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Evaluation of corn (*Zea mays* L.) hybrids in corn growing areas of Ecuador

Evaluación de híbridos de maíz (*Zea mays* L.) En zonas maiceras del Ecuador

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Abstract: This research was conducted during the dry season in two corn production zones of the Ecuadorian coast, the selected locations were the province of Santa Elena, El Azúcar sector, and the province of Los Ríos, Puerto Pechiche sector. The purpose was to evaluate the adaptability of new high yielding corn (*Zea mays* L.) hybrids in two corn production zones of Ecuador. A factorial design with six corn hybrids and two production zones was used. Statistical analysis indicated significant differences for: plant height, day of flowering emergence, disease incidence, ear insertion height, ear diameter and length, number of rows, 100 kernel weight, ear cover, percentage of lodged plants, percentage of ears with rot and yield per hectare. The hybrids with outstanding agronomic and yield characteristics were ADV248, followed by ADV407 and ADV762L6.

Keywords: adaptation, yield, corn varieties

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Resumen: La presente investigación fue realizada durante la época seca en dos zonas de producción maicera de la costa ecuatoriana, las localidades seleccionadas fueron la provincia de Santa Elena sector El Azúcar y la provincia de Los Ríos sector Puerto Pechiche, El propósito fue evaluar la adaptabilidad de nuevos híbridos de maíz (*Zea mays* L.) de alto rendimiento en dos zonas maiceras del Ecuador. Se utilizo un diseño factorial con seis híbridos de maíz y dos zonas de producción. El análisis estadístico indico diferencias significativas para: altura de planta, día de emergencia de la floración, incidencia de enfermedades, altura de inserción de mazorca, diámetro y longitud de mazorca, número de hileras, peso de 100 granos, cobertura de mazorca porcentaje de plantas acamadas, porcentaje de mazorcas con pudrición y rendimiento por hectárea. Los híbridos con destacadas características agronómicas y productivas fueron ADV248, seguido de ADV407 y ADV762L6.

Palabras clave: adaptación, rendimiento, variedades maiz

Introduction

Worldwide, corn (*Zea mays L.) is a* cereal of great economic and nutritional importance. The main producers of this grass, according to FAO (2017) are: United States of America with approximately 370 million tons per year, followed by Continental China with 259 million T/year, Brazil ranks third with 97 million T/year, and lastly Argentina with 4 million T/year. It is considered a representative cereal that creates economic sources within the food agroindustry.

The production of this grass is one of the most important agricultural activities on the Ecuadorian coast, as it is the raw material for the production of balanced products for the animal industry. In 2017, it was estimated that the planted area of this species was 388,534 Has with an average yield of 4Tm/Ha. On the other hand, 79.26% of the planted area is registered in the provinces of Los Ríos, Manabí and Guayas (National Institute of Statistics and Geography). (Instituto Nacional de Estadistica y Censos (INEC), 2017)..

At present, on the Ecuadorian coast it is one of the most important socioeconomic crops, due to the work it provides to farmers in large rural areas. The Central Bank of Ecuador (2018) in its report describes that nowadays, farmers adopt new technologies such as the use of certified seeds that has become daily in agricultural fields. The planting of hybrids is a fundamental factor to increase yields, however, it is not the only factor that has an impact on production, Ortiz (2014) refers

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that there are other factors such as: the zone, climatic conditions, management and agricultural work (weed management, fertilization, integrated pest and disease management), the type of investment and the type of farmer(Roca et al., 2013)..

The release of high-yielding hybrids tolerant to adverse biotic and abiotic factors will contribute to minimize losses of this grass. Therefore, the present research work on the adaptability of new maize (*Zea mays* L.) hybrids in Ecuador was carried out to determine the yield in two zones of the Ecuadorian coast.

Materials and methods

The research work was carried out in two areas of the Ecuadorian coast in the province of Santa Elena, Santa Elena canton, in the town of "El Azúcar" with UTM coordinates of 547143 E; 9751329 N, at 39 m.a.s.l., with an average temperature of 24ºC and average annual rainfall of 1000 mm, with clay loam soils, In the province of Los Ríos canton Puebloviejo, in the locality "Puerto Pechiche" with UTM coordinates 660176.9 E; 9842171.9 N, at 179 m.a.s.l., with an average temperature of 24ºC to 26ºC and average annual rainfall of 1867mm. The productive history in the province of Los Ríos is extensive in short-cycle and permanent crops, and in the province of Santa Elena there has been a productive growth in the last five years in short-cycle crops, especially corn. The research method was based on a factorial design of 6 corn hybrids and two production zones with 3 replications. The statistical evaluation was made through an analysis of variance (ANDEVA), with Tukey's test with a significance at 5%, thus analyzing the adaptability of the different hybrids tested in each zone. Diseases that occurred at 90 days were identified in the plots studied and the percentage of damage caused was evaluated using a severity scale.

Table 1. *Rating scale for foliar diseases*

Ordinal scale Rating	Damage identification
1 Excellent	No damage
2 Resistant	Slight infection in the third of the plant.
3 Moderately sensitive	Severe infestation on the lower leaves of the plant.
4 Sensitive	Severe infestation in the lower and middle leaves of the plant.
5 Deficient	Very heavy infestation

CIMMYT, 1999

Ten plants were randomly selected in each of the plots with the different treatments, thus evaluating, through a scale from 1 to 5, the corn cob cover. The estimation was based on a general average expressed in scale.

Table 2. *Cob cover rating scale.*

Ordinal scale Rating		Coverage by bracts
1	Excellent	The bracts tightly cover the tip of the cob and extend beyond it.
2 Regular		They tightly cover the tip of the cob.
3 Exposed tip		Loosely cover the cob to the tip.
4 Exposed grain		The bracts do not cover the ear adequately and leave the tip somewhat exposed.
5 Completely unacceptable		Poor coverage; the tip is clearly exposed.

CIMMYT, 1999

Data were taken on the total number of ears with rot in each of the plots of the study treatments and these values were given as a percentage according to the following scale.

Table 3. *Grading scale for ear rot.*

Scale	Damage identification
1	0% infected grains
2	10% of infected grains
3	20% of infected grains
4	30% of infected grains
5	40% of infected grains

CIMMYT, 1999

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Table 4. *Treatments under study formed by location and Hybrid corn*

N°	Zone	Corn Hybrid	Origin/ Country
1	St. Helena	ADV 762L6	Thailand
2	St. Helena	ADV 407	Thailand
3	St. Helena	ADV 248	Thailand
4	St. Helena	HVM 110427	Argentina
5	St. Helena	SOMMA	Colombia
6	St. Helena	DK 7088	Brazil
7	Los Rios	ADV 762L6	Thailand
8	Los Rios	ADV 407	Thailand
9	Los Rios	ADV 248	Thailand
10	Los Rios	HVM 110427	Argentina
11	Los Rios	SOMMA	Colombia
12	Los Rios	DK 7088	Brazil

3. Result

Agronomic variables (plant height and days to male flower emergence).

Table 5 shows the data for the variable plant height in cm at 100 days after planting, where the most representative treatments showed a higher average in the evaluated variable were HVM110427 with 252.70 cm followed by ADV248 with 242.77 cm and DK7088 with 237.33 cm planted in the zone of Los Ríos, while the HVM110427 treatment planted in the zone of Santa Elena showed the lowest height with 201.27 cm. In the analysis of variance, there was no statistical significance for the factors evaluated (hybrids, zones) and their interaction. However, the variable male flowering emergence of the plant at 60 days, where the most representative treatment that presented the best average in the evaluated variable was ADV248 with 60.00 days, having 100% male flowering planted in the zone of Santa Elena, while the corn hybrid HVM110427 planted in the zone of Los Ríos presented the lowest flowering emergence with 98.36% at 61.67 days. The analysis of variance showed statistical significance for the evaluated factors, hybrids and zones; therefore, the alternative hypothesis is accepted because there is a statistical difference for the treatments and zones. In the interaction of the AxB factor, there was no significance.

Table 5. *Agronomic variables of maize (plant height and days to male flower emergence)*.

NO.	Factor A Hybrids	Factor B Zones	Height 100 Days /cm		Days to male flower emergence	
1	HVM110427	Los Rios	252,70	a	61,7	a
2	ADV248	Los Rios	242,77	a	61,0	ab
3	DK7088	Los Rios	237,33	a	61,0	ab
4	ADV407	Los Rios	236,10	a	60.3	
5	ADV407	St. Helena	233,30	a	60,3	ab
6	ADV762L6	Los Rios	233,20	a	61,0	ab
7	DK7088	St. Helena	232,43	a	61,0	ab
8	ADV762L6	St. Helena	232,40	a	60,3	ab
9	ADV248	St. Helena	232,33	a	60,0	b
10	SOMMA	Los Rios	207,53	a	61,0	ab
11	SOMMA	St. Helena	207,47	a	60,3	ab
12	HVM110427	St. Helena	201,27	a	61.00	ab
E.E			13,59		0,25	0,25
C.V % C.V			10,27		0,73	0,73

Means with a common letter are not significantly different (p > 0.05).

Table 6 shows the diseases that occurred in the crop at 90 days with their respective leaf severity scale for the hybrids under study, where the treatments ADV248, ADV762L6, ADV407 and HVM110427 showed a moderately sensitive scale for diseases caused by the fungus Curvularia spp, ADV407 and HVM110427 presented a moderately sensitive scale for the disease caused by the fungus *Curvularia spp (*2.71) and resistance for diseases caused by the fungi

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*Helminthosporium spp (*1.99), *Cercospora spp* (2.19) and *Phyllachora maydis* (2.03); Through the analysis of variance it can be observed that there is statistical significance for *Hemilthosporium spp, Cercospora spp, Banded blight spp and Phyllachora maydis* for the factors under study, however there is no statistical significance for *Curvularia spp* in both factors. Banded blight showed an interaction between the factors, accepting the alternative hypothesis. As for the coefficient of variation, *Helminthosporium* presented a value of 13.82% *Curvularia* 11.51% *Cercospora* 6.58% *Banded blight* 5.66% and *Phyllachora maydis.*

Table 6. *Identification of foliar diseases*

NO.	Factor A Hybrid	Factor B Zones	Helminthosporium	Curvularia	Cercospora	Banded blight	Phyllachora maydis
1	SOMMA	Los Rios	2,33 a	2,50 a	3,00 a	2,00 a	3,33 a
2	SOMMA	St. Helena	2,33 a	2,50 a	1,50 b	1,50 b	1,33 b
3	ADV762L6	Los Rios	2,17 a	2,67 a	3,00 a	1,50 b	3,00 a
4	HVM110427	Los Rios	2,00 a	3,17 a	3,00 a	1,50 b	2,83 a
5	HVM110427	St. Helena	2,00 a	2,50 a	1,50 b	1,50 b	1,00 b
6	ADV762L6	St. Helena	2,00 a	2,83 a	1,50 b	1,50 b	1,00 b
7	ADV248	St. Helena	2,00 a	2,67 a	1,50 b	1,50 b	1,00 b
8	ADV248	Los Rios	2,00 a	2,50 a	3,00 a	1,50 b	3,17 a
9	Dk7088	Los Rios	1,83 a	2,50 a	2,67 a	1,00 c	3,00 a
10	ADV407	Los Rios	1,83 a	3,33 a	3,00 a	1,50 b	3,00 a
11	Dk7088	St. Helena	1,83 a	2,67 a	1,17 b	1,17 c	1,17 b
12	ADV407	St. Helena	1,67 a	2,67 b	1,50 b	1,50 b	1,00 b
	E.E		0,16	0,18	0,80	0,50	0,12
	C.V		13,82	11,51	6,58	5,66	9,86

Means with a common letter are not significantly different (p > 0.05).

The averages of ear insertion height (AM) at 100 days, ear diameter, ear length, rows per ear, and ear cover (Table 7).The data of the variable of the height of ear insertion at 100 days in centimeters, where the most statistically representative treatments presented a higher average in the evaluated variable were HVM110427 with 126.83 cm followed by ADV248 with 120.30 cm ADV407 with 115.87 cm SOMMA with 113.07 cm and DK7088 with 110427 with 110427 with 113.07 cm,07 cm and DK7088 with 110.37 cm planted in the Los Rios zone, HVM110427 with 118.03 cm followed by DK7088 with 114.33 cm and

ADV407 with 109.03 cm planted in the Santa Elena zone, while the ADV762L6 treatment planted in the Santa Elena zone presented the lowest average ear insertion height of 103.47 cm.

On the other hand, ear diameter showed the highest average DK7088 with 5.50 cm followed by SOMMA with 5.44 cm and HVM110427 with 5.42 cm planted in the Santa Elena area, while treatments ADV248 with 4.88 cm followed by ADV762L6 and ADV407 with 4.85 cm planted in the Los Ríos area showed the lowest ear diameter. The ear length variable, the treatments that presented the highest average in the evaluated variable were ADV762L6 with 19.37 cm followed by ADV407 with 19.20 cm HVM110427 with 19.10 cm SOMMA with 18.33 cm DK7088 with 18.00 cm and ADV248 with 17.80 cm planted in the zone of Santa Elena, while the treatment DK7088 with 15.87 cm planted in the zone of Los Ríos presented the lowest ear length. The variable number of rows in the ear, presented a higher average in the evaluated variable were Dk7088, SOMMA with 18.00 rows sown in the zone of Los Ríos and Santa Elena, while treatments ADV762L6 and ADV407 sown in the zone of Los Ríos presented the lowest average number of rows in the ear with 14.00 rows. Finally, the treatments HVM110427, DK7088, SOMMA with a score of 2 (regular), planted in the zone of Santa Elena and Los Ríos, had the highest average ear coverage, while treatments ADV762L6, ADV248, and ADV407, planted in the zone of Los Ríos and Santa Elena, had the highest ear coverage with a score of 1 (excellent). In the analysis of variance, there was statistical significance in the variables ear insertion height (AM) at 100 days, ear diameter, ear length, rows per ear, ear coverage for the factors evaluated between hybrids and zones, therefore, the alternate hypothesis is accepted because there are statistical differences in the treatments and zones; in the interaction of the AxB factor there was no statistical significance for the variables evaluated.

Table 7. *Ear characteristics of maize hybrids in the study areas.*

NO.	Factor A Hybrids	Factor B Zones	AM (cm)		DM (cm)		LM (cm)		HM (cm)		CM Scale (1-5)	
1	HVM110427	Los Rios	126,83	a	4,99	def	16,97	def	14,67	bc	2,00	a
2	ADV248	Los Rios	120,30	ab	4,88	ef	16,30	ef	16,00	abc	1,00	b
3	HVM110427	Santa. Elena	118,03	ab	5,42	ab	19,10	abc	15.33	abc	2,00	a
4	ADV407	Los Rios	115,87	ab	4,85	f	16,93	def	14,00	c	1,00	b
5	DK7088	St. Helena	114,33	ab	5,50	a	18,00	abcd	18,00	a	2,00	a

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6	SOMMA	Los Rios	113,07	ab	5,16	bcde	17,53	cde	18,00	a	2,00	a
7	DK7088	Los Rios	110,37	ab	5,07	cdef	15,87	f	18,00	a	2,00	a
8	ADV407	St. Helena	109,03	ab	5,28	abcd	19,20	ab	14,67	bc	1,00	b
9	SOMMA	St. Helena	108,13	b	5,44	ab	18,33	abcd	17,33	ab	2,00	a
10	ADV248	St. Helena	107,90	b	5.32	abc	17,80	abcde	16,00	abc	1,00	b
11	ADV762L6	Los Rios	107,10	b	4,85	ef	17,67	bcde	14,00	c	1,00	b
12	ADV762L6	St. Helena	103,47	b	5,38	abc	19,37	a	14,67	bc	1,33	b
E.E			3,28		0,06		0,30		0,51		0,10	
C.V	%		5,04		1,86		2,89		5,55		10,91	

(AM) ear insertion height at 100 days, (DM) ear diameter, (LM) ear length, (HM) rows per ear, (CM) ear coverage, (CM) ear length, (HM) rows per ear, (CM) ear length.
Means with a common letter are not significantly different ($p > 0.05$).

In the variable on the percentage of lodged plants in both root and stem, there was no presence of lodging in any of the treatments, both in the Los Ríos zone and in the Santa Elena zone, qualifying the hybrids under study as tolerant to lodging. In the variable on the percentage of ears with rot, there was no presence of rot in any of the treatments, both in the Los Ríos and Santa Elena zones, qualifying the hybrids under study as excellent.

The weight of 100 grains of corn, where the most statistically representative treatments presented the highest average in the evaluated variable were ADV762L6 with 40.03 grams, followed by HVM110427 with 39.57 grams and ADV407 with 38.83 grams, planted in the zone of Santa Elena, while the treatment Dk7088 planted in the zone of Los Ríos presented the lowest weight of 100 grains of corn with 29.57 grams. The yield per hectare showed a high percentage of yield in the treatments ADV248 with 9435.79kg, ADV407 with 9241.78kg, and ADV762L6 with 9208.37kg planted in the zone of Los Ríos, while the treatments planted in the zone of Santa Elena such as the hybrid ADV47 with 6081.99kg followed by HVM110427 with 6000.92kg and SOMMA with 5652.71kg presented lower yields in the experimental study. In the yield variable, the analysis of variance presented a high statistical significance in the zones, accepting the alternate hypothesis because there are statistical differences in the zones and there was no statistical significance for the hybrid factor, therefore, the null hypothesis is accepted because there is a statistical equality for the treatments; in the AxB interaction there was no statistical significance. The coefficient of variation was 10.22% (Table 8).

Table 8. *Weight of 100 kernels of corn*

NO.	Factor A Hybrids	Factor B Zones	100 grains (Gr)		Humidity %		Yield (kg/ha)	
1	ADV762L6	St. Helena	40,03	a	14,90	bcd	6533,93	bc
2	HVM110427	St. Helena	39,57	a	14,53	bdcef	6000,92	c
3	ADV407	St. Helena	38,83	ab	15,20	bc	6081,99	bc
4	ADV762L6	Los Rios	38,77	ab	13,97	def	9208,37	a
5	ADV407	Los Rios	37,80	ab	13,87	ef	9241,78	a
6	ADV248	St. Helena	37,17	abc	15,27	b	6672,56	bc
7	HVM110427	Los Rios	37,00	abc	13,73	f	8527,13	ab
8	ADV248	Los Rios	35,80	abc	13,93	def	9435,79	a
9	SOMMA	Los Rios	34,00	bcd	14,23	cdef	8015,67	abc
10	SOMMA	St. Helena	34,00	bcd	14,73	bcde	5652,71	c
11	DK7088	St. Helena	32,33	cd	16,87	a	6291,99	bc
12	DK7088	Los Rios	29,57	d	13,80	ef	7697,53	abc
E.E			0,90		0,18		439,28	
C.V%			4,32		2,09		10,22	
C.V%								
C.V%								
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C.V%								
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Means with a common letter are not significantly different (p > 0.05).

According to the results obtained, for the variable plant height at 100 days, it was observed that the development of plant height is determined by the genotype used and by the environmental conditions. However, there are no statistical differences on height in the study treatments. According to Bodnár et al, (2018) hybrids have different genetic backgrounds, therefore, they develop differently, inferring the agro-technical factor and climatic conditions of the area where the crop is developed.

Male flowering emergence at 60 days was presented by treatments ADV248, SOMMA, ADV762L6 and ADV407 planted in the Santa Elena zone. In the present experimental research work, the average

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number of days to male flowering for the two study zones was 60 and 61 days, being considered early. However, Bastidas et al, (2015) mentioned that early varieties are not considered early when there is a maximum difference of 1 to 2 days in different locations. On the other hand, Martinez-Sanchez et al, (2017) that there are cases where, the results on phenology indicate that it is possible to find early cycle populations in areas of lower fertility and with higher drought stress, expressing fashion for male and female flowering at 60 and 61 days in warm climates. But in this experimental research study they did not present drought stress in any of the two study zones, but male flowering at 60 and 61 days according to what the author mentions.

Ear insertion height at 100 days had high statistical significance across treatments and zones with an ear insertion height of 126.83cm with wide internodes in treatment HVM110426. Sangoi et al.,.(2002) indicate that increasing the number of plant population causes lengthening of the internodes, increasing not only plant height, but also increasing the height of ear insertion, but there is a decrease in the diameter of the stem, causing plant lodging. This was not the case in this experimental research study because there was no stem or root lodging. However, Quiroz et al, (2017) the humidity and temperature of the locations is an important factor for the genotype to register its maximum expression in its development.

The ear length (LM), ear diameter (DM) and number of rows (NH) of the ear presented high statistical significance ($p \leq 0.05\%$) in the treatments and zones, presenting a LM of 19.37cm the ADV762L6 treatment, the highest DM 5.50cm had the DK7088 treatment, the highest NH of the ear showed the DK7088 and SOMMA treatments with 18 rows. The NH had an average of 15.89 rows in the ears in this study. Borroel et al, (2018) depends on the genetic capacity of the hybrids evaluated to present differences in ear development, number of rows and that floral emergence also influences these developmental characteristics. According to Ramírez-Díaz et al. (2015) the crossing of hybrids with different characteristics, in a varied environment and with optimal nutrient supply, are essential factors that influence ear formation and yield. Rodriguez et al,(2016) report in relation to LM that variability is given by the morphological characteristics of the genotype. This agrees with what Laverde, De la Cruz and Rojas (as cited in Borroel et al, (2018)) the biological capacity for growth and functional ear development is a characteristic that is influenced by plant genetics, variety or hybrid, crop conditions and environmental characteristics.

According to the CIMMYT ear cover rating scale, treatments HVM110427, SOMMA and DK7088 had a regular ear cover (2), while ADV248, ADV407 and ADV762L6 had excellent ear covers (1). Acosta, Martínez, Colomer and Ríos (2013) in the morphoagronomic evaluation in a maize population reported excellent (1) and regular (2) cob coverings without presenting damage to the grain by rotting, which is similar to the values obtained in this research. According to Guzmán (2017) indicates that it is essential to select a hybrid with excellent ear closure because, being exposed to rainfall at different times of the year, temperature, humidity, different zones during grain filling and physiological maturation can cause the appearance of diseases in the corn grain, a fact that was not reflected in this experimental research study because there was excellent ear coverage and the climatic conditions were stable.

In the variable evaluated in grain moisture, the highest percentage was presented by the hybrid DK7088 planted in the Los Ríos area with 16.87% moisture, according to Blanco et al. (2016) The higher the moisture content of the grain, the greater the biological activity of external organisms. Therefore, agronomic management from the beginning of planting to harvest is essential, since, if the grain is wet there is a reduction in its price, being disadvantageous for the farmer according to the table described by MAG (2019). The previous authors express that grain moisture also influences industrial yield. Although in the dry season the area of Santa Elena presents an increase in relative humidity and wind speed, grain moisture did not reflect a problem for this research study.

In terms of yield in this experimental research study, the ADV248 hybrid planted in the Los Ríos area had the highest yield of 9435.79 kg/ha when considering genotypes with desirable characteristics and adequate agronomic management. According to Iglesias et al, (2018) a good agronomic management, helps to obtain good yields, since, by carrying out an effective fertilization the plant will extract the necessary nutrients for its development in the different physiological stages, an argument that agrees with Barragán et al, (2018)indicating that hybrids require high nutritional amounts to obtain good yields and productivity.

This study obtained yield values higher than those indicated by the Sistema de Información Publica Agropecuaria (2018) the average

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productivity in the province of Los Rios is 6290 kg/ha. While in the province of Santa Elena has an average production of 6470kg/ha, this value is similar to that obtained in this study when working with hybrids ADV248, ADV762L6, ADV407, HVM110427, planted in Santa Elena; it should be emphasized that this province has the highest corn productivity in the country according to the SIPA, however, in this study the highest productivity was obtained in the province of Los Rios when working with hybrids ADV248, SOMMA and ADV407.

4. Conclusions

The agronomic response of the hybrids under study showed similarity in the plant height variable in the two zones evaluated; however, in the variables ear insertion, diameter, length, and ear rows, and flower emergence, there were statistical differences in the treatments under study. However, there were ranges in the rating scale of disease incidence by CIMMYT, being resistant hybrids HVM110427, ADV762L6 and ADV248 with low percentage of grain moisture and good cob cover in the evaluated zones.

The hybrids with the highest productivity were ADV248, ADV407, ADV762L6, HVM110427, SOMMA and DK 7088 in the Los Rios area with a higher production range of 7697 kg to 9435 kg per hectare.

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