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Evaluation of agronomic traits and severity of foliar disease of three commercial hybrids and five advanced triple hybrids of hard yellow maize

Evaluación de características agronómicas y severidad de enfermedades foliares de tres híbridos comerciales y cinco híbridos triples avanzados de maíz amarillo duro

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ABSTRACT

Field experiments were conducted to evaluate agronomic traits and response to foliar fungal diseases of five advanced triple hybrids of hard yellow maize (*Zea mays* L.) and three commercial hybrids. An A × B factorial experiment was used with eight treatments, four repetitions and the Tukey test to compare means of the treatments (P>0.05). The most limiting disease is rust. The agronomic characteristics of breeding lines: h1, h2, h3, h4 and h5 (triple hybrids) were evaluated and compared with h6, h7, and h8 (commercial hybrids). Field trials were conducted in two locations of Central Coast of Ecuador (Quevedo and Balzar). Both locations showed significant differences for agronomic traits; Balzar presented lower yield (6,205.46 kg ha^{-1}) and greater severity of curvularia leaf spot (3.34 CIMMYT scale) compared to Quevedo (7,368.21 kg ha^{-1}) and

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(2.47 CIMMYT scale). For hybrids, h6 had significantly lower yield (5,306.83 kg ha^{-1}), compared to h5 (6,914.09 kg ha^{-1}), h1 (7211, 80 kg ha^{-1}), and h3 (7,266.83 kg ha^{-1}), and h8 (8036.85 kg ha^{-1}). Significant differences were also detected for the orthogonal comparison (INIAP hybrids) with 5,634.44 kg ha^{-1} and the promissory lines with 6,997.68 kg ha^{-1}. The highest net profit was achieved with the hybrid h2 with US$1,405.76 followed by the hybrid h1 with US$1,385,92, obtaining a Benefit - Cost ratio of 2.32 and 2.30 respectively, which indicates that for each monetary unit invested $ 1.32 and 1.30 additional or profit was obtained for the two hybrids, respectively.

Key words: breeding plant, yield, disease resistance, cultivars new, *Zea mays* L., Ecuador.

RESUMEN

Se realizaron experimentos de campo para evaluar las características agronómicas y la respuesta a las enfermedades fúngicas foliares de cinco híbridos triples avanzados de maíz amarillo duro (*Zea mays* L.) y tres híbridos comerciales. Se utilizó un experimento factorial A × B con ocho tratamientos, cuatro repeticiones y la prueba de Tukey para comparar las medias de los tratamientos (P>0.05). La enfermedad más limitante es la roya. Se evaluaron las características agronómicas de líneas mejoradas: h1, h2, h3, h4 y h5 (híbridos triples) y se compararon con h6, h7 y h8 (híbridos comerciales). Se realizaron experimentos en dos localidades de la costa central de Ecuador (Quevedo y Balzar). Ambas localidades mostraron diferencias significativas para las características agronómicas; Balzar presentó menor rendimiento (6.205,46 kg ha^{-1}) y mayor severidad de la mancha foliar por curvularia (escala CIMMYT 3,34) en comparación con Quevedo (7368,21 kg ha^{-1}) y (escala CIMMYT 2,47). Para los híbridos, h6 tuvo un rendimiento significativamente menor (5306,83 kg ha^{-1}), en comparación con h5 (6914,09 kg ha^{-1}), h1 con (7211, 80 kg ha^{-1}), y h3 (7266,83 kg ha^{-1}), y h8 (8036,85 kg ha^{-1}). También se detectaron diferencias significativas para la comparación ortogonal (híbridos INIAP) con 5.634,44 kg ha^{-1} y las líneas promisorias con 6.997,68 kg ha^{-1}. La mayor utilidad neta se logró con el híbrido h2 con US$1.405,76 seguido del híbrido h1 con US$1.385,92, obteniendo una relación Beneficio - Costo de 2,32 y 2,30 respectivamente, lo que indica que por cada unidad monetaria invertida $ 1,32 y 1,30 adicionales o se obtuvo ganancia para los dos híbridos, respectivamente.

Palabras clave: mejoramiento de plantas, rendimiento, resistencia a enfermedades, nuevos cultivares, *Zea mays* L., Ecuador.

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INTRODUCTION

Maize is one of the most important cereal crops in the world, currently, is grown on every continent except Antarctica, and is most productive where rainfall or irrigation is adequate. The origin of maize has been a matter of discussion for a long time. Currently the most accepted theory is a combination of the works of George Beadle and Deborah Pearsall. Beadle proposed that the current maize would initially be the result of a mutation of a wild grass, the Teosintle, in the southern Mexico around 9,000 years ago (Matsuoka *et al*., 2002).

Many different maize products can be obtained. Approximately 24% of the crops produced in the United States are transformed for food, alcohol, and industrial uses. The US produces approximately 40% of the world's maize. Other important producers are: China, Brazil, Europe, Mexico, Argentina, India, and South Africa (OECD/FAO, 2020).

Maize breeding and production programs in each country are based on knowledge of the environments to which it is directed. The success of maize for food and feeding livestock can be attributed in large part to its hybrids. Farmers accepted these hybrids because of their superior yields and more vigorous growth. Varietal hybridization through controlled pollination or open pollination was the origin for the development of many maize varieties; even today, new varieties evolve in farmers' fields generated by crosses derived from open pollination (Troyer, 1996) and adaptation to increased planting density (Wang *et al*., 2020).

In Ecuador, maize is a crop of greater importance at the national level for its production and consumption. More than 291,867 ha of maize are planted for 2022 and the main

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destination is the formulation of food balanced to generate protein type meat, chicken and pork (Ibarra-Velásquez *et al*., 2023).

Maize is attacked by a large number of insects and affected by several pathogens causing significant economic damage; therefore evaluations of genotype × environment are necessary to identify the type of hybrid more suitable and productive for different zones exacerbated by Climate Change (OECD/FAO, 2020).

Some additional features that influence the adaptation and acceptance of maize genotypes in a specific environment are: a) the type of maturity; b) the type of grain; and c) color of the grain, which indicates the area sown in the most important environments of the Coastal zone of Ecuador, adding flowering time, days to anthesis and the relative height of the ear from genome-wide changes that occurred during maize domestication (Wang *et al*., 2020).

Farmers use local varieties or their own varieties or seed from open-pollinated varieties and various types of hybrids. As a general rule, farmers on marginal land or in environments unfavorable to their cultivation use seeds of their own varieties, thus lowering the cost of this input. On the other hand, farmers in safe rainfall areas or in irrigated crops more quickly adopt the use of hybrids and use higher levels of inputs. Understanding the socio-economic aspects of maize environments is essential for proper planning and for carrying out breeding and production programs (Beck and Vasal, 1993), known in Ecuador as recycled seed (Ibarra-Velásquez *et al*., 2023).

The National Maize Program of the National Institute of Agricultural research (INIAP) has generated varieties, such as INIAP-513, INIAP-526 hard yellow, and INIAP 527, H-550, H-551, and H-553 hard white hybrids. Many of these materials are grown in Guayas, Los Ríos, Loja, Manabí and serves for feeding (https://eva.iniap.gob.ec/web2/maiz-duro/hibridos-maiz-duro/). Genetic improvement has allowed gaining of important agronomic traits such as higher grain yield (Arias, 2003; Wang *et al*., 2020).

The introduction of new maize hybrids will provide information that will help to obtain great productive capacity in the area and good grain quality and agronomic parameters

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of importance for farmers (Ibarra-Velásquez *et al*., 2023). Therefore, the objectives of this study were to evaluate the agronomic behavior and foliar disease severity of five promissory triple hybrids of hard yellow maize and compare against three commercial hybrids in the rainy season, also to determine the best location for adaptability and the cost benefit analysis of these hybrids.

MATERIALS AND METHODS

Plant material

Original crosses to develop maize triple hybrids were conducted in 2003 by the Unidad de Investigación Científica y Tecnológica (UICYT) - Universidad Técnica Estatal de Quevedo. Two selection cycles per year were conducted and are summarized in Table 1 and Figure 1.

Table 1. Development of advanced maize triple hybrids adapted to the Central coastal conditions of Ecuador.

Year	Rainy season (January - April)	Dry season (June-September)
2003		Planting of original wild materials, selection and self-fertilization of S0 lines in populations 1, 2, 3, 4, 5, 6
2004	Sowing of S0 lines, and selection of S1 lines of populations 1 -6	Planting of S1 lines, and selection of S2 lines of populations 1-6
2005	Planting of S2 lines, and selection of S3 lines of populations 1 -6	Sowing of S3 lines, and selection of S4 lines of populations 1 - 6
2006	Planting of S4 lines, and selection of S5 lines of populations 1 – 6	Planting of S5 lines, and selection of S6 lines of populations 1 - 6
2007	Crossing of lines selected from the populations 1- 6 by a tester (top cross) which can be the composed of the populations 1, 2, 3, 4, 5 or 6 for the lines of those population	Diallellic crossing selected in each population

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2008	Formation of the best simple hybrids selecting by additive gene activity and specific combining ability of populations 1-6	Evaluation of simple hybrids in several localities (four)
2009	Development of triple hybrids	Evaluation of simple and triple hybrids in several localities
2010	Evaluation of simple and triple hybrids in several localities	

H1= (SM45-1× SSD08) × SV39-1

H2= (SM45-1× SV15-1) × SV39-1

H3= (SM45-1× SV 35-1) × SV39-1

H4= (SV15-1× SV 45-1) × SV39-1

H5= (SV15-1× SV 45-1) × SV39-1

Figure 1. Promissory triple hybrid lines used in this study developed by the Unidad de Investigación Científica y Tecnológica (UICYT) - Universidad Técnica Estatal de Quevedo.

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Commercial hybrids evaluated in this study were: INIAP H-553, simple hybrid, that has as parents two inbred lines (S4 L49 Pichilingue 7928 × L237 Population A1); INIAP H-551, a triple hybrid that has as parents three inbred lines (S4B-523 × S4B-521) × S4B-520. These lines were obtained by successive free cross pollination and come from different basic maize with a broad genetic base and good yield potential. The third hybrid evaluated was AGROCERES AG-003, a semi-early triple hybrid of the latest generation, with semi-erect leaves with excellent performance, with good tolerance to insect pests and diseases.

Location and description of the experimental site

Field trials were carried out in the localities, location 1 (Quevedo) in the experimental farm "La María" of the State Technical University of Quevedo (UTEQ) located at km 7 of the Quevedo-El Empalme road, whose geographical coordinates are: 79°47”W and 01°32” S, at 76 meters above the sea level (m a.s.l.).

Location 2 (Balzar) corresponded to the experimental farm of the Agrarian University of Guayaquil located at km 37 of the Guayaquil road, whose geographical coordinates are: 79°46” W and 1°09” S, at 60 m a.s.l. The research was carried out in 2011.

Planting and management of the crop

Experimental plots were 5 × 3.60 m with a net plot size of 5 × 1.80 m, 9.00 m^2 with 4 rows. Row distance was 0.90 m, and distance between plants was 0.20 m. For calculations the total population was 55.500 plants/ha.

Plots were arranged in a randomized complete blocks design (RCBD), with a factorial experiment (A × B) were A is localities (two) and B is hybrids (eight) in four repetitions. To evaluate the hybrids, standard agricultural practices were conducted. Soil preparation consisted of manual cleaning of the experimental area, sowing was done manually using a "espeque" holes were made at a depth of 4 to 5 cm, in which two seeds were deposited per site. After 12 days (d) the most vigorous plant per site was selected, and manual removal of the second plant was done. Weed control was performed using a pre-emergent Paraquat in doses of 1.5 L ha^{-1} and after 50 d weeds were removed manually.

Fertilization was done applying 138 kg ha^{-1} of N, 46 kg ha^{-1} of P_2O_5 and 60 kg ha^{-1} of K_2O. Nitrogen application was carried out at 8, 15, and 35 days after planting (dap).

Insect control was done with Syngenta® Karate Insecticide cihalotrina-lambda, in doses of 40 mL in 20 L of water, and also chlorpyrifos was applied mixing with sand (bait) in doses of 100 mL in a liter of water in 100 pounds of sand direct to the bud of the plant. Harvest was done manually 120 dap.

Agronomic traits and foliar disease severity

Days to flowering was determined by the number of days elapsed from planting to 51% of the plants of each plot that were presented of 2-3 cm of their visible pistils or male panicles. Plant height was taken from ground level to the base of the male flower. The sample was 10 plants randomly taken from each net plot. Height of insertion of the cob was determined by the distance between the ground level and the main cob. Acame (stem lodging) was evaluated at 95 dap counting the number of plants with an inclination with respect to ground level, and root lodging by counting all plants broken from the insertion of the cob to the ground level.

Rates of foliar disease severity curvularia leaf spot (*Curvularia lunata* (Wakker) Boedijn), helminthosporium leaf blight (*Exserohilum turcicum* [Pass.] Leonard & Suggs and *Bipolaris maydis* [Nisikado & Miyake] Shoemaker), physoderma brown spot (*Physoderma maydis* [Miyabe] Miyabe), rust (*Puccinia* spp.) and corn stunt spiroplasma (*Spiroplasma kunkelii* Whitcomb *et al*.) were done at 90 dap at R8 growth stage, following the CIMMYT scale (CIMMYT, 1985) and rated on 1 to 5, where 1 indicates no diseases and 5 very heavy infection. The field guide for identification of corn diseases was used to differentiate symptoms (CIMMYT, 2004). Although other studies have used more accurate phytopathometry, quantifying the number of lesions cm^{-2} (Garcés *et al*., 2011), we used a simpler scale due to time constrictions.

Length of the cob was done in ten cobs randomly taken and then individually measured their length in centimeters from the base to the apex. Diameter of the cob was done using a calibrator, the diameter was measured in the third of each cob and its unit expressed in centimeters. Number of rows per cob was counted. Cob uniformity was evaluated following the CIMMYT 1-5 scale where 5 is large and 1 is small. Yield per hectare was done using the weight of the grains obtained in each net plot and adjusting to moisture content at 13%. The methodology of the economic analysis determination: yield, utility (1 kg of corn = US$ 0.34), fixed cost, variable cost, total cost, utility, benefit/cost ratio, cost-benefit and is detailed in Table 9.

Data analysis

Statistical analysis consisted in ANOVA. To measure the differences between the means of the treatments, the Tukey test (*P*>0.05) was used in INFOSTAT (Universidad de Cordoba, Argentina).

RESULTS AND DISCUSSION

Summary of weather variables during the rainy season in the locaties showed that Quevedo presented higher precipitation and the year 2010 (Tab. 2). There were no differences compared to temperature.

Table 2. Precipitation and temperature by month for location 1 (Quevedo) and location 2 (Balzar), from January to May of 2010 and 2011.

Location 1 (Quevedo)					Location 2 (Balzar)			
Months	**Precipitation (mm)**	**Mean Temp. °C**	**Absolute Maximum °C**	**Absolute Minimum °C**	**Precipitation(mm)**	**Mean Temp. °C**	**Absolute Maximum °C**	**Absolute Minimum °C**
2010								
January	389	26.6	34.8	21.9	137,6	27,50	34,90	19,00
February	804.3(R)	27.1	33.1	23	373,7	27,60	33,00	23,50
March	489.1	27.4	33.5	22.2	72,9	28,10	32,90	23,40

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April	694.4	27.6	34.2	21.5	187	28,10	34,30	23,00
May	231.9	27.1	33.2	21.2	19,7	27,30	33,10	21,80
2011								
January	369.6	25.7	32.5	20.5	128,7	26,8	35,1	21,5
February	490.5	26.3	33.2	20.9	170,7	27	33,1	21,7
March	144.1	27	34.5	20.7	31,3	28	33,3	22,7
April	725.6	26.7	32.5	21.4	278,3	27,7	32,9	22,4
May	9.9	26.4	33.2	20.9	7	27,3	34,6	21,3

Source: INAMHI (National Institute of Meteorology and Hydrology).

Agronomic parameters

For days to male flowering and female flowering, significant statistical differences were observed for localities (Quevedo and Balzar) and for hybrids, and without differences between the interaction localities × hybrids. The overall average for days to male flowering was 52.29 d and for female flowering was 55.89 d. Mean squares of the ANOVA for male flowering and female flowering, in the evaluation of the agronomic behavior of five advanced triple hybrids of hard yellow corn (*Zea mays* L.) and three commercial hybrids in the rainy season are presented in Table 3. Additionally, the hybrids presented significant differences for days to male flowering (h6 51.5 d and h8 55.75 d). Likewise, for days to female flowering (INIAP H-h6 54.13 d and h8 59.88 d) (Tab. 4).

Significant differences were found for days for flowering between locations, Quevedo showed 50.94 d for male flowering and Balzar 54.84 d. The days to flowering in Quevedo were shorter because it had higher relative humidity (83.5 %) compared to Balzar (72.9 %) (Tab. 5).

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Table 3. Mean squares of the analysis of variance for days to male and female flowering, agronomic traits: plant height, cob insertion height, acame (stem lodging), lodging (root), cob diameter and length, number of rows, and cob uniformity and yield of five promissory triple hybrids of hard yellow corn (*Zea mays* L.) and three commercial hybrids in the rainy season in Central coast of Ecuador.

Source	**Df**	**Days to male flowering**	**Days to female flowering**	**Plant height**	**Cob insertion**	**Acame (stem lodging)**	**Root lodging**	**Cob diameter**	**Cob length**	**Number of rows**	**Cob uniformity**	**Yield**
Total	63											
Locations	1	118.27*	70.14*	3.27*	0.90 *	0.11 ns	1.05 ns	0.01 ns	2.78*	0.20*	0.00 ns	21631848.00*
Hybrids	7	16.10*	23.05*	0.05*	0.0014 ns	0.13 ns	3.08*	0.05 *	6.24*	0.57*	1.00*	557108.00*
h8 *vs.* h1-h7	1	109.02*	145.15*	0.29*	0.0002 ns	0.22 ns	0.65 ns	0.013 ns	21.33*	1.53*	2.28*	14286057.00*
h6-h7 *vs.* h1-h5	1	0.30 ns	5.80 ns	0.04 ns	0.01 ns	0.09 ns	6.38*	0.06 *		0.30 ns	0.00 ns	2124225.00*
Localities × Hybrids	7	0.30 ns	1.71 ns	0.01 ns	0.0028 ns	0.32 ns	0.36 ns	0.03 ns	0.66 ns	0.42 ns	0.14 ns	332548.80 ns
Repetitions	3	0.72	0.35	0.00	0.00	0.23	0.62	0.03	0.43	0.09	0.04	79298.91
Experimental error	45	0.40	0.53	0.01	0.0033	0.27	0.36	0.01	0.33	0.23	0.17	525017.00
Mean		52.29	55.89	2.11	0.9	59.8	55.05	4.68	15.99	13.26	2.50	6786.83
CV (%)		1.20	1.30	4.73	6.27		1.35	2.13	3.59	3.62	16.49	10.68

* = significant at level 0.05. ns = not significant. h1 = (SM45-1 × SSD08-1) × SV39-1; h2 = (SM45-1 × SV15-1) × SV39-1; h3 = (SM45-1 × SV35-1) × SV39-1; h4 = (SV15-1 × SV15-1) × SV39-1; h5 = (SV15-1 × SV45-1) × SV39-1; h6 = INIAP H-551; h7 = INIAP H-553; h8=AG-003.

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Table 4. Days to male and female flowering, plant height, cob diameter, cob length, number of rows, cob uniformity (CIMMYT scale) and yield of five advanced triple hybrids of hard yellow corn (*Zea mays* L.) and three commercial hybrids in the rainy season in Central Coast -Ecuador.

Hybrids	**Days to male flowering**	**Days to female flowering**	**Plant height (cm)**	**Cob diameter (cm)**	**Cob length (cm)**	**Number of rows**	**Cob uniformity (1-5)**	**Yield (kg ha^{-1})**
h1	51.75 a	55.00 ab	2.11 a	4.77 b	16.46 c	13.39 ab	1.99 a	7211.80 cd
h2	51.75 a	55.63 b	2.11 a	4.76 b	16.16 bc	13.55 ab	2.75 b	7266.83 cd
h3	51.63 a	55.63 b	2.13 a	4.68 ab	16.44 c	13.09 ab	2.38 ab	6881.97 bc
h4	52.38 a	55.75 b	2.06 a	4.72 b	15.34 ab	13.25 ab	2.63 ab	6714.25 bc
h5	51.75 a	55.63 b	2.11 a	4.71 b	16.14 bc	13.23 ab	2.5 ab	6914.09 bcd
h6	51.50 a	54.13 a	2.01 a	4.51 a	15.13 a	12.85 a	2.88 b	5306.83 a
h7	51.88 a	55.50 b	2.06 a	4.63 ab	14.78 a	13.23 ab	2.88 b	5962.06 ab
h8	55.75 b	59.88 c	2.29 b	4.73 b	17.53 d	13.70 b	2.00 a	8036.85 d

Numbers followed by the same letter in a column are not significantly different (Tukey, $P<0.05$). h1 = (SM45-1 × SSD08-1) × SV39-1; h2 = (SM45-1 × SV15-1) × SV39-1; h3 = (SM45-1 × SV35-1) × SV39-1; h4 = (SV15-1 × SV15-1) × SV39-1; h5 = (SV15-1 × SV45-1) × SV39-1; h6 = INIAP H-551; h7 = INIAP H-553; h8=AG-003.

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Table 5. Agroecological and meteorological characteristics of the experimental site.

Parameter	Quevedo	Balzar
Temperature (ºC)	23-28	24.7
RH (%)	83.5	72.9
Heliophany (horas month)	76.62	881
Annual precipitation (mm)	1,500 a 3,000	1,222
Ecological zone	Bh-t	T-seco
Topography	Irregular	Curly
Texture	Loamy	Clayey-sandy
pH	5.5-6.5	5.9-7.1

Source: INAMHI (2006).

The mean plant height was 2.11 m and cob insertion height 0.95 m (Tab. 3). Significant differences were found for the localities, Balzar with 1.89 m and Quevedo 2.34 m in plant height. In the same way, significant differences were found for the height of insertion of the ear with 1.03 m in Quevedo and 0.8 m in Balzar (Tab. 6). This indicates that the locality of Balzar under conditions of greater heliophany (Tab. 5) has a lower plant height. H8 with 2.29 m of height of the plant was significantly taller than the other hybrids (Tab. 4). Acame (stem lodging) and root lodging showed percentages above 50 % in all hybrids (data not shown).

Table 6. Plant height and cob insertion height of five advanced triple hybrids of hard yellow corn (*Zea mays* L.) and three commercial hybrids in the rainy season in Central Coast -Ecuador.

Localities	Plant height (cm)	Cob insertion height (cm)
Quevedo	2.34 b	1.03 b
Balzar	1.89 a	0.80 a

Numbers followed by the same letter in a column are not significantly different (Tukey, P<0.05).

There were significant differences between hybrids and for the orthogonal comparison h6 and h7 (INIAP hybrids) *vs.* h1, h2, h3, h4 and h5 (promissory hybrids) in root lodging,

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showing higher resistance to lodging in the promissory lines (Tab. 3). Performance depends on when lodging occurs and whether the cobs remain in contact with the ground. Poor lodging is the result of two sub processes stem bending and root pulling out (Wang *et al*., 2022). In the case of the hybrids, although a significant effect was detected, lodging occurred late in the growing season therefore hybrids were not susceptible to yield losses due to root lodging.

The analysis of variance showed significant differences between locations for ear length, but not for ear diameter. Likewise, the hybrids presented differences for both variables (Tab. 3). The overall mean for cob diameter was 4.68 cm and for cob length was 15.99 cm.

The differences between hybrids was significants, placing the hybrid h6 with 4.51 cm the small diameter of the cob and the best h1 hybrid with 4.77 cm. For length of the cob, the shortest hybrid was h7 with an average length of 14.78 cm and the largest cob h8 with 17.53 cm (Tab. 4). The agroclimatic conditions of the Central Coastal of Ecuador are good for the development of the cob for h1 being the hybrid with the largest diameter of the cob and the hybrid h8 is the one with the longest length of the cob.

Analysis of variance for the number of rows per cob, showed significant statistical differences for localities and no significant differences for cob uniformity (Tab. 3). Given the statistical significance for the hybrids, the overall mean for the number of rows per cob was 13.26 rows/cob and for cob uniformity was 2.50. According to the CIMMYT scale a moderately large cobs were detected in this study (CIMMYT, 1985). Hybrid h6 had significantly lower threads per cob (12.85 threads/cob) compared to h8 with 13.70 threads/cob. According to the CIMMYT scale, cob uniformity was significantly higher in h6 (large cobs) compared to h8 (medium-large cobs). The agronomic advantage it has is on grain yield and production.

Number of cobs, and weight were variables related to yield. When performing the analysis of variance for yield, statistical significance was detected for localities and hybrids. No statistical significance for the interaction between localities × hybrids (Tab. 3). The overall mean of the yield was 6786.83 kg ha^{-1} and the coefficient of variation for

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the experiment was 10.68%. The yield small was Balzar with 6205.46 kg ha^{-1}, and best for Quevedo with 7368.21 kg ha^{-1}, due to increased water supply (Tab. 2 and 5).

The yield showed significant differences between hybrids in four groups, the first of h6 and h7 with 5306.83 and 5962.06 kg ha^{-1}, respectively; the second h3, h4 and h5 with 6881.97, 6714.25 and 6914.09 kg ha^{-1}, respectively; the third by h1 and h2 with 7211.80 and 7266.83 kg ha^{-1}; and fourth for h8 with 8036.85 kg ha^{-1}, the fourth rank for hybrids (Tab. 4). Significant differences were detected for the orthogonal comparison h6-h7 (INIAP hybrids) with 5634.44 kg ha^{-1} and h1, h2, h3, h4 and h5 (promising lines) with 6997.68 kg ha^{-1} (Tab. 3). Yields in maize cultivation are very essential for successful agriculture, they have increased over time thanks to more resistant maize hybrids and agronomic improvement.

Foliar disease severity

There was low corn stunt spiroplasma (*S. kunkelii*) incidence and severity in the experimental plots (Tab. 7). The overall mean of stunt Spiroplama was 1.65 – CIMMYT scale. Environmental conditions (rainy and hot) were not favorable for the development of the vector (*Empoasca* sp.) (Donoso, 2008). Hybrid resistance to corn stunt spiroplasma have shown that antibiosis could be related to the resistance as decreased nymph survival and adult longevity has found on X1297J (Carpane, 2007).

Table 7. Mean squares of the analysis of variance for corn stunt spiroplasma, curvularia leaf spot, helminthosporium leaf blight, phishoderma brown spot, and rust, in the evaluation of the agronomic traits and foliar disease severity of five promissory triple hybrids of hard yellow corn (*Zea mays.* L.) and three commercial hybrids during the rainy season in the Central Coast Ecuador.

Source	DF	Spiroplasma	Curvularia	Helminthosporium	Physoderma	Rust
Total	63					
Locations	1	0.56 ns	12.25*	0.11 ns	0.25*	1.27*
Hybrids	7	0.17 ns	0.67*	0.32*	0.07 ns	0.16 ns
H8 *vs.* h1-h5	1	0.01 ns	3.22*	1.88*	0.04 ns	0.19 ns

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H4 *vs.* h5	1	0.25 ns	0.00 ns	0.06 ns	0.25*	0.06 ns
H1 *vs.* h2h3	1	0.02 ns	0.53 ns	0.02 ns	0.02 ns	0.08 ns
Localities×Hybrids	7	0.17 ns	0.21 ns	0.21 ns	0.07 ns	0.16 ns
Repetitions	3	0.35	0.73	0.06	0.00	0.02
Experimental error	45	0.23	0.20	0.11	0.06	0.09
CIMMYT scale		1.65	2.90	2.17	2.06	1.14
CV%		28.96	15.42	15.28	11.89	26.31

* = significant at level 0.05. ns= not significant. h1 = (SM45-1 × SSD08-1) × SV39-1; h2 = (SM45-1 × SV15-1) × SV39-1; h3 = (SM45-1 × SV35-1) × SV39-1; h4 = (SV15-1 × SV15-1) × SV39-1; h5 = (SV15-1 × SV45-1) × SV39-1; h6 = INIAP H-551; h7 = INIAP H-553; h8=AG-003.

For curvularia leaf spot (*C. lunata*) had the highest magnitude of damage of all evaluated diseases. Statistical significance was determined for localities and hybrids, and the the Tukey test at 5% AG-003 (h8) *vs*. INIAP promissory hybrids (h1-h5) (Tab. 7). The overall mean of the variable was 2.90 according to the CIMMYT scale, which affected the presence of the disease almost half of the plant. When performing the 5% Tukey Test for localities it was determined that location1 (Quevedo) had significantly lower Curvularia Leaf Spot incidence (2.47) than location 2 (Balzar) with (3.34), according to the CIMMYT scale, (Tab. 8), which is equivalent to the established presence of the disease in more than half of the plant. In a different study, in location 1 (Quevedo) Curvularia leaf spot severity was evaluated on promissory auto pollinated S4 lines and found values as higher as 8 lesions by cm^2 which can have a significant effect on yield due to plant stage and the part of the plant affected (lower leaves) (Garcés *et al*., 2011).

Table 8. Curvularia leaf spot incidence in of five promissory triple hybrids of hard yellow corn (*Zea mays* L.) and three commercial hybrids during the rainy season in the Central Coast Ecuador.

Localities	Curvularia (scale CIMMYT)
Quevedo	2.47 a
Balzar	3.34 b

Numbers followed by the same letter in a column are not significantly different (Tukey, *P*<0.05).

The significant differences between hybrids (Tab. 9) it was determined that the hybrid h2 with 2.00 had a lower severity of curvularia leaf sopt than h8 with 3.5, according to the scale from CIMMYT. It is important that the especies of curvularia are saprophytic or phytopathogenic and are found mainly in tropical and subtropical areas, and can be isolated from the soil, air, organic matter, plants, animals, including humans. As with other foliar pathogenic fungi, this fungus is transmitted by seed, affects yield since it infects the ear, causing rotting of the grain.

Table 9. Foliar disease severity (scale 1-5 CIMMYT) of curvularia leaf spot and helminthosporium leaf blight of five promissory hybrids of hard yellow maize (*Zea mays* L.) and three commercial hybrids during the rainy season in the central coast of Ecuador.

Hybrids	Curvularia	Helminthosporium
h1	3.00 ab	2.12 ab
h2	2.63 a	2.13 ab
h3	2.75 ab	2.25 ab
h4	2.75 a	2.00 a
h5	2.75 a	2.13 ab
h6	2.75 a	2.00 a
h7	3.13 ab	2.13 ab
h8	3.50 b	2.63 b

Numbers followed by the same letter in a column are not significantly different (Tukey $\alpha = 0.05$). h1 = (SM45-1 × SSD08-1) × SV39-1; h2 = (SM45-1 × SV15-1) × SV39-1; h3 = (SM45-1 × SV35-1) × SV39-1; h4 = (SV15-1 × SV15-1) × SV39-1; h5 = (SV15-1 × SV45-1) × SV39-1; h6 = INIAP H-551; h7 = INIAP H-553; h8=AG-003.

Physoderma brown spot is caused by the chytridiomycete fungus, *P. maydis* (Wise *et al*., 2018). Physoderma brown spot severity was significantly different in Quevedo (2.00 according to the CIMMYT scale) compared to Balzar (2.13). Physoderma was distinguishable from curvularia due to brown-purple spots appearing or near the midribs (Wise *et al*., 2019) (data not shown).

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For helminthosporium leaf blight, analysis of variance showed statistical significance for hybrids. The hybrids h6 and h4 had significantly lower helminthosporium leaf blight severity than hybrid h8 (Tab. 9).

Rust had the lowest disease severity under the field conditions of locations (Quevedo and Balzar). A significant effect of location was detected, with Balzar showing significantly higher foliar disease severity (1.28 scale-CIMMYT) compared to Quevedo (1.00).

Economic analysis

The economic analysis (Tab. 9), it is observed that the highest gross income US$ 2732.53 was obtained with the hybrid h8, on the two localities, followed by the hybrid h2, with $ 2470.73. The total costs were higher for the AG-003 hybrids with the highest yield; with $ 1485.07. El items with highest production cost is fertilization, while for the rest of hybrids the total costs were similar. The highest net profit was achieved with the h2 hybrid with $ 1405.76 followed by the h1 hybrid with $ 1385.92, obtaining a Benefit - Cost ratio of 2.32 and 2.30 respectively, which indicates that for each monetary unit invested $ 1.56 and 1.54 additional or profit was obtained for the two hybrids.

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Table 9. Economic analysis of five promissory hard yellow corn hybrids (*Zea mays* L.) and three commercial hybrids during the rainy season, in the Central Coast of Ecuador.

Hybrids	Yield	P*	FC	VC	TC	U	R B/C	CB US$
	(kg ha^{-1})	US$						
h1	7211.80	2452.01	1060.77	5.32	1066.09	1385.92	2.30	1.30
h2	7266.83	2470.72	1060.77	4.20	1064.97	1405.76	2.32	1.32
h3	6881.97	2339.87	1060.77	2.81	1063.58	1276.29	2.20	1.20
h4	6714.25	2282.85	1060.77	5.98	1066.75	1216.10	2.14	1.14
h5	6914.09	2350.79	1060.77	2.94	1063.71	1287.08	2.21	1.21
h6	5306.83	1804.32	1060.77	6.88	1067.65	736.68	1.69	0.69
h7	5962.07	2027.10	1060.77	6.13	1066.90	960.21	1.90	0.90
h8	8036.85	2732.53	1060.77	424.30	1485.07	1247.46	1.84	0.84

*1 kg of corn = US$ 0.34. P: Profit, FC: Fixed cost, VC: Variable cost, TC: Total cost, U: Utility, R B/C: benefit/cost ratio, CB: Coste-beneficio. h1 = (SM45-1 × SSD08-1) × SV39-1; h2 = (SM45-1 × SV15-1) × SV39-1; h3 = (SM45-1 × SV35-1) × SV39-1; h4 = (SV15-1 × SV15-1) × SV39-1; h5 = (SV15-1 × SV45-1) × SV39-1; h6 = INIAP H-551; h7 = INIAP H-553; h8=AG-003.

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Results found are due to genetic factors specific to each of these materials since corn is a plant endowed with a wide response to the environmental conditions, quality being exploited by man to get varieties and hybrids adapted to scattered conditions (Matsuoka *et al*., 2002; Wang *et al*., 2020).

In the tropics, corn grows from sea level to altitudes close to 4,000 m. The Best yields are obtained in the rango between 0 to 900 m a.s.l. and size at 2 to 2.65 m. Corn is a plant endowed with a wide response capacity to the opportunities (IICA, 2019).

Maize plants are factories that produce energy. To obtain high yields, it is sought to increase the quantity and weight of each grain (Yara Ecuador, 2023).

This study found that in location Quevedo, an average of 50.94 and 54.84 d were obtained for male and female flowering respectively in contrast to the 53.66 and 56.94 d for male and female flowering respectively in the location 2 (Balzar). This is because in location 1 (Quevedo) agro-climatic conditions favor development or maize crop.

Foliar disease severity: corn stunt spiroplasma (*S. kunkelii*), curvularia leaf spot (*C. lunata*), helminthosporium leaf blight (*E. turcicum*), physoderma brown spot (*P. maydis*), and rust (*Puccinia* spp.) was low. However, disease severity was consistently higher in location 2 (Balzar), compared to location 1 (Quevedo); therefore, adaptability of hybrids was due to higher tolerance as well as agronomic traits. The hybrid SM45-1XSV35-1 × SV39-1 had better tolerance than the commercial hybrid AG-003. In the area of Quevedo the highest yield was obtained with an average of 7368.21 kg ha. Determining that hybrids had greater adaptability to location 1 (Quevedo). Maize hybrid (AG-003) was the hybrid that presented the highest yield and better yield (8036.85 kg ha), followed by the promissory hybrid SM45-1XSV35-1 × SV39-1 (7266.83 kg ha) which also had better tolerance to Curvularia Leaf Spot. The economic analysis presented the highest gross income $ 2732.53 with the hybrid AG-003 followed by the hybrid M45-1XSV35-1 × SV39-1 with $ 2470.73.

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