Paper 13

PROSPECTS OF BREEDING MAIZE CULTIVARS SPECIFICALLY FOR NEW ZEALAND CONDITIONS

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INTRODUCTION

Cultivars of maize (*Zea mays* L.) used in mechanized agriculture in New Zealand are hybrids derived from the Corn Belt Dent race. In some isolated parts of the country, small areas of open-pollinated varieties derived from other races are still grown, but their use is declining and many of these open-pollinated varieties may soon become extinct (Rhodes and Eagles, 1984).

Hybrids derived from the Corn Belt Dent race are used extensively for maize production in temperate regions of the world (Goodman, 1976; Hallauer and Miranda, 1981). Inbred lines used to produce these hybrids have been developed in the U.S.A., Canada, Europe, Argentina and elsewhere, but most of the lines used in hybrid production in New Zealand were developed in the Corn Belt of the U.S.A.

The New Zealand maize industry could continue to depend on inbred lines developed from the Corn Belt Dent race in the U.S.A. Inbred lines developed overseas from other races could also be used. Another alternative is to develop inbred lines specifically for New Zealand conditions using Corn Belt Dent and other races.

In this paper we will discuss the adaptation of Corn Belt Dent hybrids to New Zealand and the reasons for including other races in a programme to breed cultivars specifically for New Zealand conditions. Later, we will outline the progress made by our programme, but firstly, we will digress to briefly review the breeding of Corn Belt Dent hybrids in the U.S.A.

BREEDING CORN BELT DENT HYBRIDS

Extensive breeding programmes to produce hybrid cultivars have been conducted in the U.S.A. for the past 60 years. Initially, inbred lines used to produce the hybrids were derived directly from open-pollinated varieties, especially Reid's Yellow Dent, Funk's Yellow Dent and Lancaster Sure Crop (Goodman, 1976). Later, synthetics produced by intercrossing selected inbred lines or planned crosses among inbred lines were used as sources of improved inbred lines (Hallauer and Miranda, 1981). This breeding effort continues to produce hybrids with higher yields, improved resistance to lodging and improved resistance to diseases and insect pests, especially at high plant densities (Russell, 1974; Duvick, 1977).

CORN BELT DENT MAIZE IN NEW ZEALAND

Average grain yields of Corn Belt Dent hybrids are usually higher in New Zealand than in the U.S. Corn Belt (Kerr, 1975). However, these hybrid cultivars were developed for a region with a continental climate characterised by high summer temperatures. Summer temperatures at Ruakura, in the major maize growing region of New Zealand, are much lower than those at Madison, Wisconsin, which is typical of the northern Corn Belt of the U.S.A. to where most hybrids currently grown in New Zealand are adapted (Table 1). Reduced maize yields in New Zealand have been associated with cool seasons (McCormick, 1979; Eagles and Sinclair, 1983), which suggests that cultivars developed for a cooler growing season than the U.S. Corn Belt would produce higher and more stable grain yields in New Zealand.

Table 1: Mean monthly maximum and minimum temperatures (°C) during the maize growing seasons of Ruakura, New Zealand and Madison, Wisconsin, U.S.A.

Ruakura[1]			Madison[2]		
Month	Max.	Min.	Month	Max.	Min.
Nov.	19.9	8.9	May	20.7	7.5
Dec.	22.0	10.6	June	26.2	13.2
Jan.	23.5	11.5	July	29.8	15.7
Feb.	24.0	12.0	Aug.	28.4	14.6
Mar.	22.6	10.6	Sept.	23.1	10.3
Apr.	19.8	8.3	Oct.	16.3	4.2

[1] 1930-1970. Source: Anon (1973).
[2] 1921-1950. Source: Waite (1960).

Corn Belt Dent hybrids possess adequate resistance or tolerance to most diseases and insect pests of the U.S. Corn Belt. Generally, these levels of resistance are adequate in New Zealand, or the diseases or insect pests can be economically controlled by fungicides or insecticides.

However, root rots initiated by fungi of the genus *Rhizoctonia* may be an exception. These root rots have caused economically important yield losses in New Zealand (Fowler, 1985) but are not considered a problem in the U.S. Corn Belt. This suggests that in New Zealand, cultivars with a higher level of resistance to *Rhizoctonia* would be desirable and that these are unlikely to be produced by maize breeders in the U.S.A.

The time interval between physiological maturity and low enough grain moisture levels for efficient harvesting is usually less than one month in the U.S. Corn Belt (Schmidt and Hallauer, 1966). In the cooler maize growing regions of New Zealand, a period in excess of 3 months is required in some seasons. Furthermore, drying costs, which depend on the moisture content of the grain, can exceed 10% of the value of the grain in New Zealand. This implies that hybrids which can stand in the field for long periods without lodging and dry rapidly after reaching physiological maturity are required.

SOURCES OF TOLERANCE TO COOL CONDITIONS

Over the past 8 years we have conducted a programme to identify useful sources of genes for improving the yield level of maize in cool environments. Races such as Conico from the highlands of Mexico emerge more rapidly and more reliably from cool soil than Corn Belt Dent (Eagles and Brooking, 1981). Races such as San Geronimo from the highlands of Peru have a lower temperature threshold for autotrophic, or photosynthetically-based growth than Corn Belt Dent hybrids (Hardacre and Eagles, 1980). The early maturing race, Confite Puneno, from very high altitudes of Peru, has a superior resistance to chilling temperatures near 0 °C (Hetherington *et al.*, 1983).

The Highland Early Yellow Dent population (Pool 5), developed by CIMMYT in Mexico for highland areas of the tropics (CIMMYT, 1974), has been especially valuable to our programme. Lines and families from this population have shown outstanding seedling growth under cool controlled-environment conditions (Eagles and Hardacre, 1979a and b; Eagles *et al.*, 1983). Furthermore, in experiments reported by Eagles *et al.* (1983), testcrosses of one line from Pool 5 (5-514-1) produced higher grain yields at both Palmerston North and Gisborne than hybrids produced by crossing Corn Belt Dent inbred lines to the same testers. Unfortunately, 5-514-1 has been difficult to inbreed but is being utilized as a source of genes for high yield.

Two promising inbred lines already developed from Pool 5 are NZ1A and NZ1C. These two inbred lines were derived by self-pollination of the progeny of the line 5-154, a line selected from Pool 5 for its rapid and reliable seedling growth under cool conditions (Eagles and Hardacre, 1979b; Eagles, 1982). These lines have thick leathery leaves, a low tassel branch number, conical ears, pale yellow kernels and strongly pigmented, pubescent stems. Except for kernel colour, NZ1A and NZ1C have all the characteristics of the Conico race.

Hybrids produced by crossing the extensively used Corn Belt Dent inbred line A632Ht, with NZ1A, A659, A619Ht and H99 were included with the commercial hybrid Pioneer brand 3709, in grain yield evaluation trials in the Manawatu in the 1980-81, 1981-82, 1982-83 and 1983-84 seasons. A632Ht x A619Ht was widely-grown hybrid in the northern U.S. Corn Belt, and A632Ht x A659 has a high yield potential in that area (J.L. Geadelmann, University of Minnesota, personal communication), while A632Ht x H99 is a hybrid with a high yield potential under U.S. conditions (W.A. Russell, Iowa State University, personal communication).

A632Ht x NZ1A produced mean grain yields in excess of those produced by A632Ht x A659 and A632Ht x A619Ht in all seasons and in the extremely cool 1982-83 season this difference was statistically significant (Table 2). The grain moisture level of A632Ht x NZ1A was intermediate between A632Ht x A659 and A632Ht x A619Ht (Table 2), but in the cool 1982-83 season the grain moisture level of A632Ht x NZIA was significantly lower than for all other hybrids. These results indicate that NZ1A

Table 2: Mean grain yields of six hybrids grown in the Manawatu for four seasons and mean grain moistures of the six hybrids across seasons. (Two row plots with a harvest area of 5.34 m² in a randomized complete block design with 3 replications in each season. Plant density 71,000 plants/ha. Grain yield as tonnes/ha at 15% moisture. Grain moisture at harvest.)

Hybrid	Grain yield 1980-81	1981-82	1982-83	1983-84	mean	Grain moisture
		t/ha				%
A632Ht x NZ1A	13.3	12.6	7.4	12.0	11.3	26.8
A632Ht x A659	11.2	12.3	6.4	11.6	10.4	25.9
A632Ht x A619Ht	11.1	12.5	5.9	11.0	10.1	29.8
A632Ht x H99	13.6	13.9	7.1	12.1	11.7	28.2
A632Ht x BSD	13.9	13.5	7.1	11.0	11.4	28.2
Pioneer brand 3709	13.8	13.1	6.5	11.8	11.3	31.7
Mean	12.8	13.0	6.7	11.6	11.0	28.4
L.S.D. (P = 0.05)	1.7	1.6	0.7	0.9	0.9	2.2

possesses highly desirable genes for improving grain yields of maize in the cooler maize-growing regions of New Zealand, especially in seasons with below average temperatures. Further trials are being conducted at Palmerston North and Pukekohe in the 1984-85 season using hybrids produced by crossing NZ1A and its sister line, NZ1C, with six Corn Belt Dent inbred lines of diverse genetic background.

SOURCES OF RESISTANCE TO ROOT ROT

A programme to identify sources of resistance to *Rhizoctonia* root rot was started by DSIR in 1978. Using both glasshouse and field procedures, Dr M. Fowler, of Plant Diseases Division, identified an unreleased inbred line from the U.S.A. as having a worthwhile level of resistance. This line has been given the code "BSD".

To the best of our knowledge this line has never been used to produce commercial hybrids in the U.S.A. Nevertheless, under Manawatu conditions the hybrid A632Ht x BSD produces comparable grain yields to A632Ht x H99 and Pioneer brand 3709, and approximately 10% higher grain yields than A632Ht x A619Ht and A632Ht x A659 (Table 2). Root lodging levels were low in the Manawatu experiments. From testcross evaluation data produced in Minnesota (Gaedelmann, personal communication) A632Ht x BSD was expected to produce grain yields approximately 15% below those of A632Ht x A619Ht and A632Ht x A659. This suggests that A632Ht x BSD is better adapted to the cool Manawatu climate than either A632Ht x A619Ht or A632Ht x A659. Alternatively, root rots may reduce grain yields in the Manawatu even when there are no visible symptoms of root lodging and BSD increases grain yields by reducing the level of root rot in its hybrids.

SOURCES OF RAPID GRAIN DRYING

Genetic differences for grain drying rate in the field have long been known to maize breeders in the U.S.A. (Hallauer and Russell, 1962). To improve grain drying rates in New Zealand, we have concentrated our crossing effort on inbred lines which are known to produce fast drying hybrids in the U.S.A.

BREEDING OBJECTIVES

The objective of the DSIR maize breeding programme is to produce hybrid cultivars with higher and more stable grain yields in New Zealand than hybrid cultivars from the U.S.A. We anticipate that hybrids with higher and more stable yields in New Zealand will have faster growth rates under cool conditions than hybrids introduced from the U.S.A. and for some areas will have higher levels of resistance to *Rhizoctonia*.

With limited resources available, we have emphasized the production of full-season hybrids for the Waikato, with a small effort toward the production of earlier maturing hybrids for use as full-season cultivars in the Manawatu or late-sown cultivars in the Waikato. No effort has been made to produce hybrids early enough for the South Island or late enough for use as full-season cultivars in the Gisborne district.

To achieve our objective without sacrificing the gains made by 60 years of maize breeding in the U.S.A., we decided to use an introgression, or backcross breeding, approach. Basically, we are attempting to improve the adaptation to cool conditions of elite Corn Belt Dent inbred lines or synthetic populations, while maintaining the desirable characteristics of these inbred lines or populations. Because the objective of our programme is to produce hybrid cultivars, synthetic populations are regarded solely as sources of inbred lines.

BREEDING PROGRESS

Planned crosses

Planned crosses have been made in an attempt to produce inbred lines with commercial potential within a 10 to 12 year time period. Usually these crosses have involved a cross between an elite Corn Belt Dent inbred line (A632Ht, B73, Mo17Ht, H99 etc.) and a partially or fully inbred line from CIMMYT Pool 5 (5-514-1, NZ1A, etc.), followed by a backcross to the original Corn Belt line or a cross to a third Corn Belt line. After 1980 BSD has been used extensively because of its resistance to *Rhizoctonia* and recently more emphasis has been placed on the field drying rates of the lines used.

Segregating generations from crosses involving BSD have been self-pollinated at Pukekohe on a field with a high incidence of *Rhizoctonia*. Seed sown on this field is not dusted with a fungicide, instead *Rhizoctonia* inoculum is placed around the seed as it is sown. Both root and stalk lodging in this field have been spectacular. To date, 108 partially inbred lines have been identified which have resistance to *Rhizoctonia* and better early seedling growth under cool conditions than Corn Belt Dent inbred lines. Testcrosses of 60 of these partially inbred lines have been made and will be evaluated for grain yield, lodging resistance and grain moisture levels during the 1984-85 season. Testcrossing of the remaining 48 lines is scheduled for the 1984-85 season and these lines should be evaluated for grain yield in 1985-86.

Segregating generations from most crosses have been self-pollinated in field nurseries at Palmerston North. Selection among and within lines has been practised for root strength, stalk strength and plant health. Later, selection has been practised among lines for early seedling growth in cool controlled-environment rooms and grain yield and lodging have been evaluated in trials at Palmerston North and Pukekohe. The first inbred lines from the programme have been produced and their detailed evaluation in hybrid combination is scheduled to commence in the 1985-86 season. However, based on testcross yield data, the most promising lines are still in the inbreeding phase of the programme.

Synthetic populations

Three synthetic populations have been produced at Palmerston North for long-term maize breeding in New Zealand. These are NZS1, NZS2 and NZS3. NZS1 was produced by crossing Conico with AS-3(HT)C3, then backcrossing to AS-3(HT)C3; NZS2 was produced by crossing San Geronimo with BS22, then backcrossing to BS22; NZS3 was constructed by intercrossing 4 inbred lines of Corn Belt Dent origin (A671, A239, H99 and A658) and 4 partially inbred lines from CIMMYT Pool 5 (5-154, 5-250, 5-536 and 5-514). AS-3(HT)C3 is a Corn Belt Dent synthetic from the University of Minnesota (Peterson *et al.*, 1976) and BS22 is a Corn Belt Dent synthetic from Iowa State Universtiy (W.A. Russell, personal communication). Therefore, NZS1 and NZS2 are 75% Corn Belt Dent germplasm and NZS3 is 50% Corn Belt Dent germplasm.

During the 1983-84 season the five synthetics NZS1, NZS2, NZS3, AS-3(HT)C3 and BS22 plus the hybrid cultivars Pioneer brand 3709 and Pioneer brand 3901 were grown in yield evaluation trials at Palmerston North and Pukekohe. NZS1 produced a significantly higher mean grain yield than its Corn Belt Dent parent, AS-3(HT)C3 (Table 3). Furthermore, for both grain moisture and stalk lodging, the means for NZS1 were lower than those for AS-3(HT)C3, although the differences were not statistically significant. NZS2 produced a higher mean grain yield than its Corn Belt Dent parent, BS22, but the difference was not statistically significant. Unfortunately, NZS2 had a significantly higher grain moisture than BS22. NZS3 was earlier maturing than the other synthetics but more prone to stalk lodging.

Table 3: Mean grain yields, grain moistures and stalk lodging percentages for five synthetic varieties and two hybrids grown at Pukekohe and Aorangi in the 1983-84 season. (Two row plots with a harvest area of 5.34 m² in a randomized complete block design with 5 replications at each site. Site x entry interaction used to calculate L.S.D. Plant density 71,000 plants/ha. Grain yield as tonnes/ha at 15% moisture. Grain moisture and stalk lodging at harvest.)

Synthetic or hybrid	Grain yield t/ha	Grain moisture %	Stalk lodging %
AS-3(HT)C3	11.1	28.9	20.7
BS22	10.5	26.3	16.1
NZS1	13.0	27.7	16.7
NZS2	11.8	28.7	11.8
NZS3	11.7	25.4	28.2
Pioneer brand 3709	13.4	27.1	0.5
Pioneer brand 3901	13.7	22.8	0.3
L.S.D. (P = 0.05)	1.5	1.9	13.3

Synthetic populations, such as the five in our programme, are highly variable and are not expected to be superior to elite hybrids, such as Pioneer brand 3709 and Pioneer brand 3901 for both grain yield and lodging resistance. Only hybrids, produced from a small proportion (less than 1%) of inbred lines obtainable from synthetics, are expected to reach such performance levels. The fact that NZS1 produced a grain yield only 3% less than Pioneer brand 3709 suggests that inbred lines can be selected from NZS1 which should produce hybrid cultivars with much higher grain yield levels than those currently available in New Zealand.

Lodging levels were higher for the synthetics than for the hybrids (Table 3). Currently, we are testing 180 partially inbred lines from NZS1 for grain yield, lodging and grain moisture at harvest, and by 1987 we should know if any of these lines has the ability to produce high yielding, lodging resistant, fast drying hybrids under New Zealand conditions.

CONCLUSION

Grain yields in New Zealand from hybrid cultivars produced from inbred lines developed in the United States are high by world standards. However, information obtained from testcrosses, hybrids and synthetic populations which include genes from highland Mexican races suggests that even higher yields are possible from hybrids which contain combinations of genes from highland Mexican and Corn Belt Dent races.

Modern Corn Belt Dent hybrids have excellent resistance to lodging. Further research is required to determine whether hybrids containing highland Mexican races can be selected with levels of lodging resistance equivalent to the best Corn Belt Dent hybrids.

REFERENCES

Anon. 1973. Summaries of climatological observations to 1970. *New Zealand Meteorological Service Miscellaneous Publication 143.* New Zealand Ministry of Transport, Wellington.

Centro Internacional de Mejoramiento de Maiz y Trigo 1974. *CIMMYT Report on Maize Improvement 1973.* El Batan, Mexico.

Duvick, D.N. 1977. Genetic rates of gain in hybrid maize yields during the past 40 years. *Maydica 22:* 187-196.

Eagles, H.A. 1982. Inheritance of emergence time and seedling growth at low temperatures in four lines of maize. *Theoretical and Applied Genetics 62:* 81-87.

Eagles, H.A., Brooking, I.R. 1981. Populations of maize with more rapid and reliable seedling emergence than Cornbelt Dents at low temperatures. *Euphytica 30:* 755-763.

Eagles, H.A., Hardacre, A.K. 1979a. Genetic variation in maize for early seedling growth in a low temperature environment. *N.Z. Journal of Agricultural Research 22:* 553-559.

Eagles, H.A., Hardacre, A.K. 1979 b. Genetic variation in maize (*Zea mays* L.) for germination and emergence at 10 °C. *Euphytica 28:* 287-295.

Eagles, H.A., Hardacre, A.K., Brooking, I.R., Cameron, A.J., Smillie, R.M., Hetherington, S.E. 1983. Evaluation of a high altitude tropical population of maize for agronomic performance and seedling growth at low temperature. *N.Z. Journal of Agricultural Research 26:* 281-287.

Eagles, H.A., Sinclair, K.I. 1983. Report on commercial maize hybrids 1982-83 season. *Technical Report 17,* Plant Physiology Division, DSIR, Palmerston North.

Fowler, M. 1985. Diseases of maize. In: *Maize; Management to Market. Agronomy Society of N.Z. Special Publication 4:* 59-64.

Goodman, M.M. 1976. Maize. In: *Evolution of Crop Plants.* Ed. N.W. Simmonds, Longman, London: 128-136.

Hallauer, A.R., Miranda Fo., J.B. 1981. *Quantitative Genetics in Maize Breeding,* Iowa State University Press, Ames.

Hallauer, A.R., Russell, W.A. 1962. Estimates of maturity and its inheritance in maize. *Crop Science 2:* 289-294.

Hardacre, A.K., Eagles, H.A. 1980. Comparisons among populations of maize for growth at 13 °C. *Crop Science 20:* 780-784.

Hetherington, S.E., Smillie, R.M., Hardacre, A.K., Eagles, H.A. 1983. Using chlorophyll fluorescence *in vivo* to measure the chilling tolerances of different populations of maize. *Australian Journal of Plant Physiology 10:* 247-256.

Kerr, J.P. 1975. The potential for maize production in New Zealand. *Proceedings Agronomy Society of N.Z. 5:* 65-69.

McCormick, S.J. 1979. The effect of seasonal variation in temperature on the yield of maize in the Waikato and Gisborne regions. *Proceedings Agronomy Society of N.Z. 9:* 93-96.

Peterson, R.H., Geadelmann, J.L., Rinke, E.H., Sentz, J.C. 1976. Registration of six maize germplasm populations. *Crop Science 16:* 605-606.

Rhodes, L.L., Eagles, H.A. 1984. Origins of maize in New Zealand. *N.Z. Journal of Agricultural Research 27:* 151-156.

Russell, W.A. 1974. Comparative performance for maize hybrids representing different eras of maize breeding. *Proceedings Annual Corn and Sorghum Research Conference 29:* 81-101.

Schmidt, J.L., Hallauer, A.R. 1966. Estimating harvest date of corn in the field. *Crop Science 6:* 227-231.

Waite, P.J. 1960. *Climate of Wisconsin.* U.S. Weather Bureau, Washington, D.C.