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EFFECT OF THREE GREEN MANURES ON THE AGRONOMIC CHARACTERISTICS OF NATIVE X'MEJEN NAAL MAIZE IN CAMPECHE, MEXICO

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ABSTRACT

In the agronomic management of maize (*Zea mays* L.), chemical fertilizers can be substituted for fertilizing techniques that reduce the pollutant effect of the excessive use of commercial fertilizers. The hypothesis was the green manure of legumes with or without the inoculation of microorganisms are capable of promoting agronomic characteristics of X'mejen Naal maize, comparable to conventional fertilization. In order to measure the effect in the agronomic characteristics of X´mejen Naal maize, an experiment was designed in complete randomized blocks in a bifactorial arrangement with four repetitions, in which three green manures were tested, with or without the inoculation of Fosfonat (endomycorrhizas, EM, plus nitrogen fixating bacteria, NFB). Treatments were Mucuna (*Mucuna pruriens*, T1=MUC), Xpelón (*Vigna unguiculata*, T2=PEL), Ibes (*Phaseolus lunatus*, T3=IBE), inoculated Mucuna (T4=MUCEM), inoculated Xpelón (T5=PELEM), inoculated Ibes (T6= IBEEM) and the control with the incorporated biomass of weeds plus the addition of 200 kg ha^{-1} of diammonium phosphate (T7=ARDAP). Results showed that there were only differences caused by the types of green manure and their interaction with the inoculated symbionts in the fresh weight or biomass in X´mejen Naal maize. IBE and ARDAP stood out in fresh weight (1162 and 1251 g), dry weight (168.6 and 163.6 g), 7.3 Mg ha^{-1} (Megagrams per hectare) in the dry aerial biomass in the maize plants, respectively. Despite the grain yield of maize was similar among treatments, it was noticeable that the higher average yields were also observed in IBE and ARDAP with 3.5 and 3.3 Mg ha^{-1} respectively. All yields (fodder and grain) managed to express the potential of the X´mejen Naal, which is relevant to recommend the use of green manures as an agro-environmental alternative to conventional fertilization in the Luvisol soils of Campeche.

Keywords: *Zea mays* L., fertilization, agroecology, tropical soil, Yucatan Peninsula.

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INTRODUCTION

In the state of Campeche, the nutritional management in basic crops such as maize (*Zea mays* L.) is carried out conventionally with the use of chemical fertilizers that account for 27 % of all production costs. Diammonium phosphate (DAP) is frequently used in annual doses of 50 to 150 kg ha^{-1}, to obtain yields ranging between 3.5 and 4.0 Mg ha^{-1} of grain between May and July (rainfed) and between 0.4 and 0.6 Mg ha^{-1} between July and November (autumn-winter) (Medina-Méndez *et al*., 2018). Chemical fertilization may cause damages to the environment.

Contemporary agricultural production demands the use of sustainable agronomic practices and alternative to conventional fertilization. The use of green manures is a technique that tends to be used more as a source of nutrients in the soil for crops (Castro *et al*., 2017). In crops such as maize, the incorporation of green manures has shown a direct relationship with grain yields, biomass and nutritional content (Sosa-Rodrigues and García-Vivas, 2018).

The high costs of synthetic fertilizers and improved seeds reduce the cost effectiveness of maize for farmers (Alvarado-Teyssier *et al*., 2018). It is therefore important to find alternate and competitive sources for the fertilization of this crop, basic for the nutrition of the Mexican population. In the light of this situation, since maize demands nitrogen throughout life cycle, green manures may be a feasible option (Karyoti *et al*., 2018). In the state of Campeche there are few studies on the problem of fertilizers, underground pollution related to maize production; and even less on the use of green manures in the region.

The hypothesis was that the green manures of legumes, whether inoculated or not, are able to promote agronomic characteristics in native maize (X'mejen Naal) comparable to conventional fertilization. The aim of the research was to evaluate the agronomic behaviour (plant growth and development, and grain yield) of X'mejen Naal maize in response to the application of three legumes as green manures, inoculated or not with a mixture of endomycorrhizae and beneficial nitrogen fixating bacteria, with the incorporated biomass of weeds plus the addition of 200 kg ha^{-1} of diammonium phosphate.

MATERIALS AND METHODS

Location of the study site

The experiment was established during the agricultural cycle between July and December 2020 in the Rancho Xamantún production unit of the Chiná Institute of Technology, located in the homonymous municipal area, in the state of Campeche (19° 42' N and 90° 25' W and 44 m) (González-Valdivia *et al*., 2019). The climate in the area is warm sub-humid, with a rainfall of 900 to 1200 mm and an average annual temperature of 25.5 to 26.4 °C. The most rainfall takes place between June and October, with a dry period or *canícula* between July and the beginning of September. The soil type is ferric Luvisol, with a good productivity, a moderate depth and a calcareous origin, saturated with bases, with a high content of expandable clays of the smectic and vermiculite groups with reddish tones with ionic exchange activity (Palma-López *et al*., 2017).

Experimental design

The experiment had a complete randomized block design in a 3×2 factorial arrangement plus the control (fertilization with 200 kg ha^{-1} of diammonium phosphate) with four replicates. The levels of factor A were three species of green manure (*Mucuna pruriens* L., *Vigna unguiculata* L., and *Phaseolus lunatus* L.); levels of factor B were the inoculation or not of legumes with Endomycorrhizae (EM) and beneficial nitrogen fixating bacteria (BFN). Thus, a total of seven treatments were evaluated (Table 1). The experimental unit consisted of 4×8 m plots for a total of 24 experimental units, with both study factors (A and B) inside the blocks. The control treatment was fertilized with diammonium phosphate used in the region along with wild plants (considered natural competitors to the main crop) used as green manure; that is why those were not inoculated.

Planting and incorporation of green manure

The seeds of the legumes Xpelón (*Vigna unguiculata* L.), Ibes (*Phaseolus lunatus* L.) and Mucuna (*Mucuna pruriens* L.) were obtained from farmers from the region and the seeds chosen were those with the best physical and health characteristics. The seeds were divided into two lots, one to be inoculated and the other with a mixture of endomycorrhizae (EM) and beneficial nitrogen fixating bacteria (BFN). The symbiotic microorganisms were added via the Fosfonat commercial consortium, with the recommendations of the company Tecnologías Naturales Internacional, S.A de C.V. (Guanajuato, Mexico). The planting with green manures (GM) was made on April 15, 2020. A distance of 0.20 m was considered between plants and 0.80 m between rows to obtain a density of 62 500 plants ha^{-1}, for *Vigna unguiculata* and *Phaseolus lunatus* (Jara-Claudio and Alejos-Patiño 2016; Batista de Sousa *et al*., 2020). Mucuna was planted with a distance of 0.50 m between plants and 0.80 m between rows to achieve a density of 25 000 plants ha^{-1} (Sanclemente-Reyes *et al*., 2013; Rojas-Molina *et al*., 2019). During the development of the GM, the agronomic management consisted of pest and disease control, and weed management.

Table 1. Treatments with green manure (*Mucuna pruriens* L., *Vigna unguiculata* L. and *Phaseolus lunatus* L.) with and without inoculating symbiotic microorganisms in X′mejen Naal maize in Chiná, Campeche, Mexico (July - December 2020).

Treatment	Description
MUC	Mucuna (*Mucuna pruriens*) without inoculation
PEL	Xpelón (*Vigna unguiculata*) without inoculation
IBE	Ibes (*Phaseolus lunatus*) without inoculation
MUCEM	Mucuna inoculated Endomycorrhizae (EM) and Beneficial nitrogen fixating bacterias (BFN)
PELEM	Xpelón inoculted with EM and BFN
IBEEM	Ibes inoculated with EM and BFN
ARDAP	Control: fertilization with 200 kg ha^{-1} of diammonium phosphate, applied by hand when maize plants reached a height of 25 cm

Sixty days after planting, the green manures were cut, which coincided with the stage of the highest vegetative development and the beginning of flowering. Plant material was weathered for 19 d and left on the surface of the experimental plot to favour the decomposition of the plant biomass. Next, they were incorporated evenly into the soil with a disc harrow, avoiding the mixture of manures in each experimental unit (Rivero-Herrada *et al*., 2016). Before the incorporation, plant tissue samples were taken from green manure the central rows of each experimental unit and they were sent to the laboratories of the company AGQ Labs to know the amount of nutrients contained in the total biomass before incorporating them into the soil.

Planting of maize

The X´mejen Naal maize, of an intermediate cycle was planted by hand on July 26, 2020, with a planting framework of 0.80 m between rows and 0.20 m between plants, for a density of 60 000 plants ha^{-1}. The control was fertilized 15 d after plantation, and the agronomic management followed the recommendations by Villalobos-González *et al*. (2019). Throughout the experiment, plants were irrigated using a spraying system.

Growth variables

Plant height (ALTP, m); value obtained at the end of the female flowering; measured from the base of the stem in the ground up to where the spike ramification begins. Stem diameter (DT, cm), ear height (AM, cm), length of the ear leaf (LHDM), width of the ear leaf (AHDM), total of leaves (TH) (Ramírez-Mandujano *et al*., 2016). The leaf area index per plant (IAF) was estimated using the average product of length times width for each leaf in five plants, weighed by a factor 0.75 (area of the leaves of the plant, m^2); then divided by the plant cover area above the soil (Castellanos-Reyes *et al*., 2017).

Phenological variables

Days to male flowering (DFMAS), considered as the moment of sampling, when 50 % of the spikelet present in the spike of the plant displayed anthers in dehiscence and exposed outside the glumes. Days to female flowering (DFFE), determined when the plants displayed the silk or female inflorescence with the stigmas exposed. Floral asynchrony (ASF), considered as the difference between DFFE and DFMAS (Ramírez-Mandujano *et al*., 2016).

Yield variables

Grain and ear characteristics in X'mejen Naal

Length of grain (LG, cm); grain width (AG, cm), grain thickness (GG, cm), weight of 1000 grains (P1000G); number of grains per row (NGH); number of normal grains per ear (NGNM), value obtained with the number of normal or completely formed grains after threshing a sample composed of 10 ears. Number of aborted grains per ear (NGAM), obtained by counting the number of grains that did not reach full development on the ear. Ear length (LM, cm); ear diameter (DM, cm); number of rows per ear (NHM). Cob diameter (DOL, cm); cob weight (POL, g); and ear weight (PM, g.) (González-Martínez *et al*., 2019; Villalobos-González *et al*., 2019).

Fodder and grain yield variables

Fresh weight of the aerial part of the plant (PF, g); the *in situ* weight of five plants from the central rows of each experimental unit was recorded. Final aerial biomass (BAF, g m^{-2}), determined after the physiological maturity when harvesting the plants in an area of 1 m^2 of four central rows and the total dry weight of the aerial section [leaves (blade + pod) stem, ear, bracts, cob or rachis and spike] was obtained, divided by the area harvested. Total biomass (BMT, Mg ha^{-1}) was estimated by obtaining the dry matter per plant and multiplying this value by the density of plants per hectare (Franco-Martínez *et al*., 2015). Grain yield per plant (RG), value obtained after threshing the ears of each plant and weighing them to determine the weight of the grain per plant. Grain yield per plant (RGPH, Mg ha^{-1}), estimated with a commercial humidity adjustment at 14% of the total weight of the grains of 10 ears obtained from four central rows of the experimental unit. Harvest index (IC), calculated as the quotient between the grain yield and the final aerial biomass [(IC = RG / BM) * 100] (Zamudio-González *et al*., 2016).

Statistical analysis

An analysis of variance was carried out for the variables studied for a complete randomized block design in a 3×2 factorial arrangement. Normality (Shapiro–Wilk test, QQ Plot graphical method) and homoscedasticity of the data (ncvTest: score test for non-constant error variance) were tested beforehand. The means comparison was carried out using Tukey's means test ($p \leq 0.05$). For the analysis of data, the statistical program R version 4.0.5 (R Studio Team, 2021) was used.

RESULTS AND DISCUSSION

Content of nutrients in the green manure before incorporation

The results of the aerial biomass nutrient contents analysis of the green manures found the highest content of nitrogen in the PELEM tissue, followed by MUC and MUCEM. The outstanding contribution of P, K, Ca and S of the green content of PELEM must be highlighted, particularly regarding contents of sulphur (Table 2). This element, due to its acidity, favours the assimilation of other macronutrients in soils with high contents of Ca (Bender *et al*., 2013; Correndo and García, 2014). In the Yucatan Peninsula, Ca becomes antagonistic to elements such as phosphorous, which is the reason the use of this species is favoured as green manure in this region.

The contribution of nutrients by all treatments with green manures was enough to satisfy the requirements for maize, both macro and microelements (Table 2). Since it is considered that in the maize crop, the nutrients considered for fertilization formulas are N, P and K (Conceição dos Santos *et al*., 2019). It is important to consider that the

Table 2. Contribution of nutrients by green manures (*Mucuna pruriens*, *Vigna unguiculata* and *Phaseolus lunatus*) with and without inoculation with symbiotic microorganisms in the X´mejen Naal maize crop in Chiná, Campeche, Mexico (July – December 2020).

Treat.	DM[†] (Mg ha^{-1})	Macronutrients (kg ha^{-1})						Micronutrients (kg ha^{-1})					
		N	P	K	Ca	Mg	S	Mo	Fe	Mn	Cu	Zn	B
MUC[¶]	3.73	83.77	11.23	83.8	73.47	11.7	6.6	0.01	2.13	0.5	0.08	0.12	0.11
PEL[§]	5.31	65.21	11.07	93.5	66.77	16.17	8.07	0.01	1.57	0.8	0.04	0.13	0.14
IBE[♭]	2.46	47.69	7.03	55.63	44.7	5.33	4.37	0.00	1.07	0.18	0.02	0.06	0.06
MUCEM[¤]	3.76	89.29	8.57	64.67	64.83	10.77	6.83	0.01	1.1	0.61	0.07	0.11	0.11
PELEM[††]	6.25	104.22	15.73	127.33	67.87	20.1	11.77	0.01	0.88	0.71	0.05	0.18	0.18
IBEEM [¶¶]	2.72	52.35	7.9	66.47	40.77	5.7	5.03	0.00	0.71	0.23	0.02	0.09	0.06
ARV[§§]	1.33	20.84	2.5	26.37	12.2	2.67	2.73	0.00	0.48	0.06	0.01	0.03	0.02

Treat= treatment, [†]DM= dry matter, [¶]MUC=*Mucuna pruriens*, [§]PEL= *Vigna unguiculata*, [♭]IBE= *Phaseolus lunatus* (L), [¤]MUCEM= *M. pruriens* with added EM and BFN, [††]PELEM= *V. unguiculata* with added EM and BFN, [¶¶]IBEEM= *P. lunatus* (L) with added EM and BFN, [§§]ARV= control with wild plants.

nutritional requirements for *Zea mays* L. in kg ha^{-1} of macronutrients are found between 56-120 (N), 36-50 (P), 10-127 (K), 0-24 (Ca), 0-25 (Mg) and 5-21 (S) in order to reach yields of 3 to 6, Mg ha^{-1} in grain production (Machado-Silva *et al*., 2018; Restrepo-Díaz *et al*., 2017). In the case of micronutrients for estimated yields of 3 to 6 Mg ha^{-1} of grain, the nutritional requirements are found between 0.00-0.01 (Mo), 0.32-0.64 (Fe), 0.48-0.97 (Mn), 0.03-0.07 (Cu), 0.14-0.27 (Zn) and 0.05-0.10 (B) (Bender *et al*., 2013; Correndo and García, 2014). This nutritional demand is comprised within the contribution of nutrients achieved by the green manures studied.

The high contributions of Ca in the plant biomass of the green manures did not surpass the maximum requirements near the 57 kg ha^{-1} for high yielding maize (Machado-Silva *et al*., 2018). The supply of microelements Fe, Cu and B remained within range of nutritional requirements for high productivity maize (9 to 12 Mg ha^{-1}), which vary from 1.12-1.28, 0.12-0.13 and 0.18-0.21 respectively (Correndo and García, 2014; Restrepo-Díaz *et al*., 2017).

In the particular case of Fe, Stewart *et al*. (2020) mentioned that this micronutrient does not represent a problem of excess for *Zea mays* L., and there is even a deficiency of this element in calcareous soils. Due to lower solubility, originated by higher values of pH in this type of soils. This deficiency was corrected due to the contribution of Fe made by the green manures, which in every case surpassed the maximum requirements of this element for maize. In general, no sign of scarcity or phytotoxicity caused by elements was found on the field during the study.

Growth variables

There were no differences between the green manure used or regarding the inoculation management, or in the interaction between these two factors ($p>0.05$). Growth averages of those variables were as follows: ALTP (2.1 and 2.3 m), DT (2.4-2.7 cm), AM (1.3-1.4 m), LHDM (82.3-95.8 cm), AHDM (9.5-10.3 cm), TH (12.5-14.0) and IAF (3.5-4.2). These values coincide with reports by Cázares-Sánchez *et al*. (2015) and Villalobos-González *et al*. (2019) in varieties of X´mejen Naal.

Plant height and stem diameter in X'mejen Naal are within the usual range in varieties resistant to lodging caused by rain and winds (Velázquez-Cárdelas *et al*., 2018). The similarity between averages of growth variables (p>0.05) shows that the green manures studied may be used as an alternative to chemical fertilization of maize, recommended for farmers in Campeche by Medina-Méndez *et al*. (2018).

Phenological variables

These variables showed no differences between treatments for the factors studied or in their interaction (p>0.05), with averages of 52 to 54 for DFMAS, from 54 to 56 for DFFE and between 2 and 4 d for floral asynchrony. The management of fertilization did not interfere with the expression of the phenological characteristics, which are defined by the genetic of X´mejen Naal (Villalobos-González *et al*., 2019) and which are expressed in a stable way in the absence of abiotic stress. The green manures used in the study are comparable to the effect of ARDAP and they contributed to produce plants without any evidence of physical alteration due to being properly nourished, as Alvarado-Teyssier *et al*. (2018) also observed.

Yield variables

Green manures and interactions with the inoculation only showed differences in fodder yield (p≤0.05). The values reached with IBE and the other green manures for PF, MS, BAF and BMT (Table 3) were near to those obtained with ARDAP (1251.00 g p^{-1},163.6 g, 822.8 g m^2, 8.3 Mg ha^{-1}); therefore, legumes are as efficient as chemical fertilizers. In addition, their contribution of essential nutrients stands out for the formation of plant biomass, particularly P, which participates in the development of roots and thus, in the improvement of nutrient absorption capacity for other nutrients in maize planted on calcareous soils.

All treatments obtained similar values to each other regarding the number of normal grains per ear (NGNM), except for MUC (338.6 NGNM, p≤0.05) with values between 359.7 and 405.2 NGNM. *Vigna unguiculata* and *Phaseolus lunatus* displayed their potential as green manures against *Mucuna pruriens*. Even without inoculations, they equated to ARDAP in favouring that number of normal grains per ear. Consequently, both species displayed respectively the lowest averages in numbers of aborted grains per ear (6.4 and 6.2 NGAM). These were also low in comparison with the 17 to 36 NGAM reported by Villalobos-González *et al*. (2019) for X´mejen Naal under chemical fertilization.

Treatments did not affect the averages of the variables of the grains and ear, nor were there any effects of green manure plus an inoculation with symbionts (p>0.05). The intervals recorded were as it follows: LG (0.9-1.1 cm), AG (0.8-0.9 cm), GG (0.4-0.4 cm), P1000G (268.5-321.3 g), NGH (26.2-30.5), LM (13.8-14.9 cm), DM (4.0-4.3 cm), NHM (12.3-13.5), DOL (2.4-3.0 cm), POL (18.7-21.8 g), y PM (101.9-120.2 g). These values

Table 3. Yield of X´mejen Naal maize with the influence of green manures (*Mucuna pruriens*, *Vigna unguiculata* and *Phaseolus lunatus*) with and without the inoculation with symbiotic microorganisms in Chiná, Campeche, Mexico (July to December 2020).

Treatment	Factor	PF (g)	MS (g)	BAF (g m^{-2})	BMT (Mg ha^{-1})	PPAU	MPAU	DFPH	RG (g)	RGPH (Mg ha^{-1})	IC
MUC¶	A	779.0 b	97.4 b	536.5 b	5.4 b	109.0	79.5	51904.8	77.3	2.9	0.6
PEL§		942.0 b	119.1 ab	534.9 b	5.4 b	89.8	76.4	42738.0	72.5	2.7	0.5
IBEÞ		1162.0 ab	168.6 a	653.8 ab	6.5 ab	95.3	83.3	45357.0	81.4	3.2	0.5
ARDAP§§		1251.0 a	163.6 a	822.8 a	8.3 a	105.5	85.3	50238.3	81.5	3.3	0.4
MUC¶	AB	779.0 b	97.4 b	513.0	5.1	114.3	81.5	54404.8	70.0	2.7	0.6
PEL§		942.0 ab	119.1 ab	561.0	5.6	98.0	83.0	46666.5	73.5	3.0	0.6
IBEÞ		1162.0 a	168.6 a	725.1	7.3	93.0	87.3	44285.5	83.5	3.5	0.5
MUCEM¤		937.0 ab	115.7 ab	560.1	5.6	103.8	77.5	49404.8	84.5	3.1	0.6
PELEM††		990.8 ab	127.5 ab	508.9	5.1	81.5	69.8	38809.5	71.4	2.4	0.5
IBEEM ¶¶		935.5 ab	126.5 ab	582.5	5.8	97.5	79.3	46428.5	79.3	3.0	0.5
ARDAP§§		1251.0 a	163.6 a	822.8	8.3	105.5	85.3	50238.3	81.5	3.3	0.4

Means with different letters indicate significant differences (Tukey, $p \leq 0.05$), means without letters were not different (Tukey, $p > 0.05$), Treat: treatments, ¶MUC: *Mucuna pruriens*, §PEL: *Vigna unguiculata*, ÞIBE: *Phaseolus lunatus* (L), ¤MUCEM: *M. pruriens* with added endomycorrhizae (EM) and beneficial nitrogen fixating bacteria (BFN), ††PELEM: *V. unguiculata* wth added EM and BFN, ¶¶IBEEM: *P. lunatus* (L) with added EM and BFN, §§ARDAP: control with incorporated weeds plus 200 kg ha^{-1} diammonium phosphate. PF: fresh weight, MS: dry matter, BAF: final aerial biomass, BMT: total biomass, PPAU: plants per useful plot, MPAU: ears per useful plot, DFPH: final density of plants per hectare, RG: grain yield per plant, RGPH: grain yield per hectare, IC: harvest index.

coincide with those mentioned by Conceição dos Santos *et al*. (2019) in X'mejen Naal maize.

Grain yields were similar in both green manure and fertilization with ARDAP (p>0.05), thus, they are efficient techniques to ensure nutrition for maize, that can replace the use of chemicals in Campeche and the Yucatan Peninsula. To develop eco-friendly alternatives that also solve the problem of maize nutrition in Campeche would help to achieve profitable and sustainable yields (Ramírez-Jaramillo *et al*., 2018).

Medina-Méndez *et al*. (2018) and Villalobos-González *et al*. (2019) mentioned that fertilizer formulas rich in N and P (such as 92-92-00 and 110-46-00) optimize maize nutrition in Campeche with yields between 3.0 to 6.2 Mg ha^{-1} of grain, although only 3% of farmers can afford this technology. When improved varieties and hybrids are used, Campeche state-wide yields range from 2.0 to 3.5 Mg ha^{-1}, which coincides with the results of this study with the X'mejen Naal native variety, which also has the advantage of being precocious (crop cycle is shorter than 75 d).

Regarding the nutritional management in native maize, Conceição dos Santos *et al*. (2019) chose the fertilization formula 120-80-00 and included X'mejen Naal maize, with which they obtained yields between 56.0 and 82.7 g p^{-1}. Those values were surpassed by the three green manures evaluated in this study. Yields of IBE and MUCEN are noticeable for their higher average values. Results proved the efficiency of green manures, particularly in the case of *Vigna unguiculata* and *Phaseolus lunatus*, which are part of the *milpa* system at the local scale and are also preferred in the area, compared to *Mucuna pruriens* (Uuh-Narváez *et al*., 2021).

The yields of fodder and grain produced and favoured by the green manures in X´mejen Naal maize are significant in terms of animal nutrition, as Cázares-Sánchez *et al*. (2015) stated this native variety also has high protein content. Therefore, fertilization with green manures may be an option for the agricultural and livestock production sectors in terms of fodder production. In addition to the reduction in the use of synthetic fertilizers, along with the environmental benefits of this agricultural practice. All of which favours the use of green manures in the ferric Luvisol soils of the state of Campeche, Mexico.

CONCLUSIONS

The agronomic characteristics measured coincided with the descriptors of X'mejen Naal maize and the green manures tested with and without the addition of symbiotic microorganisms. The green manures turned out similar to the treatment with wild plants plus the addition of 200 kg ha^{-1} of diammonium phosphate in their effect on the variables of growth and yield.

Due to this, the green manures proved to be an alternative to fertilization when planting maize. Bean Ib (*Phaseolus lunatus*) produced higher yields than with conventional fertilization in dry matter and grain in maize and it got to be the best option, along with *Vigna unguiculata*. Both species are part of the ancient Mayan *milpa* culture.

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