Revista de Biotecnologia & Ciência, v.10, n.2, 2021
ISSN 2238-6629
Universidade Estadual de Goiás

Potential of corn hybrids for fresh consumption

Potencial de híbridos de milho para o consumo fresco

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Recebido: 12/08/2021; Aceito: 04/09/2021

ABSTRACT

The objective of this work was to evaluate the potential of corn hybrids for grain productivity and fresh produce marketability in two crop seasons. The experiment applied the completely randomized block design with three replications, during 2013-14 and 2014-15 crops. Ten hybrids indicated for the Midwest region of Goiás state were used, namely 2B512PW, 2B587PW, 2B707PW, 30F35HR, 30F53YH, BRS1055, BM3061, P3646H and P3862YH. Hybrid AG1051 was used as control. The studied variables were ear height (EH), unhusked ear productivity (UEP), husked ear productivity (HEP), marketable ear productivity (MEP), marketable ear length (MEL), marketable ear diameter (MED), grain mass (GM), and gross revenue (GR). Records show that hybrid P3646H achieved results lower than the control in all the analyzed variables, regardless of the crop season, whereas hybrids 2B512PW, BRS1055 and P3862YH showed figures similar to AG1051 in 2013/14 crop and lower ones in 2014/15. Therefore, would not represent direct market competitors, as the control hybrid holds a significant share in the domestic market. Hybrids 2B587PW, 30F35HR, 30F53YH and BM3061 presented the greatest suitability for fresh corn consumption, as featured the highest number of favorable traits for that market.
Keywords: *Zea mays L.; unhusked ears; marketable ears; gross revenue.*

RESUMO

O objetivo do trabalho foi avaliar o potencial de híbridos de milho destinados a grãos e com a possibilidade de comercialização *in natura*, durante duas safras. O delineamento experimental utilizado foi o de blocos casualizados, com três repetições, durantes as safras 2013/14 e 2014/15. Foram utilizados dez híbridos indicados para a região Centro-Oeste de Goiás, sendo os híbridos 2B512PW, 2B587PW, 2B707PW, 30F35HR, 30F53YH, BRS 1055, BM 3061, P3646H e P3862YH, além destes, o híbrido AG1051, utilizado como controle. As variáveis estudadas foram altura de espiga (EH), produtividade de espigas empalhadas (UEP), produtividade de espigas despalhadas (HEP), produtividade de espigas comerciais (MEP), comprimento de espigas comerciais (MEL), diâmetro de espigas comerciais (MED), massa de grãos (GM) e renda bruta (GR). Registra-se que o híbrido P3646H obteve desempenho inferior ao controle para todas as variáveis analisadas, independente da safra. Já os híbridos 2B512PW, BRS1055 e P3862YH, demonstraram desempenho similar ao AG1051 na safra 2013/14 e inferior na safra 2014/15, deste modo, não seriam concorrentes diretos de mercado, visto que o híbrido

controle possui uma fatia importante do mercado nacional. Os híbridos 2B587PW, 30F35HR, 30F53YH e BM3061 foram os que apresentaram maior aptidão para o mercado de milho, visando o consumo *in natura*, os quais apresentaram maior número de caracteres favoráveis a este mercado.
Palavras-chave: *Zea mays* L., espigas empalhadas, espigas comerciais e renda bruta.

INTRODUCTION

Corn (*Zea mays* L.) is one of the main grains grown all over the world, including Brazil, and can be used in human and animal feeding and also as industrial feedstock, especially for its high nutritional quality and versatility in Brazilian cuisine. The Mid-South region of the country accounts for 88% of domestic production, and the Mid-West was responsible for 53% of the total yield produced in 2018/19 crop, according to data from the National Supply Company (CONAB, 2019). Productivity in the state of Goiás is above the national average, approximately 17% higher, and comprises 1,523 thousand planted hectares, which demonstrates the importance of this crop for the region (CONAB, 2019).

The Brazilian market contains a large amount of grain hybrids, but for the specialty corn hybrids market is far below and with few options. Thus, only a small slice is intended for consumption of fresh produce. In addition, this group of hybrids and, in some cases, varieties serve only a few regions, reducing this percentage to even lower values, and it is common not to occupy 4% of the seed market. This leads producers to apply hybrids targeted to other market niches, which may deliver lower quality product or one that does not meet the basic demands of the consumer market.

The grain is the most important input in the crop, and as such, careful choice must be made in order to ensure greater performance and profitability (GALVÃO et al., 2014). However, with a low number of cultivars and the difference between the types and levels of technology adopted, the potential for achieving the demands of the market and of different planting environments is minor, which does not promote the market (MORAES et al., 2010).

Achieving economically feasible fresh corn production and supplying the region’s demand requires high sustainable productivity (PAIVA et al., 2012). Therefore, hybrids destined for grain production that suit the regional producers’ needs may represent interesting alternatives in fresh corn cropping (COSTA et al., 2015). On the other hand, producers may assess the market and choose whether to sell it in grains or as fresh produce if they wish to obtain higher profits.

Thus, this research was aimed at evaluating the potential of corn hybrids for grain productivity with the possibility of fresh produce trading in two crops.

Corn Market

The growth of the agricultural sector in recent years is also linked to plant genetic improvement, the technological efficiency of cultural treatments and the advance of mechanization, as well as correlated with population increase. This with alarming estimates of population growth and levels to be reached in ten years are currently being verified. Among the main commodities produced in Brazil, corn stands out, with huge use in human, animal and as raw material for industry, mainly due to its nutritional quality and versatility in Brazilian gastronomy (RODRIGUES et al., 2018).

Global demand for corn is increasing and has been rising in recent years, as the world's largest producer, the USA, has allocated part of its crop for ethanol production and invested in increasing the area destined for this niche (WALTER, 2007). Another fact that contributes to a greater participation of Brazil in the international market is the implementation of new technologies and the expansion of planted areas, with increased productivity and, of course, the good price paid last harvest (CONAB, 2019).

Brazil is an important food producer and holder of different climatic conditions, which offers the opportunity to grow crops for a huge number of agricultural products, producing with quality and exporting a huge variety of commodities. Thus, agribusiness has been vital to the national economy, accounting for approximately a quarter (23%) of the country's GDP (ARTUZO et al., 2019), mainly driven by corn and soybean production.

Corns intended for human consumption, such as popcorn, white corn and vegetable corn are called specials corns and represent a specific niche in the market. The seed companies are working to obtain vegetable corn cultivars that meet the traits required by the market for both fresh consumption and the canning industry (PEREIRA FILHO et al., 2019).

The production of vegetable corn, so-called harvested before physiological maturation, at the milky grain stage (R_3), has been increasing its market share in recent years, both due to the demand for fresh product and the good price paid in the market. However, its cultivation has some specific recommendations that differ from corn cultivation for grains and with cultivars and/or hybrids specific to that crop.

Corn hybrid for fresh consumption

Constant productivity gains are directly related to the development of new cultivars or hybrids, which are more responsive and linked to more appropriate agronomic practices for different cultivation environments, in different Brazilian regions. The breeding programs of private and public companies are dynamic and provide a high number of seeds and, of course, from different genetic bases, in order to serve most Brazilian producers and the most diverse technological levels (HANASHIRO et al., 2013). In addition to meeting the demands of the consumer market, especially regarding products consumed *in natura*.

For the corn market, 298 cultivars were available for the 2017/18 crop, 195 transgenic, with one or more events inserted, and the other 103 are conventional, which means that 65.4% of the corn cultivars are transgenic and only 34.6% are conventional (PEREIRA FILHO and BORGHI, 2018). However, the number of seeds destined for the specific production of green corn for this crop is only five, representing a share of only 1.7% of the market, which is consumed all year round and throughout the national territory.

The hybrids for green corn production are described in Table 1 for the 2017/18 crop, which shows that only one material is a simple hybrid (GNZ 2004) and thus with greater vigor and yield potential. However, it has the highest technological level, which raises the price of seed and production costs. Another obstacle is the specificity of some materials, such as the hybrids AG 4051 VT PRO YG and BM 3061, which prevents the use in some agricultural areas and which have greater genotype and environment interaction, further reducing the range for producer options.

The ideal is to use cultivars or hybrids with good adaptation and good productivity in the region, in this case, were evaluated for the potential for the production of fresh corn, allowing the producer to choose the product to be marketed and compared with a high-performance hybrid and good commercial acceptance, as is the case of AG 1051, confirmed in several studies (ALBUQUERQUE et al., 2008; RODRIGUES et al., 2018).

MATERIAL AND METHODS

The region's soil is classified as Dystrophic Red-Yellow Latosol, according to criteria defined by EMBRAPA (2006), and the data on its chemical analysis are shown in Table 2. The region has tropical humid climate, with two distinct seasons, dry and rainy. The experiment was conducted between October and December, in 2013/14 crop and during the same period in 2014/15 (Figure 1).

The experiment applied the completely randomized blocks design, with three replications during 2013/14 and 2014/15 crops. Each parcel comprised four one-meter-long rows, spaced 0.5m, with three plants per linear meter, and using only the two central rows, which resulted in a 4-m2 usable area. Ten hybrids recommended for the Mid-West region of Goiás were used (Table 2), hybrid AG1051 being taken as control (market standard).

Table 1. Agronomic traits of corn cultivars available for 2017/2018 crop for fresh consumption.

Hybrid	Type	Cycle	Application	Kernel color	Ear Height (m)	Plant height (m)	Technology leve	Region of adaptation
BRS 3046	TH	SE	FC	YE	1.06	2.04	I/H	Brazil
AG 1051	DH	SE	FC/WPS	YE	1.06	2.06	I/H	Brazil
AG 4051*	TH	SE	FC/WPS	YE	-	-	I/H	Specific[1]
BM 3061	TH	E	FC/WPS	YE	1.06	2.8	I/H	Specific [2]
GNZ 2004	SH	E	K/FC/WPS	Y/OR	2.3	2.7	I	Brazil

Font: Adapted from Pereira e Borghi, 2019; *: GM – genetically modified VT PRO YG; Type: TH – triple-cross hybrid, DH – double-cross hybrid, SH – single-cross hybrid; Cycle: E – early, SE – semi-early; Application: K – Kernels; WPS – whole plant silage, FC – fresh corn; Kernel color: OR – orange, YE – yellow, RE – red; Technology level: H – high, I – intermediate; 1 : Sul MG, SP (Alto e Sul e Cer. alto), RS, SC(Alto), Matopi e NE (Cer. baixo) DF/Oeste BA (Cer. alto) PR(Alto) Tring. MG, Sul e Sudeste de GO, 2: SUL, SE, CO, NE, N.

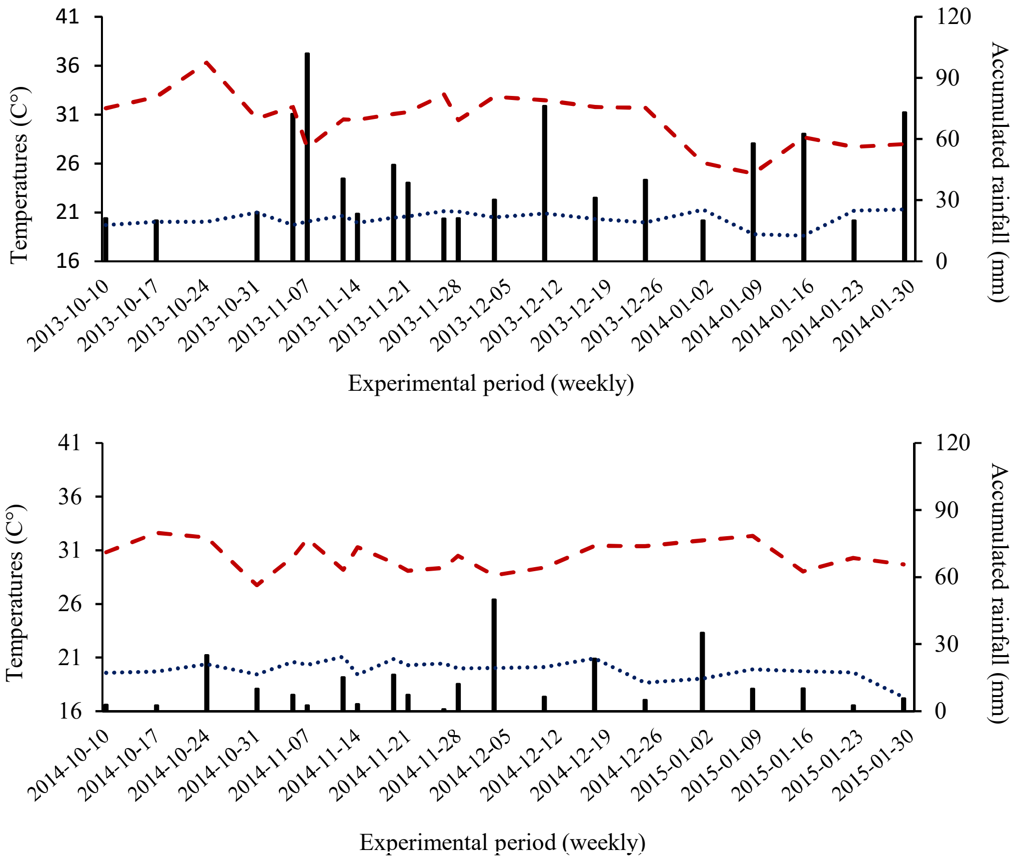

Figure 1. Temperatures (--- maximum and .... minimum) and accumulated rainfall of 7 days during the experimental period in 2013/14 and 2014/15 crops.

Table 2. Chemical attributes of the soil (0-20 cm depth) after limestone application (2013/14) 2013/14 and 2014/15 crop under full fertilizer.

Soil	pH	O.M.	P_{resin}	H+Al	Al^{3+}	K^{+}	Ca^{2+}	Mg	CEC	V
	$CaCl_2$	g dm^{-3}	mg dm^{-3}	————	————	cmolc dm^{-3}	————	————	————	%
Without fertilizer (2013/14 crop)										
0 – 20 cm	5.4	22.6	3.25	2.06	0.1	0.41	2.03	0.9	3.4	64
20 – 40 cm	4.8	18.6	1.50	3.70	0.0	0.29	1.60	0.6	2.6	40
With fertilizer - 2013/14 crop										
0 – 20 cm	5.2	28.3	25.7	2.2	0.0	0.75	4.7	0.9	6.3	74
20 – 40 cm	5.0	13.5	2.5	2.1	0.0	0.58	1.8	0.5	3.3	61
With fertilizer - 2014/15 crop										
0 – 20 cm	5.6	29.7	29.9	2.0	0.0	0.83	5.0	1.2	7.0	77
20 – 40 cm	5.0	14.2	3.0	2.0	0.0	0.57	1.9	0.6	3.3	62

pH = active acidity; OM = organic matter; P = available phosphorus; H+Al = potential acidity; Al - exchangeable acidity; K = available potassium; Ca = exchangeable calcium; Mg = exchangeable magnesium; CEC = effective cation exchange capacity; V% = base saturation a $pH_{7,0}$.

Nine hundred (900) kg of dolomitic limestone were applied, with 70% PRNT, mixed into the 0–20-m layer. After 25 days, conventional soil preparation began with plowing and disking and the aid of a cultivator to furrow the planting lines.

Planting and coverage fertilization was accomplished as recommended for fresh corn crops, aiming at productivity between 15,000 and 17,000 kg ha^{-1} unhusked ears (120 kg of N, 120 kg of ha^{-1} P_2O_5 and 90 kg ha^{-1} K_2O), according to Pereira Filho (2003). Nitrogen was parceled into two equal rates, the first being applied during planting and the second, 30 days after sowing, in coverage and using urea (45% of N).

Applications of phytosanitary products were made, using 240g L-1 methoxyfenozide (Intrepid®), at 150mL ha^{-1} dose, beta-cypermethrin (Akito®), at 75 mL ha-1, combined with manual weeding performed every three weeks.

Harvest was accomplished manually, as ears reached milky stage, R_3, when kernels had 70–80% of water content, about 90 days after planting, which is considered the ideal time for fresh produce commercialization.

The following characteristics were evaluated: EH – ear height (cm), determined after female flowering by measuring the height of six representative plants from the usable area in each parcel, from the plant base to the base of main ears; UEP – unhusked ear productivity, obtained by summing the total weight of unhusked ears in the usable area of each parcel and then converting it into tons per hectare; HEP – husked ear productivity, obtained by summing the weight of husked ears from each parcel and then converting it into tons per hectare; MEP – marketable ear productivity, obtained by summing the weight of husked ears longer than 15 cm, with diameter greater than 3 cm and free of pests and diseases; MEL – marketable ear length, obtained by measuring the length of five marketable ears taken randomly from each parcel, and assigning the arithmetic average of those ears to the respective parcels; MED –marketable ear diameter, determined with the aid of a pachymeter through the average diameter of five commercial ears taken randomly from each parcel, the arithmetic average being assigned to the respective parcels.

The GM – grain mass, obtained by extracting the mass of grains from three marketable ears at close cut with graters and then weighing the fresh mass; and GR – gross revenue, calculated through the average value of UEP, converted into 25-kg sacks at the value of R$ 20/sack, paid in February 2015, according to information from CEASAGO (2019).

Initially, the experiment was analyzed through statistical model $Y_{ijq} = m + c_i + a_q + b_{(q)j} + (ca)_{ij} + e(q)_{ij}$, where: Y_{ij}: observation of hybrid i in block j within crop q; m: overall average; c_i: effect of the i-hybrid; aq: effect of crop q; $b_{(q)j}$: effect of j-block within crop q; $(ca)_{ij}$: effect of interaction between hybrids i and those of crop q; $e_{(q)ij}$: standard deviation, with the exception of GR, using computer software SISVAR (FERREIRA, 2011).

For each hybrid was assigned the average by Scott-Knott, per crop (2013/14 and 2014/15), so the hybrid with average 10, 11 or 12 tons per hectare of productivity, but allocated in the "a" cluster, received the same mean value. In this case, 11 tons per hectare. In order to show only significant differences in the graph. In addition, for all values to be transformed into percentages, AG1051 was advocated as 100%, which the hybrids were adjusted to this standard based on their mean. That is, if the ear height of the AG1051 was 106 cm and that of the 2B512PW was 140 cm, the adjusted values would be 100% and 132%, respectively, showing the upper or bottom value and the difference for the multiple variables.

Subsequently, a radar graph was built, pair by pair, hybrid AG1051 being used as standard quality (control) and then compared with the other hybrids, using the averages achieved in the crops.

RESULTS

The results of the variance analysis shown in Table 4 demonstrate that most traits presented significant differences (p>0.01). Variations in Crops, excluding EH, MED and GM; Hybrid, MED; and interaction between Crops x Hybrids, EH, MED and GM, were not significant, which allows stating that the hybrids presented similar behavior in both crops studied.

Table 4. Mean square and averages achieved by hybrid AG 1051 in ear height (EH), unhusked ear productivity (UEP), husked ear productivity (HEP), marketable ear productivity (MEP), marketable ear diameter (MED), marketable ear length (MEL) and grain mass (GM), in different corn hybrids destined for fresh produce consumption.

Source of Variation	DF	EH	UEP	HEP	MEP	MED	MEL	GM
		- cm -	-------- tons per hectare ------			--------- cm --------		- g -
Crop (C)	1	569.7$^{n.s.}$	1105.2**	320.6**	269.3**	1.4$^{n.s.}$	70.2**	1038.9$^{n.s.}$
Hybrid (H)	9	225.9**	8.3**	3.5**	7.5**	0.2$^{n.s.}$	9.2*	4310.1**
C x H	9	106.5$^{n.s.}$	9.3**	3.52**	7.9**	0.1$^{n.s.}$	13.2**	3997.2$^{n.s.}$
Block	3	1221.9	14.3	6.6	6.1	0.2	2.2	2249.6
Deviation	57	81.61	0.9	0.5	0.5	0.1	3.9	1390.1
C.V. (%)	79	9.9	9.6	10.9	13.7	6.1	10.7	14.2
AG1051 (13/14)		96.8	14.3[1]	9.1	6.8	4.5	22.8	263.0
AG1051 (14/15)		96.8	9.5[2]	6.1	4.4	4.5	18.3	263.0

Significant at *5% and**1% probability on F test; $^{n.s.}$– non-significant; CV% – coefficient of variation; [1, 2] – Gross revenue in 2013/14 = R$ 11,427 and 2014/15 = R$ 7,645, respectively, using UEP as calculation basis.

During the crops, drought periods occurred at different stages of plant development (Figure 1). In the first evaluation, 2013/14 crop, it occurred during the plant early development, between stages V_1 and V_3, which had little effect on the hybrid's performance. However, in 2014/15 crop, it happened at the end of the vegetative cycle and beginning of the reproduction cycle, between stages V_{10} and R_1, which greatly impacted the final yield and, thus, confirmed the significant effect observed in source of variation Crops.

Hybrid 2B587PW had superior performance in UEP (Figure 2A) and 2B707PW in MEP (Figure 2E), increasing by 32% and 28% in comparison to the control, indicating the potential of those hybrids for concurrent commercialization of unhusked ear sand husked ears in Styrofoam trays.

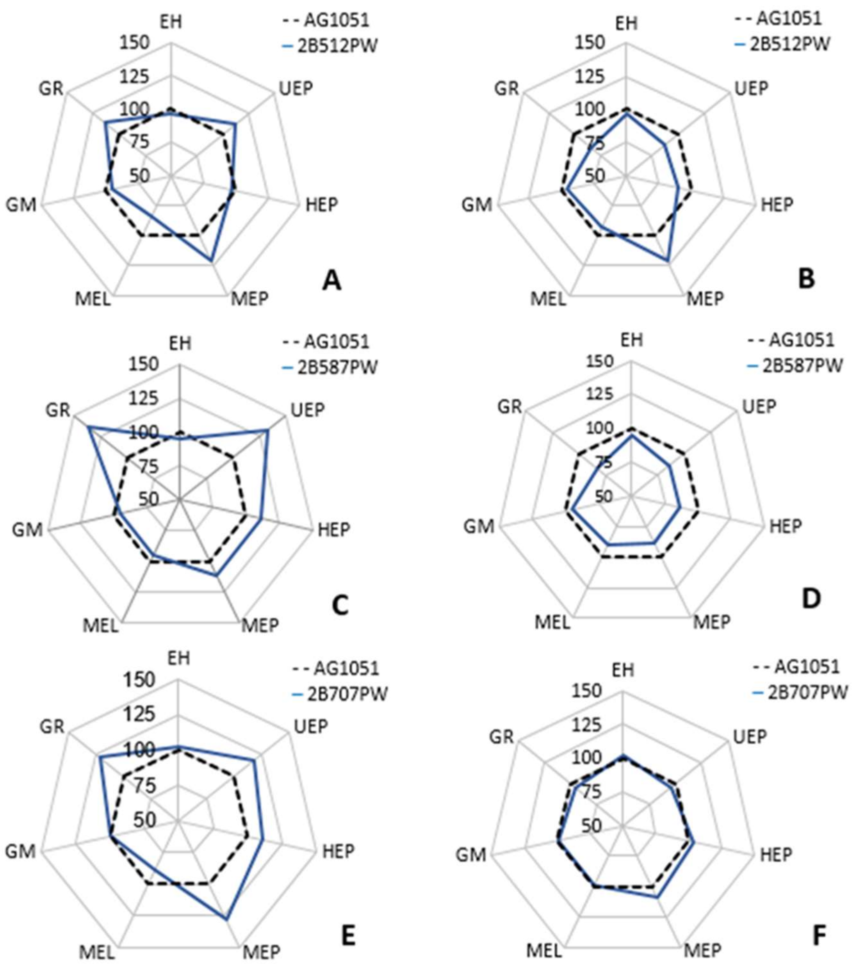

Figure 2. Average performance of hybrids 2B512PW, 2B587PW and 2B707PW, compared to AG 1051 (control – 100%) in variables: ear height (EH), unhusked ear productivity (UEP), husked ear productivity (HEP), marketable ear productivity (MEP), marketable ear length (MEL), grain mass (GM) and gross revenue (GR), during 2013/14 and 2014/15 crops.

The results achieved during 2014/15 crop are seen to be directly associated to the dry period (Figure 1). Figures 2, 3 and 4 show that hybrids had worse performance than the control in most of the variables studied, which indicates greater tolerance of AG1051 in comparison to the studied hybrids.

Hybrids 30F35HR, 30F53YH and BM3061 were found to be superior to the control in all productivity variables, demonstrating their suitability for the corn market. Values obtained by those hybrids about UEP in 2013/14 crop were on average 20% superior to AG1051 values (Figure 3).

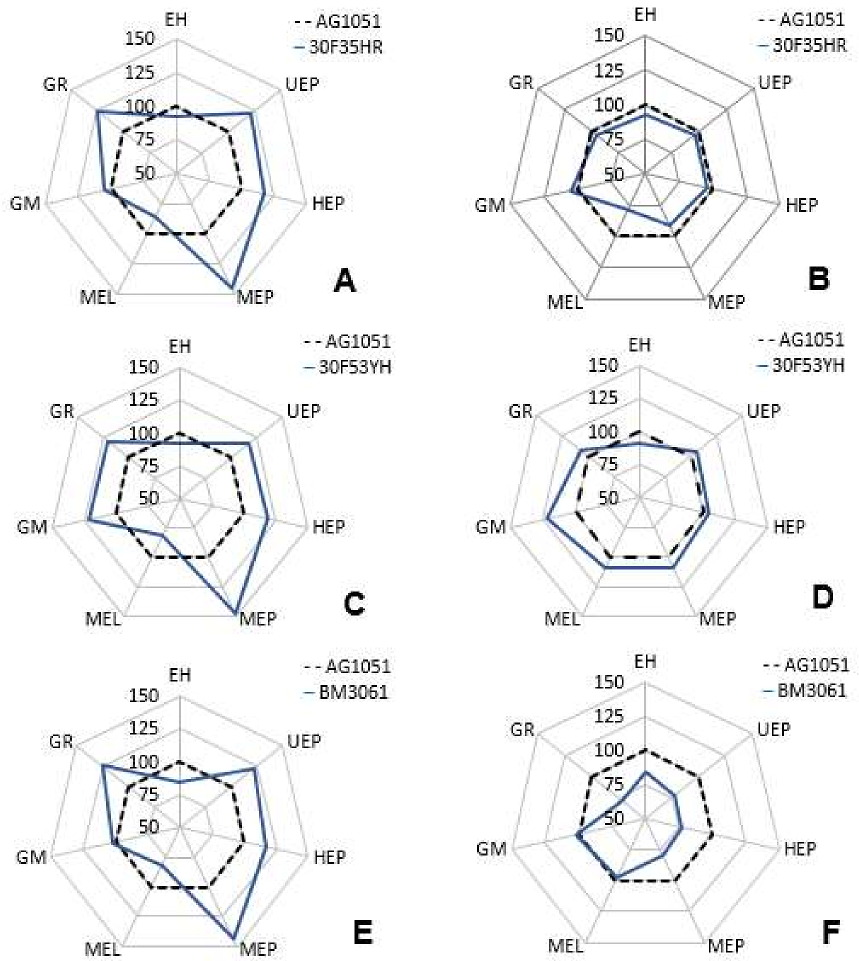

Figure 3. Average performance of hybrids 30F35HR, 30F53YH and BM 3061, compared to AG 1051 (control – 100%) in variables: ear height (EH), unhusked ear productivity (UEP), husked ear productivity (HEP), marketable ear productivity (MEP), marketable ear length (MEL), grain mass (GM) and gross revenue (GR), during 2013/14 and 2014/15 crops.

These values were corroborated in the values of HEP, 10.7 t ha^{-1}, and MEP, 9.9 t ha^{-1}, using the average of the above-mentioned hybrids, and presented low cull rate (Figure 3). Cull is considered the amount of husked ears that fail to meet the dimensions required by the consumer market or that present defects such as pest attacks, varying-color kernels and irregular or missing kernel rows, the latter having been more frequent in the second crop.

In addition, the profit generated would be R$ 1,460, compared to BRS1055, and only R$ 470 for hybrid P3862YH, with lower or similar percentage of GM, respectively, and also with higher risks for producers, should dry periods occur near flowering and/or in the beginning of reproduction stages, as seen in 2014/15 crop (Figure 4).

The hybrids EH feature presented value lower or near the control average (Figures 2, 3 and 4). Thus, all hybrids proved advantageous due to easy harvest and fast transportation, an important requirement for timely extraction and handling of perishable products, which are accomplished manually.

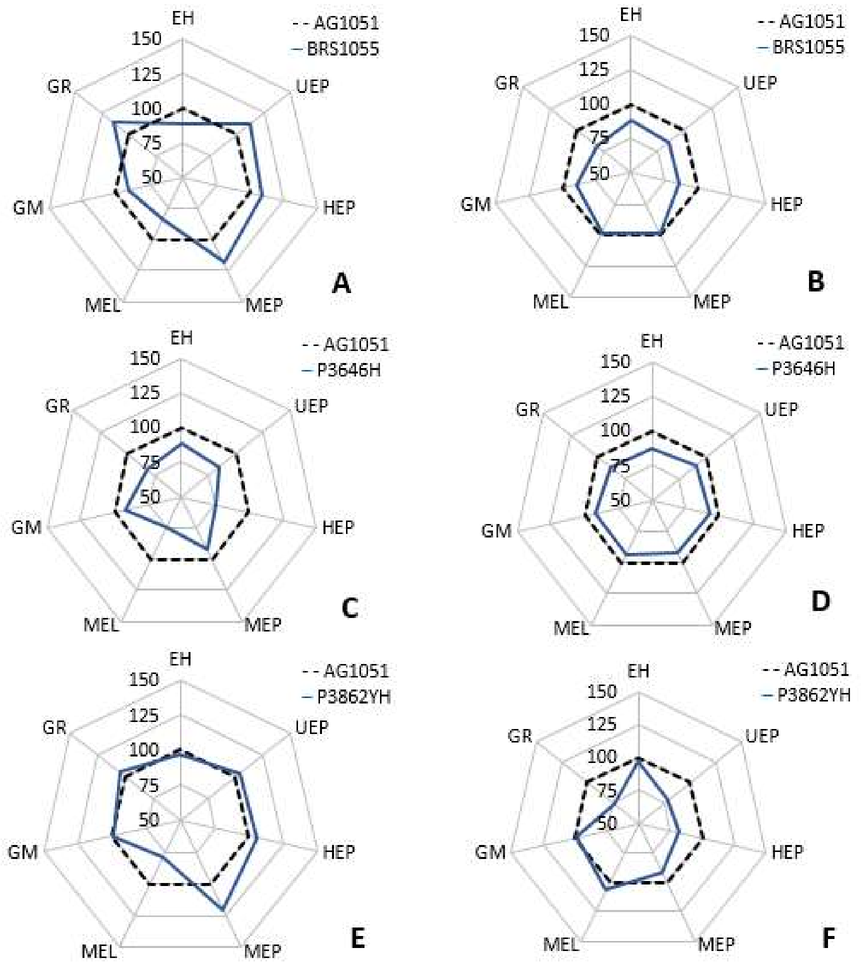

Figure 4. Average performance of hybrids BRS1055 (A and B), P3646H (C and D) and P3862YH (E and F), compared to AG 1051 (control – 100%), in variables: ear height (EH), unhusked ear productivity (UEP), husked ear productivity (HEP), marketable ear productivity (MEP), marketable ear length (MEL), grain mass (GM) and gross revenue (GR), during 2013/14 and 2014/15 crops.

DISCUSSION

According to Galon et al. (2010), corn crops require between 400mm and 600mm rainfall in order to achieve their maximum genetic potential. In both crops, those rates were higher than 640mm, yet they were unevenly distributed. However, Wagner et al. (2013) claim that if water shortage occurs during stages V_E and V_6, reduction in grain production comes to only 5%, whereas when it happens between stages V_T and R_1, that percentage rises and may reach 35% depending on the duration. Such values were corroborated in variables UEP, HEP and MEP, for AG1051, in the studied crops, 33, 35 and 32%, respectively, being the reduction in those variables, despite reduced productivity, which was also observed in the first crop.

The experiment precision was similar to that of studies carried out in corn destined for fresh produce consumption. It ranged from 6% to 14% and was corroborated in EH, UEP, HEP, MED and MEL by the values obtained by Santos et al. (2015), while studying agronomic traits and productivity of corn cultivars for fresh produce consumption under organic and conventional cropping.

The performance of hybrids 2B512PW, 2B587PW and 2B707PW in comparison with the control is presented in Figure 2. It is observed that the behavior of hybrids was superior in all variables during 2013/14 crop, except for MEL, hybrid 2B512PW being 15% less to AG1051, that is, ears with average length of 19 cm. Nonetheless, the minimum length required by the market is 15 cm (Albuquerque et al., 2008) and, according to Vieira et al. (2010), the ideal length of a fresh corn ear should be 17 cm. Thus, it meets the consumer market demands quite well. According to Guillen-Portal et al. (2003), double-cross hybrids featured greater stability than single-cross ones under dry conditions, possibly indicating that AG1051 broader genetic base bestowed it better performance under such experimental conditions.

The AG1051 is reported to have presented cull rates between 25% and 28% during 2013/14 and 2014/15 crops (Table 3), respectively, considered to be medium values when compared to those in other studies. In the research carried out by Grigulo et al. (2011), while studying corn hybrids for fresh produce consumption in Tangará da Serra – Mato Grosso state, values were 12% on average, lower than those obtained by Moraes et al. (2010), when studying second-season performance of fresh corn hybrids, whose value was 31%.

The GR generated by the same hybrids would be R$ 2,454, R$ 1,956 and R$ 2,496, higher than that obtained by the control. Moreover, 30F35HR (Figure 3A) and, in particular, 30F53YH (Figure 3C) reached GM values 14% and 56% higher than the control, an essential trait for corn pastry, which is an extremely important dish in the Mid-Western region cuisine (Kuwae et al., 2009).

The values of production costs obtained by Zárate et al. (2009), while studying corn hybrids and carrying out more detailed economic analysis, would come near R$ 1,500 by hectare, which implies that even in face of the fertilization-based increases generated between years 2009 and 2015, these representing most of the costs according to the author, those hybrids would still be more economically feasible than AG1051, given its higher profitability and higher final yield of fresh grain mass.

Records are that hybrids BRS1055 (A and B) and P3862YH (E and F), as shown in Figure 4, performed similarly to AG1051 in 2013/14 crop and lower in 2014/15 crop. Thus, they would not be direct competitors in this market. This is due to the significant domestic market share already held by the control (AG1051), as it features proven traits to produce mini-corn (Castro et al., 2013) and whole plant dry matter (Pereira et al., 2011), as well as potential for use in feed for milk-producing cattle (Oliveira et al., 2007).

Hybrids 2B587PW (Figure 2C), 30F35HR (Figure 3A), 30F53YH (Figure 3C) and BM3061 (Figure 3E) presented higher suitability for the fresh corn market, as they delivered high productivity, both of husked and marketable ears, and greater gross revenue for producers. It is essential to report that these hybrids are destined for the grain market, with the exception of BM3061, and that commercialization should be accomplished as fast as possible, since it is a highly perishable product. Therefore, sensorial analyses are required to ensure quality to the final product, that is, fast delivery to market shelves and other peculiarities not observed in field analyses, mainly regarding flavor, aroma and even regional receptivity, as reported by Camilo et al. (2015).

CONCLUSION

The hybrids 2B587PW, 30F35HR, 30F53YH and BM3061 showed greater suitability for fresh corn market, since they featured the highest number of favorable traits for that market.

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