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Heterotic Groups of Canadian Maize Inbred Lines Based on Pedigree and SSR Markers
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Corn breeders of Agriculture and Agri-Food Canada (AAFC) have collected maize genotypes from around the world and adapted them to the different short growing season regions of Canada. In many cases, the heterotic backgrounds of these genotypes were unknown, while others had been developed from mix of two or more heterotic groups. In the early years of inbred development at AAFC, testers of known heterotic backgrounds were not available with maturities suitable to Canadian climates. This sometimes resulted in the release of inbreds with little knowledge on their combining ability with the different heterotic patterns. Over the past few years, we have been evaluating the inbred lines released from AAFC during the last 20 years and classifying them into known heterotic groups based on pedigree and Simple Sequence Repeat (SSR) markers.

A total of 129 inbred lines were classified into nine groups based on pedigree (Table 1). Eighteen inbred lines with five major sources (BSSS, B73, B14, B37, and BSTE) were categorized into Group I (BSSS group); 19 inbred lines with three major sources (Inra 258, Pfister 44 and Lethbridge Gene Pool) were classified into Group II (European flint group); Group III (Lancaster group) included 15 inbred lines with the major sources of MO17, OH43, LH83, W153 and H99; Group IV (Minnesota #13 group) consisted of seven inbred

31   lines with the major source of Minnesota #13 and Pride 5; Group V (Early Butler group)

32   consisted of seven inbred lines; Group VI (Iodent group) consisted of four inbred lines;

33   Group VII (Pioneer 3990 group) consisted of 11 inbred lines; Group VIII (Pioneer 3994

34   group) consisted of 13 inbred lines; and 35 inbred lines with no major sources were classed

35   as Group IX.

36   The 129 inbred lines analyzed with 105 SSR primers were distributed across the 10

37   maize chromosomes, with an average of 10.5 primes per chromosome. A total of 380

38   alleles were detected with 2 to 7 per locus, with an average of 3.62. The results indicated

39   that such variation was significantly associated with the number of alleles detected. Cluster

40   analysis was carried out based on the matrix of genetic similarities using the Unweighted

41   Pair Group Method Using Arithmetic Average clustering algorithm using NTSYS-pc

42   version 2.2 (Exeter Software New York, USA). All the inbred lines were classified into 13

43   groups (Table 1).

44   When comparing the pedigree groups with the SSR groups, the two groupings were

45   basically identical for the majority of the inbred lines (Table 1). The results showed that

46   there were two to six SSR groups per pedigree group, while group VII included two SSR

47   groups and the group VIII included six groups.

48   Ordinations were conducted by using canonical discriminant analysis (Kshirsagar,

49   Multivariate analysis. 1972) and classification probabilities by carrying out classificatory

50   discriminant analyses (Fig. 1). The analyses were performed using SAS (SAS Institute, Inc

51   1989) version 9.1.3 (2007). Comparing the groups based on the discriminant analysis of

52   SSR data with the pedigree groups, the inbred lines in the ninth pedigree group with

53   unknown sources were classified into eight other groups (Table 1), some inbred lines in the

54   same pedigree group were classified into different groups. According to the cross-

55   validation results, this classification was 94.7% probability reliable.

56   We are currently conducting further classification analysis based on combining

57   ability data of these inbreds with testers of known heterotic patterns.

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58   Table 1. Major pedigree and three types of classifications of 129 maize inbred lines

59   released by AAFC (inbreds prefixed with CB, CL, CM or CO) and several check inbreds.

Inbred	Major pedigree	Pedigree group†	Discriminant analysis group‡	SSR cluster group§
B73	BSSS/B73	I	I	I
CM105	B14	I	I	II
CM174	B14	I	I	II
CO269	BSSS	I	I	XII
CO360	B37/B14/Minnesota#13	I	I	II
CO362	B14	I	I	II
CO363	B14	I	I	II
CO364	B14	I	I	XII
CO370	BSTE	I	I	VI
CO388	B73/BSTE/Early Butler	I	I	XII
CO389	B73/BSTE/Early Butler	I	I	IX
CO408	B37/Pfister44	I	I	XII
CO434	B14	I	I	II
CO435	B14	I	I	XII
CO439	BSSS	I	I	II
LH300	B14	I	I	II
MBS1236	B14/Pioneer 3978	I	I	VI
TR4033	B14	I	I	II
CL30	European flint	II	II	V
CO251	Pfister44/Early Butler	II	II	XII
CO255	Inra 258	II	II	XIII
CO343	MO17/Inra 258	II	III	XII
CO344	MO17/Inra 258	II	II	XII
CO345	Pfister44/Inra 258/OH43	II	II	XIII
CO349	Inra 258/B14	II	II	XII
CO365	Pfister44/BSSS	II	II	XII
CO382	Inra 258/MO17	II	II	XIII
CO383	Inra 258/MO17	II	II	XII
CO384	Inra 258/B14	II	II	XII
CO409	Inra 258/Pioneer 3977	II	II	XIII
CO412	Inra 258/OH43/B14	II	II	XII
CO414	Inra 258/B14	II	II	XII
CO416	Pfister 44/B14	II	II	II
CO418	European hybrids	II	II	VI
CO422	Inra 258/OH43/B14	II	II	XII
CO437	European hybrids	II	II	VII
LH290	Pioneer 3978/F2	II	II	XIII
CO359	W153R/LH82	III	III	VI
CO367	W153R/LH82	III	III	VI
	W153R/LH82	III	III	VI

CO369	W153R/LH82	III	III	VI
CO386	MO17/MAG	III	I	IV
CO390	H99/OH43	III	III	XIII
CO393	Pioneer 3990/MO17	III	III	IV
CO394	Pioneer 3990/MO17	III	III	IV
CO395	Pioneer 3990/MO17	III	III	IV
CO427	OH43/H99	III	III	IV
CO428	OH43/H99	III	V	XII
CO429	W153R/LH82	III	III	VI
LH176	LH82/Pioneer 3704	III	III	XIII
Mo17	MO17	III	III	IV
OH43	OH43	III	III	XIII
CB21	Pfister 44/Minnesota #13	IV	IV	III
CO106	Minnesota #13	IV	IV	X
CO303	Pride 5/BSSS	IV	IV	XII
CO328	Pride 5/BSSS	IV	IV	XII
CO350	Pride 5/Pioneer 3977	IV	IV	III
CO415	Pride 5/Pioneer 3968	IV	IV	III
CO440	Pride 5/BSSS	IV	IV	III
CO220	Early Butler	V	V	IX
CO325	Early Butler/BSSS	V	V	V
CO346	Early Butler	V	V	XI
CO361	BSSS/BSTE/Early Butler	V	VII	XII
CO387	Pioneer 3990/BSTE/ Early Butler	V	V	IV
CO424	BSSS/ Early Butler	V	V	XII
CO443	BSSS/ Early Butler	V	V	IX
CO421	Iodent/F2	VI	VI	III
CO442	Iodent	VI	VI	III
LH162	Iodent/MO176	VI	VI	IV
TR1957	Iodent	VI	VI	VI
CO266	Pioneer 3990	VII	VII	IV
CO289	Pioneer 3990	VII	VII	IV
CO377	Pioneer 3990	VII	VII	XII
CO378	Pioneer 3990	VII	VII	IV
CO380	Pioneer 3990	VII	VII	IV
CO381	Pioneer 3990	VII	VII	XII
CO396	Pioneer 3990/Inra 258/BSSS	VII	VII	XII
CO397	Pioneer 3990/Inra 258/BSSS	VII	VII	IV
CO398	Pioneer 3990/Inra 258/BSSS	VII	VII	IV
CO406	Pioneer 3990	VII	VII	XII
CO407	Pioneer 3990	VII	VII	IV
CB12	Pioneer 3994	VIII	VIII	III
CO341	BSSS/Pioneer 3994	VIII	VIII	V
CO366	Pioneer 3994/Minnesota #13	VIII	VIII	III
CO375	Pioneer 3994/Minnesota #13	VIII	VIII	XII
CO376	Pioneer 3994/Minnesota #13	VIII	VIII	III
CO403	Pioneer 3994/Minnesota #13	VIII	VIII	XII
CO404	Pioneer 3994/Minnesota #13	VIII	VIII	XIII
CO405	Pioneer 3994/Minnesota #13	VIII	VIII	XIII
CO410	BSSS/Pioneer 3994	VIII	VIII	VI

CO417	Pioneer 3994/Minnesota #13	VIII	VIII	IV
CO425	BSSS/ Pioneer 3994	VIII	VIII	VI
CO436	Pioneer 3994/Minnesota #13	VIII	VIII	III
CO438	Pioneer 3994/Unknown	VIII	VIII	III
CO253	Unknown	IX	II	V
CO342	Unknown/Ottawa	IX	III	VII
CO347	Unknown	IX	III	VIII
CO348	Unknown	IX	VI	VI
CO351	Unknown/Ottawa	IX	V	VII
CO352	Asgrow RX777	IX	I	I
CO353	Asgrow RX777	IX	I	XII
CO354	Asgrow RX777	IX	I	I
CO355	Pioneer 3389	IX	III	I
CO356	Pioneer 3389	IX	V	I
CO357	Pioneer 3389	IX	III	IV
CO358	Pioneer 3389	IX	V	XII
CO371	Unknown	IX	IV	VIII
CO372	Unknown	IX	II	XIII
CO373	Unknown	IX	IV	XIII
CO374	Unknown	IX	II	VIII
CO379	Unknown	IX	V	III
CO385	Unknown	IX	II	VI
CO391	Asgrow RX777	IX	I	I
CO392	Ottawa	IX	II	XII
CO399	Pioneer 3925	IX	IV	VI
CO400	Pioneer 3925	IX	IV	VI
CO401	Unknown	IX	VIII	V
CO402	Unknown	IX	VIII	VII
CO411	Pioneer 3995	IX	II	III
CO413	Pioneer 6124/Pioneer 3968	IX	VII	V
CO419	Unknown	IX	IV	V
CO420	Unknown	IX	VI	V
CO423	Unknown	IX	V	III
CO426	Unknown	IX	III	VI
CO430	Unknown	IX	VII	IV
CO431	Unknown	IX	VI	IV
CO432	Unknown	IX	IV	VI
CO433	Pride K127	IX	IV	VI
CO441	Unknown	IX	III	VI

60 † Groups based on the pedigree.

61 ‡ Groups based on the discriminant analysis of SSR data.

62 § Groups based on the genetic similarities using the Unweighted Pair Group Method Using Arithmetic
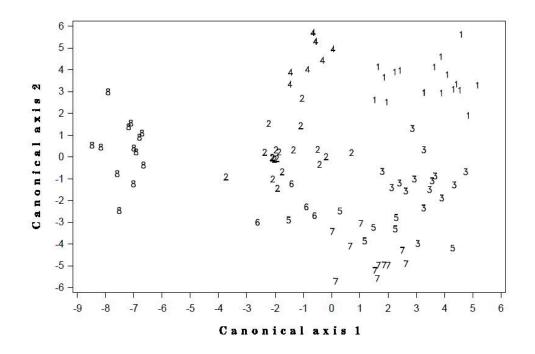
63 Average clustering algorithm.

64

65   Fig. 1 Canonical discriminant analyses of the SSR markers. 1 = BSSS group; 2 = European

66   flint group; 3 = Lancaster group; 4 = Minnesota #13 group; 5 = Early Butler group; 6=

67   Iodent group; 7= Pioneer3990 group; 8= Pioneer 3994 group.