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ASSESSMENT OF HYBRID VIGOR IN YIELD TRAITS OF HYBRID MAIZE

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Abstract

The analysis of the hybrid vigor of yield traits in high-yield maize variety Jikeyu 817 showed that it had a significant yield increasing effect, with increase of 2.50 and 17.60% compared to the control varieties, respectively. All yield traits exhibited a high level of heterosis, with relative heterosis ranging from 4.52 to 67.89%, with an average of 29.70%. The advantage of Chinese relatives ranges from 4.57 to 205.81%, with an average of 57.56%. The hybrid vigor index ranges from 104.47 to 301.71%, with an average of 157.80%. Among the traits, the hybrid vigor of yield is the highest, with relative hybrid vigor, mid-parent vigor, and hybrid vigor index of 67.89 , 205.81 and 301.71%, respectively.

Introduction

Hybrid vigor has revolutionized global food production, driving unprecedented advancements throughout the 20th century (Shi *et al.* 2025, Wang *et al.* 2025, Zhang *et al.* 2025). Hybrid vigor is essential for crop improvement because it significantly enhances the yield, resilience, and overall performance of plants. When two genetically distinct parent plants are crossed, their offspring often exhibit superior traits compared to either parent. This phenomenon results in increased biomass, higher seed or fruit production, improved resistance to diseases and environmental stressors, and better adaptability to varying climates.

In agriculture, hybrid vigor has revolutionized food production by enabling farmers to cultivate high-performing crops with greater efficiency. Corn, rice, wheat, and various vegetables have benefited immensely from hybrid breeding, ensuring stable and abundant harvests that sustain growing populations. Additionally, hybrids can be tailored to possess desirable traits like drought tolerance or pest resistance, reducing the need for excessive chemical inputs and promoting sustainable farming practices.

By harnessing hybrid vigor, scientists and farmers continue to push the boundaries of agricultural innovation, ensuring food security and fostering a more resilient global food system. It's a game-changer for modern crop genetic improvement. Among the outcrossing crops, maize (*Zea mays* L.) has become a model crop for studying heterosis due to its unique genetic characteristics (Feng *et al.* 2024, Guo *et al.* 2025, Zhao 2025). The hybrid vigor of corn is achieved through the high combining ability between the parents, resulting in hybrid offspring exhibiting various target traits that are superior to those of the parents (Wei *et al*. 2022). Generally, in theoretical research, hybrid vigor index and super parental vigor value are used to measure the magnitude of hybrid vigor (Yang *et al.* 2022). The population super parental advantage of corn can also reflect the hybrid advantage produced by the cumulative effect of genes (Xu *et al.* 2022). Corn hybrids play a crucial role in the development of corn production, and the current increase of about 30% in corn yield in China is attributed to the utilization of hybrid advantages. The utilization of hybrid vigor has gradually become an effective measure to improve crop yield, quality, resistance, etc. It is an extremely important genetic improvement technology in current

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production practice and plays an important role in maize genetic breeding (Pei *et al.* 2022). Focusing on the mechanism of yield in maize hybrids, existing literature has conducted systematic research from three dimensions: analysis of yield components, optimization of field cultivation techniques, and setting of different density gradients, and innovatively explored high-yield cultivation models by combining precision sowing techniques. However, there has been no analysis of the heterosis of maize yield (Qu and Zhao 2021, Chen *et al.* 2024) This study takes the maize variety Jikeyu 817 as the research object, and systematically explores the mechanism of high-yield formation of this variety by analyzing the heterosis performance of its yield related traits, providing scientific reference for the genetic analysis of maize heterosis.

Materials and Methods

The experimental materials were the maize variety Jikeyu 817 and its parental inbred lines JM040 and JF008 which were provided by the Corn Germplasm Genetics and Innovation Laboratory of Jilin University of Agricultural Science and Technology. The control varieties used were Tianyu 108 and Xianyu 335.

The experiment was conducted in the Corn Breeding Base of Jilin Agricultural Science and Technology University. A randomized block design was used, with 3 replicates, 10 rows, a total length of 4 meters, a row spacing of 0.625 m, and a density of 60000 plants per hectare. Field management was carried out under conventional production conditions. All 6 rows in the middle of the plot were harvested at full maturity and measured the moisture content of the grains. After the ears are air dried, 10 representative ears were selected for yield trait determination, including ear length, ear thickness, number of rows per ear, kernels per row, axle thickness, seed yield, hundred grain weight, and grain weight. The remaining grains were weighed after removal, and the grain yield and hundred grain weight were adjusted to the weight under the condition of uniform moisture content (14%). The yield per mu was then converted, and the seed rate was calculated.

The analysis of hybrid vigor in yield traits of Jikeyu 817 was conducted between Jikeyu 817 and its parental inbred lines, using a randomized block design with three replicates, six rows, a total length of 4 meters, a row spacing of 0.625 m, and a density of 60000 plants/hm^2. The field management was conducted according to conventional production conditions. Field investigations were conducted on plant height and ear height. After maturity, all four rows in the middle of the plot were harvested and determine their characteristics and methods as described above.

Statistical analysis was performed based on the average values of various traits. Basic statistical analysis and variance analysis were conducted using DPS V14.1 software. The magnitude of heterosis was calculated based on absolute heterosis, relative heterosis, mid-parent heterosis, super-parent heterosis, and the heterosis index.

Results and Discussion

The analysis of variance was conducted on the yield traits of Jikeyu 817, Tianyu 108, and Xianyu 335 varieties, and the results showed significant differences in yield and correlation traits. The yield of Jikeyu 817 was the highest, with an increase of 2.50 and 17.60% compared to Xianyu 335 and Tianyu 108, respectively. For yield-related traits, compared with Tianyu 108, Jikeyu 817 exhibits significant advantages in ear length, ear thickness, ear row number, axle thickness, hundred grain weight, and water content at harvest. The first five traits are 6.51, 10.57, 4.75, 7.44 and 8.44% higher, respectively, while the water content at harvest was 3.53% lower, and the seed yield was 2.18% lower. Compared with Xianyu 335, Jikeyu 817 has advantages in axle thickness, hundred grain weight, and ear thickness, with increases of 4.47, 4.69 and 8.47%, respectively. However, the kernels per row and ear length were 2.48 and 0.55% lower, respectively (Table 1).

Table 1. Comparison of yield performance and agronomic parameters of maize genotypes under field conditions.

Variety	Yield kg/mu	Ear length (cm)	Ear diam. (cm)	Ear row	Kernel number per ear	Cob diameter (cm)	Kernel ratio%	100-kernel weight (g)	Grain moisture content (%)
Jikeyu 817	889.62Aa	21.77ABa	7.43Aa	17.64a	43.34b	4.91Aa	86.86Bb	51.55Aa	33.3Bc
Tianyu 108	756.27Bb	20.44Bb	6.72Bb	16.84b	42.54b	4.57Bc	88.8Aa	47.54Cc	34.52Aa
Xianyu 335	868.04Aa	21.89Aa	6.85Bb	17.84a	44.44a	4.7Bb	87.18Bb	49.24Bb	35.01Bb

Lowercase and uppercase letters indicate significance at the 0.05 and 0.01 probability levels, respectively.

The analysis of variance showed that all yield related traits have reached extremely significant differences, and Jikeyu 817 and its parents have reached extremely significant differences. Except for seed yield and moisture content during threshing, which were lower than JF008, all other traits were significantly higher than the parental inbred line (Table 2). There were significant differences in phenotype and yield traits between the two parental inbred lines. JM040 has a hard grain type with excellent quality and high resistance to maize leaf spot disease, leaf curl disease, gray spot disease, stem rot disease, and smut. JF008 has a semi pursula shaped grain, which is resistant to corn leaf spot disease, gray leaf spot disease, stem rot disease, corn borer, and has good root and stem quality and strong lodging resistance. There are significant differences between the two in terms of yield, individual plant yield, ear length, kernels per row, axle thickness, seed yield, hundred grain weight, moisture content during threshing, plant height, and ear height, while there was little difference in ear thickness and number of rows per ear (Table 2).

Table 2. Comparison of yield traits between Jikeyu 885 and its parental inbred lines.

Variety	Yield kg/mu	Yield per plant (g)	Ear length (cm)	Ear diameter (cm)	Ear row	Kernel number per ear	Cob diameter (cm)	Kernel Ratio (%)	100-kernel weight (g)	Grain moisture content (%)	Plant height	Ear height
JM040	239.11C	71.16C	13.60C	6.12B	15.39B	19.88C	4.57B	77.05C	48.17B	19.01C	197.13C	69.46C
JF008	448.07B	126.38B	17.76B	6.17B	14.51B	33.47B	4.11C	87.24A	46.21C	21.91A	251.68B	96.02B
Jikeyu 817	1026.84A	258.14A	22.21A	7.03A	17.37A	43.24A	5.05A	86.14B	54.64A	20.91B	310.57A	144.35A

Lowercase and uppercase letters indicate significance at the 0.05 and 0.01 probability levels, respectively.

The analysis of the hybrid vigor of various yield-related traits in Jikeyu 817 showed that all traits have high absolute hybrid vigor. The relative heterosis ranges from 4.52 to 67.89%, with an average of 29.70%. The advantage of Chinese relatives ranges from 4.57 to 205.81%, with an average of 57.56%. The hybrid vigor index ranges from 104.47 to 301.71%, with an average of 157.80%. Among the measured traits, the hybrid vigor of yield was the highest, with relative hybrid vigor, mid-parent vigor, and hybrid vigor index of 67.89, 205.81 and 301.71%, respectively. The ranking of other traits from high to low was as follows: yield per plant, ear height, kernels per row, ear length, plant height, axle thickness, ear thickness, ear row, hundred grain weight, seed yield, and moisture content during threshing (Table 3).

Jikeyu 817 also has a high superparent advantage, ranging from -0.05 to 130.76%, with an average of 36.67%. The superparent advantage for yield was the largest, with traits ranked from high to low as yield, individual plant yield, ear height, kernels per row, ear length, plant height, hundred grain weight, ear thickness, shaft thickness, ear row, seed yield, and moisture content during threshing. Among them, the traits of seed yield and moisture content during threshing have no superparent advantage. The super low parent advantage ranges from 12.82 to 333.30%, with an average of 91.44%. The super low parent advantage for yield was the highest, ranked in descending order of traits as yield, individual plant yield, kernels per row, ear height, ear length, plant height, shaft thickness, ear row, ear thickness, hundred grain weight, seed yield, and moisture content during threshing.

Table 3. Analysis of heterosis differences in yield traits between Jikeyu 817 and parental inbred lines.

Trait	Absolute heterosis	Relative heterosis	Mid-parent heterosis	Ultra-high-parent heterosis	Ultra-low-parent heterosis	Heterosis indexes
Plant height	87.4	29.09	39.84	24.74	60.04	138.74
Ear height	62.84	44.28	76.83	52.23	111.9	177.73
Spike length	66.56	32.38	46.48	28.18	71.85	147.38
Ear diameter	10.53	16.6	19.39	18.79	20.89	120.29
Suixing	3.66	16.26	18.92	15.25	23.74	119.82
Kernels per row	17.79	40.66	66.34	31.53	127.43	167.24
Shaft thickness	8.32	20.86	24.12	15.73	34.74	125.02
Seed yield rate	5.22	5.93	6.17	-0.05	14.12	107.07
100 grain weight	8.68	15.18	17.44	19.98	15.91	118.34
Threshing moisture content	2.68	4.52	4.57	-3.61	12.82	104.47
Yield per plant	160.7	63.3	164.9	106.52	270.57	265.8
Yield	684.48	67.89	205.81	130.76	333.3	301.71

Jikeyu 817 has been widely used due to its excellent traits, such as high yield, high quality, and disease resistance, especially its high yield potential. Jilin Province has made breakthroughs in the comprehensive production capacity of medium maturing corn, and has achieved breakthroughs in the coordinated development of yield, quality, and resistance in similar products and technology application fields. Through this study, it has been confirmed that Jikeyu 817 has a high level of heterosis in various traits, such as yield, with the highest heterosis in yield. Since the 1980s, at densities of 45000 plants per hectare and 75000 plants per hectare, the relative heterosis (67.89%) has been 6.82-23.54 percentage points higher than that of maize varieties in northern China, and the mid parent heterosis (205.81%) and heterosis index (301.71%) have been 36.43-105.13 percentage points higher.

From the analysis of pedigree sources, the parental inbred lines JM040 and JF008 belong to two major hybrid vigor groups, PA and Lancaster, with a hybrid vigor pattern of PA group × Lancaster group. The PA group inbred lines have strong hybrid vigor with the main hybrid vigor groups in China, such as the Tangsipingtou and Lvdahonggu groups, and are a relatively independent and new hybrid vigor group. From the analysis of genomic genetic structure, the genetic distance between the parental inbred lines of Jikeyu 817 was relatively far (0.83), with significant genetic differences on chromosomes 3, 5, 1, 2, 4, 6, 7, and 10, with a proportion of differential loci exceeding 52%. Jikeyu 817 has a strong hybrid advantage, which may be mainly due to the significant genetic differences in functional genes between its parental inbred lines, leading to complementary effects of dominant genes beneficial to growth in F1 heterozygotes.

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