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RESEARCH PAPER

Efficiency of Recurrent Selection for Combining Ability of Yield Trait in Maize Population Yuzong 5

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Abstract: Population improvement is a basis of germplasm enhancement and developing inbred lines in maize (*Zea mays* L.). For evaluating the combing abilities of Yuzong 5 developed populations derived from 5 cycles of recurrent selection, 30 testcrossing combinations were made using Huangzao 4, Dan 340, Zhongzong 5, Qi 319, Ye 478, and Mo17 as the female parents in 2 locations under the NCII design. The yield per plant of testcrossing combinations was enhanced by 3.57% per cycle, showing a remarkable effect of recurrent selection. Both half-sib recurrent selection (HS-RS) and half-sib reciprocal recurrent selection (HS-RRS) were effective for improving the general combining ability (GCA) of kernel yield and the GCA was improved in each cycle of the populations. After 3 cycles of improvement in Yuzong 5 by HS-RS, the GCA significantly increased from −11.63 of C_0 to 5.57 of C_3 population ($P < 0.01$). After 1 cycle of improvement by HS-RRS, the GCA increased from 5.57 of C_3 to 9.75 of C_4 population. The specific combining ability (SCA) of improved Yuzong 5 × Huangzao 4 was enhanced, which indicated an approaching Reid × SiPT heterotic pattern during Yuzong 5 improvement cycle by cycle.

Keywords: maize; population improvement; recurrent selection; combining ability

Narrow genetic basis is a major problem in maize (*Zea mays* L.) breeding in China. The critical solution is germplasm enhancement, in which recurrent selection in population improvement serves as an importance technique [1]. Recurrent selection can continuously accumulate favorable genes in the population, eliminate adverse genes, break gene linkage, and increase opportunities for recombinant; as a result, relatively rich favorable variation is preserved in the improved population, and the population containing elite genes provides excellent materials for breeding maize inbred lines and hybrids [2]. Hallauer et al. [3] revealed the advantages for recurrent selection in details. The recurrent selection could improve the general combining ability (GCA) and specific combining ability (SCA) of maize populations, as well as agronomic traits. The most popular methods for recurrent selection are half-sib recurrent selection (HS-RS) and half-sib reciprocal recurrent selection (HS-RRS) aiming at combining ability for yield [1]. Iowa University has carried out HS-RS and HS-RRS using maize population BSSS since 1939 and populations BSSS and BSCBI since 1949. In over 15 cycles of population selection, some elite inbred lines, such as B14, B37, B73, B84, and B85, were selected from different cycles. The population BSSS has played an important role in the utilization of elite germplasm resources and maize production in the US [4]. In China, Chen et al. [5] conducted HS-RS in 2 maize populations for 2 cycles and showed that the population production and the combining ability were improved by 6.1% and 8.9% per cycle, respectively. Liu et al. [6] demonstrated that HS-RS had an effect on population yield increase by 7.4% after 3 cycles of selection in Zhongzong 2 population; simultaneously, the GCA increased from −10.08 of C_0 to 15.92 of C_3. Peng et al. [7] improved the Zhongzong 4 population using 4 cycles of HS-RS with the average yield of tester hybrid combinations increased by 6.0% per cycle and

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the average yield of heterosis by 6.9% per cycle. Using HS-RRS method for 2 cycles of HS-RRS, Peng et al. [8] showed that the yields of improved populations Zhongzong 3 and Zhongzong 4 and tester hybrids were increased with the recurrent cycles, and high heterosis was observed between Zhongzong 4 and Huangzong 4 or Dan 340.

Yuzong 5 was developed from the heterotic pattern of alien line × domestic line by the Henan Agricultural University in 1990. It was a synthesis of 16 American inbred lines and selected after 3 cycles of HS-RS and 1 cycle of HS-RRS with typical domestic testers. Yuzong 5 is of great value in maize breeding, from which many elite inbred lines and maize cultivars have been developed and released, for example, the inbred lines Xinzi 534, Xinzi 588, Yu 537, and Yu 82 and the released cultivars Xinyu 34, Xinyu 39, Xinyu 41, Yudan 2001, and Yudan 998.

Heterotic utilization is the heart of maize breeding. Improved population by recurrent selection for enhancing level and efficiency of heterotic utilization has high combining ability, excellent agronomic traits, specific heterotic grouping, and heterotic pattern. In an earlier study, we evaluated the yield performance of Yuzong 5 improved populations [9]. As a follow-up, in this study, we used different improved populations of Yuzong 5 to test-cross with Huangzao 4, Dan 340, Qi 319, Ye 478, Mo 17, and Zhongzong 5 for assessing the improvement effect of combining abilities in Yuzong 5 during recurrent selection.

1 Materials and methods

1.1 Basic materials and improvement procedure

The basic population of Yuzong 5 was developed by the Henan Agricultural University, Zhengzhou, China in 1990, which has combined 16 inbred lines containing the US germplasm resources, i.e., Ye 478, Ye 8112, Shen 5003, Mei 3184, Shen 5005, Zheng 32, Tie 7922, Ye 107, 27-263, Xu 05, Mo 17, Qi 302, Qi 35, Yuza 3, Yuza 16, and Yu UMU. From 1991, we carried out population improvement in Yuzong 5 using single-cross combination between Huangzao 4 (SiPT group) and Dan 340 (Lüdahonggu group) as the tester, with the major objective of combining ability and additional consideration of important agronomic traits. By means of HS-RS, we completed 3 cycles of selection and obtained improved populations C_1, C_2, and C_3 in 2001.

In the first-cycle selection, more than 200 plants with excellent performance were selected from 2000 plants of the basic population of Yuzong 5. They were selfed and simultaneously crossed with 6–8 individuals of the tester derived from Huangzao 4 × Dan 340, and the individuals were numbered from 1 to 6 or 8, which were planted next to the plants of Yuzong 5. The testcrossing combinations were first planted in Zhengzhou and Xinzheng of Henan Province, China for yield comparison, and then 30 self-pollinated ears with the best performance of combining ability and agronomic traits were selected, with the selection strength of 15%. The self-pollinated ears were reproduced by the pollination strategy of one maternal plus multiple paternal parents. As a result, the C_1 population of Yuzong 5 was obtained. In the second- and third-cycle selections, 198 and 203 selfed plants and the testcrossing combination plants were selected, with the strengths of 15.2% and 14.8%, respectively. Finally, the C_3 population of Yuzong 5 was obtained.

In 2002, we made the hybrids between the C_3 population and the Gold population (a comprehensive population of Golden Queen improved domestically and 12 inbred lines in SiPT group) using HS-RRS method. The combining ability was the main target of selection. In either Yuzong 5 or Gold population, 200 excellent individuals were selected from a total of 4000 plants and produced self-pollinated seeds. Their tassels were also used to pollinate 4–6 ears randomly selected from a corresponding tester population. At maturity, 182 and 180 selfed ears were harvested for Yuzong 5 and Gold populations, respectively. Besides, seeds of testcrossing combinations were also obtained. In summer of 2003, we designed field experiments in Zhengzhou and Xinzheng of Henan Province to compare the yields of testcrossing combinations. According to the yield levels of testcrossing combinations, we selected 25 selfed ears of Yuzong 5 corresponding to the testers in high combining ability and elite agronomic traits, with the selection strength of 13%. In 2004, seeds of each of the 25 ears were planted in a single line, and pollinated with multiple male parents. Finally, the C_4 population of improved Yuzong 5 was obtained.

In winter of 2005, the C_0, C_1, C_2, C_3, and C_4 populations of Yuzong 5 were planted in Sanya, Hainan Province. Under a mixed pollination strategy, each population had at least 300 paternal plants and 100 maternal plants. To assess the effect of population improvement and possible heterotic pattern of Yuzong 5, 5 inbred lines and a population were used as the testers to cross with Yuzong 5 populations in different improved cycles. Among the 6 testers, Zhongzong 5 is a synthetic population from 16 improved lines of Huangzao 4, and both Zhongzong 5 and Huangzao 4 are the representatives of SiPT group; Dan 340 is a typical inbred line of Lüdahonggu group; and Ye 478, Mo17, and Qi 319 are involved in Reid, Lancaster, and P groups, respectively.

During reproduction procedure of each cycle population, 30 testcrossing combinations were prepared according to the NCII design. The C_0, C_1, C_2, C_3, and C_4 populations of Yuzong 5 were used as the paternal plants, whereas the testers were used as the maternal plants. A mixture of pollen from at least 100 individuals was used to pollinate at least 10 ears. The ears from different individuals within a testcross were bulked.