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Recurrent selection for intrapopulation improvement and cultivar development in maize (*Zea mays* L.) — An analysis

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Abstract

Recurrent selection is widely used in maize (*Zea mays* L.) breeding. Extensive studies have been carried out on recurrent selection for intrapopulation improvement in elite populations by the Indian maize breeders. In the present study, the results of some experiments conducted at the Punjab Agricultural University, Ludhiana, have been analysed with respect to improvement in the elite populations *per se* and development of open-pollinated (OP) cultivars. The analysis indicates that, though, recurrent selection has been effective in enhancing the performance of elite populations *per se*, recurrent selection accompanied by germplasm introgression in elite population has been more successful in OP cultivar development. It suggests that step-wise intervarietal hybridization accompanied by recurrent selection for intrapopulation improvement may be a better approach than recurrent selection within populations without germplasm introgression, for the development of OP cultivars.

Key words: Maize, recurrent selection, intrapopulation improvement, varietal hybridization, open-pollinated cultivar

Introduction

Recurrent selection is the selection, generation after generation, with the recombination of selects (families or plants), for gradually increasing the frequency of favourable alleles and at the same time maintaining genetic variability. Recurrent selection may be carried out for intrapopulation or interpopulation improvement. Intrapopulation improvement is carried out in a population and it aims at enhancing the frequency of alleles in a manner that the mean performance of improved population is maximized. Interpopulation improvement involves simultaneous selection in two populations and it accumulates genes to maximize the mean performance of interpopulation cross between the improved populations and the inbred lines derived from them. The improved population(s) may be used *per se* as OP cultivars or non-inbred parents of hybrids, or as sources to derive inbred lines and families for use as parents of hybrids or OP cultivars [1].

Extensive studies on recurrent selection for intrapopulation improvement have been carried out by the Indian maize breeders since 1974. In most of the studies, modified full-sib selection has been employed. Other methods used included modified mass selection, modified ear-to-row selection, half-sib selection and unit selection.

Materials and methods

At the Punjab Agricultural University, Ludhiana, recurrent selection for intrapopulation improvement has been carried out in many closed elite populations (intrapopulation improvement without germplasm introgression). These populations included released composite cultivars, namely, Vijay, Ageti 76, Navjot, Pratap, Parbhat, Kesri, Kiran, Makki Safed 1 and Rattan, and many elite experimental populations, such as, J109, J607, J650, J659, J661, J663, J1413, JC1441, J2022, J2078 and J3022. Recurrent selection has also been carried out for the improvement of populations developed by hybridizing or compositing elite composites with other desirable germplasm (intrapopulation improvement accompanied by germplasm introgression).

Results and discussion

The selection has been effective in enhancing grain yield, shortening duration (days to silk and maturity), reducing plant stature (plant and ear heights) and lodging, improving resistance to diseases (maydis leaf blight caused by *Drechslera maydis*, late wilt caused by *Cephalosporium maydis*, charcoal rot caused by *Macrophomina phaseolina*, common rust caused by *Puccinia sorghi* and tolerance to cold (expressed as increased early vigour and reduced yellowing of leaves) [2-8], increased prolificacy [9]; and enhanced resistance to brown stripe downy mildew caused by *Sclerophthora rayssiae* var. *zeae* [10] and to maize stem borer, *Chilo partellus* [11-12].

In the present paper, the results obtained in some recurrent selection experiments with or without germplasm introgression have been analysed in relation to OP cultivar development. The analysis is presented

for three ecologies of maize cultivation, namely, (i) maize cultivation during the traditional monsoon season under high input management (irrigated, timely sown, good input supply); (ii) maize cultivation during the monsoon season under lower input management (rainfed, irrigated late sown, irrigated low input supply etc.); and (iii) maize cultivation during the non-traditional winter season. The important desirable traits of the commercial cultivars for the three ecologies are high yield, management responsiveness and full season maturity for cultivation under high input management during the monsoon season; early maturity, stress tolerance and high and stable yield for the lower-input average management during the monsoon season; and high yield, management responsiveness, full season maturity and cold tolerance for the winter season.

Monsoon season-high input management: Six composites were released in India for general cultivation in 1967. This was the first instance of release of composite cultivars. Among these, Composite Vijay, that was developed by improving a bulk of selected OP ears representing Caribbean, Mexican, U.S. and Indian germplasm, proved to be the most promising for grain yield potential and stability of performance. It was also released in Pakistan with its experimental name JI and in Nepal as Rampur Yellow. Three cycles of modified full-sib selection were carried out in Vijay. The selection was carried out primarily for higher grain yield, and other traits considered were earlier silking and reduced ear placement. The improved population, Vijay C3 registered 4 per cent gain per cycle for grain yield in comparison to Vijay [6]. It also silked earlier and had reduced ear and plant heights than Vijay.

Vijay was also crossed with a large number of germplasm. Three crosses (Vijay × P102, P114 × Vijay, Ganga 5 × PI04) were composited and the broad population, thus, developed was subjected to two cycles of modified mass selection and one cycle of selective sib-mating. This resulted in the development of Composite Partap (experimental name J54), that was released for general cultivation in the Punjab state in 1980 [13] and later on in other states.

Four cycles of modified full-sib selection were carried out in Partap [9], primarily for increased number of ears. Other traits considered were reduced days to silk and plant and ear heights. The selection resulted in significant improvement in the number of ears per plant and in a correlated response for increased grain yield. Plant and ear heights were also reduced. One of the improved populations, J54 C4, showed 5.5 per cent gain per cycle for grain yield.

Partap was also involved in hybridization, and a population was developed by backcrossing (Partap × Suwan 1) with Partap and subjected to modified mass selection. (Suwan 1 has been developed in Thailand and has proved to be a very promising population [14]). The new population, thus developed, Composite Parbhat, was released for general cultivation in Punjab in 1987 [15] and at the national level in 1988. Thus, recurrent selection in composites Vijay and Partap when accompanied by germplasm introgression seemed to be more effective for OP cultivar development in comparison with intrapopulation improvement in Vijay and Partap without germplasm introgression.

Monsoon season-low input management: Composite Ageti 76 (experimental name J603), an early maturing cultivar, was developed by intrapopulation improvement, two cycles of mass selection and one of selective sib-mating, in a base population generated by bulking chain crosses of 26 lines (13 from Vijay, 10 from J236, and 1 from each Puerto Rico Gr. 1, MVSc 620 and CM105). It was released for general cultivation in Punjab in 1976 [16] and at the national level in 1982. Modified full-sib selection, primarily for grain yield, was carried out in Ageti 76 [3,8]. After four cycles, Ageti 76 C4 registered 4.2% gain per cycle over Ageti 76 for yield [8].

Composite Partap was hybridized with early maturing germplasm including Composite Tarun, a cultivar developed by Govind Ballabh Pant University of Agriculture and Technology, Pant Nagar, and the resultant population was subjected to intrapopulation improvement (one cycle each of modified mass selection, half-sib selection and modified full-sib selection). This led to the development of Composite Navjot (experimental name J684) which was released in the Punjab state in 1982 [17] and at the national level in 1988. Similarly, Composite Navjot was successfully subjected to three cycles of selection for grain yield; but Composite Kesri was developed and released in the Punjab State in 1992 [18] as a result of two cycles of modified mass selection in a population developed from (Parbhat × J2014) × Kailpur local (J2014 had been developed from 12 selected top-crosses of J663, a composite based on elite locals). These results also indicated better output with respect to OP cultivar development through intrapopulation improvement accompanied by germplasm introgression rather than in the absence of germplasm introgression.

Winter season: Maize is traditionally grown during the monsoon season. Its cultivation during winter season started probably during 1960s. It has become an important crop in Andhra Pradesh and Karnataka states in South India, and Bihar state in eastern Indo-Gangetic plains. Maize during winter season generally gives higher and stable yield than that during monsoon

season. Thus, extensive studies were carried out at Punjab Agricultural University to develop cold tolerant, high yielding cultivars and their production technology for North-West India [2,5]. An extensive evaluation of germplasm led to the identification of Composite Partap as a promising population. Intrapopulation improvement programme was carried out in it for cold tolerance and grain yield. After three cycles of selection (mass selection, half-sib/S_1 family selection, half-sib selection), the improved version, Composite Partap 1, was released, for general cultivation in Punjab state in 1983 [19] and in Haryana later on. Partap 1 had better grain yield, cold tolerance and resistance to post-flowering stalk rots and common rust. It may, however, be stated that the experiments on maize during winter season were initiated during 1978-79 season. Though, large germplasm were evaluated, but there was no other intrapopulation improvement programme going on parallel to that in Partap, as in case of breeding programmes on cultivar development for monsoon season.

The information presented above on recurrent selection for intrapopulation improvement of an elite composite vs. intrapopulation improvement of a base population generated by hybridizing/compositing elite composites and other desirable germplasm is summarized in Fig. 1. Apparently, intrapopulation improvement accompanied by germplasm introgression/varietal hybridization seemed to be more effective than intrapopulation improvement in elite composites *per se*, for the development of OP cultivars. The conclusion is supported by the fact that recurrent selection for intrapopulation improvement has been carried out in a large number of elite composites at the national level by various centres of All-India Coordinated Maize Improvement Project but only Diara 3 could be released as commercial cultivar.

It may be added that it would have been desirable to conduct parallel experiments on alternative approaches, that is, recurrent selection for intrapopulation improvement of a population with and without germplasm introgression. But such a large scale field experimentation is quite difficult. The conclusion presented above is based on recurrent selection conducted over one and a half decade at the Punjab Agricultural University, and should be useful in plant breeding.

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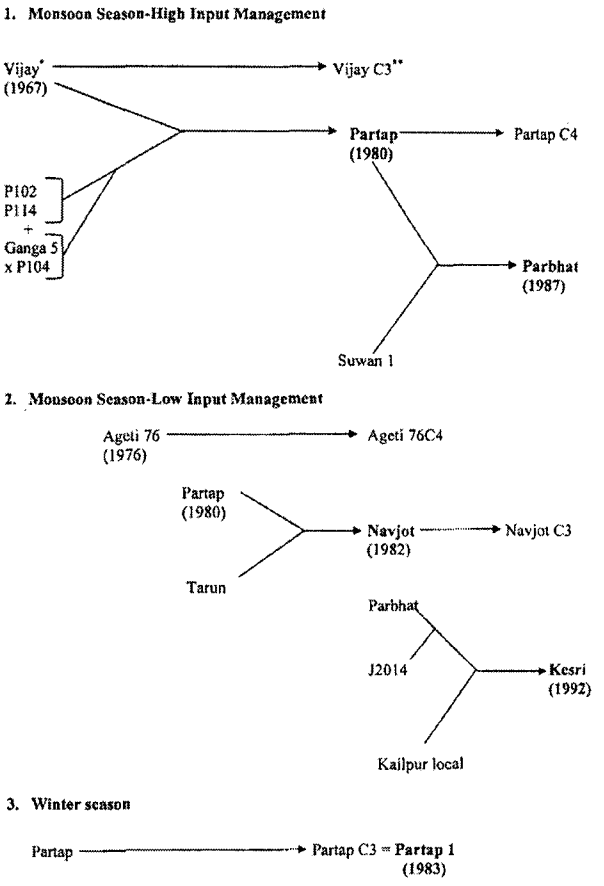

Fig. 1. Recurrent selection for intrapopulation improvement and development of cultivars for different agro-ecologies (*open-pollinated cultivars developed are given in bold letters and the year of release is given in parenthesis, **C = cycles of selection)

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