Breeding Method of Spring-Sown Maize in Northern China

Honglin HU[1,2], Tao GUAN[1], Qingfeng GUO[1], Weizheng GAO[3], Yanli LI[1], Kuo ZHANG[1], Chenglong WU[1], Wei WANG[1]

1. Heilongjiang Academy of Land Reclamation Sciences, Jiamusi 154007, China; 2. Jiamusi Maize Experiment Station, CARS, Jiamusi 154007, China; 3. Tieling Academy of Agricultural Sciences, Tieling 112001, China

Abstract This paper outlines effective methods for selecting and breeding maize varieties, with a focus on early and late hybridization, superior line re-selection, multi-part selection, and other techniques. The goal is to facilitate the innovation of northern spring-sown maize germplasm resources, the selection and breeding of new varieties, thereby contributing to food security in China.

Key words Spring-sown maize; Breeding method; High yield and high efficiency

1 Introduction

Maize is the most significant crop in China, taking up a large proportion of China's agricultural output. A triad of "grain, industry, and feed" plays a pivotal role in ensuring food security, providing industrial raw materials, and serving as a source of animal feed. The spring-sown maize area represents a significant advantage for maize production in northern China. The sown area and output have accounted for approximately half of China's total in recent years[1-2]. A phenomenon can be observed that varieties contribute approximately half of the increase in maize yield per unit area. With time went on, the competition between varieties has become fierce, and the varieties still fail to meet industrial demands[3-4].

We have integrated conventional breeding and haploid breeding methods[5], in order to adapt to the new requirements of the local spring-sown maize market in northern China. The objective is to develop new germplasm and select varieties that exhibit high yield and high efficiency, resistance to adversity, lodging resistance, fast dehydration, and machine-harvestability. This selection is particularly focused on the certification of excellent traits such as high water-fertilizer use efficiency, high photosynthetic efficiency, and machine-harvestability.

The fundamental principle of selection is to prioritize efficiency for the sustainability of breeding and to increase the probability of variety success. This paper provided an overview of maize breeding methods with the aim of facilitating the innovation of germplasm resources and the selection of new varieties of spring-sown maize in northern China. This will make a contribution.

2 Breeding methods

2.1 Test before selection, early and late hybridization It has been down to identify heterotic groups and determine their advantages and disadvantages before targeted assembly of basic materials for line selection that pre-testing and selection foreign materials are tested and matched.

In order to accelerate the selection and breeding process, the individual materials that have been tested as excellent can be tested and selected simultaneously. The selection of the fundamental combination of line matching represents the foundation of the breeding process. A poor combination often leads us to mountain in labour, or even worse, particularly when the purpose is not clearly defined in mind prior to matching.

The term "early and late hybridization" encompasses two distinct meanings. The first refers to the preparation of selected combinations with early and late hybrids, meeting the objective of achieving a balance of early maturity, yield resistance and stress resistance. And the second pertains to use late-maturing inbred lines as female parents and early-maturing inbred lines as male parents when configuring hybrids.

This approach is typically employed with the objective of ensuring that the hybrid is well adapted, exhibits early maturation, displays high dominance, and exhibits a high seed yield. Kendan 1563 (NSY 20220015) is a hybrid from very early maturing line to late as a model. It displays notable adaptability, high and stable yield and performs well in water and fertilizer utilization efficiency, resistance to lodging, field disease resistance, grain dehydration, quality, bulk density. The above factors have resulted in good economic benefits.

2.2 Pedigree selection, combining induction with inbred, population improvement, reciprocal crossing, three lines A balance should be struck between the short-term (induction), the medium-term (pedigree selection), and the long-term (population). A pedigree selection system is employed, with backcrossing serving to reinforce its efficacy. Although backcrossing is a more favorable approach for progeny selection, the number of backcrosses made is found to be inversely proportional to the difficulty of reaching the standard of DNA fingerprinting. Backcrossing aimed at transferring a specific trait should be performed only once. In order to expedite the selection process, it would be advisable to induce selection on the superior line combination S_0 (BC_1S_0). In order to enhance the selection efficiency, it would be beneficial to induce selection on the superior S_3 (BC_1S_2) and its previous generation following one mating test. The superior quality of the middle and high generations, which can be achieved through two or

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E-mail: HHL79@163.com

three rounds of mating, allows for the reorganization of the genetic material, thereby expanding the genetic diversity and enriching the genotypes. This process ultimately provides a more robust foundation for the selection of varieties. To date, five reorganizations have been completed in clusters A and B, and self-cross selection has commenced, with the certification of superior traits. The mating stage has also been initiated. Two reorganizations have been completed in cluster C as well. A selection of inductive lines with an average induction rate of more than 10% and an average selection accuracy of more than 90% for seed markers has been made. Additionally, hybrids derived from inbred lines (DH lines) selected by DH technique have been submitted for validation[6-7].

With regard to traits inherited from the nucleus, the genetic effects of reciprocal cross are identical. Conversely, with traits inherited from the cytoplasm, the genetic effects of reciprocal cross may vary. For instance, the F_1 yield of reciprocal crosses of maize exhibits minimal variation, yet there may be discrepancies in disease resistance. Single crosses of maize cytoplasmically inherited T-type sterile line are highly susceptible to *Bipolaris maydis*[8]. In practice, there are also notable differences in flavor and other qualities of fresh maize in reciprocal crosses. It is essential to ascertain the distinctions between reciprocal crosses for optimal combinations, particularly in the context of fresh maize. It is of paramount importance to prioritize the influence of cytoplasmic inheritance in the selection of line combinations. Furthermore, both reciprocal crosses should be conducted when feasible.

The cytoplasmic male sterile material T type is highly susceptible to *B. maydis*. In contrast, the S type is susceptible to environmental factors, resulting in unstable sterility. The C type, however, is stable and unaffected by the environment, which is of great application value in production. The absence of robust paternal restorer lines in C-type sterile seed production has constituted a significant obstacle to the utilization of C-type materials[7]. Parent lines that lack the capacity to restore C-type materials may be subjected to backcrossing in order to enhance their recovery ability. The sterilization of the female backbone line corresponding to the parent line with a strong restoring ability to C-type material allows for the use of male sterility in seed production. This approach not only saves a significant amount of labor and reduces the cost of seed production, but it also avoids the decline in seed purity that can result from incomplete castration of the female parent. Consequently, the quality of the seed is improved, and the yield potential of the varieties is ensured.

2.3 Testing and matching at early generation and alternate generation, superior line re-selection The probability of obtaining high-fit inbred lines is low even when the S_4-S_6 genotypes, which are essentially stable, are tested for combining ability. This is because the selected inbred lines may possess desirable traits but may not necessarily exhibit high combining ability. It is crucial to conduct combining ability testing in the early generations. In order to obtain accurate data, it is essential to conduct early generation measurements of combining ability at the first segregating generation (S_1) in the basic plants or S_2 spike rows. However, in the selfing segregating generation, it is important to note that the combining ability of different individuals is different, indicating that combining ability is also segregating. It is therefore not possible to determine the combining ability of the first segregating generation (S_1) of basic plants or S_2 spike rows on their own. The measurement of combining ability is typically conducted at least to S_4-S_6 spike rows. In order to reduce the workload associated with mating and certification, mating can be conducted in alternate generations. Furthermore, the starting and ending generations and times of mating can be adjusted according to the stability of the tested lines and hybrids.

Given that combining ability is a trait that can be segregated in a manner analogous to epistatic traits, the choice of combining ability is of equal importance. In addition, the combining ability of different traits varies from one parent to another. Furthermore, the combining ability of the same trait varies among parents. Consequently, it is impossible to obtain parents with high combining ability for all major traits, given that the combining ability of some traits are negatively correlated with each other. Hence, in the process of selecting and breeding inbred lines, it is imperative to prioritize the selection of general trait combining ability, based on the core trait combining ability.

To enhance the efficacy of the selection and breeding process, it is recommended to re-select or induce the favorable lower-generations (S_0-S_3) following replanting, or re-select and induce the fundamental combinations, while concurrently moderately expanding the size of the selected line group. This approach allows for the certification of the optimal selection within the larger group.

2.4 Multi-stage selection, interior cold frame germination Selective breeding can be defined as a continuous process of elimination, during which observations, records, and elimination can be made at the whole growth period. This approach reduces the workload associated with the process. The following issues must be addressed during each period of selection, although this list is not exhaustive.

Seedling stage: seedling emergence, early germination, lodging resistance, drought, waterlogging, insect and herbicide tolerance; jointing to tasseling stage: lodging resistance; pollen dispersal and silking to milk maturity: ASI, drought tolerance, heat tolerance, insect resistance, leaf spot, plant height, panicle position; wax ripening stage: leaf spot, stem rot, grain filling rate; mature stage: yield, development of the female spikes, head smut, ear rot, stem rot, lodging resistance, dehydration; seed test: seed yield, seed depth, bulk density, and intragranular fissure. The use of an interior cold frame germination process for the certification of cold hardiness can reduce the workload associated with field certification.

It is important to note that the use of hybrids with excessive resistance, particularly those with high resistance to serious local pests and adversities may result in excessive energy consumption and yield reduction. It is sufficient to use hybrids with high resistance to serious local pests and adversities, and others with medium resistance.

2.5 Whole-field inoculation, multiple densities and fertilization, and herbicide screening The inoculation of maize with *Sphacelotheca reiliana* from the contemporary generation (S_0) has the effect of increasing the selection pressure and amplifying the genetic variance, which facilitates selection.

The number of seedling-holding capacity of selected lines is 150 000 – 200 000 plants per hectare in S_0-S_4 (BC_1S_0-BC_1S_3) and 75 000 – 100 000 plants per hectare in S_5 (BC_1S_4) and above. The number of seedling-holding capacity for certification is 75 000 – 100 000 plants per hectare, and the different densities of the selected lines could be used to effectively evaluate the production capacity of single plants, the population yield, and the comprehensive stress tolerance.

In order to ascertain the efficacy of fertilizer utilization and tolerance to weeds, environmentally friendly maize varieties have better performance. The amount of fertilizer and herbicide applied in the one-year certification and selection nursery is approximately half of the level typically utilized in field production. And, it should be noted that varieties in production are often adapted to local mainstream agro-mechanical and agronomic, cultivation and management levels. In order to facilitate the assessment of the selected varieties, the two-year appraisal is repeated on a one-half basis. This involves the customary amount of fertilizer, fertilizer application methods and herbicide types and dosages in field production. The selected varieties are more suitable for the conditions of field production.

The cultivation techniques that match the variety can play a leading role, but can not be radical. It is difficult to implement and promote radical techniques. We need pragmatic methods.

2.6 Multi-point certification, multi-year certification It is essential to conduct a multi-year, multi-point appraisal and evaluation, in order to ascertain the yield stability, broad adaptability, or regionality of varieties. In particular, it is crucial to perform an effective appraisal and scientific evaluation of the stability of yield and resistance to adversity. This necessitates that the appraisal site is representative and that the design of experiments adheres to the principle of unique difference. In order to reduce the workload, it is advisable to certify the middle and low-generation materials at multiple points and to set aside a sufficient amount of backup seeds. In an effort to further reduce the workload, it is necessary to prohibit self-crossing. Following the selection process, mating and self-pollination can then be carried out.

2.7 Multi-stage sowing, late harvest and early harvest The practice of early sowing in northern China allows for the certification of varieties with high germination hardiness and resistance to soil-borne diseases. Spring low-temperature chilling damage represents the primary factor influencing the sustained high and stable yield of spring-sown maize in the northern regions. A type of low-temperature chilling damage that frequently occurs at high latitudes is low temperature during germination. This results in low seed germination, a high incidence of soil-borne diseases such as head smut, and low seedling rate, which directly affects the yield and quality of maize.

In the northern region, late planting necessitates the selection of varieties that are resistant to lodging and exhibit a rapid rate of grain filling and dehydration under low temperatures in the autumn. The timing of sowing has an impact on the horizontal development of the root system, as well as the rapid development of the stalks, which in turn affects the plant's lodging resistance. This phenomenon is conducive to the screening of lodging resistance. A number of factors can influence the grouting process, including temperature, light, nutrients and water. A positive correlation exists between the average daily temperature and the rate of grouting and dehydration of kernels within a certain range. Late sowing also facilitates the selection of varieties that are insensitive to low temperatures in the later stages of grouting and that are quick to dewater in the later stages of grouting. This mitigates the effects of low temperatures on maize yields and quality.

The practice of late sowing in Hainan can intensify the selection pressure of the environment, which is conducive to the selection of insect resistance, disease resistance, and cold tolerance during flowering. Furthermore, multi-stage sowing can also alleviate the seasonal work pressure during pollination and harvesting[9].

The practice of late harvesting after frost in the northern regions of China allows for the screening of dehydration rates and lodging resistance. Conversely, the practice of early harvesting, occurring approximately 4 – 5 weeks after pollination in Hainan, allows for the screening of pre-grouting rates.

3 Conclusions

The intensifying competitive landscape within the seed industry underscores the necessity for unceasing innovation. It is also important to consider the following points in order to achieve the sustainability of breeding and increase the probability of variety success, in addition to the aforementioned breeding methods. It is of the utmost importance to apply a plentiful and efficient use of germplasm resources, as well as to provide adequate and stable inputs for research and development (R&D). This is to ensure the sustainability of the inputs. Furthermore, it is crucial to ascertain the feasibility of the technological route, to repeatedly deliberate on the bottlenecks of the key links, to optimize the implementation of the program, and to deduce the risks of possible failures and to devise prevention and control plans. The application of efficient and practical tools, equipment, instruments, certification and selection methods is essential in order to improve operational efficiency and increase the accuracy of certification and selection. A team that can accurately and efficiently complete the program is also necessary. Breeders must possess professional knowledge and skills, confidence and courage, and a clear understanding of the future needs of the industry. This knowledge must be integrated with research and development activities, and conveyed to those working at the front line. The unity of knowledge and action is of great benefit.

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cumvented the climatic conditions suitable for disease occurrence and can effectively reduce the incidence of brown spot. By adjusting the transplantation period and improving cultivation methods to provide a favorable environment for the growth of tobacco plants, the disease resistance of tobacco plants has been enhanced, and the incidence of virus diseases has been reduced. Accordingly, in the context of the natural conditions of the tobacco-growing region in Shiyan, the timely and early transplanting of tobacco can serve to reduce the incidence of leaf spot diseases. Furthermore, in the cultivation management, reducing the overlap time of tobacco plants in the field and the precipitation period to a minimum can be an effective strategy for reducing the impact of brown spot. The prevention and treatment of brown spot disease should be combined with precipitation in May to prevent the disease in advance and reduce the source base of disease.

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