CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

UENF WS01: popcorn hybrid with water use efficiency for the State of Rio de Janeiro

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Abstract: *The UENF WS01 is a hybrid that has an early cycle and high grain yield capacity under low water and nitrogen availability. It maintains popping expansion even under abiotic stress, thus being recommended for cultivation in the North and Northwest of the State of Rio de Janeiro.*

Keywords: *Plant breeding, abiotic stress, drought, nutritional deficiency.*

INTRODUCTION

Brazil is the second largest producer and consumer of popcorn worldwide. Its production is expanding mainly in Mato Grosso (MT) and Goiás states (Paterniani et al. 2020). Among the Brazilian states, only MT has official records, which reached over 220 thousand tons in 2019 (Kist et al. 2019, Carvalho et al. 2020). It represents more than 70% of the total popcorn produced in the country (Paterniani et al. 2020).

Despite the increased popcorn demand, production is still limited by a small number of Brazilian popcorn cultivars (Bombonato et al. 2020). Most popcorn seeds used in Brazil are imported from the United States and Argentina, which increases production costs (Paterniani et al. 2020).

In an attempt to reverse this bottleneck, it is necessary to develop popcorn cultivars adapted to the edaphoclimatic conditions in Brazil jointly with favorable agronomic traits (Ribeiro et al. 2016, Bombonato et al. 2020, Paterniani et al. 2020). Yet, cultivars more tolerant to climate change and focusing on sustainable agriculture (low water and nutrients demand) are urgently needed. It is noteworthy that it is also recommended by the action plan of the UN Agenda 2030 sustainable development goals (http://www.agenda2030.com.br/).

Accordingly, popcorn breeding program of the State University of Northern Rio de Janeiro Darcy Ribeiro has been developing varieties and hybrids adapted to regional edaphoclimatic conditions (Amaral Júnior et al. 2013, Ribeiro et al. 2016). Moreover, recently our research group began studies aiming to identify

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popcorn genotypes tolerant to abiotic stresses, including water (Kamphorst et al. 2018, Lima et al. 2019, Kamphorst et al. 2020) and nutritional stresses (Gerhardt et al. 2019, Santos et al. 2019, Santos et al. 2020) in order to reduce vulnerability of the crop when facing water shortage (Oliveira-Júnior et al. 2018) and nutrient-poor soils in the region.

Therefore, the objective of this work is to present the first popcorn hybrid that is efficient in the use of water and nitrogen for the North and Northwest regions of the State of Rio de Janeiro, designated UENF WS01.

BREEDING METHOD

The UENF WS01 hybrid originated from the cross between the L61 and L76 inbred lines, which derive from the BRS Angela and Viçosa-Viçosa populations, respectively. These genotypes belong to the Active Germplasm Bank of the Popcorn Genetic Improvement Program of the State University of Northern Rio de Janeiro - UENF. Prior to registration of this hybrid at the *Ministério da Agricultura*, *Pecuária e Abastecimento* (MAPA), both genitors and hybrid underwent a series of evaluations, which followed the standards and Minimum Requirements for the determination of the Value for Cultivation and Use (VCU) for corn (MAPA 2020).

The aforementioned hybrid was initially selected based on water use efficiency (WUE), and later promising results were identified for nitrogen use efficiency (NUE). These results were included in the hybrid registry at MAPA. WUE is defined as the ratio of grain yield to unit of water applied or transpired or evapotranspired (Tambussi et al. 2007, Jákli et al. 2018). Regarding nutrient use efficiency (NUE), it is defined as the relation between grain yield per unit of nitrogen applied to the soil.

Previous studies reported that selection to enhance WUE grouped more productive genotypes for well-watered and water stress conditions (Kamphorst et al. 2018). However, the most efficient genotypes may not be those most tolerant to water limiting conditions (ratio obtained between grain yield (GY) to unit of water applied under water stress and well-watered conditions). It means that genotypes might not present the lowest proportional losses when comparing across water conditions (Tambussi et al. 2007, Jákli et al. 2018, Kamphorst et al. 2018). On the other hand, cultivars development with high NUE is a strategy to reduce fertilization and still reach higher productivity (Santos et al. 2019, Santos et al. 2020).

The experiments involving these genotypes regarding their WUE and EUN were done as follows: initially, 29 and 20 S_7 inbred lines were evaluated for EUN (Santos et al. 2019) and WUE (Kamphorst et al. 2018, Kamphorst et al. 2020), respectively. In each study, ten contrasting inbred lines were selected, where we included L61 and L76 parents. The selected inbred lines were crossed in a complete diallel scheme obtaining 45 hybrids without reciprocals for WUE (Lima et al. 2019). For NUE, 90 hybrids including reciprocal hybrids were considered (Santos et al. 2019, Santos et al. 2020).

For WUE, 45 hybrids together with the 10 parents were evaluated in two years (2018 and 2020) at the Experimental Station of the Antônio Sarlo State Agricultural College (lat 21° 42’ 48” S, long 41° 20’ 38” W, alt 14 m asl). We designed the experiment as a complete block, in which each experimental unit consisted of a 4.20 m row spaced 0.80 m apart from each other and 0.20 m spacing between plants. The experiments were conducted at two levels of water availability: the first was a well-watered condition (WW) where we kept the soil always at water potential of field capacity (FC) (-0.01 MPa). The second level was under water stress (WS) condition, which consisted of irrigation suspension between pre-flowering (15 days before flowering) and the end of the cycle. Drip irrigation was used, with control of the amount of water applied and water potential of the soil throughout the experiment. In 2019, WS condition received 217.50 mm and WW environment 335.10 mm. It represented a reduction of 35% in water application which caused a reduction of 39% in grain yield when comparing both water conditions (Lima et al. 2019). In 2020, WS environment received 195.20 mm and WW environment 295.80 mm, representing a reduction of 34% in water application, which caused a reduction of 56% in grain yield when comparing both water conditions (unpublished data).

For NUE, 90 hybrids were evaluated together with the ten S_7 parents in a triple 10x10 lattice design, in which each experimental unit consisted of a 4.20 m row spaced 0.60 m apart from each other and 0.25 m spacing between plants. The experiments were conducted with either low or optimal N availability in two different locations. In the experiment with optimal N availability, planting fertilization was done based on the soil chemical analysis. We applied 32 kg ha^{-1} of N at planting time and 128 kg ha^{-1} of N as sidedressing. In the experiment with low N availability, fertilization at planting

time was similar to the previous experiment and the sidedressing consisted of 30% of the total applied considering the ideal N dose (38.4 kg ha^{-1}). The evaluation sites were: Campos dos Goytacazes - RJ, at the Experimental Station of the Antônio Sarlo State Agricultural College (lat 21° 42' 48" S, long 41° 20' 38" W, alt 14 m asl) and at the Itaocara Experimental Station - RJ (lat 21° 38' 50" S, long 42° 03' 46" W, alt 58 m asl), representing, respectively, the North and Northwest regions of the State of Rio de Janeiro (Santos et al. 2019, Santos et al. 2020). The climate in both environments is tropical humid (Aw), according to the Köppen classification, and the soil is classified as Red-Yellow Latosol (Santos et al. 2020).

For WUE, the selection was performed based on the mean productivity between the environments and the lowest water demand of the cultivar. Additionally, evaluation of morphological and agronomic traits was included, i.e. popping expansion, male and female flowering, mean height of the plant and ear. We also assessed yield parameters as follows: mean ear diameter, mean ear length and mean mass of 100 grains). The same traits were included for NUE experiments. Under each water condition and N availability, the analysis of variance for grain yield was performed and the significance evaluated by F test. The individual analyses addressed the variation between mean values and experimental coefficient of variation.

Agronomic water and N use efficiencies of the hybrid WS01 were estimated and compared with experimental mean values under each condition. Between water and N conditions, the average grain yield of the hybrid WS01 was compared with the experimental and control treatment averages which included other hybrids and UENF 14 variety.

PERFORMANCE

During WUE evaluations, water conditions in each crop season showed significant differences in grain yield. We observed a coefficient of variation (CVe) between 11.33 and 16.42 % in 2018, and between 12.61 and 16.71% in 2020 for WW and WS, respectively, which indicates good experimental accuracy. The UENF WS01 hybrid displayed mean productivity of 4.2 t ha^{-1} under well-watered conditions and 2.6 t ha^{-1} under water stress (Table 1).

In each crop season, WS01 hybrid displayed similar values of WUE for GY, and values around 2 to 5 kg of grains per liter of water above experimental mean in 2018 and 2020, respectively. The grain yield values of this hybrid were above-average under different water conditions (Figure 1). Regardless of water condition, the hybrid had greater grain yield than UENF 14 (Figure 1), a cultivar adapted for the north and northwest of Rio de Janeiro state conditions (Amaral Júnior et al. 2013, Ribeiro et al. 2016).

For NUE, N availability in each location displayed significant differences for grain yield. We observed a coefficient of variation (CVe) of 6.30 to 8.67 % in Campos dos Goytacazes and 5.68 to 8.58 % in Itaocara for the higher and lower N doses, respectively, which indicates good experimental precision (Table 1). Grain yield was lower in Campos dos Goytacazes than in Itaocara, regardless of N availability (Table 1). In Itaocara, mean grain yield was above 3 t ha^{-1} even under low N availability (Table 2). The mean yields of cultivar UENF WS01 were higher than the experimental means at

Table 1. Summary of the analysis of variance, coefficient of variation, water and N use efficiencies and mean values of WS01 hybrid under different experimental conditions (in the crop seasons of 2018 and 2020, under well-watered (WW) and water stress (WS)), and nitrogen fertilization (Campos dos Goytacazes and Itaocara, RJ), with low or high soil N availability

Identification	Environment							
	2018		2020		Campos dos Goytacazes		Itaocara	
	WW	WS	WW	WS	High N	Low N	High N	Low N
Middle square	0.9682 **	0.6686 **	1.6031 **	0.5443 **	0.5767 **	0.5205 **	1.1378 **	0.7525 **
CVe (%)	11.3	16.42	12.61	16.71	6.3	8.67	5.68	8.58
Experimental means (t ha^{-1})	3.24	1.97	3.31	1.49	1.71	1.35	3.18	2.70
Means (L61/L76)	3.84	2.49	4.63	2.65	2.53	1.95	4.44	3.52
	Agronomic water-use efficiency (WUE) kg of grains / Liters of water (kg L^{-1})				Nitrogen use efficiency (NUE) kg of grains / kg of N			
Experimental means	9.67	9.06	11.19	7.63	10.69	19.18	19.88	38.35
L61/L76	11.46	11.45	15.65	13.58	15.81	27.70	27.75	50.00

** Significant at 0.01 probability by the F test.

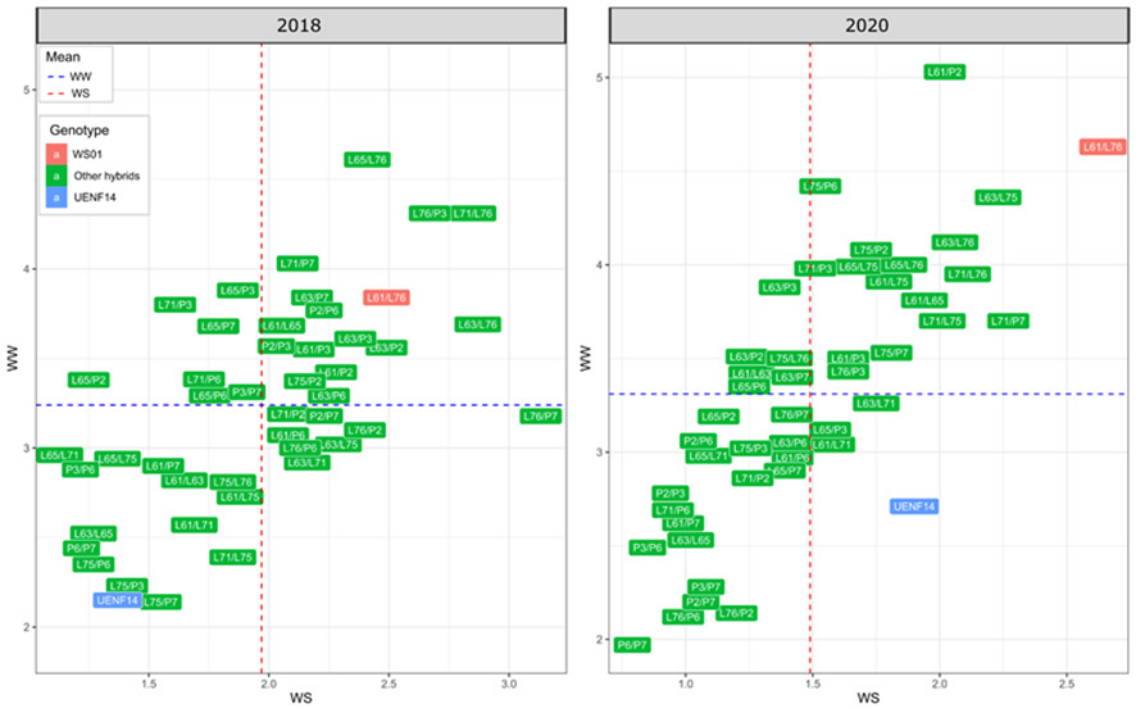

Figure 1. Performance comparison of grain yield (t ha^{-1}) of popcorn UENF WS01 hybrid with controls (UENF14 and hybrids) and mean experimental values in crop seasons of 2018 and 2020 under well-watered (WW) and water stress (WS) conditions.

all N doses and locations (Table 2). The UENF WS01 hybrid has an above-average grain yield in both N availability conditions (Figure 2). The hybrid showed N use efficiency and also response to N fertilization and therefore UENF WS01 is considered suitable for both conditions (Santos et al. 2020).

Table 2. Means of the agronomic and morphological traits of the UENF WS01 popcorn hybrid under ideal cultivation conditions (IC), water stress (WS), and low nitrogen (N) availability

Traits	IC	WS	N
Male flowering (days after sowing)	61	60	60
Female flowering (days after sowing)	62	63	61
Plant height (m)	1.75	1.40	1.74
Ear Height (m)	1.05	0.89	1.01
Prolificity (ears/plant)	1.56	1.10	1.52
Ear diameter (mm)	35.33	31.47	-
Ear length (cm)	13.83	12.21	-
100-grain weight (g)	15.31	13.45	11.47
Popping expansion (mL g^{-1})	31.86	33.11	31.94

OTHER TRAITS

Additional characteristics were assessed based on a cultivar inscription form for registration by the National Cultivar Register (RNC). The hybrid presented an early cycle with a mean male and female flowering of 60 and 62 days after sowing, respectively. The mean height of plant was 1.75 m and the mean height of ears was 1.05 m. The ear had a mean length of 13.83 cm and a mean diameter of 35.33 mm. The grain weight was greater than 15 g and the popping expansion exceeded 30 mL g^{-1} (Table 2), the minimum value recommended by MAPA for registering a popcorn cultivar (MAPA 2021). The grains of the cultivar were classified as light yellow in color.

The cultivar did not present variations in flowering and ability to expand the grains due to the abiotic stresses. In addition to yield parameters (mean diameter of the ear, mean ear length, and mean mass of 100 grains), the mean height of plant and ear were affected by water stress (Table 2). The variations in grain yield, yield components and plant development (represented by the height of the ear and plant) are directly associated with the amount of water available during the cultivar cycle. Variations in these traits will result from the greater or lesser water availability. In the case of

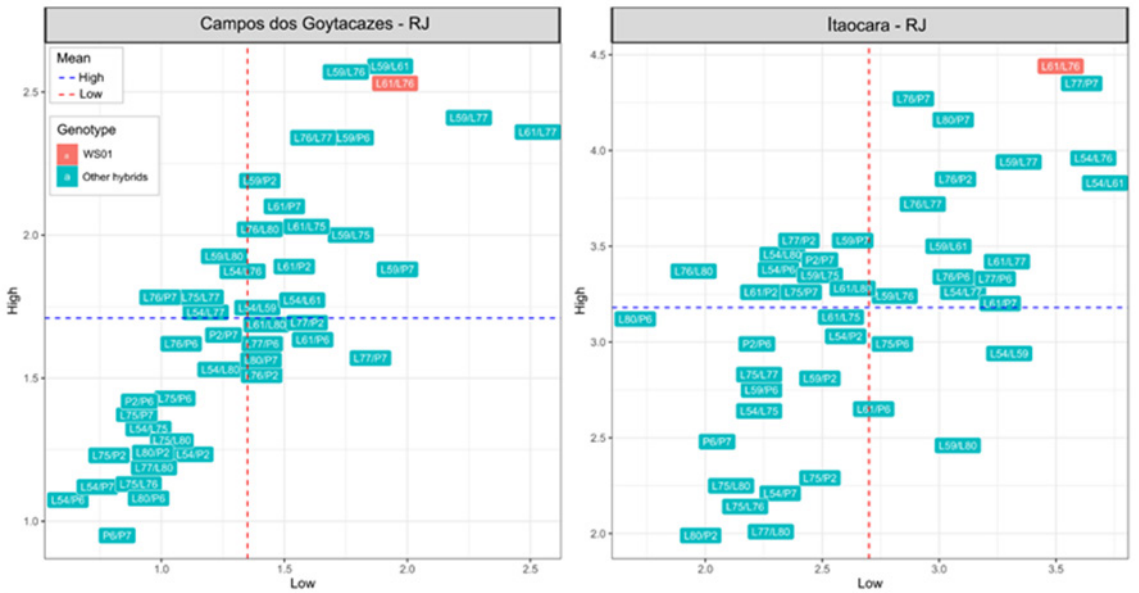

Figure 2. Performance comparison of grain yield (t ha^{-1}) of popcorn UENF WS01 hybrid with controls (UENF14 and hybrids) and mean experimental values in Campos dos Goytacazes and Itaocara, RJ, under low and high soil N availability.

low soil N availability, among the evaluated traits, only the grain mass showed significant variations. However, the other yield components were not evaluated in this study but may be affected by the low N availability (Santos et al. 2020).

BASIC SEED MAINTENANCE AND DISTRIBUTION

The cultivar UENF WS01 was registered with the Ministério da Agricultura, Pecuária e Abastecimento - MAPA on February 12, 2021, under the number 46965. The Universidade Estadual do Norte Fluminense Darcy Ribeiro – UENF, together with the seed company Rio Norte Sementes based in Campos dos Goytacazes, RJ, are responsible for the production and trade of hybrid seeds.

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