Article

Performance of corn grain with and without fertilization in the state of Campeche

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Abstract

Maize is of great importance for the state of Campeche based on the number of producers and the cultivated area, because it is a priority crop for research and technology transfer. In the present investigation, the main objective was to determine the effect of fertilization on grain yield. The 11 hybrids were used, which were subjected to two environments, with and without fertilization. The experiment was supplied only with rainwater. The statistical analysis showed highly significant differences between fertilization treatments and hybrids. Treatment without fertilization recorded the lowest average performance. The average response to fertilization was 1 231 kg ha^{-1} and was in a range of 749 to 2 558 kg ha^{-1}. On the other hand, although all hybrids responded positively to fertilization, this response was differential, influenced by the genotype-environment interaction. Fertilization was valued at $2 900 ha^{-1}, equivalent to 878 kg of grain at current prices of 2017. With fertilization the best materials were 7W69C, MH-9058 with average yield of 6 172, 6 004 kg ha^{-1}, which it represents net income of 9 743 and 9 188 pesos per hectare, respectively, which translates into a productivity of 0.97 and 0.92 pesos per square meter. Likewise, in unfertilized corn, the best materials were DKB-399 and 7W79C, with average yields of 5 185 and 4 748 kg ha^{-1}, which gives rise to net income of 9 386 and 7 943 pesos per hectare, respectively and it translates into a productivity of 0.94 and 0.79 pesos per square meter. The formula of fertilization 110-46-00 applied to corn, caused an increase in net income that on average was $1 162 ha^{-1}, which could amount to $3 815 ha^{-1} on average, if the most outstanding hybrids are used.

Keywords: fertilization, corn, yield,

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Introduction

In Campeche, corn production takes place from two sowing cycles. Spring - summer, in which about 145 thousand hectares are cultivated in their entirety of temporary with purposes mainly of grain production and autumn - winter, in which they cultivate from 4 to 5 thousand hectares in the center and South of the state, whose Water supplement is given by the temporary plus the residual moisture, and an approximate quantity of 500 hectares, which are sown under irrigation with the main purpose of producing corn for fresh consumption.

In relation to the productivity in the mentioned cases of corn for grain, this is of the order of 3.5 to 4.0 t ha^{-1} under temporary in mechanizable soils, either in spring-summer or in autumn-winter and from 0.4 to 0.6 t ha^{-1} in soils under the rose-tomb-burning system, when native materials are used (Medina, 2011b). Of the planted area, 60 to 70% are located in soils of the Luvisols type.

The number of producers in the entity is approximately 30 thousand. The sowing takes place at the beginning of the rainy season, june, and extends until the beginning of august. The most common planting materials flower from 52 to 55 days after sowing and the harvest occurs between 120 and 130 days after sowing. Predominantly, the preparation of the soil with machinery on the slash-and-burn, the use of mechanical sowing on manual sowing, and the use of improved seed of hybrids and varieties of free pollination on the creole varieties.

Fertilization generally includes a fertilizer application at the time of planting, based on a source, Diammonium Phosphate, used in amounts ranging from 50 to 150 t ha^{-1}. Weed control is mostly done with herbicides and the harvest is done with machinery (Medina *et al.*, 2009; Medina *et al.*, 2011). The cultivation of corn presents less and less profit margin for producers given the high cost of inputs for production.

The total cost to produce one hectare of this grain in the state of Campeche was $10 625 ha^{-1} in 2017. Of this cost, fertilization occupied about 27%, 28% seed and planting, 19% soil preparation, 10% weed control, 7% pest control and 9% harvest. The 100% dependence of the crop on maize results in a high risk, which limits the investment of resources and before this scenario, the maize becomes a highly extractive soil agrosystem, as some producers aim to save as much as possible. They use inadequate formulas of fertilization and even some reach the degree of not fertilizing. The objective of this research was to quantify the effect of fertilization on grain yield.

Materials and methods

The field data were obtained from a trial with different varieties, carried out during the spring-summer 2011 cycle. Production costs according to the technology applied in the trial were updated at current prices of 2017 to also apply the value of locally registered production in that year.

Location, type of soil and climate of the study area

The locality where the planting took place was the common Cayal, in lands of the Produce-Campeche Foundation (19° 45' 11.57" north latitude, 90° 09' 52.65" west longitude). The approximate altitude is 34 m above sea level. The soil is known as Kancab type in Mayan language, is clayey and is classified as Luvisol Ferric by FAO/UNESCO (1970). These soils are found in mechanizable soils of high potential for corn production in the state (Medina, 2006). They are flat topography with a slightly undulating microrelief.

The analysis of this soil in the profile of 0-20 cm reported 3% of organic matter, 15 to 20 ppm of nitrates, Olsen phosphorus 8 to 12 ppm, high in interchangeable potassium, without problems of salinity and neutral to slightly acid pH. The climate in the locality is of type AW_1, being the intermediate variant of the warm-subhumid climates with rains in summer. It presents 85% of annual rainfall in the months of May to October, with amounts ranging from 450 to 700 mm from planting to the physiological maturity of the grain. The average temperature in the crop development cycle ranges from 21 to 28 ºC.

Treatments under study

The research was developed using 11 maize hybrids as a genetic material, from the companies Monsanto and Syngenta, as well as a commercial hybrid released by INIFAP, recommended for planting in the Entity (Table 1). These materials were evaluated in two environments, one including fertilization with the formula recommended for commercial sowings and another without fertilization. For the treatment with fertilizer formula 110-46-00 was used, with fertilization sources such as diammonium phosphate and urea (FAO, 2002).

Experimental design

The distribution of the treatments (hybrids) and field repetitions was done according to Figure 1, which denotes an experimental design of random blocks with four repetitions (blocks). As can be seen in Table 1, the trial had 11 treatments and four repetitions. Of these repetitions, only three were fertilized and one of them (the II) was not fertilized. The size of the experimental plot was four rows of 6 m in length separated at 0.8 m from each other, the useful plot were the two central furrows. The arrangement of the plants within the furrows was of two plants every 35.7 cm, for a density of 70 thousand plants per hectare.

The statistical analysis of grain yield was carried out through the experimental designs program of the Autonomous University of Nuevo León (Olivares, 1994). Two analysis of variance was carried out with the randomized block design, the first of them considered four repetitions, including the unfertilized one, and the second only included the three fertilized repetitions.

Table 1. Field sketch.

Treatments	Blocks			
	With fertilizer	Without fertilizer	With fertilizer	With fertilizer
	I	II	III	IV
1. Murano	1	10	8	4
2. 7W69C	2	8	3	7

Treatments	Blocks			
	With fertilizer	Without fertilizer	With fertilizer	With fertilizer
3. Impacto	3	6	5	6
4. 7W79C	4	1	11	10
5. NK-254	5	2	7	3
6. 8H08C	6	3	9	8
7. H-431	7	11	2	1
8. DKB-399	8	5	6	2
9. BG-9720	9	4	1	11
10. MH-9058	10	9	4	5
11. DK-380	11	7	10	9

Agronomic management of the crop

The sowing date was July 09. The arrangement of the plants within the furrows was of two plants every 35.7 cm, for a density of 70 thousand plants per hectare. The preparation of the soil consisted of two semi-heavy harrow passes, which were applied in the months of May and june. The sowing took place on the ninth of July, the soil being humid. There were no setbacks between the sowing and the emergence of the crop, making the seedlings visible five days after sowing, with very few failures of germination. Initially, three seeds were planted per site to ensure adequate population and in the three-leaf phase, thinning was done to leave only two plants per site, as shown in Figure 1.

Figure 1. Aclareo of plants to leave two of them per site.

The fertilizer was applied once only 20 days after sowing (Figure 2) in the aforementioned repetitions, incorporating the fertilizer to the soil with a hoe. In the second treatment, where no fertilizer was applied, it was also hoened and in this way we tried to avoid any difference in handling. The most important pest was the armyworm and its control was carried out with a single application of *Cypermethrin*.

Figure 2. Application of fertilization in stage V5-V6.

The weed was manually combed with hoe in stages V5-V6, just when the fertilizer was applied and it was also combated chemically using *Nicosulfuron* in mixture with 2,4-D amine, at 35 days after sowing. The harvest was carried out on november 28 (Figure 3), 141 days after sowing, with the grain at a humidity between 18 and 21%. Only the plants that had complete competition in the useful plot were harvested. Although different characteristics of the plant were recorded, such as days to flowering, health, plant height and stubble production, the main variable in this study was grain yield adjusted to 14% moisture (INIFAP, 2017).

Figure 3. Harvesting of the hybrid trial with and without fertilization.

Results and discussion

Meteorological conditions

The climate was characterized by an average temperature of 27.6 °C in the month of July, 22.4 °C in the month of October and finally 21.8 in the first tenth of the month of november, which indicates that this factor was more stressful for the plant at the beginning of development and more favorable at the end of it. The most critical stage in the development of the plant, flowering, was affected by the rainfall deficit that took place during the month of august during the drought period called 'canicula' (Figure 4). During the development of the plant, from the sowing to the physiological maturity of the grain, 603 mm were rained, of which 343 were between sowing and flowering and 260 mm between flowering and the physiological maturity of the grain. This volume of rainfall was close to ideal for the good development of corn (600-700 mm), but had an unequal distribution over time, which undoubtedly had a negative impact on grain yield (Paliwal *et al*., 2001), avoiding that these could show their true potential of yield.

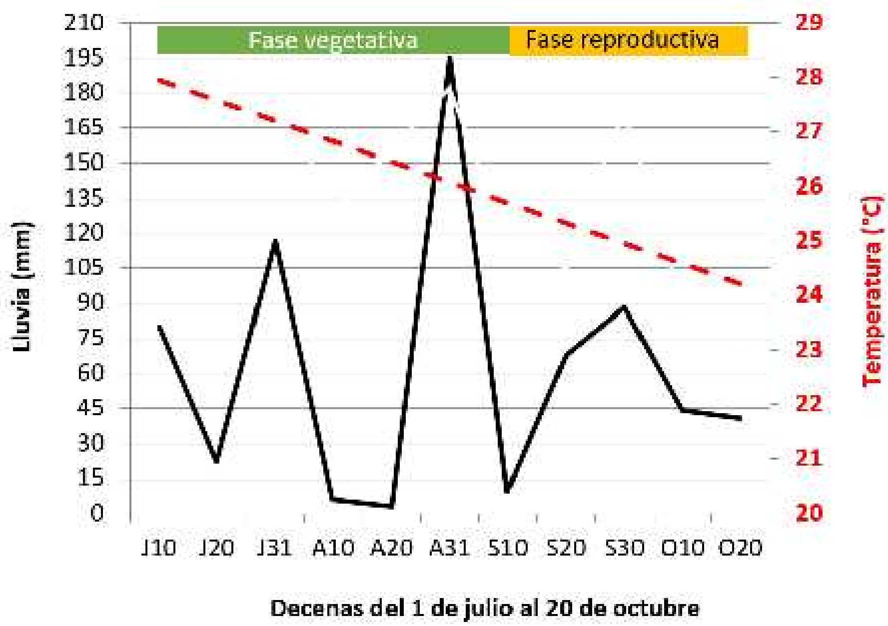

Figure 4. Accumulated rainfall and average temperature during the phases of crop development.

Statistical analysis of grain yield

Two variance analyzes were performed for the yield, one considering the four repetitions and another without considering the unfertilized repetition. In both cases, this analysis indicated the existence of highly significant differences in the treatments and in the blocks (Table 2), which indicated that there was a differential response of the hybrids in the yield, and that at least one of the repetitions recorded a performance different to the others. This gave the guideline to analyze the means of the hybrids and identify and if necessary select the best ones and also analyze the means of the repetitions to verify if in fact the repetition that was not fertilized and that by the way had the lowest performance, was statistically different from the fertilized repetitions Martínez (1988).

Table 2. Results of the analysis of variance.

Variation source	Degrees of freedom	Sum of squares	Average square	F calculated
Treatments	10	9008512	900851.2	5.9**
Blocks	3	19787008	6595669.5	43.2**
Error	30	4580480	152682.7	

Total	43	33376000		
C.V.= 7.63%				
FV	G.L.	S.C.	C.M.	F.C.
Treatments	10	8403072	840307.2	6.9**
Blocks	2	7289536	3644768	29.8**
Error	20	2447744	122387.2	
Total	32	18140352		
C.V.= 6.45%				

The means test of the treatments (Table 3) considering only the fertilized repetitions indicated that five statistical groups were formed, the group with the best performances being the hybrids 7W69C, MH-9058, DKB-399, NK-254, which had an average yield of 5 982 kg ha^{-1}; while the group with the lowest performance and statistically different from the first group included the hybrids 8H08C, Murano, H-431 and impact, with an average yield of 48 60 kg ha^{-1}.

Table 3. Yields of hybrids.

Treatments	Yield (kg ha^{-1})	DMS (0.05= 596 kg)				
7W69C	6 172	a				
MH-9058	6 004	a	b			
DKB-399	5 993	a	b			
NK-254	5 758	a	b	c		
7W79C	5 554		b	c	d	
DK-380	5 450		b	c	d	
BG-9720	5 313			c	d	
8H08C	5 140				d	e
Murano	4 973				d	e
H-431	4 691					e
Impacto	4 637					e

The test of means of the repetitions (Table 4), indicated that in effect, the non-fertilized reptile (block II) obtained the lowest yield (4 194 kg ha^{-1}) and was statistically different from the three fertilized, I, III and IV, which recorded average yields of 4 773, 5 645 and 5 860 kg ha^{-1}, respectively.

Table 4. Average yields of the blocks.

Block	Average (kg ha^{-1})	DMS (0.05= 340 kg)
IV. (Fertilized)	5 860	A
III. (Fertilized)	5 645	A
I. (Fertilized)	4 773	B
II. (Not fertilized)	4 194	C

Analysis of the impact of fertilization and genetic material on performance

According to Figure 5, all hybrids showed a positive response to fertilization by increasing their yields; however, this response was differentiated, undoubtedly influenced by genetic and environmental aspects and their interaction (Etchevers *et al*., 1991; Turrent *et al*., 2005). As shown in Table 5, the average response to fertilization was 1 231 kg ha^{-1} and was in a range of 749 to 2 559 kg ha^{-1}.

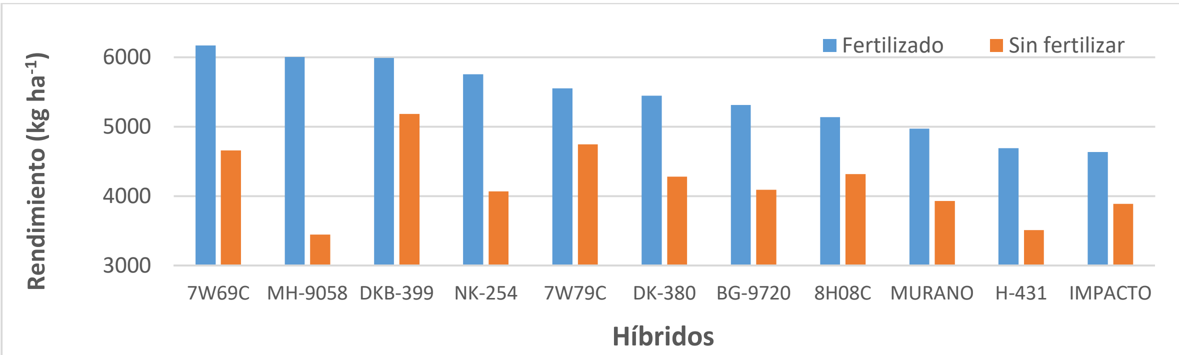

Figure 5. Response of 11 maize hybrids to two fertilization environments.

The increase in yield could be due to the fact that the fertilization impelled the development of the root and this helped the plant to cushion the effect of the drought that occurred in the vegetative phase and thus the fertilized corn produced greater biomass in general (Marcano *et al*., 1994; Dhuyvetter and Schlegel, 1994). For its response to fertilization the best materials were 7W69C, MH-9058 with average yield of 6 172, 6 004 kg ha^{-1}, for the case in which it was not fertilized, the best materials were DKB-399 and 7W79C, with average yields of 5 185 and 4 748 kg ha^{-1}. The procedure for the discrimination and selection of these materials was by adding the mean and the standard deviation in each fertilization environment.

Table 5. Average yields of hybrids.

Hybrids	Fertilized	Without fertilized	Difference
	kg ha^{-1}		
MH-9058	6004*	3446	2558
NK-254	5758	4072	1686
7W69C	6172*	4660	1512
BG-9720	5313	4093	1220
H-431	4691	3514	1177
DK-380	5450	4284	1166
Murano	4973	3931	1042
8H08C	5140	4319	821
DKB-399	5993	5185*	808
7W79C	5554	4748*	806
Impacto	4637	3888	749
Average	5426	4195	1231
Desv. standard	529	523	

Financial and productivity analysis

From the average yield values reported in Table 6, it is found that with the application of fertilizer 5 426 kg ha^{-1} is obtained, which is higher in 1 231 kg than the yield obtained without fertilization, of 4 195 kg ha^{-1}. At current prices of 2017, the cost of fertilization treatment with formula 110-46-00 was $2 900, which included the input and the cost of its application. Also, at current prices of 2017, with a value of $3.30 kg of corn, the value of 1 231 kg of corn was $4 062.3, if at this value we subtracted $2 900, which is the cost of fertilization, obtains that the application of fertilizer to corn left an average profit margin of $1 162.3 ha^{-1}, which is considered an incentive for the producer to fertilize corn with the recommended fertilization formula.

In the profitability aspect, according to Table 6 indicates that the cost of the technological package of unfertilized corn was $7 725 per hectare, while in the fertilized corn it was $10 625. This leads us to obtain income net of $6 618 for unfertilized corn, due to its lower yield and $7 280 per hectare, for fertilized corn, which demonstrates the profitability of fertilization (CIMMYT, 1988; UF/IFAS, 2014). Translating the above to pesos per hectare, the fertilized corn registered a higher productivity (0.73), being lower (0.61) for the non-fertilized corn.

One way to maximize the income in the fertilized corn is to use the genetic material of higher productivity, such is the case of the hybrids 7W69C, MH-9058, DKB-399, NK-254, 7W79C and DK-380, which have an above-average productivity of unfertilized corn.

At the same time, it is necessary to point out that some specific trends were found among the hybrids; for example, the MH-9058 and the NK-254 respond better to the fertilized environment, while the 8H08C stood out in the unfertilized environment and is probably a hybrid with aptitude for disadvantaged or low fertility environments. Likewise, it can be observed that four of the 11 materials stood out in both fertilization environments, being these 7W69C, DKB-399, 7W79C and DK-380, so they are considered stable hybrids before the environmental variability (Carballo and Márquez, 1970; Orona *et al*., 2013).

Table 6. Financial analysis of maize production with and without fertilization.

Treatments	Cost ($ ha^{-1})			Yield	Income ($ ha^{-1})		Productivity
	Fixed	Variable	Total	(kg ha^{-1})	Total	Net	($/m^2)
Not fertilized	7 725	0	7 725	4 195	13 843	6 118	0.61
DKB-399	7 725	0	7 725	5 185	17 111	9 386	0.94
7W79C	7 725	0	7 725	4 748	15 668	7 943	0.79
7W69C	7 725	0	7 725	4 660	15 378	7 653	0.77
8H08C	7 725	0	7 725	4 319	14 253	6 528	0.65
DK-380	7 725	0	7 725	4 284	14 137	6 412	0.64
Fertilized	7 725	2 900	10 625	5 426	17 905	7 280	0.73
7W69C	7 725	2 900	10 625	6 172	20 368	9 743	0.97
MH-9058	7 725	2 900	10 625	6 004	19 813	9 188	0.92
DKB-399	7 725	2 900	10 625	5 993	19 777	9 152	0.92
NK-254	7 725	2 900	10 625	5 758	19 001	8 376	0.84

Treatments	Cost ($ ha^{-1})			Yield	Income ($ ha^{-1})		Productivity
	Fixed	Variable	Total	(kg ha^{-1})	Total	Net	($/$m^2$)
7W79C	7 725	2 900	10 625	5 554	18 328	7 703	0.77
DK-380	7 725	2 900	10625	5 450	17 985	7 360	0.74

Finally, according to this study, the cost of fertilization formula 110-46-00 was $2 900.00 and represented 27% of the total cost of $10 625.00; however, its importance is based on the fact that, according to the conditions in which the study was carried out, its effect was estimated at 16% of the net benefit obtained. Also, from the information provided by the present study it was estimated that a crop without fertilizer like the present one would be extracting from the soil about 61 kg ha^{-1} of nitrogen, 13 kg of phosphorus and 17 kg of potassium, according to estimates by authors such as García (S/F) and Campitti and García (2007) which is useful information for the calculation of fertilizer quantities that should be applied annually through fertilization to maintain the soil in its current fertility status (Mallarino, 2005).

Conclusions

The recommended fertilization had a positive effect on grain production.

The response of the hybrid to fertilization was differential.

In the fertilized maize, the best hybrids contribute 52% more than the average net income.

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