CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

UENF EXPLOSÃO: A popcorn cultivar featuring superior yielding potential and moderate resistance to polysora rust

Crop Breeding and Applied Biotechnology
25(2): e514425214, 2025
Brazilian Society of Plant Breeding.
Printed in Brazil
http://dx.doi.org/10.1590/1984-70332025v25n2c29

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Abstract: *UENF EXPLOSÃO single-cross hybrid is a popcorn cultivar (Zea mays var. everta) developed by the Universidade Estadual do Norte Fluminense Darcy Ribeiro. It was released in 2019 for cultivation in Rio de Janeiro. This cultivar stands out for its superior productivity, offering a promising alternative for the agricultural sector.*

Keywords: *Biotic stress, disease resistance, simple hybrid, testcross,* Zea mays var. everta

INTRODUCTION

The UENF EXPLOSÃO hybrid was developed in response to the growing need for cropping alternatives in the northern and northwestern regions of Rio de Janeiro state, which lack popcorn cultivars. Despite being a highly valued crop and having its global market valued at USD 13.4 billion in 2023 (Gopinath et al. 2024), the lack of cultivars adapted to some Brazilian regions still represents a gap in the expansion of popcorn maize cultivation in Brazil.

For maize, according to data from the Food and Agriculture Organization of the United Nations (FAO), Brazil secured its position as the world's second-largest exporter in 2023, with a harvest area of approximately 22.4 million hectares and a production of approximately 132 million tons, of which about 56 million tons were exported. On the other hand, recent data on popcorn are more limited, as its production is included in the total maize production. However, according to the 2018 Brazilian Corn Yearbook (Kist et al. 2019), Brazil had a production of approximately 268 thousand tons in a cultivated area of 60 thousand hectares, which expanded to about 67 thousand hectares in 2019. Over the past two decades, popcorn production has surged by 135%, attributed largely to breeding efforts and the technification of farming practices. This

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Received: 29 November 2024
Accepted: 17 April 2025
Published: 02 June 2025

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period saw yields increase from 1,500 to around 3000 kg per hectare, with high-quality levels matching those of the United States, the leading global producer (Stipp et al. 2024).

Despite these advancements, almost all seeds used for cultivation are imported, predominantly from the United States. To mitigate this reliance on imports, Universidade Estadual do Norte Fluminense Darcy Ribeiro (UENF) has dedicated 25 years to crop improvement, aiming to introduce elite cultivars to the market. The UENF EXPLOSÃO hybrid, a new popcorn cultivar with orange kernels, was developed as a result. It features high popping expansion and yield potential, along with broad adaptability to the climatic conditions of the State of Rio de Janeiro.

For this purpose, 75 hybrids resulting from crosses between 15 inbred lines (S_7) and five testers in a testcross configuration were assessed for agronomic traits, grain yield, popping expansion, and resistance to diseases caused by the fungi *Puccinia polysora*, *Exserohilum turcicum*, and *Bipolaris maydis*. This evaluation identified the F_1 genotype UENF EXPLOSÃO as an advantageous option for commercial use.

Briefly, the development of the UENF EXPLOSÃO popcorn cultivar represents 25 years of effort in breeding *Zea mays* L. var. *everta*. This process began with acquiring accessions from national institutions such as the State University of Maringá (UEM), the Brazilian Agricultural Research Corporation (Embrapa – Maize and Sorghum), the Federal University of Viçosa (UFV), and the Agronomic Institute of Campinas (IAC), as well as international institutions like the International Maize and Wheat Improvement Center (CIMMYT) in Mexico. This collaborative effort led to the establishment of the Active Germplasm Bank at UENF.

In this context, it is worth highlighting that previous efforts of the UENF Popcorn Breeding Program have primarily focused on the evaluation and selection of genotypes under adverse abiotic conditions, resulting in the identification and registration of hybrids with tolerance to drought, low nitrogen, and low phosphorus availability, always associated with high yield potential. This historical accumulation of knowledge and genetic resources enabled the establishment of a well-characterized and diversified germplasm panel. The present study capitalized on this panel, which, beyond its known potential for abiotic stress tolerance, also exhibited promising levels of resistance to *Puccinia polysora*. Therefore, the evaluation and selection of 75 experimental hybrids enabled not only the identification of superior genotypes with higher yield potential but also confirmed the presence of disease resistance within the previously explored germplasm.

BREEDING METHOD

The UENF EXPLOSÃO hybrid was derived from the cross between lines L681 and P1, both in an advanced cycle of selfing (S_7). L681, originating from the UENF14 popcorn open-pollinated variety (OPV), exhibits yellow-orange kernels, high grain yield and popping expansion, and resistance to *E. turcicum* (Amaral Júnior et al. 2013). P1, derived from the Zélia hybrid, shows intermediate resistance to *E. turcicum* and *P. polysora* and susceptibility to *B. maydis* (Pacheco et al. 2001, Santos et al. 2017, Mafra et al. 2018). The registration of the UENF EXPLOSÃO cultivar with the Ministry of Agriculture, Livestock, and Supply (MAPA) involved comprehensive evaluations of both parent lines and the hybrid, adhering to the standards and minimum requirements for inclusion in the National Cultivar Registry (MAPA 2020).

In December 2017, testcrosses were conducted between 15 S_7 inbred lines, being 14 derived from the UENF 14 OPV (L681, L682, L683, L684, L685, L686, L688, L689, L691, L692, L693, L694, L695 and L696) and one from the IAC 125 hybrid (L204) and five testers. These testers included four with a narrow genetic base (line L270 from the OPV PARA-172, resistant to *E. turcicum*, *P. polysora*, and *B. maydis*; L651 from the OPV ARZM-13050, a susceptible population; P1, from the Zélia hybrid, with intermediate resistance to *E. turcicum* and *P. polysora* and susceptibility to *B. maydis*; and L70 from the OPV BRS Angela, with susceptibility to *E. turcicum*, resistance to *B. maydis*, and intermediate resistance to *P. polysora*) and one with a broad genetic base (OPV PARA-172, resistant to *E. turcicum*, *P. polysora*, and *B. maydis*). In September 2018, evaluations were performed to assess hybrid resistance to polysora rust (*P. polysora* Underw), maydis leaf blight (*B. maydis* [Nisik.] Shoemaker), and turcicum leaf blight (*E. turcicum* [Pass.] Leonard and Sugg).

The experiment was set up in a 10 × 10 lattice design, including 75 hybrids, 15 parental S_7 lines, five testers, and five controls (OPVs UFV M2-Barão de Viçosa and ARZM-13050, the simple hybrid UENF HS 02, and S_7 lines L51 and L88). Plots consisted of 5.00-m rows spaced 0.80 m apart, with plants spaced 0.20 m apart, bordered by line L80, susceptible

to *E. turcicum*, *B. maydis*, and *P. polysora*. This setup ensured uniform inoculum distribution and a consistent source of infection, simulating natural disease occurrence without inoculation.

Key traits for popcorn cultivation were assessed, namely, plant height (PH); ear height (EH); grain yield (GY) in kg ha^{-1}; popping expansion (PE) in mL g^{-1}; 100-grain weight (W100); and tolerance to polysora rust, turcicum leaf blight, and maydis leaf blight. Evaluation sites were in Campos dos Goytacazes at the Experimental Station of the Antônio Sarlo State Agricultural School (lat 21° 42' 48" S, long 41° 20' 38" W, alt 14 m asl), representing the northwest region of Rio de Janeiro - characterized by its humid tropical climate (Aw according to the Köppen classification) and red-yellow latosol soil.

The reaction of genotypes to foliar diseases was quantified by identifying and estimating symptoms. For this purpose, two strategies were adopted to obtain the estimates: measuring the percentage of symptoms throughout the plant (disease incidence) and measuring the percentage of symptoms on the leaf immediately below the first ear (disease severity on the leaf).

To assess the incidence of *P. polysora* (IPp) in the entire plant, the diagrammatic scale adopted by Agroceres (1996) was used, which has a range of grades between 1 and 9 where: grade 1 refers to 0% incidence; grade 2, up to 0.5% incidence; grade 3, up to 10% incidence; grade 4, up to 30% incidence; grade 5, up to 50% incidence; grade 6, up to 70% incidence; grade 7, up to 80% incidence; grade 8, up to 90% incidence; and grade 9, up to 100% incidence. To assess the severity of *P. polysora* (SPp), the leaf below the first ear was used, adopting the modified Cobb scale with gradations ranging from 5 to 100%.

The incidence of *B. maydis* (IBm) in the plant was measured with the aid of the diagrammatic scale of notes proposed by Agroceres (1996). The severity of *B. maydis* (SBm) was measured with the aid of a diagrammatic scale proposed by James (1971). The incidence of *E. turcicum* (IEt) in the plant was measured with the aid of the diagrammatic scale of notes proposed by Agroceres (1996). To classify the severity of *E. turcicum* (Set), the diagrammatic scale was used.

Statistical analyses were performed using the Genes software, and the GT Biplot was generated using RStudio (R Foundation 2025) with the 'GGEbiplotGUI' package (Wickham 2010). To generate the GT Biplot graph, the scores assigned to incidence and severity traits were inverted, as genotypes with lower pathogen attack observations were assigned lower scores for these traits, according to the diagrammatic scales.

PERFORMANCE

The UENF EXPLOSÃO hybrid was assessed for its agronomic traits and disease resistance in line with the criteria set by the National Plant Protection Office (SNPC, *Serviço Nacional de Proteção de Cultivares*) for its registration with MAPA. Experimental precision was determined by the coefficient of experimental variation (CVe), which indicates the reliability of the experimental results (Pimentel et al. 2014). The CVe ranged from 19.93% for PE to 38.04% for GY, suggesting satisfactory experimental precision according to the standards proposed by Scapim et al. (1995) and Gomes (2000). The UENF EXPLOSÃO (L681×P1) hybrid exhibited orange kernels, an average plant height of 178 cm, and an average ear height of 162 cm (data not shown). Popping expansion was recorded at 35.56 mL g^{-1}, and grain yield at 4,610.83 kg ha^{-1} (Table 1).

The GT Biplot procedure consists of a simultaneous graphical representation of the rows and columns of a data matrix (Gabriel and Zamir 1979). This technique is based on multivariate analysis and was developed by Gabriel (1971). In the present study, the arrangement of genotypes in the GT Biplot graph was derived from hybrid estimates with standardized means for the trait related to the incidence of diseases caused by the pathogens *P. polysora*, *B. maydis*, and *E. turcicum*. The first two principal components accounted for the entirety (100%) of the variation in the data for traits related to the incidence of diseases caused by *P. polysora* (IPp), *B. maydis* (IBm), and *E. turcicum* (IEt) in the hybrids (Figure 1).

For this set of traits, the GT Biplot graph revealed a polygon forming seven groups, three of which are of interest as they represent low incidence levels. Accordingly, for IPp, a group was formed consisting of 13 hybrids (1, 2, 12, 17, 21, 23, 33, 46, 51, 52, 61, 64, and 66), including the hybrid UENF EXPLOSÃO (46), classifying it as moderately resistant to *P. polysora* rust.

BASIC SEED MAINTENANCE AND DISTRIBUTION

The UENF EXPLOSÃO cultivar has been officially registered with the Ministry of Agriculture, Livestock, and Supply (MAPA) under registration number 41750. The State University of Northern Rio de Janeiro (UENF), in collaboration with Rio Norte Sementes, a seed company located in Campos dos Goytacazes, in the state of Rio de Janeiro, oversees the production and distribution of the hybrid seeds.

Table 1. Estimated means[1] of the main agronomic traits of 75 popcorn hybrids

Genotypes	Grain Yield (kg ha^{-1})		Popping Expansion (mL g^{-1})		Genotypes	Grain Yield (kg ha^{-1})		Popping Expansion (mL g^{-1})	
L681 × PARA172	1669.2	b	16.89	d	L692 × L651	2010.8	b	12.44	e
L682 × PARA172	1011.7	b	10.85	e	L693 × L651	3305.8	b	14.2	e
L683 × PARA172	676.7	b	19.58	d	L694 × L651	2865	b	21.39	d
L684 × PARA172	2238.3	b	13.61	e	L695 × L651	3985	a	15	e
L685 × PARA172	2088.3	b	16.05	d	L696 × L651	3833.3	a	18.78	d
L686 × PARA172	2807.5	b	10.17	e	L204 × L651	3268.3	b	17.28	d
L688 × PARA172	4230.8	a	19.47	d	L681 × P1	4820	a	35.56	a
L689 × PARA 172	4287.5	a	14.73	e	L682 × P1	3423.3	b	23	c
L691 × PARA172	3855.8	a	16.71	d	L683 × P1	3493.3	b	33.56	a
L692 × PARA172	3885.8	a	12.89	e	L684 × P1	4050	a	29.5	b
L693 × PARA172	3301.7	b	10.78	e	L685 × P1	4980	a	35.63	a
L694 × PARA172	1730.8	b	16.22	d	L686 × P1	3198.3	b	22.61	c
L695 × PARA172	2843.3	b	12.06	e	L688 × P1	4530.8	a	36.67	a
L696 × PARA172	3820	a	12.89	e	L689 × P1	4487.5	a	35.72	a
L204 × PARA172	4039.2	a	15.78	d	L691 × P1	4420.8	a	35.55	a
L681 × L270	3703.3	a	17.17	d	L692 × P1	3071.7	b	22.89	c
L682 × L270	4597.5	a	15.63	d	L693 × P1	3985	a	32	b
L683 × L270	5046.7	a	15.67	d	L694 × P1	4540.8	a	38.17	a
L684 × L270	4270	a	16.89	d	L695 × P1	4290.8	a	27.5	c
L685 × L270	5551.7	a	20.39	d	L696 × P1	3212.5	b	24.61	c
L686 × L270	5372.5	a	14.28	e	L204 × P1	2002.5	b	29.78	b
L688 × L270	4130	a	21	d	L681 × L70	4065	a	33.33	a
L689 × L270	4290	a	22.5	c	L682 × L70	3650.8	a	25.72	c
L691 × L270	3868.3	a	18.56	d	L683 × L70	2704.2	b	31.28	b
L692 × L270	5068.3	a	14.06	e	L684 × L70	3746.7	a	22.61	c
L693 × L270	5231.7	a	12.11	e	L685 × L70	2905	b	27.94	c
L694 × L270	4421.7	a	24.33	c	L686 × L70	2209.2	b	23.78	c
L695 × L270	3732.5	a	14.78	e	L688 × L70	3097.5	b	25.11	c
L696 × L270	3713.3	a	14.28	e	L689 × L70	4282.5	a	28.5	c
L204 × L270	3160	b	21.72	c	L691 × L70	3301.7	b	29.95	b
L681 × L651	3910.8	a	15.17	e	L692 × L70	3061.7	b	19.17	d
L682 × L651	4094.2	a	12	e	L693 × L70	2760	b	24.39	c
L683 × L651	4180.8	a	15.94	d	L694 × L70	4154.2	a	27.28	c
L684 × L651	3103.3	b	14.28	e	L695 × L70	3563.3	a	23.05	c
L685 × L651	3430	b	13.61	e	L696 × L70	4298.3	a	21.67	c
L686 × L651	3582.5	a	12.22	e	L204 × L70 (Divíbrido)	3210.8	b	33.22	a
L688 × L651	5068.3	a	14.5	e	PARA172*	3029.2	b	25.06	c
L689 × L651	3210	b	18.56	d	Bar. Viçosa*	3400	b	24.06	c
L691 × L651	4015.8	a	16.11	d	UENFHS02*	3975.8	a	35.28	a

[1] Means followed by the same letter within a column are not statistically different according to the Scott-Knott grouping method (*commercial varieties).

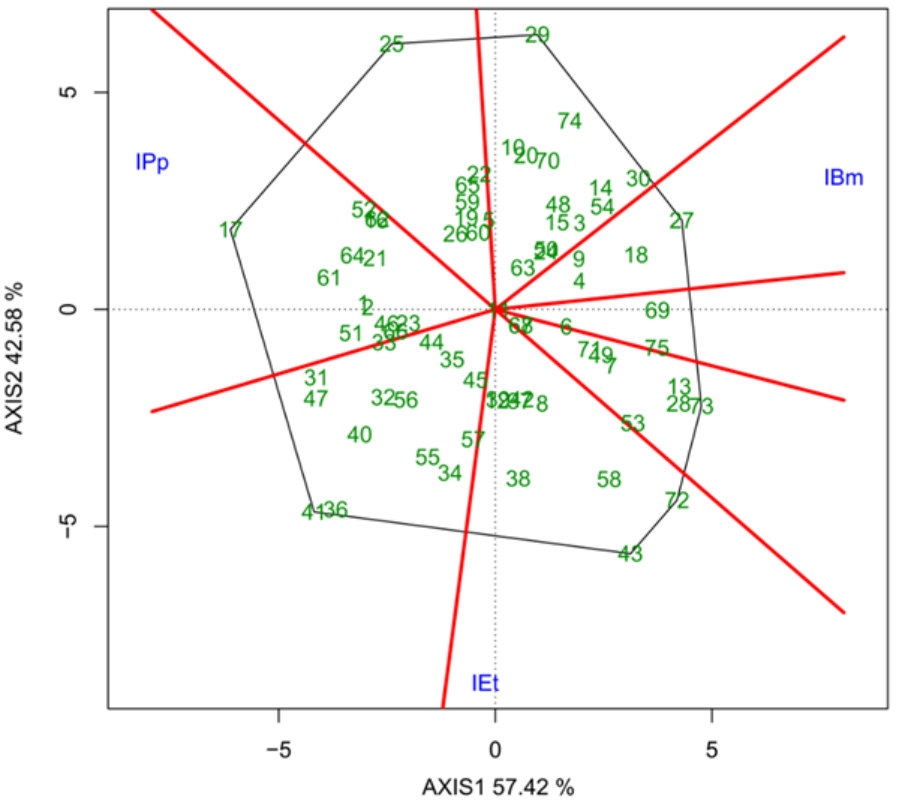

Figure 1. "Which-won-where" Biplot of popcorn maize hybrids for traits related to the incidence of diseases caused by *P. polysora* (IPp), *B. maydis* (IBm), and *E. turcicum* (IEt). Hybrid identification – 1: L681×PARA-172; 2: L682×PARA-172; 3: L683×PARA-172; 4: L684×PARA-172; 5: L685×PARA-172; 6: L686×PARA-172; 7: L688×PARA-172; 8: L689×PARA-172; 9: L691×PARA-172; 10: L692×PARA-172; 11: L693×PARA-172; 12: L694×PARA-172; 13: L695×PARA-172; 14: L696×PARA-172; 15: L204×PARA-172; 16: L681×L270; 17: L682×L270; 18: L683×L270; 19: L684×L270; 20: L685×L270; 21: L686×L270; 22: L688×L270; 23: L689×L270; 24: L691×L270; 25: L692×L270; 26: L693×L270; 27: L694×L270; 28: L695×L270; 29: L696×L270; 30: L204×L270; 31: L681×L651; 32: L682×L651; 33: L683×L651; 34: L684×L651; 35: L685×L651; 36: L686×L651; 37: L688×L651; 38: L689×L651; 39: L691×L651; 40: L692×L651; 41: L693×L651; 42: L694×L651; 43: L695×L651; 44: L696×L651; 45: L204×L651; 46: L681×P1; 47: L682×P1; 48: L683×P1; 49: L684×P1; 50: L685×P1; 51: L686×P1; 52: L688×P1; 53: L689×P1; 54: L691×P1; 55: L692×P1; 56: L693×P1; 57: L694×P1; 58: L695×P1; 59: L696×P1; 60: L204×P1; 61: L681×L70; 62: L682×L70; 63: L683×L70; 64: L684×L70; 65: L685×L70; 66: L686×L70; 67: L688×L70; 68: L689×L70; 69: L691×L70; 70: L692×L70; 71: L693×L70; 72: L694×L70; 73: L695×L70; 74: L696×L70; 75: L204×L70.

ACKNOWLEDGEMENTS

We express our gratitude to the Carlos Chagas Filho Foundation for Research Support of the State of Rio de Janeiro (FAPERJ) and the Coordination for the Improvement of Higher Education Personnel (CAPES), Finance Code 001, for their valuable support.

DATA AVAILABILITY

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

REFERENCES

Agroceres (1996) **Guia Agroceres de sanidade**. Sementes Agroceres, São Paulo, 72p.

Amaral Júnior AT, Gonçalves LSA, Paiva Freitas Junior S, Candido LS, Vittorazzi C, Pena GF, Ribeiro RM, Conceição Silva TR, Pereira MG, Scapim CA, Viana AP and Carvalho GF (2013) UENF 14: A new popcorn cultivar. **Crop Breeding and Applied Biotechnology 13**: 218-220.

Gabriel KR (1971) The biplot - graphic display of matrices with application to principal component analysis. **Biometrika 58**: 453-467.

Gabriel KR and Zamir S (1979) Lower rank approximation of matrices by least squares with any choice of weights. **Technometrics 21**: 489-498.

Gomes FP (2000) **Curso de estatística experimental**. Degaspari, Piracicaba, 477p.

Gopinath I, Hossain F, Thambiyannan S, Sharma N, Duo H, Kasana RK, Katral A, Devlash R, Veluchamy SSKR, Zunjare RU, Sekhar JC, Guleria SK, Rajasekaran R and Muthusamy V (2024) Unraveling popping quality through insights on kernel physical, agro-morphological, and quality traits of diverse popcorn (*Zea mays* var. *everta*) inbreds from indigenous and exotic germplasm. **Food Research International 191**: 114676.

James W (1971) **A manual of assessment keys for plant diseases.** American Phytopathological Society, St. Paul, 74p.

Kist BB, Carvalho C and Beling RR (2019) **Anuário brasileiro do milho 2019**. Editora Gazeta Santa Cruz, Santa Cruz do Sul.

Mafra GS, Amaral Júnior AT, Vivas M, Santos JS, Silva FHL, Guimarães AG and Pena GF (2018) The combining ability of popcorn S7 lines for *Puccinia polysora* resistance purposes. **Bragantia 77**: 519-526.

MAPA - Ministério da Agricultura, Pecuária e Abastecimento (2020) Formulários para registro de cultivares. Available at <https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/insumos-agricolas/sementes-e-mudas/registro-nacional-de-cultivares-2013-rnc-1/formularios-para-registro-de-cultivares>. Accessed on November 20, 2020.

Pacheco CAP, Gama EGG, Parentoni SN, Santos MX, Lopes MA, Ferreira AS, Fernandes FT, Guimarães PEO, Correa LA, Meirelles WF, Feldman RO and Magnavaca R (2001) BRS Angela - Variedade de milho-pipoca. Embrapa Milho e Sogro, Sete Lagoas, 4p. **(Comunicado Técnico, 95)**

Pimentel AJB, Guimarães JFR, Souza MA, Resende MDV, Moura LM, Rocha JRASC and Ribeiro G (2014) Estimação de parâmetros genéticos e predição de valor genético aditivo de trigo utilizando modelos mistos. **Pesquisa Agropecuária Brasileira 49**: 882-890.

R Foundation (2025) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available at <http://www.R-project.org/>.

Santos JS, Amaral Júnior AT, Vivas M, Mafra GS, Pena GF, Silva FHL and Guimarães AG (2017) Genetic control and combining ability of agronomic attributes and northern leaf blight-related attributes in popcorn. **Genetics and Molecular Research 16**: 1-11.

Scapim CAS, Carvalho CGP and Cruz CD (1995) Uma proposta de classificação dos coeficientes de variação para a cultura do milho. **Pesquisa Agropecuária Brasileira 30**: 683-686.

Stipp OJ, Possatto Junior O, Rossi E, Rosa JC, Uhdre RS, Rizzardi DA, Freitas PSLD and Pinto RJB (2024) Agricultural traits and popping expansion of the popcorn hybrid IAC 125 under different plant densities and irrigation water depth levels. **Acta Scientiarum. Agronomy 46**: e62929.

Wickham H (2010**)** ggplot2: Elegant graphics for data analysis. **Journal of Statistical Software 35**: 65-88.