Research Article

Experimental double hybrids of fresh corn grown under low and high phosphorus availability[1]

Leandro Ferreira Damaso[2], Cecília Leão Pereira Resende[3], Daniel Diego Costa Carvalho[2], Fernanda de Cássia Silva[4], Fabricio Rodrigues[2]

ABSTRACT

A serious problem in fresh corn growing regions is the low availability of phosphorus (P), especially in the Cerrado (Brazilian Savanna) biome. This study aimed to evaluate the performance of experimental double hybrids of fresh corn intended to *in natura* consumption grown under low and high P availability. A randomized blocks experimental design was used, in a 2 × 21 factorial arrangement, consisting of two P availabilities (37.5 and 75 mg dm^{-3} of P_2O_5) and 21 corn hybrids, with 9 replications. The following variables were evaluated: ear insertion height, plant height, male and female flowering, ear length and diameter, grain weight, husked and unhusked ear weight. The best quality and yield for the corn market focused on *in natura* consumption were observed for the experimental double hybrids DH94 and DH102 under low P availability and for DH71 and DH81 under high P availability. The DH81 hybrid performs better for the consumer market, regardless of the P availability, and, therefore, has versatility and aptitude for this market and for different technological levels.

KEYWORDS: *Zea mays* L., husked ears, unhusked ears.

RESUMO

Híbridos duplos experimentais de milho verde cultivado sob baixa e alta disponibilidade de fósforo

Um grave problema nas regiões de cultivo de milho verde é a baixa disponibilidade de fósforo (P), principalmente no bioma Cerrado. Objetivou-se avaliar o desempenho de híbridos duplos experimentais de milho para consumo *in natura* sob baixa e alta disponibilidade de P. Utilizou-se delineamento experimental de blocos casualizados, em esquema fatorial (2 × 21), sendo duas disponibilidades de fósforo (37,5 e 75 mg dm^{-3} de P_2O_5) e 21 híbridos de milho, com nove repetições. As características avaliadas foram altura da inserção da espiga, altura de planta, florescimento masculino e feminino, comprimento e diâmetro de espigas, massa de grãos, peso de espigas empalhadas e despalhadas. Os híbridos duplos experimentais DH94 e DH102, para baixa disponibilidade de P, e os híbridos DH71 e DH81, para alta, possuem a melhor qualidade e produtividade para o mercado de milho, visando ao consumo *in natura*. O híbrido DH81 possui desempenho mais adequado ao mercado consumidor, independentemente da disponibilidade de P, e, dessa forma, apresenta versatilidade e aptidão para esse mercado e para diferentes níveis tecnológicos.

PALAVRAS-CHAVE: *Zea mays* L., espigas empalhadas, espigas despalhadas.

INTRODUCTION

Corn (*Zea mays* L.) is among the three cereal crops most grown in the world, with a total production of 114.75 million Mg in 2019, which is expected to increase approximately 6.47 % in 2020, despite the economic crises due to the Covid-19 pandemic (USDA 2021).

In Brazil, the area cultivated with corn increased by 7.2 % and the yield and production showed high reductions (around 22.1 and 16.4 %, respectively), based on the 2019-2020 and 2020-2021 crop seasons (Conab 2021). The Goiás State was responsible for approximately 9.25 % of the national production in the 2020-2021 crop season, presenting a mean yield of 4,585 kg ha^{-1}, approximately 270 kg ha^{-1} higher than the national mean, denoting the importance of corn crops for the State, which are mainly intended to grain production (Conab 2021).

The Brazilian Central-West region currently comprises one of the largest agricultural and irrigated areas, corresponding to 234,226.12 ha, with a total

[1] Received: Feb. 23, 2022. Accepted: May 27, 2022. Published: June 29, 2022. DOI: 10.1590/1983-40632022v5272023.
[2] Universidade Estadual de Goiás, Ipameri, GO, Brasil. *E-mail*/*ORCID*: eng.agrodamaso@gmail.com/0000-0002-2595-8691; daniel.carvalho@ueg.br/0000-0003-0564-4051; fabricio.rodrigues@ueg.br/0000-0002-6133-6363.
[3] Universidade Federal de Uberlândia, Uberlândia, MG, Brasil. *E-mail*/*ORCID*: cecilialprr@gmail.com/0000-0003-2432-4168.
[4] Agência Goiana de Assistência Técnica, Extensão Rural e Pesquisa Agropecuária, Goiânia, GO, Brasil. *E-mail*/*ORCID*: eng.fernanda09@gmail.com/0000-0003-4881-8015.

of 3,223 central pivots in operation (Silva et al. 2019, Ana 2021), denoting the potential of the State for agriculture, including the fresh corn production, with possibility of monthly supply. This market is more restricted and demanding in quality than the dry grain market; however, husked and unhusked ears have a high added value and generate a higher profitability per hectare (Rodrigues et al. 2018). It is considered a profitable activity, concentrated in small and medium properties with areas of approximately 1-10 ha (Bastos et al. 2017).

The low availability of specific cultivars is a problem for this activity: only 4.85 % of the 103 corn cultivars available were intended to this market in the 2019-2020 crop season, represented by the BM 3051, BRS 3046, IAC 8046, IAC 8053 and SAB40V62 cultivars (Pereira Filho & Borghi 2020). In addition, most of these cultivars are specific for some regions and crop conditions with medium to high technology, what restricts even more their cultivation by small growers. Therefore, the evaluation of genotypes adapted to the region is important to increase the options and obtain cultivars that meet all technological levels (Vasconcelos et al. 2022).

In the Goiás State, corn is grown on weathered soils, which present low natural phosphorus (P) availability. P deficiency decreases the plant metabolism, biomass and size of plant organs, including leaves and roots, thus affecting the plant yield (Coimbra et al. 2014). The ability of plants to acquire phosphate from the rhizosphere is critical in these P-deficient regions. In addition, there are intra and interspecific variations in the plant's ability to grow under P-limiting conditions, being a character of complex inheritance, controlled by many induced or suppressed genes and forming an intricate epistatic regulatory network interacting with cells and the external environment, which must be studied in each genotype destined for this environment (Vasconcelos et al. 2022).

The development of fresh corn cultivars that can be grown with different technologies and are more efficient under low P availability would result in higher gains and adaptation, with the possibility of meeting the demands of a larger number of growers, with the cultivar expressing its full production potential according to the soil P availability.

Thus, this study aimed to evaluate the performance of experimental double hybrids of fresh corn intended to *in natura* consumption grown under different P availabilities.

MATERIAL AND METHODS

The first stage of the experiment was carried out from August to December 2018, with biparental crossings, in a greenhouse, at the Universidade Estadual de Goiás (UEG), in Ipameri, Goiás State, Brazil (17º43'19''S, 48º09'35''W and altitude of 773 m). Seeds of the experimental double hybrids were formed using 9 simple hybrids from the UEG breeding program (MELHORVE), crossed in a partial diallel arrangement, divided into group I (6, 7, 8, 9 and 10) and group II (1, 2, 4 and 5), which generated twenty experimental double hybrids (DH). Then, the obtained experimental double hybrids were evaluated from January to April 2019, in the same greenhouse. In addition, the commercial double hybrid AG1051 was used as a control (this hybrid presents adequate characteristics for the fresh corn market and excellent yields of unhusked and marketable ear).

A randomized blocks experimental design was used, in a 2 × 21 factorial arrangement, consisting of two phosphorus (P) availabilities, 20 experimental double hybrids and one control, with 9 replications. The plots consisted of 18-L pots, with one plant per pot.

The soil, prior to fertilization and acidity correction, had the following chemical characteristics: pH: 4.9; organic matter: 18.2 g dm^{-3}; P: 1.1 mg dm^{-3}; H + Al: 2.3 $cmol_c$ dm^{-3}; K: 0.1 $mmol_c$ dm^{-3}; Ca: 1.6 $cmol_c$ dm^{-3}; Mg: 0.7 $cmol_c$ dm^{-3}; SB: 49.8 $cmol_c$ dm^{-3}; CEC: 4.7 $cmol_c$ dm^{-3}; V(%): 15.4. The soil preparation consisted in acidity correction using dolomitic limestone (3.5 g kg^{-1} of soil) and application of 300 g of cured poultry litter at 40 days before sowing.

Irrigation was carried out every two days according to the soil field capacity, based on the weight of pots after saturation with water until constant weight (approximately 80 % during the whole crop cycle). Soil fertilizer application was carried out using 75 kg ha^{-1} (37.5 mg dm^{-3}; low P availability) or 150 kg ha^{-1} (75 mg dm^{-3}; high P availability) of P_2O_5 (super triple phosphate), 30 kg of N (15 mg dm^{-3}; urea; 42 % of N) and 90 kg of KCl (45 mg dm^{-3}; potassium chloride) at sowing, and 100 kg ha^{-1} of N (50 mg dm^{-3}; urea; 42 % of N) as topdressing at the V_3-V_4 phenological stages (Ribeiro et al. 2016).

Crop practices consisted of manual weeding and application of phytosanitary products (Ampligo®; chlorantraniliprole 100 g L^{-1} + lambda-cyhalothrin 50 g L^{-1}, at the rate of 150 mL ha^{-1}) to control *Spodoptera frugiperda* caterpillars.

The evaluations were carried out at approximately 90 days after sowing, when the ears reached the milky grain point (R_3 stage), with water content of 70-80 %, which is considered the ideal point for fresh marketing. The evaluated characteristics were: ear insertion height (cm), measured from the culm base to the main ear insertion height; plant height (cm), measured from the culm base to the tassel base; time for male and female flowering (days), from the sowing to the time that 50 % of the plot were with mature pollen grains and pre-formed ears, with presence of stigma/style; ear length (cm), measured from the base to the tip of the ear, using a ruler; ear diameter (mm), measured on the median part of the ear, using a digital caliper; unhusked and husked ear weight (g), measured by weighing the ear of the plot in a digital scale; and grain weight (g), measured by weighing the fresh grains removed from the cobs in a digital scale.

The data were subjected to normality and homogeneity tests and analysis of variance. When significant, the means were subjected to the Scott-Knott test at 5 % of probability, using the Genes software (Cruz 2013).

RESULTS AND DISCUSSION

Significant differences were found within the factors hybrids and phosphorus (P) availability for most the evaluated characters ($p \leq 0.01$), as well as significant interactions, except for the factor P availability on the variable ear length. Thus, the corn double hybrids exhibited variability, with different performances regarding P availability, with the possibility of serving producers with different technological levels (Table 1).

Similar results were reported by Fritsche-Neto et al. (2010), who found differences under different P availabilities (28 and 112 kg ha^{-1} of P_2O_5) and variability among genotypes for characters connected to P-use efficiency. Melo et al. (2017) reported differences among the performances of corn genotypes intended to grain production grown under different P rates (34 and 170 kg ha^{-1} of P_2O_5) and found a significant interaction between genotypes and P rates. According to the authors, there is a difference in the behavior and yield of the genotypes, which served as the basis for new crosses and for directing the hybrid to the most adequate availability, giving the genotype a greater capacity to produce in quantity and, in the case of the present study, with quality too, what is very important for the market.

The coefficients of variation oscillated between 2.2 and 21.8 % (Table 1), with the lowest value corresponding to the male flowering and the highest one corresponding to grain weight, probably because the hybrids present a lower genic control and were little affected by the environment due to the time of exposure. DoVale et al. (2011) evaluated the selection index of double-suitability corn cultivars (baby corn and fresh corn) and found values between 2.8 and 41.3 %, the lowest value corresponding to ear length and the highest one to unhusked ear weight, thus confirming the experimental precision and the high effect of the environment on grain yield.

The double hybrids DH65, DH75, DH91 and DH101 presented a better performance, simultaneously, under low P availability, with a higher mean for ear height and a similar mean

Table 1. Analysis of variance for ear insertion height (EIH), plant height (PH), days for male (MF) and female (FF) flowering, ear length (EL) and diameter (ED), grain weight (GW), unhusked (UEW) and husked ear weight (HEW) of 21 corn double hybrids grown under two phosphorus (P) availabilities (75 and 150 kg ha^{-1} of P_2O_5) for *in natura* consumption.

Source of variation	Degrees of freedom	EIH (cm)	PH (cm)	MF (DAS)	FF (DAS)	EL (cm)	ED (mm)	GW (g)	UEW (g)	HEW (g)
Hybrid (H)	20	2,691.43**	1,947.82**	17.87**	21.48**	36.25**	59.53**	1,470.52**	16,487.36**	5,638.89**
P availability (P)	1	2,197.10**	3,670.44**	114.44**	112.72**	1.00^{ns}	293.87**	11,768.22**	60,394.68**	28,164.01**
H × P	20	326.18**	427.17*	4.91**	5.74**	6.30**	27.84**	795.96**	7,475.69**	3,080.87**
Block	8	137.10	267.08	1.90	5.16	13.42	2.40	265.14	5,535.55	2,354.15
Error	328	129.71	269.91	1.49	1.77	1.87	5.57	234.41	1,420.45	722.11
CV (%)		9.86	7.48	2.16	2.24	7.94	5.52	21.82	14.03	15.68

*, ** and ^{ns}: significant at 5 and 1 % of probability by the F test and not significant, respectively. DAS: days after sowing.

for plant height, when compared to the AG1051 (control) (Table 2). Only the DH101 had a higher performance than the control hybrid under high P availability conditions and simultaneously for ear and plant height, with 155 and 242 cm, respectively. Moreover, taller plants are not suitable for decreases in stands, resulting in a lower profitability per hectare (Galvão et al. 2014), decreasing the number of husked or commercial ears because of the lower number of plants, but favoring the husk production, which provides nutrient cycling such as higher organic matter content, due to the higher generated mass.

Ear insertion height and plant height are important characteristics to evaluate the potential of experimental hybrids under low P availability conditions, because, under nutritional stress, there is a reduction in plant height and, as a consequence, of the leaf area, with an average reduction of around 4.6 cm, leading to a lower photosynthetic capacity and lower formation of healthy ears for the consumer market. According to Silva et al. (2020), decreases in leaf area may significantly decrease the grain yield, and, combined with conditions of diseases or other problems, compromise the plant development and the profitability of growers.

The male and female flowerings should be analyzed together, because the synchronism between them is important for the formation of grain rows and a good grain development (Araújo et al. 2013), which are connected to the product quality. Some hybrids presented differences between these flowerings at approximately three days for DH64, DH71, DH72, DH74, DH75, DH91, DH101 and DH104 grown under low P availability; thus, they have higher chances to present flaws and a small number of commercial ears, thus decreasing the crop profitability (Table 2).

The means found for plants grown under high and low P availability presented small differences, with few hours between male and female flowerings, what was confirmed by the control hybrid AG1051, indicating that the low soil P availability did not significantly affect this character (Table 2). Santos et al. (2015) evaluated 7 corn cultivars under

Table 2. Means for ear insertion height (EIH), plant height (PH), male (MF) and female (FF) flowering of 21 corn double hybrids grown under two phosphorus (P) availabilities (75 and 150 kg ha^{-1} of P_2O_5) for *in natura* consumption.

Hybrids	EIH (cm)		PH (cm)		MF (days)		FF (days)	
	75 kg	150 kg	75 kg	150 kg	75 kg	150 kg	75 kg	150 kg
DH61	105.00 cA*	105.25 fA	210.38 bA	211.39 cA	58.62 bA	57.39 bB	60.81 bA	60.72 bA
DH62	107.85 cA	106.95 fA	222.67 aA	223.44 bA	60.11 aA	57.94 bB	61.18 aA	58.60 cB
DH64	112.31 cB	123.60 dA	213.38 bA	220.96 bA	59.88 aA	59.72 aA	62.12 aA	61.97 aA
DH65	127.81 aA	125.72 dA	225.81 aA	228.22 bA	57.56 cA	57.72 bA	58.31 cA	58.94 cA
DH71	116.12 bA	124.83 dA	209.31 bB	225.08 bA	55.31 dA	54.83 dA	58.62 cA	58.07 dA
DH72	106.44 cA	111.24 eA	198.12 cA	210.39 cA	58.50 bA	55.77 dB	61.50 aA	58.67 cB
DH74	122.06 bB	135.24 cA	223.44 aA	237.10 aA	57.69 cA	56.61 cA	61.69 aA	60.25 bB
DH75	130.75 aB	141.83 bA	231.19 aA	222.17 bA	57.06 cA	55.72 dB	60.12 bA	58.39 cB
DH81	116.94 bB	133.88 cA	221.94 aA	228.92 bA	59.12 bA	55.67 dB	60.66 bA	57.47 dB
DH82	93.32 dB	106.43 fA	202.30 cB	221.40 bA	58.00 bA	56.50 cB	59.24 cA	58.73 cA
DH84	120.79 bA	125.14 dA	236.56 aA	248.18 aA	57.79 cA	56.94 cA	58.85 cA	58.24 cA
DH85	120.88 bA	117.89 eA	220.25 aA	211.28 cA	57.12 cA	56.61 cA	58.62 cA	57.61 dA
DH91	127.56 aA	118.20 eA	230.06 aA	218.31 bA	58.44 bA	56.72 cB	61.66 aA	59.25 cB
DH92	107.95 cA	103.81 fA	208.20 bB	225.14 bA	58.22 bA	58.11 bA	60.74 bA	59.36 cB
DH94	109.38 cA	107.70 fA	223.31 aA	223.76 bA	58.88 bA	56.56 cB	60.81 bA	58.36 cB
DH95	112.75 cA	109.17 eA	217.88 aA	224.83 bA	58.38 bA	57.61 bA	59.25 cA	59.11 cA
DH101	128.16 aB	154.71 aA	219.19 aB	242.08 aA	57.34 cA	55.34 dB	60.12 bA	58.54 cB
DH102	89.53 dA	94.83 fA	189.84 cA	200.20 cA	57.12 cA	57.47 bA	59.62 cA	58.89 cA
DH104	107.47 cA	111.17 eA	208.33 bA	222.89 bA	57.86 cA	58.06 bA	60.12 bA	60.89 bA
DH105	101.38 cA	108.83 eA	209.62 bA	204.28 cA	56.12 dA	56.28 cA	57.25 dA	57.28 dA
AG1051	111.57 cA	110.88 eA	224.04 aA	226.67 bA	58.63 bA	57.28 bB	59.48 cA	58.50 cA
Mean PA	113.14	117.97	216.47	222.70	57.99	56.90	60.04	58.95
General mean	115.55		219.58		57.44		59.49	

* Means followed by the same lowercase letter in the columns or uppercase letter in the rows are not different from each other by the Scott-Knott test at 5 % of probability. PA: phosphorus availability.

conventional crop system and found mean male and female flowerings of 54 and 57 days, a similar result to what was observed in the present study (approximately 57 and 59 days, respectively). This small difference may be due to the thermal stress of plants in the greenhouse, in which the internal temperature tends to be higher and continuous for a longer time, and, according to Edreira et al. (2011), may delay the flowering.

The ear length (21.4 cm) and diameter (48.1 mm) found in the hybrid AG1051 were not affected by the low soil P availability, presenting values that meet the market demand and a good profitability (Table 3). The hybrids DH91 and DH102 presented a high performance for length under low P availability, with a mean of 20.8 cm; and none of the hybrids had similar results to the control under high P availability, as also found for ear diameter under low P availability.

Some experimental hybrids have more interesting characteristics to be marketed in trays, mainly shorter lengths; however, the larger ear diameters of the hybrids DH81 and DH82 resulted in higher grain weights (97.5-85.5 g, respectively), being more attractive to consumers. Ribeiro et al. (2016) found that there is a low effect for these variables with the reduction of P doses between 75 and 150 kg ha^{-1} of P_2O_5, with increments of only 1.51 cm and 0.38 mm, respectively, what may also indicate a low number of alleles involved and a very small genotype by environment interaction, in this case, confirmed by the non-interaction of the diameter variable and low influence on the length under selection for low P availability, as stated by Resende et al. (2021).

The grain weight of the hybrids DH62, DH71 and DH81 presented a high performance for both P availabilities, indicating a higher resistance to the nutritional stress and resulting in the best ears in both conditions (Table 3). The differences between hybrids with higher and lower weights under low and high P availability were approximately 15 and 45 % by grouping, and 4 and 29 % when based on the mean by P availability, what may result in higher gains and in experimental hybrids with conditions to occupy the fresh corn market.

Table 3. Means for ear length (EL), ear diameter (ED) and grain weight (GW) of 21 corn double hybrids grown under two phosphorus (P) availabilities (75 and 150 kg ha^{-1} of P_2O_5) for *in natura* consumption.

Hybrids	EL (cm)		ED (mm)		GW (g)	
	75 kg	150 kg	75 kg	150 kg	75 kg	150 kg
DH61	18.10 bA*	18.06 bA	41.58 bB	44.52 bA	63.80 aA	72.31 cA
DH62	18.57 bA	17.18 cB	42.86 bB	45.38 bA	69.52 aB	97.57 aA
DH64	14.94 dA	15.42 dA	40.60 cA	40.74 dA	54.07 bA	57.18 cA
DH65	17.06 cA	17.28 cA	42.73 bA	42.40 cA	67.45 aA	75.34 cA
DH71	17.76 bB	19.74 bA	42.38 bA	43.05 cA	76.21 aB	92.87 aA
DH72	17.78 bA	18.54 bA	39.14 cB	43.56 cA	56.80 bB	103.63 aA
DH74	17.00 cB	18.88 bA	39.97 cB	43.10 cA	57.35 bA	63.62 cA
DH75	17.70 bA	17.75 cA	40.76 cB	43.08 cA	68.63 aA	73.18 cA
DH81	18.32 bA	18.61 bA	40.04 cB	47.72 aA	66.24 aB	97.53 aA
DH82	16.67 cA	17.28 cA	42.73 bB	47.07 aA	70.98 aB	85.54 bA
DH84	14.82 dA	16.00 dA	41.62 bB	44.74 bA	62.63 aB	68.33 cA
DH85	17.31 cA	15.81 dB	43.00 bA	43.47 cA	71.79 aA	73.34 cA
DH91	20.68 aA	18.06 bB	39.72 cB	44.74 bA	53.47 bB	69.47 cA
DH92	18.82 bA	19.36 bA	42.30 bA	40.74 dA	63.89 aA	68.37 cA
DH94	17.20 cA	16.81 cA	44.26 bA	42.64 cA	72.77 aA	64.95 cA
DH95	16.86 cA	16.54 cA	40.32 cA	41.08 dA	48.85 bA	58.78 cA
DH101	17.69 bB	19.23 bA	42.25 bB	46.18 bA	62.47 aB	87.34 bA
DH102	20.34 aA	18.70 bB	42.51 bA	42.29 cA	80.31 aA	74.87 cA
DH104	17.78 bA	18.71 bA	42.25 bA	42.76 cA	53.83 bA	62.40 cA
DH105	18.56 bA	17.95 bA	41.00 cA	39.04 dA	64.01 aA	63.48 cA
AG1051	21.44 aA	21.54 aA	48.14 aA	48.88 aA	71.48 aA	80.76 bA
Mean PA	17.88	17.97	41.91	43.68	64.60	75.76
General mean	17.92		42.79		70.18	

* Means followed by the same lowercase letter in the columns or uppercase letter in the rows are not different from each other by the Scott-Knott test at 5 % of probability. PA: phosphorus availability.

Rodrigues et al. (2018) observed that the grain weight of the control hybrid (AG1051) would be 75.47 g ear^{-1}, under a density of 60,000 plants ha^{-1}, a similar result to that found under the high P availability (80.8 g). Fourteen experimental hybrids had similar grain weights to the control (± 69 g) and four had a higher performance (± 98 g), confirming the capacity of the hybrids to meet the market requirements (Table 3).

The experimental double hybrids DH94 and DH102 presented a higher efficiency under low P availability, with mean yields of 300 and 198.4 g, respectively for unhusked and husked ear weight, with husks representing approximately 34 % of the whole ear (Table 4). These results denoted the possibility of transporting and maintaining the product with no damages, meeting several segments of this market.

Resende et al. (2019) evaluated 10 corn hybrids for fresh consumption and reported that AG1051 has a high efficiency and responsiveness to P, and that it showed good results, despite the droughts during the 2014-2015 crop season. Therefore, the hybrids DH62, DH71, DH82 and DH102 presented a higher efficiency and responsiveness to P for unhusked and husked ear weight, based on the performance of the control (AG1051), and a higher chance of success in corn markets focused on growers with low to high technological levels (Table 4). Resende et al. (2021) reported difficulties for generation of variability in hybrids under low nitrogen and P availability conditions, as breeding programs always prioritized cultivars for high P availability; thus, allelic combinations for low P availability conditions would be more difficult to be identified currently.

The hybrids DH94 and DH102 (low P availability) and DH71 and DH81 (high P availability) presented high yields for husked and unhusked ears, as well as ears with averages similar to the control (AG1051) or higher, and adequate lengths (> 15 cm) and diameters (> 40 mm) to the fresh corn market (Tables 3 and 4). In addition, these hybrids also presented lower plant heights and ear insertion heights, what enables studies on stands and higher profitability; however, other studies are needed, mainly under low P availability conditions, due to competition for nutrients (Table 4).

The double hybrid DH81 has a performance that is more suitable for the consumer market, regardless of the P availability, being superior or similar to the control for grain mass and unhusked and husked ear weight. Concerning the variables related to product quality, the hybrid obtained length and diameter results that fit in the required commercial standard and with reduced height, both for the plant and ear under the highest dose of P, thus, it has versatility and aptitude for this market and for different technological levels.

Table 4. Means for unhusked (UEW) and husked ear weight (HEW) of 21 corn double hybrids grown under two phosphorus (P) availabilities (75 and 150 kg ha^{-1} of P_2O_5) for *in natura* consumption.

Hybrids	UEW (g)		HEW (g)	
	75 kg	150 kg	75 kg	150 kg
DH61	266.24 aA*	289.36 bA	164.38 bA	180.65 cA
DH62	303.06 aA	299.05 bA	172.56 bA	190.18 bA
DH64	216.46 bA	216.97 dA	128.80 cA	130.10 dA
DH65	230.39 bB	269.44 cA	152.93 cA	169.47 cA
DH71	296.34 aA	325.57 aA	164.78 bB	199.82 bA
DH72	215.23 bB	281.12 cA	140.71 cB	180.91 cB
DH74	227.96 bB	296.40 bA	145.79 cB	188.07 bA
DH75	247.07 bA	271.36 cA	143.58 cB	173.75 cA
DH81	268.27 aB	335.42 aA	172.79 bB	221.73 aA
DH82	239.94 bB	305.66 bA	167.09 bB	206.91 bA
DH84	210.31 bB	274.64 cA	143.32 cB	177.50 cA
DH85	252.70 bA	244.48 cA	176.99 bA	167.66 cA
DH91	294.31 aB	333.54 aA	175.78 bB	203.96 bA
DH92	270.12 aA	299.21 bA	176.91 bA	176.30 cA
DH94	298.12 aA	252.64 cB	189.82 aA	166.94 cA
DH95	216.18 bA	208.04 dA	133.18 cA	135.31 dA
DH101	285.28 aA	250.18 cA	182.28 bA	166.62 cA
DH102	308.39 aA	294.17 bA	207.07 aA	195.18 bA
DH104	257.03 bA	277.22 cA	154.40 cB	175.74 cA
DH105	231.06 bA	220.12 dA	155.34 cA	150.31 dA
AG1051	241.73 bB	362.50 aA	168.64 bA	222.56 aA
Mean PA	256.01	281.29	162.72	179.98
General mean	268.65		171.35	

* Means followed by same lowercase letter in the columns or uppercase letter in the rows are not different from each other by the Scott-Knott test at 5 % of probability. PA: phosphorus availability.

CONCLUSIONS

1. The experimental double hybrids DH94 and DH102 grown under low phosphorus (P) availability and the hybrids DH71 and DH81 grown under high P availability presented the best qualities and yields for fresh corn intended to the *in natura* consumption market;
2. The experimental double hybrid DH81 presented the best performance production, regardless of the soil P availability, with the possibility of meeting not only the demands of the consumer market, but those of growers with different technological levels.

REFERENCES

AGÊNCIA NACIONAL DE ÁGUAS E SANEAMENTO BÁSICO (ANA). *Conjuntura dos recursos hídricos no Brasil*. 2021. Available at: https://relatorio-conjuntura-ana-2021.webflow.io/capitulos/seguranca-hidrica. Access on: June 22, 2022.

ARAÚJO, A. V. D.; BRANDÃO JUNIOR, D. D. S.; FERREIRA, I. C. P. V.; COSTA, C. A. D.; PORTO, B. B. A. Desempenho agronômico de variedades crioulas e híbridos de milho cultivados em diferentes sistemas de manejo. *Revista Ciência Agronômica*, v. 44, n. 4, p. 885-892, 2013.

BASTOS, E. A.; CARDOSO, M. J.; ANDRADE JÚNIOR, A. S.; NASCIMENTO, F. N.; RAMOS, H. M. Desempenho da produtividade de espigas de milho verde sob diferentes regimes hídricos. *Revista Brasileira de Milho e Sorgo*, v. 16, n. 1, p. 94-108, 2017.

COIMBRA, R. R.; FRITSCHE-NETO, R.; COIMBRA. D. B.; NAOE, L. K.; CARDOSO, E. A.; RAONI, D.; MIRANDA, G. V. Relação entre tolerância do milho a baixo teor de fósforo no solo e responsividade a adubação fosfatada. *Bioscience Journal*, v. 30, n. 2, p. 332-339, 2014.

COMPANHIA NACIONAL DE ABASTECIMENTO (Conab). *Tabela de dados*: produção e balanço de oferta e demanda de grãos. 2021. Available at: https://www.conab.gov.br/info-agro/safras/graos. Access on: Sep. 10, 2021.

CRUZ, C. D. GENES: a software package for analysis in experimental statistics and quantitative genetics. *Acta Scientiarum Agronomy*, v. 35, n. 3, p. 271-276, 2013.

DOVALE, J. C.; FRITSCHE-NETO, R.; SILVA, P. S. L. Índice de seleção para cultivares de milho com dupla aptidão: minimilho e milho verde. *Bragantia*, v. 70, n. 4, p. 781-787, 2011.

EDREIRA, J. I. R.; CARPICI, E. B.; SAMMARRO, D.; OTEGUI, M. E. Heat stress effects around flowering on kernel set of temperate and tropical maize hybrids. *Field Crops Research*, v. 123, n. 1, p. 62-73, 2011.

FRITSCHE-NETO, R.; MIRANDA, G. V.; LIMA, R. O. de; SOUZA, L. V. de; SILVA, J. da. Herança de caracteres associados à eficiência de utilização do fósforo em milho. *Pesquisa Agropecuária Brasileira*, v. 45, n. 5, p. 465-471, 2010.

GALVÃO, J. C. C.; MIRANDA, G. V.; TROGELLO, E.; FRITSCHE-NETO, R. Sete décadas de evolução do sistema produtivo da cultura do milho. *Revista Ceres*, v. 61, supl., p. 819-828, 2014.

MELO, A. V.; TAUBINGER, M.; SANTOS, V. M.; CARDOSO, D. P.; VALE, J. C. Capacidade combinatória de milho para produção de grãos sob níveis de fósforo. *Revista de Agricultura Neotropical*, v. 4, n. 4, p. 15-25, 2017.

PEREIRA FILHO, I. A.; BORGHI, E. *Sementes de milho*: nova safra, nova cultivares e contínua a dominância dos transgênicos. Sete Lagoas: Embrapa Milho e Sorgo, 2020.

RESENDE, C. L. P.; DAMASO, L. F.; ÁVILA, M. C.; CARVALHO, D. D.; MELO, P. G.; RODRIGUES, F. Agronomic efficiency of hybrids of corn to nitrogen, phosphorus and potassium targeting fresh corn. *Journal of Agricultural Science*, v. 11, n. 9, p. 120-133, 2019.

RESENDE, C. L. P.; MARTINS, J. B.; ILARIA, F. R.; SANTOS, C.; RODRIGUES, F. Phenotypic and genetic parameters estimated for fresh corn under different nutrient availability. *Revista Caatinga*, v. 34, n. 4, p. 752-762, 2021.

RIBEIRO, M. C.; DAMASO, L. F.; COSTA, F. R.; PELÁ, A.; RODRIGUES, F. Híbridos de milho sob diferentes doses de fósforo visando o consumo *in natura*. *Magistra*, v. 28, n. 2, p. 273-278, 2016.

RODRIGUES, F.; MELO, P. G. S.; RESENDE, C. L. P.; MROJINSKI, F.; MENDES, R. C.; SILVA, M. A. Aptidão de híbridos de milho para o consumo *in natura*. *Revista de Ciências Agrárias*, v. 41, n. 2, p. 484-492, 2018.

SANTOS, N. C. B.; CARMO, S. A.; MATEUS, G. P.; KOMURO, L. K.; PEREIRA, L. B.; SOUZA, L. C. D. Características agronômicas e de desempenho produtivo de cultivares de milho-verde em sistema orgânico e convencional. *Semina: Ciências Agrárias*, v. 36, n. 3, p. 1807-1822, 2015.

SILVA, R. S.; CAMPOS, H. D.; RIBEIRO, L. M.; BRAZ; G. B. P.; MAGALHÃES, W. B.; BUENO, J. N. Danos na cultura do milho em função da redução de área foliar por desfolha artificial e por doenças. *Summa Phytopathologica*, v. 46, n. 4, p. 313-319, 2020.

SILVA, W. F.; OLIVEIRA, H. F. E.; OLIVEIRA, M. H. R.; ÁVILA, E. A. S.; SANTOS, E. A.; SILVA, R. M.; OLIVEIRA, R. S.; SOUSA, A. E. C.; BRITO, G. H. M.; PEREIRA, L. S.; COSTAS, E. M.; VENTURA, M. V. A. Identification of areas irrigated by central pivot in the State of Goiás, Brazil. *Journal of Agricultural Science*, v. 11, n. 11, p. 1-7, 2019.

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA). *World corn production 2020/2021*. 2021. Available at: http://www.worldagriculturalproduction.com/crops/corn.aspx. Access on: May 14, 2021.

VASCONCELOS, M. J. V.; FIGUEIREDO, J. E. F.; OLIVEIRA, M. F.; SCHAFFERT, R. E.; RAGHOTHAMA, K. G. Plant phosphorus use efficiency in acid tropical soil. *Revista Brasileira de Milho e Sorgo*, v. 21, e1259, 2022.