CULTIVAR RELEASE

Divíbrido: high-yielding popcorn variety

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Abstract: *UENF Divíbrido is a popcorn hybrid that exhibits adaptability to Northern and Northwest regions of Rio de Janeiro State. Its attributes, including high grain yield and popping expansion, besides its tolerance to Exserohilum turcicum, the primary pathogen responsible for crop diseases, position this cultivar as an outstanding choice for agrobusiness.*

Keywords: Zea mays var. everta*, testcross, simple hybrid, biotic stress*

INTRODUCTION

Over the last twenty years, popcorn production in Brazil has increased by an impressive 135%, thereby positioning the country as the world's second-largest exporter, just behind the United States. The main reason for this success is the progress made in plant breeding, along with farmers embracing contemporary methods (Stipp et al. 2024). Despite its commercial importance, data on popcorn maize cultivation in Brazil are scarce. Based on data reported in 2018 Brazilian Corn Yearbook (Kist et al. 2019), popcorn production in Brazil reached roughly 268 thousand tons cultivated over an area of about 60 thousand hectares.

With this growing popcorn market in mind, farmers are eager to adopt new maize varieties that offer better grain yield and popping ability. These grains must also meet consumer preferences to secure competitive market prices. Consumers are primarily concerned with popcorn quality, including its texture, softness, and flavor, which largely depend on its popping capability.

To meet the needs of people involved in popcorn production and consumption, the *Universidade Estadual do Norte Fluminense Darcy Ribeiro* (UENF) has worked for over two decades to introduce new maize cultivars. Such an effort resulted in the hybrid 'Divíbrido', a new popcorn variety known for its yellow grains, strong plant structure, and high productivity, making it suitable for cultivation in Rio de Janeiro State.

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To achieve this, we conducted breeding experiments, estimated crossbreeding potential, and evaluated the performance of inbred lines (S_7) and their hybrid offspring when crossed with testers. These evaluations covered agronomic aspects like grain yield and popping expansion, as well as susceptibility to diseases caused by fungi, including *Puccinia polysora*, *Exserohilum turcicum*, and *Bipolaris maydis*. These efforts culminated in the introduction of the 'UENF Divíbrido' as a profitable variety for Brazilian farmers.

Briefly, the development of the popcorn cultivar 'UENF Divíbrido' began approximately 20 years ago when the Popcorn Maize Plant Breeding Program at *Universidade Estadual do Norte Fluminense Darcy Ribeiro* (UENF) introduced genotypes into the UENF's Germplasm Bank. These genotypes originated from exchanges between different public research institutions in Brazil, including Universidade Estadual de Maringá (UEM), Empresa Brasileira de Pesquisa Agropecuária (Embrapa), Universidade Federal de Viçosa (UFV), Instituto Agronômico de Campinas (IAC), and International Maize and Wheat Improvement Center (CIMMYT) in Mexico.

Since then, inbred lines and hybrids have improved and acquired resistance or tolerance to various stresses such as biotic factors, low nitrogen, low phosphorus availability and drought stress. Additionally, genome-wide selection has been used in a recurrent intrapopulation selection program to expedite breeding for subsequent generations.

BREEDING METHOD

The hybrid 'UENF Divíbrido' derives from a cross between the L204 and L70 inbred lines. L204 was extracted from the testcross hybrid IAC 125, known for its excellent popping ability, resistance to *Fusarium* spp., and high-yielding capacity. L70, on the other hand, originates from the BRS Angela variety, which has white grains and resistance to the causal agents of *Bipolaris maydis* and *Puccinia polysora*. To register the cultivar 'UENF Divíbrido' with the Ministry of Agriculture, Livestock, and Supply (MAPA), both the parental lines and the hybrid were subjected to a set of evaluations in accordance with the regulations and minimum criteria required for registration in the National Cultivar Registry.

Crosses between the inbred lines were conducted via testcross in December 2017. Moreover, in September 2018, trials were set up to assess the hybrids' resistance to southern rust caused by *P. polysora* Underw, Bipolaris leaf spot caused by *B. maydis* (Nisik.) Shoemaker, and northern corn leaf blight caused by *E. turcicum* (Pass.) Leonard & Sugg.

The trial was conducted under a lattice experimental design (10 × 10), with each plot consisting of a 5-meter row spaced at 0.80 meters between rows and 0.20 meters between plants. The plots were bordered by the L80 inbred line, which is susceptible to *E. turcicum*, *B. maydis*, and *P. polysora* to ensure consistent conditions for pathogen inoculation across all experimental units, as disease occurrence would happen naturally without artificial inoculation.

Four control groups were used, including two open-pollinated populations (UFV M2-Barão de Viçosa and PARA-172) and two simple hybrids (UENF HS 02 and UENF HS03). We evaluated essential traits for popcorn, including plant height (PH), ear height (EH), grain yield (GY) in kg ha^{-1}, popping expansion (PE) in mL g^{-1}, and tolerance to southern rust (*P. polysora*), northern corn leaf blight (*E. turcicum*), and Bipolaris leaf spot (*B. maydis*).

Experimental locations comprised Campos dos Goytacazes at the Experimental Station of the State Agricultural School Antônio Sarlo (lat 21° 42' 48" S, long 41° 20' 38" W, alt 14 m asl) and Itaocara at the Itaocara Experimental Station (lat 21° 38' 50" S, long 42° 03' 46" W, alt 58 m asl). These locations represent the North and Northwest regions of Rio de Janeiro State, respectively. Both environments have a tropical humid (Aw) climate according to Köppen classification, and the soil type is red-yellow latosol (Oxisol).

The response of genotypes to foliar diseases was evaluated through the identification and estimation of visible symptoms. To achieve this, two complementary approaches were employed: the estimation of symptom percentage across the whole plant (disease incidence) and the assessment of symptom percentage specifically on the leaf located just below the first ear (disease severity on the leaf). The incidence *of Phakopsora polysora* (IPp) across the whole plant was determined using the diagrammatic scale proposed by Agroceres (1996). This scale comprises nine classes: score 1 corresponds to 0% incidence; score 2, up to 0.5%; score 3, up to 10%; score 4, up to 30%; score 5, up to 50%; score 6, up to 70%; score 7, up to 80%; score 8, up to 90%; and score 9, up to 100%.

Disease severity of *P. polysora* (SPp) was estimated using a modified Cobb scale (Chester, 1950), based on visual assessment of lesions on the leaf immediately below the first ear, with severity values expressed as percentages ranging from 5% to 100%. The incidence of *Bipolaris maydis* (IBm) was determined using the diagrammatic scoring scale also proposed by Agroceres (1996), while its severity (SBm) was estimated using a diagrammatic scal. Similarly, the incidence of *Exserohilum turcicum* (IEt) followed the Agroceres (1996) scale, whereas severity (SEt) was classified according to the scale described by Vieira et al. (2013).

All statistical procedures were performed using the Genes software (Cruz 2003). The GT Biplot analysis was generated in RStudio (R Core Team 2025) with the aid of the GGEbiplotGUI package (Yan and Kang 2003). For graphical

Table 1. Estimated means of the main agronomic traits of 75 popcorn hybrids and four commercial varieties

Genotypes		Grain yield (kg ha^{-1})		Popping expansion (mL g^{-1})	
1	L681 × PARA172	1669.2	b	16.89	d
2	L682 × PARA172	1011.7	b	10.85	e
3	L683 × PARA172	676.7	b	19.58	d
4	L684 × PARA172	2238.3	b	13.61	e
5	L685 × PARA172	2088.3	b	16.05	d
6	L686 × PARA172	2807.5	b	10.17	e
7	L688 × PARA172	4230.8	a	19.47	d
8	L689 × PARA 172	4287.5	a	14.73	e
9	L691 × PARA172	3855.8	a	16.71	d
10	L692 × PARA172	3885.8	a	12.89	e
11	L693 × PARA172	3301.7	b	10.78	e
12	L694 × PARA172	1730.8	b	16.22	d
13	L695 × PARA172	2843.3	b	12.06	e
14	L696 × PARA172	3820.0	a	12.89	e
15	L204 × PARA172	4039.2	a	15.78	d
16	L681 × L270	3703.3	a	17.17	d
17	L682 × L270	4597.5	a	15.63	d
18	L683 × L270	5046.7	a	15.67	d
19	L684 × L270	4270.0	a	16.89	d
20	L685 × L270	5551.7	a	20.39	d
21	L686 × L270	5372.5	a	14.28	e
22	L688 × L270	4130.0	a	21.00	d
23	L689 × L270	4290.0	a	22.50	c
24	L691 × L270	3868.3	a	18.56	d
25	L692 × L270	5068.3	a	14.06	e
26	L693 × L270	5231.7	a	12.11	e
27	L694 × L270	4421.7	a	24.33	c
28	L695 × L270	3732.5	a	14.78	e
29	L696 × L270	3713.3	a	14.28	e
30	L204 × L270	3160.0	b	21.72	c
31	L681 × L651	3910.8	a	15.17	e
32	L682 × L651	4094.2	a	12.00	e
33	L683 × L651	4180.8	a	15.94	d
34	L684 × L651	3103.3	b	14.28	e
35	L685 × L651	3430.0	b	13.61	e
36	L686 × L651	3582.5	a	12.22	e
37	L688 × L651	5068.3	a	14.50	e
38	L689 × L651	3210.0	b	18.56	d
39	L691 × L651	4015.8	a	16.11	d
40	L692 × L651	2010.8	b	12.44	e
41	L693 × L651	3305.8	b	14.20	e
42	L694 × L651	2865.0	b	21.39	d
43	L695 × L651	3985.0	a	15.00	e
44	L696 × L651	3833.3	a	18.78	d
45	L204 × L651	3268.3	b	17.28	d
46	L681 × P1	4820.0	a	35.56	a
47	L682 × P1	3423.3	b	23.00	c
48	L683 × P1	3493.3	b	33.56	a
49	L684 × P1	4050.0	a	29.50	b
50	L685 × P1	4980.0	a	35.63	a
51	L686 × P1	3198.3	b	22.61	c
52	L688 × P1	4530.8	a	36.67	a
53	L689 × P1	4487.5	a	35.72	a
54	L691 × P1	4420.8	a	35.55	a
55	L692 × P1	3071.7	b	22.89	c
56	L693 × P1	3985.0	a	32.00	b
57	L694 × P1	4540.8	a	38.17	a
58	L695 × P1	4290.8	a	27.50	c
59	L696 × P1	3212.5	b	24.61	c
60	L204 × P1	2002.5	b	29.78	b
61	L681 × L70	4065.0	a	33.33	a
62	L682 × L70	3650.8	a	25.72	c
63	L683 × L70	2704.2	b	31.28	b
64	L684 × L70	3746.7	a	22.61	c
65	L685 × L70	2905.0	b	27.94	c
66	L686 × L70	2209.2	b	23.78	c
67	L688 × L70	3097.5	b	25.11	c
68	L689 × L70	4282.5	a	28.50	c
69	L691 × L70	3301.7	b	29.95	b
70	L692 × L70	3061.7	b	19.17	d
71	L693 × L70	2760.0	b	24.39	c
72	L694 × L70	4154.2	a	27.28	c
73	L695 × L70	3563.3	a	23.05	c
74	L696 × L70	4298.3	a	21.67	c
75	**L204 × L70 (UENF Divíbrido)**	**3210.8**	**b**	**33.22**	**a**
76	PARA172*	3029.2	b	25.06	c
77	Barão de Viçosa*	3400.0	b	24.06	c
78	UENFHS02*	3975.8	a	35.28	a
79	UENFHS03*	3177.5	b	12.22	e

Means followed by the same letter within a column are not statistically different according to the Scott-Knott ($p \leq 0.05$) grouping method (* commercial varieties).

representation in the GT Biplot, the values assigned to incidence and severity were reversed prior to analysis, as lower scores indicate reduced pathogen infection according to the adopted diagrammatic scales.

PERFORMANCE

The hybrid 'Divíbrido' was evaluated for agronomic performance and disease resistance in accordance with the technical requirements established by the National Plant Variety Protection Service (SNPC), as part of the procedures required for registration with the Ministry of Agriculture, Livestock and Food Supply (MAPA).

Experimental precision was evaluated through the coefficient of experimental variation (CVe), a parameter used to indicate the reliability of the experiments (Pimentel et al. 2014). The CVe values ranged from 10.68% for PE to 14.29% for GY, demonstrating an adequate level of experimental precision, as per the criteria outlined by Gomes (2000).

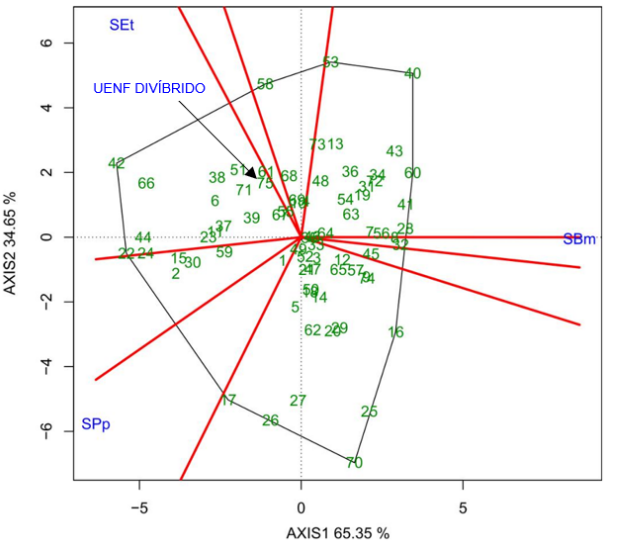

Figure 1. "Which-won-where" Biplot of popcorn hybrids for traits related to the severity of diseases caused by *P. polysora* (SPp), *B. maydis* (SBm), and *E. turcicum* (SEt). See Table 1 for Hybrid identification.

The hybrid 'UENF Divíbrido' (L204 × L70) features yellow grains, with an average plant height of 2.06 meters and an average ear height of 1.25 meters. The kernel popping capacity is 33.22 mL g^{-1}, and the grain yield is 3,210.8 kg ha^{-1} (Table 1). It takes 62 days for female flowering and 59 days for male flowering. The cultivar boasts an ear length of 16.7 cm, and an ear diameter of 36.0 mm (data not shown).

The GT Biplot methodology enables the joint graphical representation of both rows and columns of a data matrix (Gabriel and Zamir 1979), allowing a simultaneous visualization of relationships among genotypes and traits. This multivariate technique was originally introduced by Gabriel (1971) and has since been widely applied for exploratory data analysis in plant breeding studies. In the present work, genotype distribution within the GT Biplot was determined using hybrid performance estimates derived from standardized mean values of traits related to disease severity caused by *P. polysora*, *B. maydis*, and *E. turcicum*.

The first two principal components explained all of the variation100% observed in the data for traits associated with disease severity caused by *P. polysora* (SPp), *B. maydis* (SBm), and *E. turcicum* (SEt) in the hybrids (Figure 1).

For this group of traits, the GT Biplot graph displayed a polygon divided into nine groups, three of which were relevant because they were associated with low incidence levels. For SEt, one of these groups comprised 14 hybrids (66, 44, 23, 11, 37, 6, 38, 51, 71, 39, 75, 61, 67 and 55), including the hybrid UENF Divíbrido (75), which was therefore classified as moderately resistant to *E. turcicum*.

BASIC SEED MAINTENANCE AND DISTRIBUTION

The hybrid cultivar 'Divíbrido' is formally registered with Brazil's Ministry of Agriculture, Livestock, and Supply (MAPA) under no. 47000. Seed multiplication and market release are carried out by Universidade Estadual do Norte Fluminense Darcy Ribeiro Darcy Ribeiro (UENF) in partnership with Rio Norte Sementes, a seed company based in in Campos dos Goytacazes, Rio de Janeiro, Brazil.

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CREDIT STATEMENT

ATAJ: Conceptualization, Methodology, Software, Validation, Investigation, Data curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Supervision, Project administration, Funding acquisition. DRSJ; TOS; FNV; SHK; VJL; RMR; JTL; GRG; JSF; MSS; BRS; CMC; IPGF; DCG; DVTS; PCDJ: Conceptualization, Formal analysis, Investigation, Data curation, Writing – Original Draft, Writing – Review & Editing, Visualization.

DATA AVAILABILITY

The datasets generated and/or analyzed during the current research are available from the corresponding author upon reasonable request.

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