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COMBINING ABILITY OF FORAGE WATERMELON (*Citrullus lanatus* var. *citroides*) GERMPLASM[1]

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ABSTRACT - The aim of this study was to identify parents and promising hybrid combinations for the improvement of forage watermelon. Five parents were evaluated: BGCIA 996 (1), BGCIA 997 (2), BGCIA 998 (3), BGCIA 228 (4), Jojoba (5) and ten F_1 hybrids, which were obtained from balanced diallel crosses. The experimental design was in a complete randomized block, with three replications. The morphoagronomic and bromatological traits were evaluated. The highlights were the progenitors BGCIA 997, BGCIA 998, BGCIA 228 and Jojoba for protein content, fruit yield, *in vitro* digestibility of dry matter and number of seeds, respectively. The hybrid 1x4 stood out for fruit length, seed number, and ethereal extract. The hybrid 2x3 stood out for rind and pulp thickness while the hybrids 3x4, 3x5 and 4x5 had exceptional digestibility, protein content and fruit yield, respectively. The analysis of the standard deviation of the SCA estimates of both SD (Sij- Sik) and SD (Sij- Skl) indicated that no hybrids were found that had SCA estimates twice that of SD (Sij- Sik) or SD (Sij- Skl), except for the hybrid 1x4 for the number of seeds per fruit. These results suggest that the parents were more promising than the hybrids. Similarly, the GCA estimates favor the intrapopulation method, which will promote greater efficiency in selection for genetic gains.

Keywords: Diallel analysis. Genetic improvement of forage crops. Semiarid.

CAPACIDADE DE COMBINAÇÃO EM GERMOPLASMA DE MELANCIA FORRAGEIRA (*Citrullus lanatus* var. *citroides*)

RESUMO - O objetivo deste estudo foi identificar genitores e combinações híbridas promissoras para o melhoramento de melancia forrageira. Foram avaliados cinco genitores; BGCIA 996 (1), BGCIA 997 (2), BGCIA 998 (3), BGCIA 228 (4), Jojoba (5) e dez híbridos F_1's, obtidos a partir de cruzamentos dialélicos balanceados. O delineamento experimental foi em blocos casualizados completos, com três repetições. Avaliou -se as características morfoagronômicas e bromatológicas. Destacaram-se os genitores BGCIA 997, BGCIA 998, BGCIA 228 e Jojoba, quanto ao teor de proteína, produção de frutos, digestibilidade *in vitro* da matéria seca e número de sementes, respectivamente. O híbrido 1x4 destacou-se para comprimento dos frutos, número de sementes e extrato etéreo. O híbrido 2x3 destacou-se para espessura de casca e polpa, enquanto os híbridos 3x4, 3x5 e 4x5 destacaram-se pela digestibilidade, teor de proteína e produção de frutos, respectivamente. A análise do desvio padrão das estimativas de CEC tanto de DP (Sij-Sik) quanto de DP(Sij-Skl) indicaram que não foram encontrados híbridos com estimativas de CEC duas vezes maiores que DP(Sij-Sik) ou DP(Sij-Skl), exceto para o híbrido 1x4 para número de sementes por fruto. Estes resultados sugerem que os progenitores foram mais promissores do que os híbridos. Da mesma forma, as estimativas da CGC favorecem o método intrapopulacional, o qual promoverá maior eficiência na seleção para ganhos genéticos.

Palavras-chave: Análise dialélica. Melhoramento genético de forrageiras. Semiárido.

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INTRODUCTION

Since 2010, the Brazilian semiarid zone has gone through a long period of drought, which worsened in 2013 and directly impacted the region (CARVALHO, 2012; BRASIL, 2014). The constant drought affected the local economy and made the agricultural families of this region vulnerable. This resulted in higher prices for livestock and directly affected the livelihoods of these farmers. However, excessively long periods of drought led to the loss of livestock either because of death or sales prices that were well below market value; however, in a scenario of short-term drought, the loss can be minimized through the use of forage crops such as forage watermelon that require less water.

For this reason, strategies have been sought to co-exist in a semiarid climate and guarantee both water and food security. Among these strategies is the strategic use of forage crops, which involves the use of fodder that is adapted to the semiarid conditions of haymaking and silaging. The use of forage crops grown in areas that depend on rain as a source of water, energy and protein, minimizes the loss of livestock. The forage watermelon, also known as “horse” or “pig watermelon”, is generally grown by farming families without the use of fertilizers during the rainy periods and is a fodder alternative for the livestock in semiarid climates. The forage watermelon, which originates in Africa, came to Brazil from slaves and has adapted well to the conditions of the northeast, as well as in other regions of the country. Its dissemination occurred by natural crosses with other types of watermelon (ROMÃO, 2000; DANE; LIU, 2007).

This species stands out because of its protein content (>15%), energetic value (~30%), increased digestibility, and water source for animals (SILVA et al., 2009; MORAES; COSTA; ARAÚJO, 2011; LEVI et al., 2013). However, further research is required to use the potential of these species so that the farmers may further benefit, especially when considering an efficient and low-cost production system.

Considering the importance of forage watermelon for fodder production for forage crops in the Brazilian semiarid zone, the scarcity of information about its potential and the use of hybrids to increase crop productivity, highlights the necessity of carrying out further studies into the area of genetic improvement. However, pre-breeding is an earlier and crucial stage in identifying promising accessions in germplasm banks that may increase the possibility of using materials of agronomical importance (UPADHYAYA et al. 2010).

Pre-breeding of plants makes it possible to identify and select accessions with more promising traits with the diallelic scheme being one of the strategies that permits the examination of the potential of each accession to transmit such traits to its descendants as well as to estimate the genetic effects that are involved in the determination of those traits. Based on the behavior of the F_1 hybrids, the general combination ability (GCA) can be estimated, which is generally associated with the genetic additive effect. The GCA refers to the ability of a genitor to produce progenies with a given behavior because it is possible to indicate the progenitors that are to be used in improvement programs. The specific combination ability (SCA), which is related to the behavior of a specific combination, is generally connected to the non-additive genetic effects and is useful to indicate the most favorable combination of the examined traits (CRUZ; REGAZZI; CARNEIRO, 2012; BORÉM; MIRANDA, 2013).

This highlights the unique traits and importance of this study for the improvement of forage crops in the semiarid zone because the study also aims to identify progenitors and hybrid combinations of forage watermelon that are promising for improvement programs and could be, through combinations, provide traits to improve fruit productivity and bromatology.

MATERIAL AND METHODS

The parents and hybrids were evaluated at the Mandacaru Experimental Station of Embrapa Semiárido, which is located in Juazeiro-BA. The following five parental genotypes of forage watermelon (*Citrullus lanatus* var. *citroides*) were examined: BGCIA 996 (1), BGCIA 997 (2), BGCIA 998 (3), BGCIA 228 (4) and Jojoba (5). The ten F_1 hybrids were obtained by means of diallel crosses.

The parents belong to the Active Bank of Germplasm of Cucurbitaceae of Embrapa Semiárido, BGCIA 996 (1) with fruits of an elongated format, a smooth rind, a light green color and white pulp; BGCIA 997 (2) has elongated fruits, a weight between 0.5 and 3.0 kg; BGCIA 998 (3) are fruits with a weight between 2.0 and 8.0 kg; BGCIA 228 (4) are elongated fruits with a weight between 1.5 and 7.0 kg, and Jojoba (5) is a local variety that is not registered and is not protected either; however, it is considered as a standard fruit to be grown and even marketed by farmers from the Juazeiro-BA and Petrolina-PE regions.

The experiment was carried out in randomized block design with three replications and eight plants per plot, the plants were spaced with 3.0 m between them and 1.5 m between the rows. Sowing was conducted in polystyrene trays and transplanting occurred 15 days after sowing. Two liters of castor cake per hole were used because cultivation occurred during drought conditions and after 100 days all the fruits were harvested and evaluated. Due to long drought periods, to avoid crop losses, irrigation was carried out at three specific times (i.e., during transplanting, flower emergence, and initial fruit development) by gravity-fed irrigation and weeding to remove the invading plants.

The following traits were evaluated: average fruit weight (AFW), in kg, corresponding to the quotient between the total mass of all the harvested fruits and the total number of harvested fruits from the plot; the number of fruits per plant (NFP), which was obtained from the number of harvested fruits and divided by the number of surviving plants on the plot; the average fruit yield per plant (AFYP), in kg, was measured based on the average weight of the fruit and multiplied by the average number of fruits; the relationship between the fruit length and fruit diameter (FL/FD) (measuring with a ruler in cm, respectively, the largest and smallest dimension of the fruit, cut lengthwise); the average rind thickness (RT), in cm, estimated by means of the rind thickness in the region of the floral scar, from the region of the stalk and the lateral rind, measuring the extremes of the fruit; average pulp thickness (PT), in cm, quantified by means of the lengthwise and transversal thickness of the pulp, at the extremities of the fruit; the number of seeds per fruit (NS); the dry weight of the seeds (DWS), in g, which were put in a drying chamber with circulation of forced air, for 72 h at 55°C, and subsequently weighed; the gross protein content (GPC); and the *in vitro* digestibility of the dry matter (IVDDM) and ethereal extract (EE), in percent. The traits of the fruit were examined in sample of 10 fruits per plot.

For bromatological analyses, samples of the entire fruits (rind and pulp and seeds) were placed separately in a drying chamber with forced air circulation, for 72 h at 55ºC. Subsequently, these samples were mixed and ground to obtain compound samples of the fruits. For this procedure, 7 g of each completely ground fruit was taken with the compound sample totaling 70 g.

For the digestibility test, the final dry matter was established through the semi-automatic *in vitro* technique of gas production, which was proposed by Mauricio et al. (2003), and the disappearance of the sample was examined at the following incubation times: 0-2-6-12-24 and 48 hours. The chemical-bromatological analyses of the fruits were carried out at the Laboratório de Bromatologia e Nutrição Animal of the Universidade Federal do Vale do São Francisco (UNIVASF) according to the methodology of the AOAC (1990) and Van Soest, Robertson and Lewis (1991).

For statistical and genetic analysis, the GENES software (CRUZ, 2013) was used with the Griffing method (1956), adopting the 2-method (parents and F_1's) and the fixed model.

RESULTS AND DISCUSSION

Significant differences were observed between the treatments for the majority of the examined traits, showing genetic variability that can be explored in improvement programs, with the exception of the RT, NFP, AFYP and GPC, which did not differ from the general and specific combination ability (Table 1).

For the majority of the traits, the coefficients of variance were low, but for the NFP and AFYP, the coefficients were high (59.2 and 57.5, respectively), which can be explained for being quantitative variables that are heavily influenced by the environment, which can increase the estimates of the square averages. However, the genetic variability of the accessions may still have contributed to this variation.

Table 1. Analysis of variance of twelve examined traits in a partial diallelic crossing scheme involving five parents of forage watermelon. Fruit length (FL), relationship between the length and diameter of the fruit (FL/FD), rind thickness (RT), pulp thickness (PT), number of fruits per plant (NFP), average weight of the fruit (AFW), average fruit yield per plant (AFYP), number of seeds per fruit (NS), dry weight of the seeds (DWS), gross protein content (GPC), ethereal extract (EE) and *in vitro* digestibility of the dry matter (IVDDM).

Traits			Average mean squares				
			SV	Treatments	GCA	SCA	Residue
	Average	CV	DF	(14)	4	10	28
FL (cm)	29.39	10.4		40.828*	108.555*	13.737^{ns}	9.383
FL/FD (cm)	1.73	4.1		0.048*	0.114*	0.216*	0.005
RT (cm)	1.32	34.6		0.163^{ns}	0.014^{ns}	0.220^{ns}	0.210
PT (cm)	21.66	10.8		18.670*	47.416*	7.171*	5.504
NFP (unit)	8.30	59.2		23.956^{ns}	38.545^{ns}	18.120^{ns}	24.216
AFW (kg)	3.12	20.4		1.906*	4.931*	0.696^{ns}	0.401
AFYP (kg)	25.07	57.5		116.056^{ns}	74.226^{ns}	132.788^{ns}	207.740
NSF (unit)	692.16	17.4		31,917.12**	42,595.39**	27,645.813^{ns}	14,507.8
DWS (g)	86.59	19.3		675.462**	1,474.42*	355.87^{ns}	280.29
GPC (%)	13.52	16.6		4.651^{ns}	7.216^{ns}	3.625^{ns}	5.075
EE (%)	9.4	13.7		6.120*	15.176*	2.497^{ns}	1.683
IVDDM (%)	74.86	2.1		2.173*	13.177*	6.171*	2.492

^{ns} Non-significant; *Significant at the level of 1% probability; **Significant at the level of 5% probability, according to the F test; CV: coefficient of variation; SV: sources of variation; DF: degree of freedom; GCA: general combination ability; SCA: specific combination ability.

The significant absence of RT, NFP, AFYP and GPC for GCA indicates that there were no parents that contributed more than the others to express these traits in its progeny (Table 1). Sapovadiya et al. (2014), who analyzed the combination ability of table watermelon, identified a significant additive effect in relation to AFW. Souza, Queiróz and Dias (2002) observed similar results for FL in diploid ant tetraploid table watermelon. Similarly, Bahari et al. (2012), who studied production and fruit traits of watermelon did not observe any significance for NFP for GCA and SCA, the effects of which were observed in this study. The relationship FL/FD, PT, and IVDDM were significant for their general and specific abilities, which shows a joint, additive, and non-additive gene action for such traits.

The quadratic components of the general ability were superior to the specific ones in relation to the FL, PT, AWF, NFP, DWS, GPC and EE, which shows the predominance of additive gene action for these traits (Table 2). Souza, Dias and Queiróz (2013), who analyzed the combination ability of fruit traits for table watermelon, observed the same behavior for FC and PT, which was only NFP divergent with greater SCA than GCA.

Table 2. Quadratic components and variance of twelve examined traits in a partial diallelic crossing scheme involving five parents of forage watermelon. Fruit length (FL), relationship between the length and diameter of the fruit (FL/FD), rind thickness (RT), pulp thickness (PT), number of fruits per plant (NFP), average weight of the fruit (AFW), average fruit yield per plant (AFYP), number of seeds per fruit (NS), dry weight of the seeds (DWS), gross protein content (GPC), ethereal extract (EE) and *in vitro* digestibility of the dry matter (IVDDM).

	Quadratic components		Variance		
	GCA	SCA	S^2 GCA	S^2 SCA	S^2GCA/ S^2 SCA
FL (cm)	4.722	1.451	40.33	18.87	2.137
FL/TD (cm)	0.0051	0.0055	0.000045	0.000033	1.363
RT (cm)	-0.009	0.003	0.000067	0.0064	0.010
PT (cm)	1.995	0.555	7.71	5.59	1.379
NFP (unit)	0.682	-2.032	5.500	63.78	0.086
AFW (kg)	0.215	0.098	0.083	0.043	1.930
AFYP (kg)	-6.357	-24.983	42.73	4.258	0.010
NS (unit)	1,337.50	4,379.32	72.111	65.986	1.092
DWS (g)	56.86	25.19	7.566	14.054	0.53
GPC (%)	0.101	-0.483	0.195	2.716	0.071
EE (%)	0.642	0.271	0.791	0.642	1.23
IVDDM (%)	0.508	1.226	0.642	2.983	0.0002

GCA: general combination ability; SCA: specific combination ability; S²GCA: variance for general combination ability; S²SCA: variance for specific combination ability; S²GCA/S²SCA: relationship between the variance of the general and specific combination ability.

According to Souza, Dias and Queiróz (2013), genetic improvement is favored when the additive gene effect predominates because it permits the selection of groups or individuals who are superior and who will develop superior descendants. However, the non-additive gene effect permits promising hybrid combinations because the dominant interaction favors obtaining superior hybrids.

In accordance with Sapovadiya et al. (2014), a proportion between the general variance ability and the specific combination ability of less than 1 (one) indicates the presence of non-additive genic action. The same authors observed a non-additive genic effect for NFP and AFYP, which was the case in this study. Additional analysis of this proportion, with the GCA and SCA variance magnitude, showed additive and non-additive action in the expression of the examined traits (Table 2).

Determining the estimates of the general and specific combination abilities permits the selection of promising hybrid combinations to obtain base populations for improvement. According to Cruz, Regazzi and Carneiro (2012) the most favorable combination is the one that possesses the greatest specific combination ability, in which at least one progenitor has greater general combination ability and is divergent in relation to the other parent of the crossing. Baretta et al. (2016) suggest that parents with high estimates of general combination ability, positive or negative, can be superior or inferior to the other parents that are included in the diallelic analysis in relation to the average behavior of the crossings.

When analyzing the estimate of the effect of the general combination ability (Table 3), BGCIA 996 showed a positive general combination ability for FL, FL/FD, RT, PT, AFW and DWS and was negative for the other traits. In this manner, the same contributes to obtaining descendants that are more elongated and have a greater RT and PT. Fruits with a greater rind thickness can be stored longer because they are more resistant to impact and deterioration, while more elongated fruits complicate transport. Therefore, smaller fruits and more prolific progenies would be advantageous, but farmers still prefer fruits that are more elongated and weigh more. The BGCIA 998 progenitor exhibits desirable traits for the farmers, such as more elongated fruits with a greater average weight and a greater average yield per plant.

The parental BGCIA 997, which showed a positive general combination ability for RT, NFP, NS, GPC and EE, is recommended to obtain more prolific progenies, a greater AFYP, greater RT, greater NS, GPC and EE. These would be essential traits for the forage plants, especially because of the increase in protein content and ethereal extract, which is found in greater quantities in the seeds. Low protein content may compromise the growth of rumen microbiota (LAZZARINI et al. 2009), the EE and the GPC directly influence the weight of the animals (PAULA et al. 2010).

Table 3. Estimates of the effects of the general combination ability (SCA) of five forage watermelon parents for traits fruit length (FL), relationship between the length and diameter of the fruit (FL/FD), rind thickness (RT), pulp thickness (PT), number of fruits per plant (NFP), average weight of the fruit (AFW), average fruit yield per plant (AFYP), number of seeds per fruit (NS), dry weight of the seeds (DWS), gross protein content (GPC), ethereal extract (EE) and *in vitro* digestibility of the dry matter (IVDDM).

Genitors	Traits											
	FL (cm)	FL/FD (cm)	RT (cm)	PT (cm)	NFP (unit)	AFW (kg)	AFYP (kg)	NS (uit)	DWS (g)	GPC (%)	EE (%)	IVDDM (%)
BGCIA 996	1.117	0.028	0.012	0.683	-1.675	0.256	-2.858	-9.065	2.367	-0.657	-0.665	-0.186
BGCIA 997	-2.740	-0.061	0.012	-1.992	0.872	-0.391	0.375	10.653	-2.175	0.933	1.334	-0.648
BGCIA 998	2.464	0.109	0.007	1.460	-0.627	0.465	1.932	27.000	6.391	-0.133	-0.765	-0.243
BGCIA 228	-2.078	-0.071	-0.054	-1.182	1.800	-0.639	-0.71	-72.518	-13.489	0.076	0.243	1.380
Jojoba	1.236	-0.004	0.021	1.031	-0.370	0.308	1.260	43.929	6.905	-0.219	-0.146	-0.300
$SD_{(gi)}$	0.597	0.013	0.089	0.457	0.960	0.123	2.813	23.509	3.267	0.439	0.253	0.308
$SD_{(gi - gj)}$	0.945	0.022	0.141	0.724	1.518	0.195	4.448	37.171	5.166	0.695	0.400	0.487

$SD_{(gi)}$: standard deviation from the GCA estimates. $SD_{(gi - gj)}$: standard deviation from the GCA contrast estimates.

For the majority of the traits of the BGCIA 228 parent, the general ability was negative, except for NFP; however, it is the only one with a positive IVDDM, which is an important trait for the degradability of the dry matter, and with a high content of GPC and EE. On the other hand, Jojoba, a local variety that is commonly grown, showed a greater number of morpho-agronomic traits with a positive general ability, while the bromatological traits were negative, in other words, showing a low protein and energetic content. This means that better varieties than the ones grown in the region can be obtained from the examined genitors in this study.

In a study carried out in Malasyia by Bahari et al. (2012), who analyzed the combination ability of production components and fruit traits in 4 lineages of *C. lanatus*, it was found that the number of fruits, average weight of the fruit, production of the fruit and rind thickness were below the general ability estimates than those observed in this study except for that of the average weight of the fruit.

In accordance with Figueiredo et al. (2015), the GCA effects make it possible to advise farmers on the selection of the most promising intrapopulation parents for improvement programs. The standard-deviation of the contrasts, together with the GCA estimates, help in this selection, which are considered superior to those parents whose GCA estimates were at least two times greater than the standard-deviations (CRUZ; REGAZZI; CARNEIRO, 2012). With regard to the GCA estimates, standard-deviations (gi - gj) were found for the parent BGCIA 998 for FL, FL/FD, PT and AFW, in BGCIA 997 for EE and BGCIA 228 for IVDDM. However, these parents can be used to obtain base populations to improve these traits (Table 3).

To cultivate this species for animal forage, the smaller and rounder fruits, in other words, those of a smaller size and relationship to length and diameter, facilitate transport and storage when necessary.

The 3x5 hybrid showed a negative combination ability, which reduces the FL/FD ratio; whereas, the hybrid combination 2x4 showed a greater, negative specific combination ability for length and 1x5 showed a greater, negative combination ability for FL/FD (Table 4). The behavior of these hybrids occurs because of the negative general combination ability of the parents BGCIA 997 and Jojoba, respectively (Table 3). From the perspective of the farmers, larger fruits, the 1x4, 2x3, 2x5 and 4x5 hybrids, contribute to increased FL/FD; however, the 2x3 and 4x5 hybrid show a greater positive, specific combination ability for FL and FL/FD, respectively. The behavior of the 2x3 hybrid is obtained by the parent BGCIA 998 (Table 3).

Table 4. Estimates of specific combination ability (SCA) of ten forage watermelon hybrids for traits of fruit length (FL), relationship between the length and diameter of the fruit (FL/FD), rind thickness (RT), pulp thickness (PT), number of fruits per plant (NFP), average weight of the fruit (AFW), average fruit yield per plant (AFYP), number of seeds per fruit (NS), dry weight of the seeds (DWS), gross protein content (GPC), ethereal extract (EE) and *in vitro* digestibility of the dry matter (IVDDM).

Hibrids	Traits											
	FL (cm)	FL/FD (cm)	RT (cm)	PT (cm)	NFP (unit)	AFW (kg)	AFYP (kg)	NS (unit)	DWS (g)	GPC (%)	EE (%)	IVDDM (%)
1x2	-0.168	0.033	-0.382	0.006	-3.168	0.473	-7.990	28.947	1.080	-1.998	-0.606	0.306
1x3	-1.873	0.028	0.188	-1.879	1.331	-0.784	-0.614	-120.495	-15.385	-0.031	0.226	-1.131
1x4	3.036	0.009	0.184	2.163	-0.930	0.653	4.028	166.690	17.295	-1.007	1.284	-2.588
1x5	-1.411	-0.157	-0.425	-0.217	0.941	-0.260	1.023	-0.857	4.066	0.120	-0.292	-0.941
2x3	3.384	0.019	0.255	2.196	1.617	0.330	7.385	118.885	12.490	-0.055	-0.573	0.363
2x4	-3.239	0.000	-0.049	-2.460	4.355	-0.731	-1.171	-91.095	-14.561	0.368	0.784	-0.826
2x5	0.779	0.033	-0.192	0.758	0.826	0.020	4.623	-37.176	1.809	-1.336	-1.125	-0.646
3x4	1.388	-0.038	-0.144	1.120	-0.977	0.477	4.004	111.457	10.404	0.234	-1.082	2.034
3x5	-1.925	-0.104	0.179	-0.793	0.926	0.030	0.500	-24.790	-3.023	0.563	0.174	0.149
4x5	0.817	0.142	0.107	1.049	2.231	0.168	9.842	2.728	5.157	-0.112	-0.801	0.138
$SD(S_{ij})$	1.543	0.035	0.231	1.182	2.480	0.319	7.265	60.700	8.437	1.135	0.653	0.795
$SD(S_{ij}- S_{ik})$	2.315	0.053	0.346	1.773	3.720	0.479	10.89	91.050	12.655	1.702	0.980	1.193
$SD(S_{ij}- S_{kl})$	2.113	0.049	0.316	1.618	3.395	0.437	7.946	83.117	11.553	1.554	0.895	1.089

1x2: BGCIA 996 x BGCIA 997; 1x3: BGCIA 996 x BGCIA998; 1x4: BGCIA 996 x BGCIA 228; 1x5: BGCIA 996 x Jojoba; 2x3: BGCIA 997 x BGCIA998; 2x4: BGCIA 997 x BGCIA 228; 2x5: BGCIA 997 x Jojoba; 3x4: BGCIA998 x BGCIA228; 3x5: BGCIA998 x Jojoba; 4x5: BGCIA228 x Jojoba; $SD(S_{ij})$: standard-deviation of the GCA estimates between distinct parents; $SD(S_{ij}- S_{ik})$: standard-deviation of the contrast of estimated GCA between hybrids with a common parent; $SD(S_{ij}- S_{kl})$ standard-deviation of the contrast of GCA estimates without common parents.

Some hybrid combinations stood out. The 1x4 hybrid showed high values of specific combination ability for NS and DWS, which are traits that may result in a better proteinaceous and energetic content of this forage plant. The 2x3 hybrid also stood out because it showed a positive specific combination ability for RT and AFW, which is promising to obtain lineages that are more resistant to impact and deterioration and results in larger fruits.

With regard to PT, the ideal case would be for it to be greater because in this way it will result in a greater pulp quantity, which guarantees a greater availability of water and dry matter. In general, that quantity of seeds should be stressed, which is a trait as important as that of the pulp because the greatest protein and fat content is found in the seeds. Thus, 1x4 and 2x3 showed a high, positive specific combination ability for NS and can therefore contribute to increase this trait.

The 1x4, 3x4 and 3x5 hybrids showed the greatest positive specific combination ability for EE, IVDDM and GPC, respectively. These components are essential to determine the quality of a fodder species because the fat (EE) and gross protein (GPC) contribute to the construction and reconstruction of tissues, which are important factors to animals, especially in periods of drought when there is a reduction in the quality and availability of native fodder in the Caatinga. High values of digestibility contribute to an increased consumption and use by the animal. In addition, the average content of EE (9.4%), GPC (13.52%) and IVDDM (74.86%) indicate that this fodder plant meets the requirements of the animal, which prevents weight loss and for the producer to discard animals prematurely.

The 2x4 hybrid stood out because it showed a positive specific combination ability for GPC and EE, which is linked to other important traits, its parents can be useful in improvement programs for fodder watermelon. In terms of yield, the 2x4, 1x4 and 4x5 hybrids showed the greatest, positive specific combination ability for NF, AFW and AFYP, respectively. All of them showed at least one genitor with general ability that was higher and discrepant from the other parent of the crossing with 2x4, where the parent BGCIA 228 stood out, for 1x4, BGCIA 996 and for 4x5, it was the parent Jojoba.

Given the standard deviation of the SCA estimates of both SD (S_{ij}- S_{ik}) and SD (S_{ij}- S_{kl}), no hybrids were found with SCA estimates twice that of SD (S_{ij}- S_{ik}) or SD (S_{ij}- S_{kl}), except for the 1x4 hybrid for NS. These results suggest that the parents were more promising than the hybrids. Similarly, the GCA estimates favor the intrapopulation method as a strategic approach for genetic gains. This study was therefore efficient in identifying potential accessions that could be incorporated in a genetic improvement program.

The cultivation of local varieties should be encouraged to guarantee the amplification of genetic diversity, and the agro-biodiversity and future studies of other accessions may contribute to this amplification, as well as selecting more prolific genetic materials. From this point of view, participatory improvement may be a viable alternative that accords with Machado (2014) whose method is essential in the rescue process. It is essential to introduce different varieties and examine their degree of erosion, adaption to agro-ecological systems, as well as their place in the community.

Additional studies are required to evaluate other cultivated accessions in distinct sites, which may increase the chance to identify and obtain more promising materials.

CONCLUSIONS

Parental genotypes have the potential to generate more productive watermelon populations and increase nutritional value for livestock. After additional analysis of the standard deviation and SCA estimates, it was found that the hybrids analyzed in this study are not promising to be used in breeding programs.

The parental BGCIA 997 stands out as the most promising for use in breeding programs aimed at obtaining fruits with higher ethereal extract. The genotype BGCIA 998 has more potential to obtain productive progenies, while the BGCIA 228 genotype may increase the digestibility of the dry matter.

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