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EFFECTS OF RECIPROCAL CROSS ON MAJOR CHARACTERS AND YIELD OF TWO SWEET-WAXY CORN (*ZEA MAYS* L.) VARIETIES

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Abstract

Two sweet-waxy corn inbred lines, Jikenuo 20 and Wannuo 2000, were used as experimental materials. A randomized block experiment was conducted to analyze the differences and similarities in plant traits, ear traits, yield, appearance quality and main cooking quality between the two sweet-waxy corn varieties. Results showed that there were no significant differences in most plant traits, ear traits and yield between the two sweet-waxy corn varieties, indicating that the inheritance of the nucleus was dominant. There were some differences in the resistance and some cooking quality of the two sweet-waxy corn varieties in the reciprocal cross combinations, which indicated that the above characters were affected by cytoplasmic inheritance to a certain extent.

Introduction

Sweet-waxy corn is a new type of corn that could meet the higher consumption demand of different regions and different people for the quality of fresh food corn. It combines the advantages of sweet corn and waxy corn, and has a better taste and nutrition and taste. In recent years, it has become a new direction of fresh food corn breeding (Peng and Tian 2004, Song *et al.* 2020, Xu *et al*. 2020, Wang 2020). On the basis of breeding sweet-waxy double recessive maize inbred lines, sweet (heterozygous) waxy (homozygous) maize hybrids can be obtained by crossing with single or multiple recessive homozygotes, and the harvested ears are sweet-waxy maize. The hybrid seed production process of waxy maize is similar to that of regular maize. In general, waxy maize inbred lines with excellent characteristics such as higher pollen content, higher plants, longer pollen holding time, strong resistance, and good taste are selected as the male parent. And choose waxy maize inbred lines with many advantages such as short plants, good fruiting ability, good appearance quality, better cooking quality, and good resistance as the female parent. Using the above types of waxy maize inbred lines for hybrid combination has the advantages of maintaining seed production advantages and yield, as well as maintaining the taste and quality of F_1 hybrid without decreasing, which is recognized by many waxy maize breeders (Ma *et al.* 2022, Lu *et al.* 2015). However, unexpected situations such as insufficient yield of waxy maize maternal inbred lines and incompatible flowering dates of both parents may occur during hybrid seed production. At this time, breeders usually use a new seed production method to meet yield requirements or regulate flowering dates, namely reverse cross seed production. Due to the existence of a situation where the intersection of sweet and glutinous maize inbred lines has adverse effects on the main agronomic traits, yield, cooking quality, etc. of the F_1 generation, it will cause significant losses to the majority of waxy maize growers and distributors. Therefore, when combining sweet-waxy maize hybrids, it is necessary to consider the genetic relationship between inbred lines and F_1 Heterosis of their progeny, select by combining agronomic traits,

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appearance traits, cooking quality and other comprehensive agronomic traits, and then judge whether to reverse cross seed production according to the performance of the positive and negative cross combinations of hybrids (Wu 2003).

This experiment was conducted to investigate whether there were some differences in some agronomic traits, cooking quality and yield of the F1 generation of positive and negative cross of different sweet-waxy corn varieties, so as to provide data support and theoretical basis for seed production enterprises in the production of sweet-waxy corn seeds and the combination of F1 generation hybrids by breeding units.

Materials and Methods

The experiment was conducted in the corn breeding experimental field of Jilin Agricultural Science and Technology in 2021. The tested sweet-waxy corn varieties were Jikenuo 20, which was selected by the authors, and Wannuo (2000), which was a sweet-waxy corn variety with a large promotion area in northeast China.

Randomized block design was adopted in the experiment. Each combination was repeated for three times. The planting density of Jikenuo 20 was 45000 plants/hm^2 (the recommended density at the time of approval), and the planting density of Wannuo 2000 was 50000 plants/hm^2,8 rows, 5 m in length and 0.65 m in line spacing. The main agronomic traits, appearance quality and cooking quality were investigated, and the data of the test traits of F1 generation of the same sweet-waxy corn variety were analyzed by variance and multiple comparisons.

Results and Discussion

Results of variance analysis and multiple comparison of yield of reciprocal cross between Wannuo 2000 and Jikenuo 20 are presented in Tables 2-5. It could be seen from Tables 1 and 2 that there was no significant difference in the yield of positive and negative cross seeds of Wannuo 2000 at $F_{0.05}$ and $F_{0.01}$ levels (Tables 3 and 4). There were no significant difference at $F_{0.05}$ and $F_{0.01}$ levels between the positive and negative cross seeds of Jinkenuo 20, indicating that the positive and negative cross combinations of different sweet-waxy corn varieties have little difference in the positive and negative cross yield (Tables 3 and 4). If only the yield is considered in actual production, the positive and negative cross seeds can be exchanged.

Table 1. Analysis table of variance for yield of Wannuo2000 in reciprocal crossing.

Source of variation	Sum of squares	Degree of freedom	Mean square	F value	significant level
Interzonal	95438.26	2	65319.42	5.18	0.11
Between the treatments	198274.14	1	198287.54	16.82	0.05
Error	19533.13	2	11534.22		
Total variation	313316.57	5			

Table 2. Multiple comparison of positive and negative cross results of Wannuo 2000.

Treatment	Average	5% significant level	1% highly significant level
Treatment 1	11989.13	a	A
Treatment 2	12488.32	a	A

Table 3. Analysis table of variance for yield of Jikenuo 20 in positive and reverse crossing.

Source of variation	Sum of squares	Degree of freedom	Mean square	F value	Significant level
Interzonal	679819.38	2	298155.58	1.91	0.17
Treatment	127932.26	1	128421.49	0.69	0.33
Error	225486.32	2	153879.33		
Total variation	1029867.26	5			

Table 4. Multiple comparison of positive and negative cross results of Jikenuo 20.

Treatment	Average	5% significant level	1% highly significant level
Treatment 1	12058.32	a	A
Treatment 2	12519.74	a	A

The difference analysis results of main test characters of Wannuo 2000 positive and negative cross combinations are presented in Table 5 which showed that in Wannuo 2000 positive and negative cross combination, there were significant differences at $F_{0.05}$ level in 7 traits, including the angle between the upper ear leaf and the main stem, plant height, ear diameter, smell and flavor, waxiness, skin thickness and skin residue rate. There were significant differences at $F_{0.01}$ level in skin thickness and skin residue rate. There were no significant differences between positive and negative cross of other traits.

The difference analysis results of main test characters of the positive and negative cross combination of Jikenuo 20 listed in Table 6 showed that in the positive and negative cross combination of Jikenuo 20, there were significant differences in the angle between the upper ear leaf and the main stem, waxiness, ear position, skin thickness, and skin residue rate at the $F_{0.05}$ level, but there were no significant differences at the $F_{0.01}$ level, and there were no significant differences between the positive and negative cross of other traits.

In the two sweet-waxy corn varieties tested, there were significant differences in waxy characters, skin thickness and skin residue rate among the positive and negative cross combinations, indicating that these three characters were greatly affected by cytoplasmic inheritance. To sum up the above results, the male parent should consider the parent with better plant type in seed production, and a good plant type is conducive to higher yield and better ear taste. Similarly, parents with low plant height and ear position, good ear taste and thin seed coat thickness were selected as female parents, which could reduce plant height and ear position and improve the edible taste of the ear of hybrid offspring.

Corn is one of the important food products in China, which plays a vital role in ensuring national food security and agricultural safety (Cao *et al*. 2017). Breeding fine varieties was one of the important ways to improve maize yield (Sun *et al*. 2017). In recent years, maize seed production enterprises found that if there was no significant difference in yield of F1 generation of maize hybrids when producing seeds in northwest China, they could use positive and negative cross to produce seeds (Zhao *et al* 2020). In the production process of maize single cross seeds, sometimes the female parent was extremely scarce and the male parent is surplus. Whether it was feasible to prepare its reverse cross seeds is often one of the problems that perplex seed production and processing enterprises (Zeng *et al.* 2020). Domestic scholars used common corn as test materials, and the research showed that there was no significant difference in main agronomic traits between the reciprocal cross F1 generation (Zhao *et al.* 2013, Zeng 2022). Sweet-waxy corn

Table 5. Analysis of main differential characters in the positive and reverse crossing combination of Wannuo 2000.

Wannuo 2000 (reciprocal cross)	Plant height	Ear position	Growth period	Silking	Resistance to head smut	Lodging resistance	Angle between upper ear leaves and main stem	Leaf width above spike	Tassel branch	Tassel length	Ear length	Ear diameter
Mean difference value	10.5542*	7.4529*	1.5672	1.0789	1.9187*	0.0105*	3.1587*	0.9137	4.6986	4.3069	0.6698	0.0458*
$LSD_{0.05}$	9.7824	7.0088	2.1547	2.1247	0.4659	0.0188	2.8518	18.3148	5.0089	7.4872	2.4438	0.0239
$LSD_{0.01}$	19.0087	10.3569	46893	6.3185	0.2428	0.0469	5.4139	40.2658	14.6168	12.8140	5.0129	0.0467
Wannuo 2000 (reciprocal cross)	Bare tip length	No. of rows	No. of grains per row	100-grain weight	Appearance quality	Odor and flavor	color and lustre	Glutinous	Flexibility	Skin thickness	Amylopectin content	Residue ratio
Mean difference value	0.3085	0.0546	1.3782	0.3518	1.2198	0.7015*	0.4396	0.6294**	0.0457	0.5295**	0.6179	1.5089**
$LSD_{0.05}$	3.3216	2.0328	12.0437	0.6093	0.3765	0.2496	0.1688	0.2399	0.0187	0.2046	0.2188	0.4297
$LSD_{0.01}$	4.8198	4.8687	25.7482	1.5763	0.1748	0.1588	0.0869	0.1176	0.0123	0.1029	0.1469	0.2136

Table 6. Analysis of main differential characters in the positive and reverse crossing combination of Jinuo 20.

Jikenuo 20 (reciprocal cross)	Plant height	Ear position	Growth period	Silking	Resistance to head smut	Lodging resistance	Angle between upper ear leaves and main stem	Leaf width above spike	Tassel branch	Tassel length	Ear length	Ear diameter
Mean difference value	10.9478*	9.1965	0.8712	0.3326	1.8185*	0.0049*	1.5187*	1.7487	4.3214	0.7351	0.1972	0.0285*
$LSD_{0.05}$	10.5579	8.5892	20.3864	1.4561	0.4122	0.0332	2.8935	27.8924	4.8589	6.2988	0.8468	0.1724
$LSD_{0.01}$	23.9469	20.2176	5.4216	3.2326	0.2425	0.0648	3.7985	62.3842	7.6631	10.9421	1.9842	0.2561
Jikenuo 20 (reciprocal cross)	Bare tip length	No. of rows	No. of grains per row	100-grain weight	Appearance quality	Odor and flavor	color and lustre	Glutinous	Flexibility	Skin thickness	Amylopectin content	Residue ratio
Mean difference value	0.3068	0.0498	1.3158	0.3980	1.2133	0.6964*	0.4086	0.5877**	0.0372	0.492**	0.5901	1.3875**
$LSD_{0.05}$	3.3216	0.3587	10.7896	0.5876	0.3562	0.2402	0.1642	0.2126	0.0129	0.1967	0.2215	0.4231
$LSD_{0.01}$	4.8189	0.5265	23.8456	1.3599	0.3189	0.2134	0.1518	0.1875	0.0111	0.1603	0.1983	0.3935

was similar to common corn, especially the single cross was the most widely promoted in the market. However, when the sweet-waxy corn hybrid was marketed, its quality and yield characters were particularly important, which was related to its promotion area. Therefore, it was more realistic to study whether the positive and negative cross F1 generation of sweet-waxy corn had a significant impact on the yield and taste.

In the present study, the sweet-waxy corn varieties Wannuo 2000 and Jikenuo 20 were used as test materials. Results showed that there was no significant difference in most characters between positive and negative cross combinations. The test results further showed that the embryo and endosperm of the F1 generation of maize hybrid offspring were different from the new generation of the maternal plant because the seed was the double fertilization product of male and female gametes. The plant type and ear characters of F1 were controlled by the genotype effect of F1 seed. There may also be cytoplasmic effects. However, the expression of F1 represents the economic yield of maize grain characters can be controlled by the cytoplasmic effect and epistasis effect of F1 maternal genotype. The above results are consistent with those results reported by Wang *et al.* (2007) and Feng *et al.* (2009).

Among the tested characters, Wannuo 2000 and Jikenuo 20 were affected by cytoplasmic inheritance in plant height, resistance to head smut, lodging resistance, angle between upper ear leaf and main stem, ear diameter, smell and flavor, waxiness, skin thickness, and skin residue rate, indicating that cytoplasmic inheritance also played a role in maize. In addition, the traits of F1 generation of different sweet-waxy corn were also closely related to their parents' inbred lines. In waxy corn seed production, not only the yield of F1 seed production should be considered, but also the "edible taste" of sweet-waxy corn should be considered. However, due to the limitation of test materials and test years, results of the present study are not comprehensive, so it is still necessary to select the optimal sweet-waxy corn combination mode in combination with the actual situation in the field in the production of sweet-waxy corn seeds.

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