FINAL REPORT

PROJECT NUMBER		M191/10
PROJECT TITLE		Maize breeding: Inbred line development
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PROJECT STATUS		Continue under project M191/13
DURATION		01/04/2006 to 31/03/2009

ABSTRACT

Maize breeding is a never-ending challenge of developing new inbred lines with improved combining ability for yield, as well as tolerance to a diverse spectrum of biotic and abiotic stress conditions, e.g. diseases, pests, low soil fertility and drought. New cultivars must also conform to changing industry requirements like grain quality for milling and ethanol production. Climatic changes, like global warming, set new challenges for breeders to develop inbred lines that will adapt to changing environmental factors. The objective of the project was to develop inbred lines with good combining ability for grain yield, prolificacy and drought tolerance. This development was done within the standard heterotic patterns contained among I137TN, US Reid and US Lancaster to ensure that heterosis as an additional drought tolerant component is captured simultaneously. These heterotic groups have over the past 30 years played a significant role in South Africa in the development of hybrid cultivars by commercial companies. Prolificacy and earliness, in combination with drought tolerance, are two of various economically important agronomic traits sought after, particularly in the drier production areas where maize is produced at lower plant densities. Emphasis was placed on prolificacy and tolerance to heat desiccation as primary selection criteria for drought tolerance. Standard maize crossing procedures for the development of inbred lines were performed. These included cross pollination, self pollination and back-crossing procedures. Field evaluation for tolerance to heat desiccation in the inbred-line development programme was performed during periods of drought and heat stress. Field evaluations were followed by greenhouse evaluation of the chlorophyll performance index of the selected lines. Elite inbred lines that have shown tolerance to extreme conditions have been supplied on a regular basis to commercial seed companies, via SANSOR, for possible commercialisation and subsequent royalty payments by the seed companies to the ARC. The maize breeding programme has contributed significantly to the commercial maize seed sector and direct benefits to ARC are forthcoming with regard to the earning of royalties. For example, during January 2007 SANSOR reported that five previously released inbred lines from ARC-GCI were used in nine different commercial hybrids marketed by three different commercial companies. Royalties to the amount of R255 584 were earned by the ARC on these five inbred lines. The

breeding programme is continuing under Project M191/13: Development of maize inbred lines and cultivars, funded by the Maize Trust and ARC.

KEYWORDS

Heterosis, combining ability, DNA fingerprinting, DNA markers, diallel crosses, drought tolerance, prolificacy, earliness.

INTRODUCTION

The project is a continuation of a classic hybrid maize breeding project which was started ca. 1940 by the National Department of Agriculture. The aim was to develop inbred maize lines for incorporation into maize hybrid cultivars. This was done to replace the low yielding open-pollinated maize cultivars which were used in the early days of maize production in South Africa. From this project were developed the first inbred lines incorporated into maize hybrids in South Africa, ca. 1950, by the Department of Agriculture. Since the inception of this national programme, it has over the years, until at present, contributed significantly to the continuous supply of newly improved maize inbred lines for use in commercial hybrid seed production.

Maize breeding is a never-ending challenge of developing new inbred lines with improved combining ability for yield, as well as tolerance to a diverse spectrum of biotic and abiotic stress conditions, e.g. diseases, pests, low soil fertility and drought. New cultivars must also conform to changing industry requirements like grain quality for milling and ethanol production. Climatic changes, like global warming, set new challenges for breeders to develop inbred lines that will adapt to changing environmental factors.

Breeding continuity over long periods of time is needed to keep pace with changing industry requirements and adaptation to new biotic and abiotic stress factors. The germplasm base will be strengthened. Through the constant development of improved inbred lines, hybrid cultivars will keep pace with changing industry requirements, as well as increase in tolerance to various biotic and abiotic stress factors.

The long-term objectives were to:

1. Develop new inbred lines by standard conventional techniques as well as marker assisted molecular breeding for release to the commercial seed industry,
2. Test cross new inbred lines in isolation crossing blocks with elite tester parent lines, and
3. Develop a market related inbred breeding programme, with emphasis on the practical utilisation of the inbred lines in commercial hybrids.

MATERIALS AND METHODS

The standard pedigree breeding, inbred line development and combining ability testing procedures were used. These were supplemented by DNA testing procedures e.g. identification of gene markers, marker assisted selection and fingerprinting to protect the intellectual property of the ARC.

Major selection pressure was placed on earliness and prolificacy because of the drought tolerant advantages associated with these two traits. Emphasis was placed on using and improving the I, K and CB heterotic groups, which were developed by ARC-GCI, and play a prominent role in South African commercial maize hybrids. Selected inbred lines were released to the commercial seed industry through SANSOR who handle the necessary licensing contracts, as well as collect royalties on behalf of the ARC.

RESULTS

Tables 1, 2 and 3 display the most recent inbred line releases to the commercial seed industry, depicting their favourable traits and heterotic classification.

The 56 inbred lines in Table 1 were released to the commercial seed industry specifically for combining ability between the US Corn Belt's Reid and Lancaster groups and the South African I137TN heterotic groups.

TABLE 1. PROLIFIC DROUGHT TOLERANT WHITE MAIZE INBRED LINES RELEASED BY ARC-GCI

NO.	HETEROTIC GROUP	INBRED NO.	PEDIGREE
1	I137TN	I9	ISYN3-3-B-1
2	I137TN	I16	ISYN3-3-B-8
3	I137TN	I20	ISYN4-4-B-1
4	I137TN	I34	ISYN6-1-B-1
5	I137TN	I35	ISYN6-1-B-2
6	I137TN	I36	ISYN6-2-B-1
7	I137TN	I37	ISYN6-2-B-2
8	I137TN	I38	ISYN6-2-B-3
9	I137TN	I39	ISYN6-2-B-4
10	I137TN	I40	ISYN6-2-B-5
11	I137TN	I41	ISYN6-2-B-6
12	I137TN	I42	ISYN6-2-B-7
13	I137TN	I43	ISYN6-2-B-8
14	I137TN	I57	ISYN6-7-B-5
15	US CORN BELT	CB200	CBS3-4-1-B-4
16	US CORN BELT	CB222	CBS3-7-1-B-1
17	US CORN BELT	CB224	CBS3-7-2-B-1
18	US CORN BELT	CB232	CBS3-8-2-B-1
19	US CORN BELT	CB235	CBS3-8-2-B-4
20	US CORN BELT	CB236	CBS3-8-2-B-5
21	US CORN BELT	CB237	CBS3-8-2-B-6
22	US CORN BELT	CB239	CBS3-10-1-B-2
23	US CORN BELT	CB255	CBS3-11-1-B-2
24	US CORN BELT	CB260	CBS3-11-1-B-7
25	US CORN BELT	CB293	CBS4-1-2-B-4
26	US CORN BELT	CB295	CBS4-1-2-B-6
27	US CORN BELT	CB299	CBS4-4-1-B-1
28	US CORN BELT	CB300	CBS4-4-1-B-2
29	US CORN BELT	CB301	CBS4-4-1-B-3
30	US CORN BELT	CB310	CBS4-4-2-B-6

31	US CORN BELT	CB315	CBS4-4-4-B-1
32	US CORN BELT	CB316	CBS4-4-4-B-2
33	US CORN BELT	CB323	CBS4-4-6-B-3
34	US CORN BELT	CB327	CBS4-5-1-B-1
35	US CORN BELT	CB331	CBS4-5-2-B-1
36	US CORN BELT	CB332	CBS4-5-2-B-2
37	US CORN BELT	CB333	CBS4-5-2-B-3
38	US CORN BELT	CB334	CBS4-5-2-B-4
39	US CORN BELT	CB335	CBS4-6-2-B-1
40	US CORN BELT	CB343	CBS4-7-1-B-1
41	US CORN BELT	CB344	CBS4-7-1-B-2
42	US CORN BELT	CB348	CBS4-7-2-B-3
43	US CORN BELT	CB349	CBS4-7-2-B-4
44	US CORN BELT	CB352	CBS4-8-1-B-1
45	US CORN BELT	CB353	CBS4-8-1-B-2
46	US CORN BELT	CB355	CBS4-8-1-B-4
47	US CORN BELT	CB356	CBS4-8-1-B-5
48	US CORN BELT	CB378	CBS4-13-4-B-1
49	US CORN BELT	CB379	CBS4-13-4-B-2
50	US CORN BELT	CB380	CBS4-13-4-B-3
51	US CORN BELT	CB384	CBS4-15-1-B-1
52	US CORN BELT	CB386	CBS4-15-1-B-3
53	US CORN BELT	CB388	CBS4-15-2-B-2
54	US CORN BELT	CB394	CBS5-3-2-B-1
55	US CORN BELT	CB400	CBS5-5-1-B-1
56	US CORN BELT	CB406	CBS6-3-1-B-1

The white inbred lines in Table 2 were released specifically for their tolerance to the major leaf diseases *Helminthosporium turcicum*, Grey leaf spot, maize streak virus (MSV) and *Puccinia sorghi.*

TABLE 2. DISEASE TOLERANT WHITE MAIZE INBRED LINES RELEASED BY ARC-GCI

No.	Line Code	Heterotic Group
1	CN05P/579	I R119W
2	CN06/442	I R119W
3	CN06/443	I R119W
4	CN06/444	I R119W
5	CN06/445	I R119W
6	CN06/447	I R119W
7	CN06/453	I R119W
8	CN06/454	I R119W
9	CN06/456	I R119W
10	CN06/458	I R119W
11	CN06/462	I R119W
12	CN06/464	I R119W
13	CN06/466	I R119W
14	CN06/472	I R119W
15	CN06/474	I R119W
16	CN06/477	I R119W
17	CN06/489	I R119W
18	CN06/491	I R119W
19	CN06/497	I^{1}.CB(L).VH
20	CN06/498	I^{1}.CB(L).VH
21	CN06/502	I^{1}.CB(L).VH
22	CN06/506	I^{1}.CB(L).VH
23	CN06/510	I^{1}.CB(L).VH
24	CN06/512	I^{1}.CB(L).VH
25	CN06/514	I^{1}.CB(L).VH
26	CN03P/119(184-2)	CB(R).SAH
27	CN04P/659(253-3)	REGOP.CB.TROP
28	CN04P/654(253-1)	REGOP.CB.TROP
29	CN04P/663(369-1)	REGOP.CB.TROP
30	CN04P/694(J10)	Cimmyt re-sel CJ10
31	CN05P/574(JD)	Cimmyt re-sel CJD
32	CN06P/541(JDOC)	Cimmyt re-sel CJDOC
33	CN06/524	F
34	CN06/531	F
35	CN06/535	F

36	CN06/537	F
37	CN06/546	REGOP.CB/CB(L)
38	CN06/548	CB(R).REGOP/CB(L)
39	CN06/550	CB(R).REGOP/CB(L)
40	CN06/556	CB.VH.CB.TROP/CB(L)
41	CN06/565	REGOP.CB.TROP/M

The 74 yellow inbred lines in Table 3 were also released on the basis of their tolerance to the major maize leaf diseases *H. turcicum*, Grey leaf spot, MSV and *P. sorghi*.

TABLE 3. DISEASE TOLERANT YELLOW MAIZE INBRED LINES RELEASED BY ARC-GCI

No.	Line Code	Heterotic Group
1	CN05P/87	I R2565Y
2	CN06/26	I R2565Y
3	CN06/28	I R2565Y
4	CN06/31	I R2565Y
5	CN06/38	I R2565Y
6	CN06/47	I R2565Y
7	CN06/51	I R2565Y
8	CN06/54	I.ICB(R)
9	CN05/857	I.ICB(R)
10	CN06/65	I.ICB(R)
11	CN06/67	I.ICB(R)
12	CN06/68	I.ICB(R)
13	CN06/77	I.ICB(R)
14	CN06/78	I.ICB(R)
15	CN06/97	I.ICB(R)
16	CN06/100	I.ICB(R)
17	CN06/112	I.ICB(R)
18	CN06/128	I R2565Y
19	CN05P/6	I R2565Y
20	CN05P/10	I R2565Y
21	CN05P/12	I3.M
22	CN05P/819(521)	I.CB.I
23	CN04P/653(523)	I.CB(R).I
24	CN04CB/205(521)/RY	I.CB.I/I
25	CN04CB/207(523)/RY	I.CB(R).I/I
26	CN04P630(106-3/61)	I.CB(R).M
27	CN04P627(106-3/59)	I.CB(R).M
28	CN04P623(106-1/52)	I.CB(R).M
29	CN04CB/112(106-3/61)/72-	I.CB(R).M/IM
30	CN04CB/111(106-3/59)/72-	I.CB(R).M/IM
31	CN04CB/108(106-1/52)/72-	I.CB(R).M/IM
32	CN05P/920(72-3)	I.M
33	CN05P/918(72-2B)	I.M
34	CN05P/924(182-2)	CB(R).SAH
35	CN05P/928(185-2)	CB(R).SAH

36	CN03P/119(184-2)	CB(R).SAH
37	CN06P/433(203-4)	CB(R).M
38	CN05P/75	K1.M.HtN
39	CN04P/27	K.M.HtN
40	CN05P/53	M1.Australia
41	CN05P/901	M.HtN
42	CN05P/895	M.HtN
43	CN05P/903	M.HtN
44	CN05P/905	M.Ht
45	CN04P/17	F
46	CN05P/35	F2.M
47	CN05P/849(253-3)	REGOP.CB.TROP
48	CN06/156	I.M
49	CN06/157	I.M
50	CN06/160	I1.M
51	CN06/161	I1.M
52	CN06/170	I1.M
53	CN06/177	I1.M
54	CN06/186	I.M/CB(L)
55	CN06/188	I.M/CB(R)
56	CN06/192	I.M/CB(L)
57	CN06/193	I.M/CB(L)
58	CN06/194	I.M/CB(L)
59	CN06/197	I.M/CB(L)
60	CN06/201	I.M/CB(L)
61	CN06/212	I.CB(R).M/CB(L)
62	CN06/217	I.CB(R).M/CB(L)
63	CN06/221	REGOP.CB.TROP/CB(L)
64	CN06/223	CB(R).SAH/CB(L)
65	CN06/234	CB(R).SAH/CB(L)
66	CN06/235	CB(R).SAH/CB(L)
67	CN06/242	M/CB(L)
68	CN06/244	I.CB(R).I/CB(L)
69	CN06/248	I.CB(R).I/CB(L)
70	CN06/250	I.CB(R)/CB(L)
71	CN06/256	I.CB(R)/CB(L)
72	CN06/261	I.CB(R)/CB(L)
73	CN06/266	I.CB(R)/CB(L)
74	CN06/273	CB(R)/I

DISCUSSION

New inbred lines have been supplied on a regular basis to commercial seed companies for commercialisation. ARC-GCI is seen as a foundation seed provider and its inbred lines are sought after due to their adaptability, drought tolerance and high levels of disease resistance. It is estimated at this stage that approximately 45% of the maize hybrids in South Africa contain genetic material originating from ARC-GCI's maize breeding and yield testing programmes.

The impact of the contribution to the maize industry and economic justification of the project can be summarized as follows:

1. Improvement in the combining ability of inbred lines for grain yield.
2. Improved drought tolerance, drought being the major yield limiting factor in South Africa.
3. Improved tolerance to maize diseases and insect damage.
4. Improvement in grain quality traits required by industry.
5. Commercialization of the research products on a royalty basis in collaboration with the commercial maize seed industry.
6. Eventual improvement of food security and financial benefits for all stakeholders.

The maize breeding programme has contributed significantly to the commercial maize seed sector and direct benefits to ARC are forthcoming with regard to the earning of royalties. For example, during January 2007 SANSOR reported that five previously released inbred lines from ARC-GCI were used in nine different commercial hybrids marketed by three different commercial companies. Royalties to the amount of R255 584 were earned by the ARC on these five inbred lines. It is firmly believed that the project will continue to make a significant contribution to the South African maize industry with ARC deriving direct benefits in the form of royalties, provided the merged project can proceed without financial obstacles and can be maintained in a satisfactory manner. The breeding project is continuing under Maize Trust project M191/13: Development of maize inbred lines and cultivars.

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ACKNOWLEDGEMENTS

The ARC-Grain Crops Institute wishes to thank the Maize Trust for their continued financial support of this project over many years.