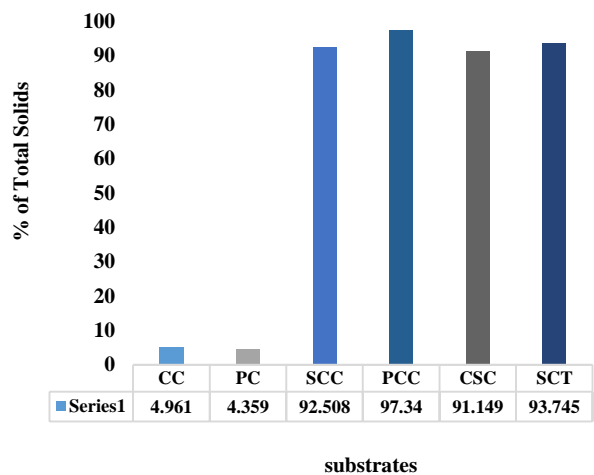
Graph 1 Percentage of total solids in the different substrates
Own Source

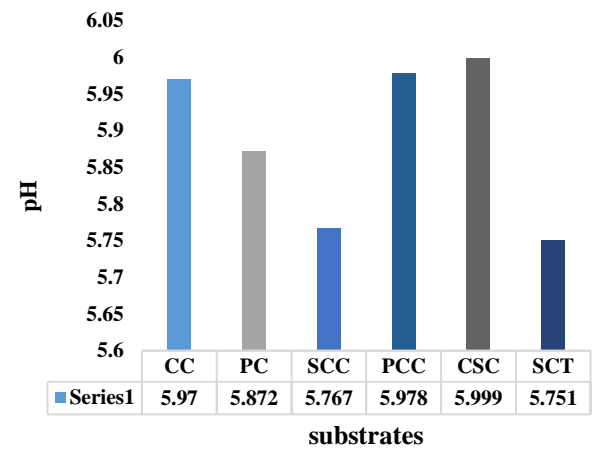|	CC	PC	SCC	PCC	CSC	SCT
■ Series1	94.986	95.595	7.229	2.558	8.806	6.158

Graph 2 Percentage of moisture in the different substrates
Own Source

      Graphs 1 and 2 correspond to the percentages of Total Solids and Moisture; the direct relationship between the contents of the substrates is observed. The pumpkin shell (CC) has 4.961% of Total Solids (St) and 94.986% of moisture; in the same way, the pumpkin pulp (PC) has 4.359% of St and 95.595% of moisture; in the same way it is observed in the substrates corresponding to the pumpkin seeds.

The direct relation of the contents of St and moisture, the whole and raw pumpkin seed "SCC" with 92.508% and 7. 229% respectively, pumpkin seed (raw) "PCC" 97 34% and 2.558%; with the same behaviour of these physical parameters, pumpkin seed husk "CSC" has 91.149% and 8.806% in line with the data; pumpkin seed (whole and roasted) "SCT" indicates 93.748% St and 9.158% moisture; it is in line with the data obtained for the pumpkin seed components. All results are within the expected range when compared to other studies (Rössel *et al.* 2018).


	CC	PC	SCC	PCC	CSC	SCT
■ Series1	323.960	330.505	320.950	0.000	0.000	0.000
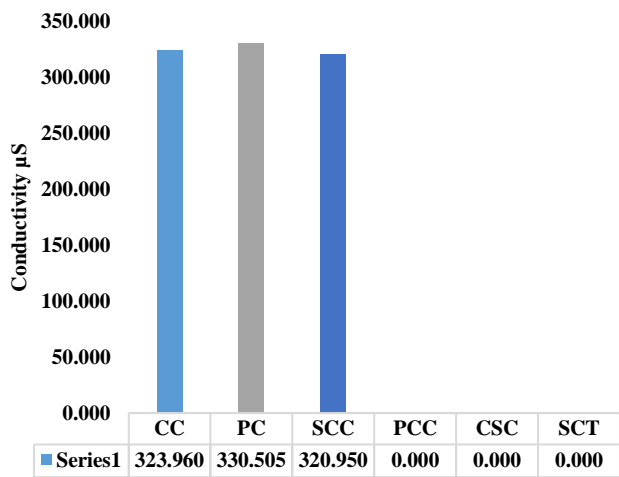
Graph 3 Conductivity μS on the different substrates
Own Source

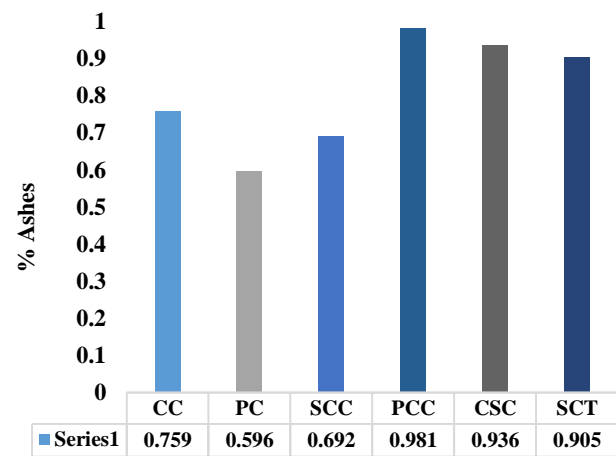|	CC	PC	SCC	PCC	CSC	SCT
■ Series1	5.97	5.872	5.767	5.978	5.999	5.751

Graph 4 pH on the different substrates
Own Source

Graph 3 shows the conductivity of the pumpkin components, of which it was only possible to measure the pumpkin shell with 323.960 μS, pulp with 330.505 μS and seed with raw shell with 320.95 μS, in agreement with those reported by other studies (Ibid.).

Graph 4 shows that, for pH, the highest value is for pumpkin seed husk with a value of 5.999 and the lowest value is 5.751 for whole and roasted pumpkin seed; both values are slightly acidic due to the presence of oils (IICA, 2018).


	CC	PC	SCC	PCC	CSC	SCT
■ Series1	3.403	3.045	4.563	2.115	75.267	4.651
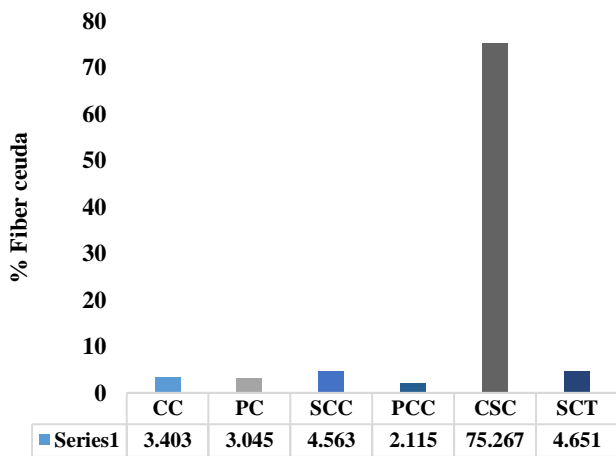
Graph 5 Percentage of crude fibre in the different substrates
Own Source

|	CC	PC	SCC	PCC	CSC	SCT
■ Series1	0.759	0.596	0.692	0.981	0.936	0.905

Graph 6 Percentage of ash in the different substrates
Own Source

In relation to crude fibre, graph 5 shows that the seed husk is outstanding in all the samples analysed, with 75.267 gr/100 grams of sample, the other data being less than 4.7 gr/100. The results of ash according to graph 6, are in a range from 0.596% to 0.981%, which reflect very close values (NOM-F-90-S-1978, 1979).

The highest fat content according to graph 7 is found in the samples with the seed; the highest is in the whole roasted pumpkin seed "SCT" and the lowest is in the pumpkin seed hull "CSC" which represents 1.46%.
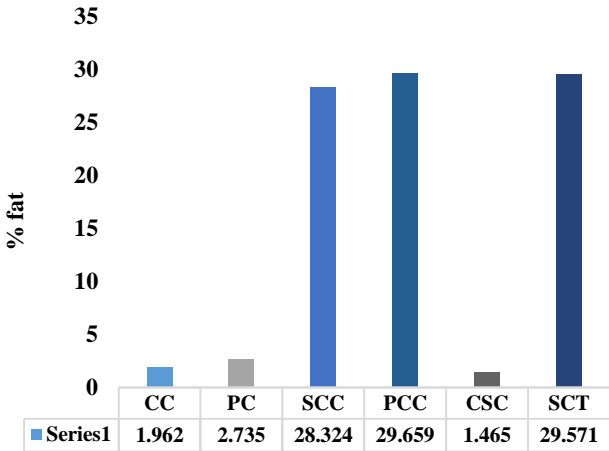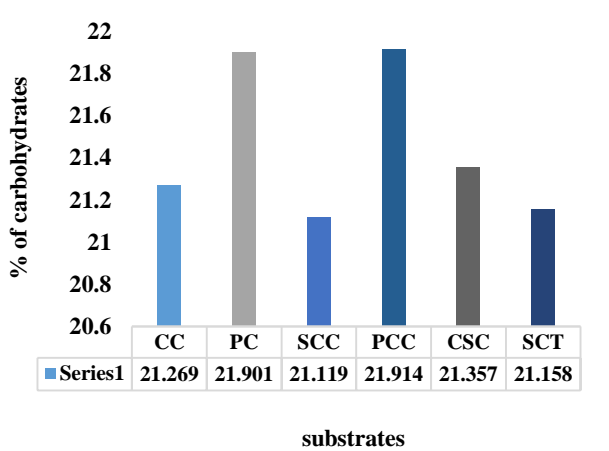
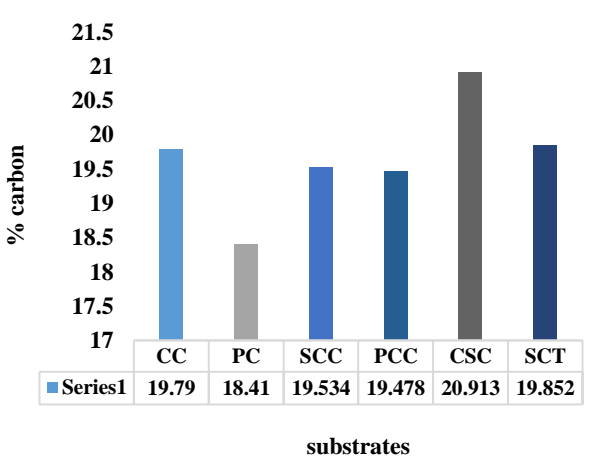**Graph 7** Percentage of fats in the different substrates
Own Source
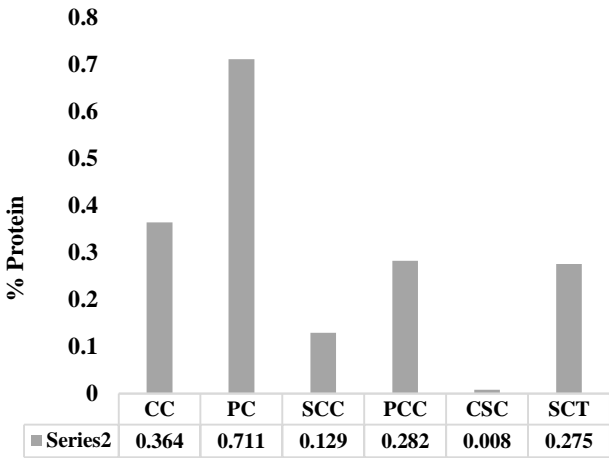
Graph 8 Percentage of proteins in the different substrates
Own Source

Graph 8 shows the percentage of protein, the pumpkin pulp "PC" has the highest value of 0.711% and the one with the lowest content is "CSC" with only 0.008%.


Graph 9 Percentage of carbohydrates in the different substrates
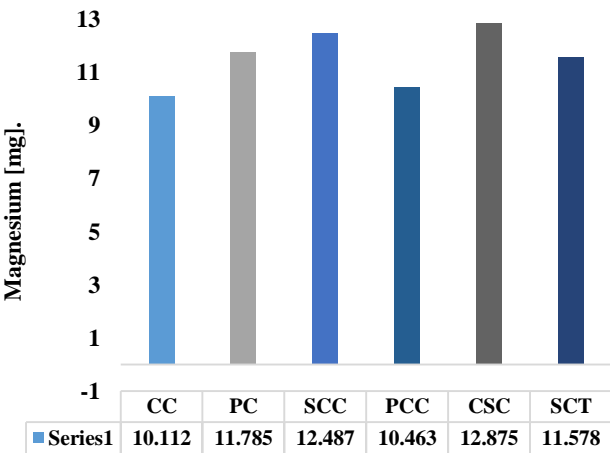*Own Source*

Graph 10 Percentage of carbon in the different substrates
Own Source

In carbohydrates (graph 9) all the values are very close, ranging from 21.119 % to 21.914%, with a minimal difference, which is not significant. In relation to the previous parameter is the percentage of carbon (graph 10), presenting the same behaviour due to the strong relationship between the two (Rodríguez Quispe, 2014).
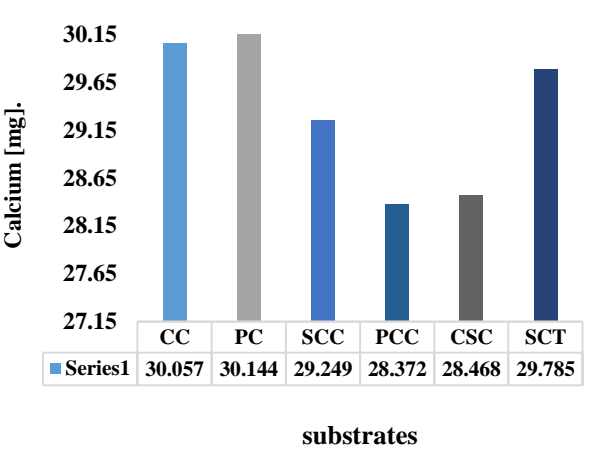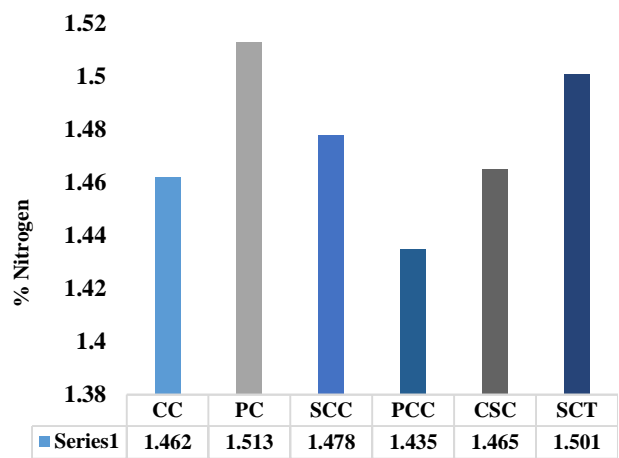

Graph 11 Calcium (mg) in the different substrates
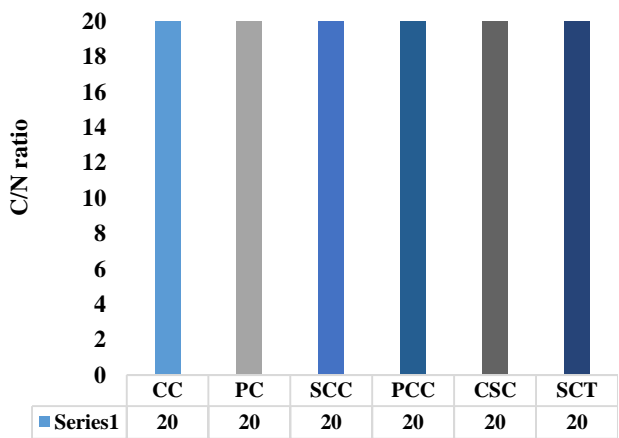*Own Source*

Graph 12 Magnesium (mg) in the different substrates
Own Source

Calcium shows a variable behaviour, according to graph 11, but the highest amount is found in the pulp with 30.144 mg and the lowest in the raw pumpkin seed with 28.372 mg. In graph 12, magnesium shows a more uniform presence, the highest rate being in pumpkin seed shell with 12.875 mg and with the lowest content in the peel with 10.112 mg (Rössel *et al*. 2018).

**Graph 13** Percentage of nitrogen in the different substrates
Own Source

	CC	PC	SCC	PCC	CSC	SCT
Series1	1.462	1.513	1.478	1.435	1.465	1.501

Graph 14 Carbon/nitrogen ratio in the different substrates
Own Source

	CC	PC	SCC	PCC	CSC	SCT
Series1	20	20	20	20	20	20

The percentage of nitrogen (graph 13) is an important parameter, which is used to calculate the amount of protein present in a foodstuff. Of this, the highest content is found in the pumpkin pulp with 1.513%, and the lowest is found in the seed with raw peel with 1.435%, showing a uniform distribution in all the substrates analysed. The C/N ratio (graph 14) is uniform in all parts of the pumpkin analysed, giving a value of 20/1.

Table 1 shows the results of the oil viscosity and graph 15 shows the viscosity profile at different temperatures and isobaric conditions.

Temperature [°C]	Oil viscosity in [cp]
10	180.490
15	104.38
20	72.187
25	48.336
30	37.543
40	20.351
50	15.213
60	11.967
70	9.183
82	7.397
90	6.704
95	6.085

Table 1 Oswald viscometer method
Own Source
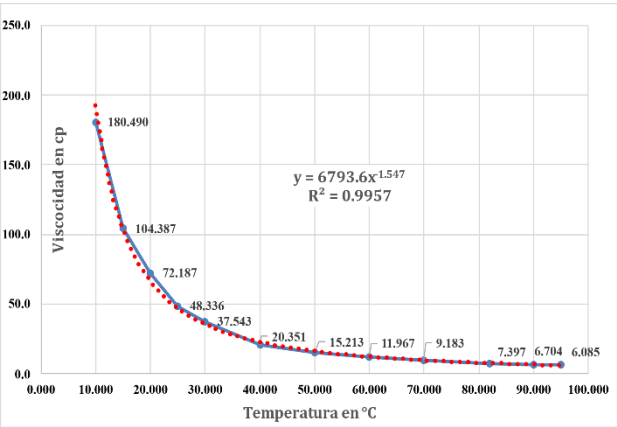
Graph 15 Viscosity isobar for pumpkin oil at one atmosphere pressure
Own Source

Viscosity shows an exponential behaviour curve, as can be seen in the equation and in the graph, viscosity is lower as the temperature increases and begins to stabilise at approximately 90°C.

Acknowledgements

Conclusions

The data obtained for the shell "CC" and pumpkin pulp "PC" have the highest moisture content above 94%; conversely, the whole and raw seed "SCC", the raw seed "PC", raw pumpkin seed "PCC" and whole and roasted pumpkin seed "SCT" have the lowest moisture content below 5% (Agrolanzarote, 2012).

With respect to conductivity, all the values obtained are in a very close range of 320 and 330 for the extracts studied; the same is true for pH, whose range is 5.751 and 5.999, which represents a slight acidity (Rodríguez Quispe, 2014).

Crude fibre is only significant in the pumpkin seed husk, the other parts analysed have a marginal contribution. The ashes of the samples are in a narrow range, from 0.596% to 0.981%.

Fats are only present in the substrates with pumpkin seeds, other substrates, their presence is marginal and can be disregarded. For proteins they are only important in pumpkin pulp; with these two terms it can be estimated that pumpkin pulp has the potential to be used as a food supplement.

Carbohydrates and carbon are present in all substrates analysed and their content is high, mainly due to the presence of proteins, fats and fibre. Similarly, calcium and magnesium are found in all pumpkin components.

Nitrogen is related to protein and to the amount of carbon present, as shown by the C/N ratio, which is twenty carbons for each nitrogen present.

In the viscosity graph of pumpkin oil, it can be seen that the inflection point is at approximately 85°C. This allows us to make decisions regarding the rheological behaviour of the fluid, which can be extracted by pressing, transported by piping or by carrying out a filtering process, allowing it to flow properly, with optimum energy expenditure.

Pumpkin is cultivated practically in all the agricultural regions of Mexico, with all the above mentioned, it is feasible to use pumpkin with great diversity, as: sweet (crystallised pumpkin), in atoles, fresh waters, confectionery, snacks, in stews, tamales, or simply as decoration; the seeds - roasted, cooked or boiled - as a complement in other preparations. In some regions the fruit, seeds and roots can be used for medicinal purposes. Some are useful as containers and are also used as fodder for livestock (cattle, goats and others) in livestock areas.

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HV-570, New maize (*Zea mays* L.) varietal prospect hybrid for the humid tropic of México

HV-570, Nuevo Híbrido Varietal de Maíz (*Zea mays* L.) prospecto para el Trópico Húmedo de México

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Abstract

Varietal hybrids represent an alternative in commercial maize production because of heterosis by crossing two maize varieties with good specific combining ability. The objectives of this research were to know the yield, agronomic traits and adaptability of varietal maize hybrids. Thus, during the spring summer season in 2016, 2017 y 2018 there were evaluated in Veracruz and Tabasco states 20 varietal hybrids, 5 experimental synthetics, the varieties VS-536 and V-537C and the hybrid H-520 used as check. These genotypes were arranged under complete blocks at random, with 28 treatments and three replications in plots of two rows 5m long, and 62,500 plants ha^{-1}. From the combined analysis for grain yield there was found high significant differences for genotypes (G), environments (E) and for the Genotype environment interaction (GE). The best hybrids at 0.05 of probability were: SINT-2BxVS-536 (HV1), SINT-4BxVS-536 (HV-570) and SINT-4BxSINT-2B with yield from 6.70 a 7.21 t ha^{-1}; Besides, the heterosis values with respect to the best parent were: 19.76, 13.46 y 11.29%, for each varietal hybrid, respectively. The varietal hybrid SINT-4BxVS-536 presented high yield, short plant and ear, good plant and ear aspect and good husk cover and it was defined for official registration as HV-570.

Zea mays **L., Heterosis, Varietal hybrids**

Resumen

Los híbridos varietales representan una alternativa en la producción de maíz debido a la heterosis de cruzar dos variedades con buena aptitud combinatoria específica. Los objetivos de este trabajo fueron conocer el rendimiento, características agronómicas y adaptabilidad de híbridos varietales de maíz. Así, durante los ciclos primavera verano 2016, 2017 y 2018 se evaluaron en Veracruz y Tabasco 20 cruzas varietales de maíz, 5 sintéticos experimentales, las variedades VS-536 y V-537C y el híbrido testigo H-520. Los experimentos se distribuyeron bajo un diseño bloques completos al azar con 28 tratamientos y tres repeticiones en parcelas de 2 surcos de 5 m de largo y densidad de 62,500 pl ha^{-1}. Del análisis combinado para rendimiento, se encontró significancia estadística al 0.01 de probabilidad para Genotipos (G), para Ambientes (A) y para la interacción GxA. Los híbridos sobresalientes fueron: SINT-2BxVS-536 (HV1), SINT-4BxVS-536 (HV-570) y SINT-4BxSINT-2B con rendimiento de 6.70 a 7.21 t ha^{-1}, Heterosis con respecto al mejor progenitor de: 19.76, 13.46 y 11.29%, para cada híbrido, respectivamente. El híbrido varietal SINT-4BxVS-536 registró alto rendimiento, planta y mazorca baja, buen aspecto de planta y de mazorca y buena cobertura de la mazorca por lo que ha sido definido para su liberación oficial como HV-570.

Zea mays **L., Heterosis, Híbridos varietales**

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Introduction

In Mexico, maize is the most important crop, because is the principal food for people, the planting area and to generate 36% of the agricultural production value. The principal use is the direct consume for human consumption. Thus, during 2018, there were sown in México, 7.95 million of de hectares with maize with an average in yield of 3.75 t ha^{-1}, and a total production of 26.67 million tons, which of them 12.6 million tons are utilized in different ways through the direct human consumption which of them 35% correspond to flour industry and 65% to masa tortilla industry through the nixtamalization process. Besides, in the same year, there were imported 17.095 million tons of maize yellow grain (SIAP, 2018).

In the humid tropic in México, there were sown 2.8 million of hectares with maize, which of them, one million are included in agronomic provinces of good and very good productivity, and 91 thousand hectares were sown under irrigation. In this area is feasible to use improved seed of synthetic maize varieties and hybrids which express their genetic yield potential under favourable conditions in clime, solil and the management by farmers (Sierra *et al*., 2019).

In maize hybridization, is important to identify parentals with high General (GCA) and Specific Combining Ability (SCA), high *per se* yield, tolerant to biotic and abiotic stress, easily in commercial seed production. (Sierra *et al.*, 2018; Gómez *et al.,* 2017; Trachsel *et al.,* 2016; Tadeo *et al* 2015a; Tadeo *et al* 2015b; López *et al.,* 2021; Ramírez *et al.,* 2019; Tadeo *et al.,* 2021).

Improved seeds are the most important input in corn production, they represent the genetic yield potential and quality production (Sierra *et al.,* 2019). In the comercial production of hybrids the kind of gene action is taken advantage, deviation of additivity when crossing different individuals genetically, as long as their genes are compatible, that is to say the yield is greater as the genetic divergence is greater (Reyes, 1985; Sierra *et al.,* 2019; Sierra *et al.,* 2018; Esquivel, *et al.,* 2011 Cordova *et al.,* 2007; Gómez *et al.,* 2015; Chuquija and Huanuqueño 2015; Velasco *et al.,* 2019).

For the tropical region, Reyes (1985), used the heterotic pattern Humid tropic x dry tropic to form the hybrids H-503 and H-507. Sierra *et al.,* (2004), used as testers the inbred lines of High Specific Combinatorial Aptitude (ACE), LT154, LT155, CML247 and CML254, which allowed to identify outstanding advanced lines and to separate heterotic groups to form best hybrids.

Varietal hybrids can be an alternative in the commercial production because of the heterosis of crossing two parents open pollinating varieties; Thus, is easier and cheaper the maintenance of their parents and the commercial seed production because they are synthetic varieties; However, is feasible to increase the use of improved seed. (Sierra *et al.,* 2018; Sierra *et al.,* 2016; Reyes, 1985; Sierra *et al.*, 2014; Tadeo *et al.,* 2016; Tadeo *et al.,* 2015b; Virgen *et al.,* 2016; Espinosa *et al.,* 2012; Cervantes *et al.,* 2016; Palemón *et al.,* 2012).

The adaptability of genotypes permit to know the response to different environments defined by the clime, soil and the agronomic management (Reyes 1990; Andrés *et al.,* 2017; Sierra *et al.,* 2018).

The model of Eberhart and Russell (1966), utilize the coeficient of regresion for measure the response of a variety across of diferent environments and the deviation of the regresion that indicate the consistence of this response. Thus, stable variety correspond to those with a coeficient of regresión equal to 1 and deviation of regression equal to 0.

The statistical model is: $\bar{Y}ij = \mu i + \beta i I_j + \delta_{ij},$

Where,
$\bar{Y}_{ij}$ = Mean of the variety i in the environment j
μ_i = Mean of the variety i in all environments
β_i = Coeficient of regresion
I_j = Environmental index
δ_{ij} = Deviation of regresión

The objectives of this research were to know the yield, adaptability and agronomic characteristics of the varietal maize hybrids across the six environments in Veracruz and Tabasco states and present to HV-570 as a new varietal maize hybrid prospect for the humid tropic of México.

Materials and Methods

Localization

The evaluation of the varietal hybrids was carried out during the spring summer season from 2016 to 2018, in Cotaxtla Experimental Station which belongs to INIFAP, México, and is located at the Km 34 through the public road from Veracruz-Córdoba in the municipality of Medellín de Bravo, Ver., in the 18º 56' North Latitude and 96º 11' West longitude and altitude of 15 masl, Carlos A. Carrillo in Veracruz and Huimanguillo, Tabasco state locations; The clime conditions are Aw1, Aw2 and Am for each location respectively, according with classification by Köppen and modified by García (2004) correspond to humid and subhumid warm conditions.

Germplasm used

The germplasm used in the present research, were 28 genotypes, which of them, 20 varietal crosses, 5 experimental synthetics, the varieties VS-536 and V-537C and the hybrid H-520, used as checks, all of them belong to the Tuxpeño race (Sierra *et al.,* 2019).

Description of the experiment

During the spring summer season in 2016, 2017 and 2018, under rainy conditions, there was carried out an experiment, for evaluating 20 varietal maize hybrids, 5 experimental synthetics the varieties VS-536 and V-537C and the hybrid H-520, used as checks which of them, were distributed in complete blocks at random, with 28 entries and three replications in plots of two rows 5 m long and 80 cm wide in a density of 62,500 pl ha^{-1} (Reyes, 1990).

The weeds were controlled by Atrazine applied before emerging plants. The fertilization was made according to the recommendations by INIFAP; Thus, in Cotaxtla experiment station, this experiment was fertilized using the formula 161-46-00, applying all the Phosphorus and a third part of Nitrogen at sowing moment, the rest of Nitrogen in bunchy stage using Urea as Nitrogen source.

Variables and data recording

During the development of the crop and at harvest time, there were recorded in the experiments the following agronomic variables: Grain yield, days to tassel and silking, Plant and ear height, measured since the base of soil even the highest leaf and the node where is inserted the principal ear, respectively; days to tassel considering 50% of the anthers in anthesis stage, days to silking when stigmas are in receptive stage, total number of plants and ears, qualification of plant and ear aspect and sanity, using a scale from 1 to 5, where, 1 correspond to the best phenotypic expression and 5 for the worst; lodging, ears with bad husk cover, dry matter and ear rot.

Statistical methods

The experimental design used was complete blocks at random with 28 entries and three replications in plots of two rows 5m long and 80 cm wide in a plant density of 62,500 pl ha^{-1}. Individual and combined analysis of variance was made for all variables recorded and were analyzed statistically and for the separation of means, the Significant Minimum Difference test was applied at 0.05 and 0.01 of probability (Reyes, 1990). Besides, there was made an stability parameters analysis (Eberhart y Russell, 1966). On the other hand, comparisons of cross groups and synthetic parent varieties were made and the t-test at 0.05 and 0.01 probability was applied. Also, the percentages of heterosis with respect to the best parent (Reyes, 1985), were calculated as follows:

$$\% \text{ of Heterosis} = \frac{F1 - \text{Best parent}}{\text{Best parent}} \times 100$$

Resultados y discusión

Grain yield

From the combined analysis for grain yield in the varietal hybrids across the six environments there were found statistical significant differences at 0.01 of probability for Genotypes (G), for Environments (E) and for the interaction VxE; Significance for interaction VxE, suggest that the grain yield in the hybrids across the environments were different (Table 1). (Reyes, 1990; Andrés *et al.,* 2017; Sierra *et al.,* 2018);

The highest variance was recorded for the source of variation environments, factor valued in 68.31**, which means that these environments were different and important in the behavior of the varietal maize hybrids (Reyes, 1990). Besides the Coefficient of Variation registered was 13.97%, value relatively low, and suggest that the results gotten and the management of the experiments are reliable (Reyes, 1990).

Source of Variation	DF	SS	MS
Genotypes (G)	27	65.27	2.42**
Environments (E)	5	341.54	68.31**
Interaction GxE	135	677.07	5.02**
Error	324		0.7697
CV (%)			13.97%

DF=Degree of freedom; SS=Square Sum; MS=Mean Square; CV= Coefficient of variation; **=Significance for source of variation at 0.01 of probability

Table 1 Combined Analysis for grain yield in varietal maize hybrids across six environments in Veracruz and Tabasco states 2016-2018. CIRGOC INIFAP

The best varietal crosses in yield at 0.01 of probability were: SINT2BxVS-536, SINT4Bx VS-536 (HV-570), SINT4BxSINT2B, SINT5Bx V537C, VS-536xV-537C, SINT3BxSINT1BQ, SINT2BxV-537C, with grain yield from 6.47 to 7.21 t ha^{-1} (Cuadro 2). These varietal maize hybrids registered yield from 1 to 13% above than the commercial hybrid H-520 used as check.

These varietal hybrids take the advantage of maintaining only two parents, which are open pollinating maize varieties with greater yield, reliability, and easier for seed production (Espinosa *et al.,* 2012; Cervantes *et al.,* 2016; Sierra *et al.,* 2018; Sierra *et al.,* 2016; Sierra *et al.*, 2014; Gómez *et al.,* 2017; López *et al.,* 2021; Ramírez *et al.,* 2019; Tadeo *et al.,* 2021; Tadeo *et al.,* 2015a; Tadeo *et al.,* 2015b; Tadeo *et al.,* 2016; Virgen *et al.,* 2016).

In the best varietal hybrids participate VS-536, the synthetic maize variety of greater use in the Mexican southeast (Sierra *et al.,* 2016). The heterosis values, with respect to the best parent were: 19.76, 13.46, 11.29, 8.54, 16.9, 5.46 y 7.64%, for each hybrid, respectively, which suggests genetic divergence between the parental varieties (Reyes, 1985; Sierra *et al.,* 2004; Córdova *et al.,* 2007; Esquivel, *et al.,* 2011; Chuquija y Huanuqueño 2015; Palemón *et al.,* 2012; Velasco *et al.,* 2019; Gómez *et al.,* 2015).

In the genotype environment interaction, according with the stability parameters for comparing varieties (Eberhart y Russell, 1966), the 28 genotypes evaluated were characterized as stables (Reyes 1990; Andrés *et al.,* 2017; Sierra *et al.,* 2018).

Environmental indexes

In relation with the environmental indexes by Eberhart and Russell (1966), the environments of the municipality Carlos A. Carrillo and Cotaxtla in Veracruz in 2016B, recorded the highest yield with 7.29** and 7.27** t ha^{-1} and the greatest environmental indexes 1.01** and 0.99** for each environment, respectively.

Entry	Genealogy	Cot 2016B	Huim 2016B	Carr 2016B	Cot 2017B	Huim 2018B	Cot 2018B	Mean	% Rel	% Het	Description
1	SINT2BxVS-536 (HV1)	7.99	6.34	9.16	6.28	6.55	6.91	7.21*	113	19.76	S
14	SINT4BxVS-536 (HV-570)	8.67	6.05	6.90	6.86	5.47	6.48	6.74*	105	13.46	S
17	SINT4BxSINT2B	7.64	5.83	8.11	6.09	5.42	7.1	6.70*	105	11.29	S
9	SINT-5B X V-537C	7.25	5.79	8.30	6.61	5.42	6.32	6.61**	103	8.54	S
20	VS-536xV-537C (HV-3)	7.14	5.23	8.13	5.85	5.69	7.36	6.57**	103	16.90	S
18	SINT3BxSINT-1BQ	7.73	6.01	7.97	3.71	6.36	7.56	6.56**	102	5.46	S
19	SINT-2BxVS-537C	7.75	5.13	6.89	6.51	5.58	7.05	6.48**	101	7.64	S
16	SINT-5B X VS-536	7.03	4.86	8.17	7.65	5.23	5.88	6.47**	101	6.24	S
13	SINT-1BQxVS-536	6.77	5.39	7.34	6.79	6.15	6.33	6.46**	101	6.07	S
15	SINT-5BxSINT-1BQ	7.01	4.57	8.54	6.82	5.13	6.62	6.45**	101	5.91	S
6	SINT-3BxVS-537C	6.69	5.42	7.41	6.42	5.24	7.36	6.42**	100	3.22	S
28	H-520	7.42	5.92	6.74	6.4	5.16	6.77	6.40	100		S
12	SINT-4B X SINT-3B	7.34	5.02	8.60	6.64	5.43	5.17	6.37	99	2.41	S
3	SINT-5B X SINT-4B	7.10	5.12	7.60	6.32	4.92	6.86	6.32	99	3.78	S
11	SINT-3B X SINT-2B	7.73	6.06	6.06	4.47	6.59	6.87	6.30	98	1.29	S
2	SINT-5B X SINT-2B	7.55	5.71	6.08	6.99	4.35	7.07	6.29	98	3.28	S
23	SINT-3B	7.02	4.36	8.47	6.22	5.76	5.5	6.22	97		S
5	SINT-4BxVS-537C	7.17	5.03	4.97	6.59	5.87	6.99	6.10	95	2.69	S
21	SINT-1BQ	8.18	4.57	7.04	6.09	6.28	4.37	6.09	95		S
8	SINT4BxSINT-1BQ	7.51	5.03	8.10	4.18	4.66	7.05	6.09	95	0	S
25	SINT-5B	7.00	4.14	6.07	6.09	6.22	7	6.09	95		S
7	SINT-5B X SINT-3B	7.34	4.91	7.37	6.61	4.51	5.7	6.07	95	-2.41	S
4	V-537C X VS-536	7.12	5.69	4.46	5.85	5.69	7.36	6.03	94	7.29	S
22	SINT-2B	7.35	4.76	6.26	6.02	5.62	6.1	6.02	94		S
24	SINT-4B	6.22	4.56	7.69	5.94	4.94	6.26	5.94	93		S
26	VS-536	6.95	4.62	6.51	5.38	4.65	5.63	5.62	88		S
27	V-537 C	5.22	4.22	8.92	5.08	4.94	5.04	5.57	87		S
10	SINT-2BxSINT-1BQ	7.78	4.82	6.16	4.36	3.49	6.61	5.53	86	-9.19	S
MEAN		7.27	5.18	7.29	6.03	5.40	6.48	6.28			
CV (%)								13.97			
MSE								0.7697			
SMD 0.05								0.5732			
SMD 0.01								0.7545			

* and **= Significance of the treatments at 05 and 0.01of probability; B= Spring Summer season; Cot= Cotaxtla Experimental Station; Carr= Municipality of Carlos A. Carrillo, Ver.; Huim= Huimanguillo, Tab.; MSE= Mean Square Error; CV= Coefficient of Variation; SMD= Significant Minimum Difference; Rel % = Relative percent in relation with the commercial check; % Het= % of heterosis with respect to the best parent; S= Genotype characterized as stable.

Table 2 Grain yield in varietal maize hybrids across the six environments in Veracruz and Tabasco states 2016-2018. CIRGOC INIFAP

On the other hand, the locations Cotaxtla, Ver., in 2017B and Huimanguillo Tabasco en 2018 y 2016B registered the lowest grain yield with 6.03, 5.40 and 5.18 t ha^{-1}, and negative environmental indexes of -0.25, -0.88, and -1.1 (Table 3). It suggest, that there are important differences in these environments in clime, soil and agronomic management for these experiments (Reyes*, et al.,* 1990; Sierra *et al.,* 2018; Sierra *et al.,* 2018).
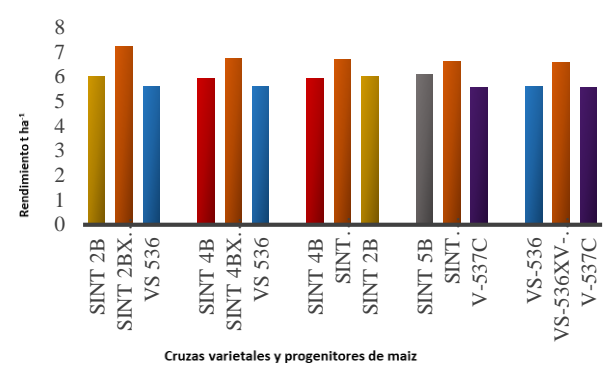
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Figure 1 Heterosis in varietal maize hybrids in Veracruz and Tabasco states 2016-2018

Environment	Yield t ha⁻¹	Índexes
Carlos A. Carrillo, Ver 2016B	7.29**	1.01
Cotaxtla, Ver 2016B	7.27**	0.99
Cotaxtla, Ver., 2018B	6.48	0.20
Cotaxtla, Ver., 2017B	6.03	-0.25
Huimanguillo 2018B	5.40	-0.88
Huimanguillo, Tab 2016B	5.18	-1.1
Promedio	6.28	

Yield t ha^{-1}= Grain yield t ha^{-1}; B= spring summer season

Table 3 Environmental indexes in varietal maize hybrids 2016-2018. CIRGOC INIFAP

Agronomic performance and characteristics

In relation with the agronomic characteristics, the varietal hybrids recorded from 51 to 53 days to tassel, short plant height with 217 to 255 cm, and 108 to 132 cm for plant and ear height, respectively (Table 4). These hybrids present good plant and ear aspect and plant and ear sanity, good husk cover and low presence of ear rot; Besides, the relation ear height/plant height was between 0.49 and 0.58, it help to show tolerance to lodging caused by the wind (Sierra *et al.*, 2018; Gómez *et al.,* 2017; Trachsel *et al.,* 2016; Tadeo *et al* 2015a; Tadeo *et al* 2015b).

The best hybrids for yield and agronomic traits were: SINT2BxVS-536, SINT4BxVS-536 (HV-570), SINT4BxSINT-2B, VS-536xV-537C, SINT5BxVS-537C, can be an alternative in commercial maize production because they are adapted to clime and soil conditions and the management by farmers in the southeast of México (Sierra *et al.,* 2019). Thus, considering the yield and agronomic characteristics it is suggested that the varietal cross SINT4BxVS-536, must be libered HV-570, as a commercial new maize hybrid for the humid tropic in México.

The hybrid HV-570, register high yield and adaptation to the humid tropic in Mexico, intermediate biological cicle with 51 days to tassel during the spring summer season under rainy season conditions; This hybrid present short plant an ear height and the leaves above the ear are in semierect position; besides, the position of the ear is desviated to the position of the leaves (Figure 2); HV-570, present good plant and ear aspect and sanity, excellent husk cover, white grain color and semident texture (Figure 3).

Figure 2 HV-570 present short plant and ear and the leaves above the ear are in semierect position

Figure 3 Ears of HV-570 hybrid expressed White grain and semident texture

Entry	Genealogy	Cot 2016B	Huim 2016B	Carr 2016B	Cot 2017B	Huim 2018B	Cot 2018B	Mean	% Rel	% Het	Description
1	SINT2BxVS-536 (HV1)	7.99	6.34	9.16	6.28	6.55	6.91	7.21*	113	19.76	S
14	SINT4BxVS-536 (HV-570)	8.67	6.05	6.90	6.86	5.47	6.48	6.74*	105	13.46	S
17	SINT4BxSINT2B	7.64	5.83	8.11	6.09	5.42	7.1	6.70*	105	11.29	S
9	SINT-5B X V-537C	7.25	5.79	8.30	6.61	5.42	6.32	6.61**	103	8.54	S
20	VS-536xV-537C (HV-3)	7.14	5.23	8.13	5.85	5.69	7.36	6.57**	103	16.90	S
18	SINT-3BxSINT-1BQ	7.73	6.01	7.97	3.71	6.36	7.56	6.56**	102	5.46	S
19	SINT2BxVS-537C	7.75	5.13	6.89	6.51	5.58	7.05	6.48**	101	7.64	S
16	SINT-5B X VS-536	7.03	4.86	8.17	7.65	5.23	5.88	6.47**	101	6.24	S
13	SINT-1BQxVS-536	6.77	5.39	7.34	6.79	6.15	6.33	6.46**	101	6.07	S
15	SINT4BxSINT-1BQ	7.01	4.57	8.54	6.82	5.13	6.62	6.45**	101	5.91	S
6	SINT-3BxVS-537C	6.69	5.42	7.41	6.42	5.24	7.36	6.42	100	3.22	S
28	H-520	7.42	5.92	6.74	6.4	5.16	6.77	6.40	100		S
12	SINT4B X SINT-3B	7.34	5.02	8.60	6.64	5.43	5.17	6.37	99	2.41	S
3	SINT-5B X SINT-4B	7.10	5.12	7.60	6.32	4.92	6.86	6.32	99	3.78	S
11	SINT-5B X SINT-2B	7.73	6.06	6.06	4.47	6.59	6.87	6.30	98	1.29	S
2	SINT-5B X SINT-2B	7.55	5.71	6.08	6.99	4.35	7.07	6.29	98	3.28	S
23	SINT-3B	7.02	4.36	8.47	6.22	5.76	5.5	6.22	97		S
5	SINT-4BxVS-537C	7.17	5.03	4.97	6.59	5.87	6.99	6.10	95	2.69	S
21	SINT-1BQ	8.18	4.57	7.04	6.49	6.28	4.37	6.09	95		S
8	SINT4BxSINT-1BQ	7.51	5.03	8.10	4.18	4.66	7.05	6.09	95	0	S
25	SINT-5B	7.00	4.14	6.07	6.09	6.22	7	6.09	95		S
7	V-537C X SINT-3B	7.34	4.91	7.37	6.61	4.51	5.7	6.07	95	-2.41	S
4	V-537C X VS-536	7.12	5.69	4.46	5.85	5.69	7.36	6.03	94	7.29	S
22	SINT-2B	7.35	4.76	6.26	6.02	5.62	6.1	6.02	94		S
24	SINT-4B	6.22	4.56	7.69	5.94	4.94	6.26	5.94	93		S
26	VS-536	6.95	4.62	6.51	5.38	4.65	5.63	5.62	88		S
27	V-537 C	5.22	4.22	8.92	5.08	4.94	5.04	5.57	87		S
10	SINT-2BxSINT-1BQ	7.78	4.82	6.16	4.36	3.49	6.61	5.53	86	-9.19	S
	MEAN	7.27	5.18	7.29	6.03	5.40	6.48	6.28			
	CV (%)							13.97			
	MSE							0.7697			
	SMD 0.05							0.5732			
	SMD 0.01							0.7545			

B= Spring Summer season; [1/]= Qualification scale from 1 to 5, where, 1 correspond to plants and ears with the best phenotypic expression and 5 for the worst; MSE= Mean square of error; CV= Coefficient of Variation

Table 4 Agronomic characteristics of varietal maize hybrids 2016-2018. Cotaxtla CIRGOC INIFAP

From the comparisons and t test at 0.05 and 0.01 of probability (Table 5), there was found that the varietal hybrids recorded an average grain yield of 6.39 t ha^{-1}, 8% more than the synthetic varieties parents with value for the calculatesd t test of 5.07**; Besides, there was registered advantages in plant and ear aspect (Reyes, 1990). It suggests that there is genetic divergence between the parents, which is also reflected in the values of heterosis with respect to the best progenitor that varied from 5.46 to 19.76%. (Reyes, 1985; Sierra *et al.,* 2004; Córdova *et al.,* 2007; Esquivel, *et al.,* 2011; Chuquija y Huanuqueño 2015; Palemón *et al.,* 2012; Velasco *et al.,* 2019; Gómez *et al.,* 2015).

omparison	Yield t ha^{-1}	% Rel	t Calc	Plant height	% Rel	t Calc	Pl asp[2/]	% Rel	t Calc	Ear asp[2/]	% Rel	t Calc
Crosses	6.39	108	5.07**	231.75	103	0.93NS	2.25	100	0.92NS	2.43	100	0.57NS
Parents	5.93	100		225.57	100		2.37	105		2.51	103	

t0.05 (54 GL) = 2.00; t0.01 (54 GL) =2.66
% Rel= Relative % in the comparison; t Calc= t calculated for the comparison; Pl asp= Plant aspect; Ear asp= Ear aspect; [2/]= Escale of qualifying from 1 to 5, where, 1 is the best and 5 is the worst

Table 5 Comparisons and t test for varietal hybrids and their parents. 2016-2018 CIRGOC INIFAP

Acknowledgment

Conclusions

The best varietal hybrids for grain yield and agronomic característics were: SINT2BxVS-536, SINT4BxVS-536 (HV-570), SINT4Bx SINT2B, VS-536xV537C, with grain yield from 6.57 to 7.21 t ha^{-} 3 to 13% more than the commercial check H-520.

The heterosis with respect to the best parent in the best varietal crosses were: 19.76, 13.46, 11.29, 16.9%, for each hybrid, respectively.

Instead of grain yield and agronomic traits it was suggested the cross SINT-4BxVS-536 for oficial registering as HV-570, new maize hybrid for the humid tropic in México

The varietal hybrid HV-570, present short plant and ear, good plant and ear aspect and sanity and good husk cover

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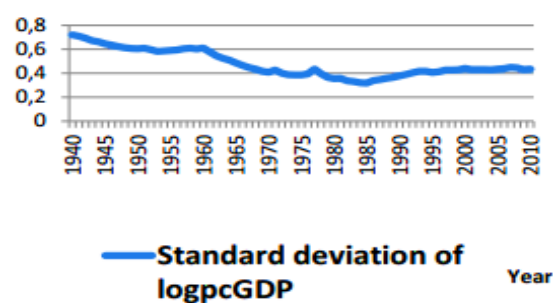
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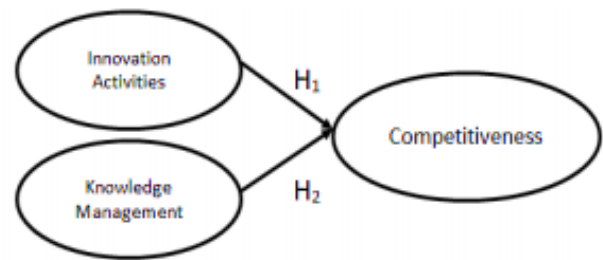
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