DEPARTMENT OF AGRICULTURE AND FISHERIES, SOUTH AUSTRALIA

Agronomy Branch Report

STUDY TOUR OF NORTH AMERICA

MARCH - APRIL, 1979

I Brief report on "Plant Breeding Symposium II" held in Ames, Iowa, 12th-16th March.

II Oat Improvement Research in North America.

Mr. A.R. Barr,
Research Officer,
Field Crops Section,
Division of Plant Industry,
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Report No. - 108

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Comments made by each person visited will be entered under the appropriate section.

SECTION I

"Plant Breeding Symposium II"

Iowa State University
Ames Iowa

March 12-16, 1979

Plant Breeding Symposium II was organized by the plant science faculty of Iowa State and sponsored by Iowa State University and private industry. It was a sequel to the Heterosis Conference in 1950 and the Plant Breeding Symposium held in 1965.

The objectives of Plant Breeding Symposium II were (1) to assess the progress made from plant breeding research especially over the past 15 years; (2) to evaluate the past, present, and future contributions of a number of major research areas to plant breeding goals that will be most beneficial to providing greater quantity and better quality of food and fibre for mankind.

To accomplish the first objective, Drs. Normal Borlaug and Glenn Burton enumerated the general progress and contributions that plant breeding has made to providing an adequate food supply for mankind. For the second objective, there were presentations and discussions on germplasm utilization, application of tissue culture to plant improvement, breeding for morphological and physiological traits, selection methods and population improvement, and chromosomal and cytoplasmic manipulations. For the third objective, presentations and discussions were held on breeding for stress and marginal environments, for disease and insect resistance and management, for multiple cropping systems and nutritional quality.

The format of the symposium was

* review of subject area by a plenary speaker
* short contributions by up to 3 other speakers.
* floor discussion aimed at a panel comprising the plenary speaker and other contributors.

The Proceedings of PBSII, which will include the Plenary Speaker and panelist addresses and all discussion, are expected to be available by approximately March 1980.

Programme was as follows:

DATE	TOPIC	PLENARY SPEAKER	PANELISTS
March 12	Selection and breeding methods	A.R. Hallauer SEA-USDA Department of Agronomy Iowa State University Ames, Iowa (Corn)	Dr. R. Hill, USDA, Penn (Alfalfa) Dr. R. Baker, Uni. Saskatchewan (Utility Wheat) Dr. J. MacKey, Uni. Sweden (Small Grains)
March 12	Germplasm collection, preservation and use	J.G. Hawkes Department of Biology University of Birmingham Brimingham, England (Potato)	Dr. Q. Jones, USDA (New Crops) Dr. E. Gerrish, Cargill Inc. (Coarse & Small Grain) Dr. C.M. Rick, U. California (tomato)
March 13	Application of tissue culture and somatic hybridization to plant improvement	R. Riley and E.E. Cocking Plant Breeding Institute Cambridge, England	Dr. E.C. Bashaw, AR-SEA-USDA, Texas (Forage Grasses Dr. K.L. Giles, Iowa State Uni. Dr. T.B. Rice, Pfizer, Conneticut
March 13	Chromosomal and cytoplasmic manipulations	S.J. Peloquin Department of Genetics University of Wisconsin Madison, Wisconsin (Potato)	Dr. E.C. Bashaw, AR-SEA-USDA, Texas (Forage Grasses Dr. J. James, Cimmyt (Maize) Dr. J.R. Laughnan. U. Illinois (Corn *et al.)*
March 14	Breeding plants for stress environments	C.E. Lewis and M.N. Christiansen SEA-USDA Beltsville, Maryland (Cotton & Physiology, respectively)	Dr. M.C. Shannon, Salinity Lab., U.S.A. Dr. S.D. Jensen, Pioneer Hi-Bred (Corn), U.S.A.
March 14	Development of plant genotypes for multiple cropping systems	C.A. Francis Department of Agronomy University of Nebraska Lincoln, Nebraska (Sorghum, Cropping Systems)	Dr. R.M. Lantican, U. Phillipines (Grain Legumes) Dr. R.K. Crookston, U. Minnesota (Crop Phys) Dr. C. Viera, Brazil (Beans, soybeans)

Programme Cont.

DATE	TOPIC	PLENARY SPEAKER	PANELISTS
March 14 (banquet)	International crop breeding	N.E. Borlaug CIMMYT Mexico City, Mexico	
March 15	Breeding for morphological and physiological traits	D. Wilson Welsh Plant Breeding Station Aberystwyth Wales, United Kingdom (Forage grasses)	Dr. R.W. Hardy, Du Pont (N. Fixation) Dr. J.W. Hanover, Michigan State U. (Tree Breeding) Dr. D.C. Rasumsson, U. Minnesota (Barley)
March 15	Control of plant pests by breeding for resistance		
	Breeding plants for insect resistance	J.N. Jenkins SEA-USDA Boll Weevil Research Laboratory Mississippi State, Mississippi (Cotton)	Dr. F.G. Maxwell, U. Florida (General Entomology & Nematology) Dr. W.D. Guthrie, Iowa State U. (Corn Insects)
	Breeding plants for disease resistance	J.E. Parlevliet Institute for Plant Breeding Agricultural University Wageningen, The Netherlands (Barley)	Dr. J.A. Browning, Iowa State U. (Oats Pathology). Dr. R.R. Nelson, Penns. State U. (General Plant Path.)
March 16	Breeding for improved Nutritional quality	J.D. Axtell Department of Agronomy Purdue University West Lafayette, Indiana (Sorghum)	Mrs. W. Martinez, AR-SEA-USDA (Nutrition) Dr. W.H. Gabelmen, Uni. Wilsconsin (Vegetable Breeding) Dr. A.W. Hovin, U. Minnesota (Forage Crops)
March 16	Meeting human needs through plant breeding - Past progress and prospects for the future	G.W. Burton SEA-USDA Georgia Plain Experiment Station Tifton, Georgia (Forage Grasses)	Dr. W.L. Brown, Pioneer Hi-Bred (Maize) Dr. S. Fonseca Martinez, CATIE (Wheat, Barley) Dr. B.J. Zobel, N. Carolina S.U. (Forest Genetics)

SUMMARY I believe that PBS II achieved its stated aims. During the week the entire spectrum of plant breeding was covered and offered one an excellent opportunity to view the profession in a new perspective.

Perhaps just as valuable was the opportunity to meet a large proportion of America's Oat Breeders (plus breeders of other crops) and thereby establish personal contact for the exchange of germplasm and information.

SECTION II

1. Personnel visited

Iowa State University, Ames, Iowa

Prof. K.J. Frey	Oat Breeder
Dr. J.A. Browning	Plant Pathologist mainly oat crown rust
Dr. M.D. Simons	Plant Pathologist mainly oat crown rust
Dr. K.S. Sadanaga	Formerly oat cytogeneticist
Mr. J.P. Murphy (Ph D student	of Frey) *A. sterilis* infusion into *A. sativa* w.r.t. yield improvement.
Mr. Jim Fawcett (Ph D student	of Frey)
Mr. Stan Cox (Ph D student of	Frey) *A. sativa* v's *A. sterilis* protein genes.

University of Wisonsin, Madison, Wisconsin

Dr. R.A. Forsberg	Project leader Oat & barley breeding
Dr. M.A. Brinkman	Oat & barley breeding
Dr. Hazel Shands	Semi-retired oat breeder (formerly in-charge)
Dr. D.M. Peterson	Oat Physiologist
Dr. V.L. Youngs	USDA Nat. Oat Quality Lab. - Leader
Mr. K. Gilchrist	USDA Nat. Oat Quality Lab. - technician

University of Minnesota, St. Paul, Minnestoa

Dr. D. Stuthman	Oat Breeder Project Leader
Dr. P. Rothman	USDA Oat Rusts
Dr. H. Rines	Oat cytogenetics, cell culture
Dr. R. Behrens	USDA Weed Research
Mr. J. Radtke	(Ph D Student D. Stuthman)
Mr. J. Lubey	Ph D Student D. Stuthman)
Mr. T. McKoy	(Ph D Student D. Stuthman)

North Dakota State University, Fargo, North Dakota

Dr. M.S. McMullen	Oat Breeder

Agriculture Canada, Winnipeg, Manitoba

Dr. R.I.H. McKenzie	Oat Breeder
Dr. D.E. Harder	Plant Pathologist Crown Rust
Dr. V. Bendelow	Cereal Quality

Discussions in Ames, Iowa whilst attending PB SII

Dr. D. Reeves	South Dakota State University, Brookings, South Dakota.

2. I OAT INDUSTRY

IOWA - Area - 1977 1.5 x 10^6 acres (normally 1.8-2 x 10^6 acres)
- Production - 1977 1.2 million t
- Yield - 1977 59 bu/ac (2.1 t/ha)
- Most popular var. - Multiline E, Stout, Lang, Noble

WISCONSIN - Area - 1977 1.3 x 10^6 acres
- Production - 1977 - 76 x 10^6 bu
- Yield - 1977 - 65 bu/ac (record)

MINNESTOA - Area - 1977 0 2.5 x 10^6 acres
- Production -
- Yield - 1977 - 68 bu/ac (record)
- Most popular var. - Froker, Rodney, Lodi, Chief, Noble, Harmon, Multiline E, Garland

NORTH DAKOTA - Area - 1977 - 1.8 x 10^6 acres
- Production - 1977 - 64.8 m bushel
- Yield - 1977 - 37 bu/ac

SOUTH DAKOTA - Area - 1977 - 2.8 x 10^6 acres

MANITOBA - Area - 1977 - 1[illegible] x 10^6 acres (Canada 4.97 x 10^6 acres)
- Yield - 1977 - 55.2 bu/ac
  - 1978 - 59 bu/ac
  - 10 yr. av. - 48 bu/ac

<u>II BREEDING PRIORITIES</u>

Frey (Iowa) - emphasis is heavily on teaching - main areas under investigation are
* *A. sterilis* introgression into *A. sativa* - yield
  - protein
  - disease resistance
* multi-line varieties for crown rust resistance
* Grain quality (protein, oil)

Forsberg, Brinkman (Wisconsin)
* Yield
* Protein %
* Crown rust resistance
* Kernel conformation
* Straw strength but not short straw
* Smut resistance
* less effort Stem Rust, BYDV, Septoria resistance

Stuthman (Minnesota)
* Yield
* Protein Yield
* Lodging resistance
* Smut resistance
* Stem rust resistance
* Crown rust resistance
* Physical quality - bushel wt, great %
* Lesser extent BYDV

McMullen (North Dakota)
* Yield
* Protection from Stem Rust whilst maintaining Yield
* Groat Yield
* Groat Protein Yield

Reeves (South Dakota)
* Yield
* Protein
* Straw Strength but not short straw

McKenzie *et al.* (Winnipeg)

* Yield
* Larger Kernel size
* Resistance to stem and crown rust
* BYDV resistance
* Straw strength and shattering resistance
* hull-less varieties

III a) SELECTION FOR YIELD

In early generations Frey (Iowa) selects plants with a harvest index in the range 44-47%.

Much of the yield testing is done in hill plots. Each hill plot contains 30 seeds (counted by electronic counter) sown at 1 foot centres with a corn skip planter. There are usually a large number of replicates (i.e. > 10). Frey claims that the correlation between hills and 4 row x 10 m plot is the range 0.85 - 0.95 (only the centre two rows are harvested).

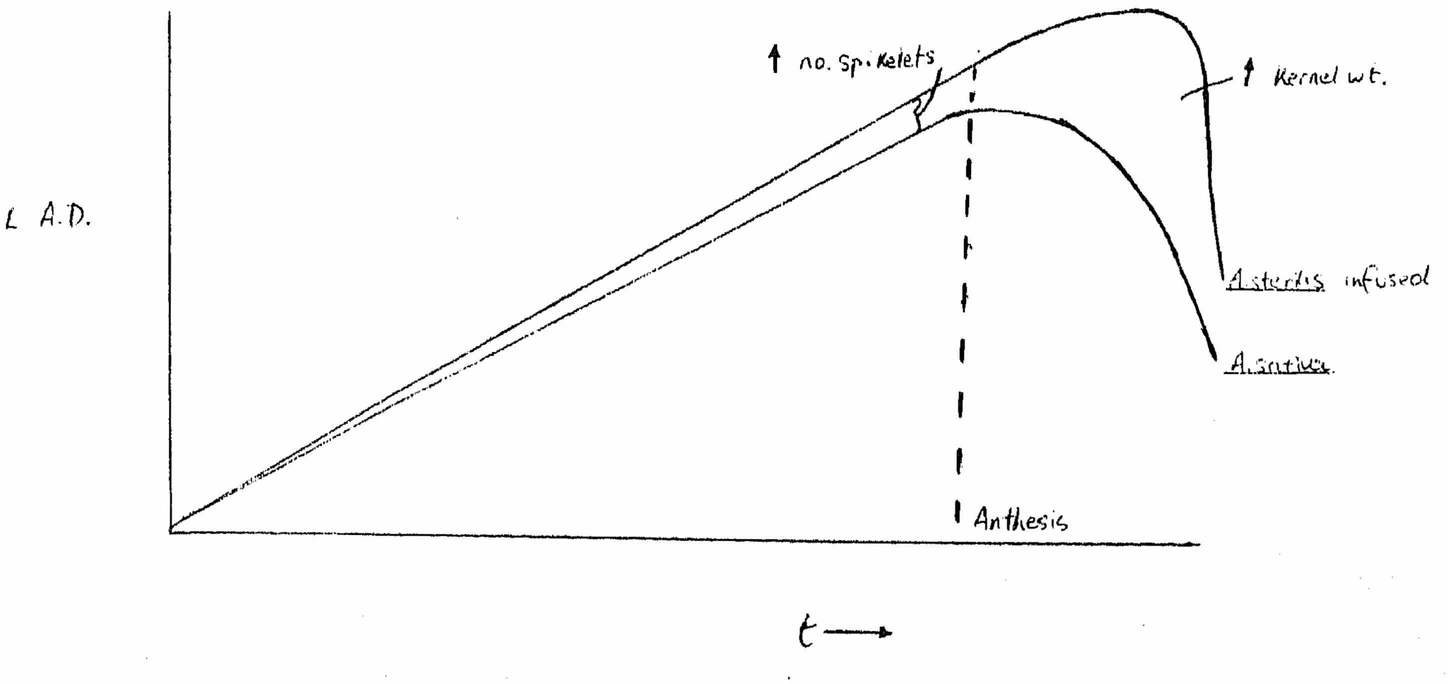
Yield (Oats in Iowa) = Growth Rate x Growth Duration x Harvest Index

1) Growth duration is limited to 105-110 days - determined by onset of hot weather

2) Harvest index - optimum 45%
   - high heritability

3) Growth rate - little variability in *A. sativa*
   - ∴ working with *A. sterilis*

Frey has found that *A. sterilis* infused *A. sativa* lines have increased growth rate (GR) and increased leaf area duration (LAD). This LAD difference is particularly significant in the post anthesis period (see diagram)



The LAD and GR increases affect yield components as follows.

1) increased number of leaves

2) fewer panicles/plant

3) slightly more spikelets/panicle

4) greatly increased 1000 Corn weight

Frey suggests using 500-1000 plants per F_2 population (Australian variety x *A. sterilis* infused lines) to be sure of recovering high yielding types.

The Wisconsin, South Dakota, North Dakota and Minnesota programmes were generally satisfied that much genetic variation for yield in *A. sativa* was available. It also seems that most of Frey's "*A. sterilis* infused high yield" lines do not exhibit yield improvement over standard varieties except in the Iowa region. McKenzie has been using some *A. sterilis* accessions (different to those used by Frey) in a similar programme. Early indications are that there are yield advances in some *A. sterilis* infused lines.

The Wisconsin breeders use basically a pedigree system of breeding. Yield plots are 4 rows x 12 feet (approx.) - the outside two rows are trimmed off and the inside 2 are harvested. Row spacing is 12" compared to farmer practice of 7" rows. The best 100 selections are elevated to an elite yield test and 30 superior lines are tested at 6 sites in Minnesota. The best of these are entered in the "Co-operative Uniform Oat Performance Nursery" (both Early and Midseason series). The scheme is sponsored by USDA and State Agricultural Experimental Stations with reports compiled by H. Rines (Research Geneticist, St. Paul Minnesota) and R.P. Halstead (St. Paul, MN). The Midseason series involves 16 states of the USA and 2 Canadian provinces whilst the Early series involves 17 states of the USA. The data collected includes yield, test weight, groat protein and oil yield, height, heading date, lodging per cent, groat %, disease resistance (crown and stem rust, BYDV, *Helminthosporium*, smut). In many ways these schemes are similar to the Interstate Wheat trial series in Australia.

There are at least two smaller schemes for inter-breeder testing - one involves Minnesota, North and South Dakota and the other involves several Canadian provinces. I believe that an "Interstate oat trial" would be of great benefit to the Australian oat industry. The problem will be to find a co-ordinator.

The Minnesota programme uses a number of interesting breeding approaches:

1) Single seed descent

2) 30 seed hill plots on 1' x 1' centres are used to eliminate the lower 30-40% of early generation lines using the method described by Frey, Crop Sci 1965.

3) most significantly, a recurrent selection system. Stuthman has achieved large increases of yield (≃ 30%) in the first cycle. The second cycle is currently underway - Stuthman is concerned that some undesirable linkages are going to reduce the usefulness of the high yielding material being developed in this programme. The details of this scheme are described in Crop Science.

Stuthman has published a number of papers on the worth of various selection methods including visual selection and diallel systems. His thinking seems to have progressed through the "traditional" methods of breeding self-pollinated crops to his present thrust of examining recurrent selection systems.

McMullen has established contacts with breeders whom he believes are making rapid yield advances - these include:

1) Illinois (Charlie Brown) - Yield is the major objective. Lang which has established a reputation of being very high yielding throughout the mid-west, was developed in Illinois.

2) Many of the lines grown in Manitoba (e.g. Kelsey, Otana, Hudson) are good parential material in N. Dakota.

3) Rothwell Plant Breeders, U.K. The breeders at Rothwell have used a very wide germplasm base. Most lines are very late but yield potential is unequalled in N.D.

F2's are field grown, the F3 is screened for stem and crown rust resistance and the F4 is grown in Arizona during winter. The F5 is then field grown in N.D. Many North American breeders use out-of-season nurseries e.g. Minnesota has Mexico and Manitoba has New Zealand.

The Winnipeg programme follows this general progression:

- 40-70 crosses/year
- F2 populations are large; at least 1,000 up to 10,000
- F3's are often grown as bulks
- 1st yield test at 3 locations with same randomisation at all 3 sites
- later testing at 7 locations
- Co-operative testing at 16 locations in Western Canada for 3 years
- Usually have 5 years of widespread testing before release is requested.

McKenzie has an intense interest in short-strawed varieties. Most North American breeders must develop relatively tall-strawed oats to produce straw suitable for animal bedding - this is not a constraint to McKenzie. In addition, lodging is often a severe problem in Manitoba. He has developed a shortened internode dwarf which was designated "O.T. 207". It was derived from Harmon and thus has good grain quality and stem rust resistance (pg 2, Pg 4 and Pg 9). The problem with this dwarf is that, under Canadian conditions, the head does not emerge fully from the boot - this often results in sterile basal spikelets and consequently lower yield. O.T. 184 has given very promising F2 and F3 lines in both the W.A. and S.A. oat breeding programmes.

McKenzie has also extensively used another dwarf line, developed in N.Z., named "Omihi". This line has the straw strength of Milford but the compact panicle and inherent low yield associated with Milford have been lost. Lines based on Kent, an Australian variety used in Manitoba because of its large kernel size, when crossed with Omihi have produced some excellent semi-dwarfs adapted to Manitoba.

An ambitious programme titled "Breeding Oat Cultivars suitable for production in developing countries" is co-ordinated from Wisconsin. An exerpt from the 1978 report follows:

This oat breeding effort was started under the auspices of the U.S. Agency for International Development in 1974, Contract No. AID/ta-C-1171, in cooperation with the Agronomy Department of the College of Agricultural and Life Sciences at the University of Wisconsin, and Agricultural Research, Science and Education Administration (SEA) of the United States Department of Agriculture. Contract AID/ta-C-1171 matured after two years, but the effort was continued with funds provided by the Quaker Oats Company and the University of Wisconsin in cooperation with SEA of the U.S. Department of Agriculture.

The *Avena* species is very versatile, including several cultivated species grown over wide areas. There are several wild self-sustaining species, not the least of which is tetraploid *A. barbata*. Wild types provide grazing and forage over millions of areas (ha) and cultivated types produce grain, hay and forage for livestock and food for the human race.

At the project's beginning, emphasis was placed on finding disease resistance in oat germplasm by testing a large collection in South America. The area was extended to the Middle East, North Africa, and Kenya. In 1978 an attempt was made to obtain agronomic and disease responses for current nursery material in Pakistan; but was unsuccessful.

After the initial evaluation of disease and agronomic responses of germplasm from the U.S. World Collection of Oats, the annual effort has been to evaluate 100 entries of "Wisconsin assembled" lines at widely different locations. Some entries were repeated from prior tests and some were newer homozygous progenies from hybrid origin. There were approximately 200 entries of F_2 bulk hybrids (rising F_3's) included each year for evaluation. This material was available for selection by the local cooperators. More than 700 segregating lots have been made available through 1979, and there are sizeable numbers of populations expected to become available within the next few years.

A total of 220 segregating populations from the 1977 production at Madison, Wisconsin was sent to cooperators during the fall and winter of 1977-78.

To date exchanges of selections (lines) and selected progenies have been made between cooperators in nine countries, thus enriching the improvement efforts. Progeny testing under advanced methods of culture is necessary in proving the value of selected progenies. Some exchanges likely will prove helpful in improving breeding programs, including those in the U.S.A.

Entries from the programme will be introduced into Australia by D.P.I. in Queensland. Programmes such as this will enhance germplasm and information exchange between widely eparate breeders. Indeed it may be the beginning of an "oat green revolution".

III (b) SELECTION FOR SHATTERING RESISTANCE

Generally the oat breeders of Mid-West do not consider shattering a great problem. This is probably due to high relative humidity and low temperatures at harvest. Frey uses a broom to beat hill plots at maturity - this is mainly done on *A. sterilis* infused material to remove the *A. sterilis* shattering gene/s. Stuthman suggests that since Lyon, Lodi and Portage are hard to thrash they may also be shattering resistant. A 6 replicate trial is sown for the final stages of breeders' evaluation at Winnipeg. 4 replicates are harvested at maturity and the remaining two 3-5 weeks later. By this time both shattering and straw break are usually significant. McKenzie suggests that Random is the pick of the Canadian varieties and that European varieties are generally good as European crops are not reapt until dead ripe. Oats are often windrowed in Manitoba; therefore shattering is not generally an important problem.

III (c) SELECTION FOR LODGING RESISTANCE

In contrast to the amount of interest in shattering, lodging is a major objective of all programmes visited. With the exception of McKenzie, breeders could not approach the problem by developing short strawed varieties because oat straw is in strong demand. In many areas, the sale of straw keeps the profit margin from oat growing in touch with those from corn. Several breeders believed that the popularity of Stout is limited by its short straw height.

Both Frey (Iowa) and Brinkman (Wisconsin) believe that Stout followed by Lang are the strongest strawed varieties. Brinkman uses both "% Lodged plants" and "slap strength" ro record straw characteristics. Slap strength is a measure of reaction to displacement of the straw. Stout has the highest slap strength of any oat tested in Wisconsin. Stuthman recommended Stout and Noble. McKenzie suggested that Random and Hudson were the pick of the "standard" varieties but neither were as good as the dwarf lines OT184 (ex Manitoba) and Omihi (ex New Zealand).

III (d) SELECTION FOR OIL CONTENT

Frey and students are looking at inter crosses between *A. sativa* and *A. sterilis* high oil lines in the hope of finding transgressive segregation for high oil content. Frey believes that the fatty acid composition is important especially if the oil content can be lifted to 16% - the level at which extraction may be economical. At present there are 11.5% groat oil *A. sativa* lines and 13% groat oil *A. sterilis* lines. Analysis of oil content is performed in Illinois using the Nuclear Magnetic Resonance (NMR) for 50¢ a sample. This analysis is non-destructive and as few as 15 kernels can be used.

Youngs (National Oat Quality Laboratory) also believes that the fatty acid composition will be an important determinant of the destiny of oats as an oil crop and as human food. Fatty acid composition varies greatly between lines and these differences are highly heritable. Youngs has in the past used the soxlet method of extracting fat but is at present trying to calibrate a Neotec (infra-red analyser) to read oil content. Problems with this analysis have not been satisfactorily solved at this stage. The Neotec has given good results for groat protein (0.98 correlation between Kjeldahl and Neotec). The Neotec has the potential to simultaneously determine moisture, protein and oil content from a sample - obviously this would be highly desirable.

Brinkman (Wisc.) Stuthman (Minn.) Reeves (S.D.) and McMullen (N.D.) concentrate on protein rather than oil content.

Breeding for higher oil content is an important facet of Ron McKenzie's programme in Winnipeg. Analysis is on 16g whole grains at the Rapeseed Centre in Sas Katoon for 25¢ per sample. Thus enough seed for analysis can be obtained from well-grown F_2 plants. Parents used extensively are CI4492. (ex South Carolina, this line also is resistant to BYDV) and CI3387 - both of these are in the Northfield variety collection. McKenzie has demonstrated that there is no correlation between oil content and yield. Prospects for high oil content in commercially acceptable lines appear to be good.

III (e) SELECTION FOR PROTEIN CONTENT

The breeders in the mid-West of the U.S.A. have protein determinations performed in Madison, Wisconsin by the National Oat Quality Laboratory. This is a U.S.D.A. facility which has heavy support from Quaker Oats. The service is free to breeders. This laboratory does approximately 30,000 analyses for breeders from 11 different states - Frey (7,000) and Stuthman (4,000) are two who use this service.

In recent years all analyses have been performed using the Udy dye binding method. This process was highly developed. Sample size was only 480 mg which was eminently suitable for early generation material. They are now in the process of changing to analysis with a Neotec 41. A comparison of speed of analysis is of interest

Kjeldahl	60/8hr day/person (samples already ground)
Udy	250-300/8hr day/2persons (samples already ground)
Neotec 41	500-700/8hr day/2 persons (samples already ground)

There are several adaptions required to make the Neotec machine an ideal breeding tool.

1) the sample cup as supplied on the Neotec 41 holds 10 grams of ground material - this is usually too much for analysis of F_2 plants. By using a black plexiglass filler to make the cup shallower and of smaller diameter the sample size is reduced to 2.0-2.5g. It seems that as long as the sample covers the base of the sample cup, satisfactory readings can be obtained.

2. To handle large numbers of samples, book keeping becomes a problem. The Neotec is connected to teletyper which records Sample no., moisture %, protein, and oil %.

3) Youngs and Gilchrist have thus far not been able to obtain satisfactory results in the estimation of oat lipids with the Neotec. Soybean lipids are routinely determined by a Neotec. This is the major problem - once overcome it will enable moisture/protein/oil to be determined at the "flick of the dial", thus dispensing with the time consuming Kjedahl protein determination and extremely time consuming soxlet (ether) extraction technique for lipid determination.

4) The analysis thus far has been on ground groats. Correlations between Kjeldahl and Neotec have been high (0.98). Youngs is not so confident about the use of ground whole grain in the Neotec. Small pieces of hull in the sample may bias the overall reflectance of the sample and thus give unreliable results. The solution to this problem probably lies in the grinding of the samples. At present a "Cyclo-tec" (R) grinder is used (Supplied by Tecator Inc., 1898 S. Flatiron Ct., Boulder, Colorado 80301.)

Youngs has studied the quality of oat protein as well as the quantity. Research on quality has now halted because

a) little variation was found between lines in amino acid composition
b) oat protein was found to be of a high quality - better than most other cereals.

Other investigations this laboratory have undertaken were fractionation of oat proteins to give high protein (50%) portion, the use of oat flour in bread for people with celiac disorder and the relationship between whole grain and groat protein content. No study of whole grain vs. groat oil content has been undertaken but this relationship can be estimated from the protein relationship.

The personnel and work performed in the laboratory impressed me greatly - all breeders I met spoke highly of this group. In fact, several suggested that they would probably give very little attention to oat quality if it were not for the service offered by the National Oat Quality Laboratory.

Frey has studied the relationship between harvest index (HI) and protein percentage and found that high protein lines generally have a low HI. Jaycee (ex Illinois) is one variety which breaks this correlation i.e. high protein and high HI.

In the past, selection has been first for protein then for yield. Now Frey applies a lax (25%) selection for yield and agronomic type, then determines protein content and retests yield in later generations. The emphasis is now on protein yield per acre not yield or groat protein percentage per se. Stan Cox is studying the relationship between *A. sativa* and *A. sterilis* protein genes for his PhD. He is looking at

6 crosses *A. sativa x A. sterilis* 70 F_2 derived lines/cross
2 crosses *A. sativa x A. sativa* 70F_2 derived lines/cross
2 crosses *A. sterilis x A. sterilis* 70 F_2 derived lines/cross

The high protein *A. sativa* lines used include Otee and Dal.

The Wisconsin breeding programme has been very successful in developing high protein cultivars which are acceptable in agronomic features and yield. Dal and Goodland are two of their varieties. A new high protein oat named Marathon (X2456-2: Holden/3/Trispernia/Belar/2/Beedee) has just been released. This success is not surprising in view of capabilities of the Wisconsin team - they have chemistry, physiology, agronomy and breeding expertise within the group.

Stuthman also is heavily committed to the development of high protein oats. Several have been released in recent years e.g. the new variety Benson has just been registered. Reeves has just released Spear (a high protein line) and McMullen is also working on protein yield per acre.

In contrast to the Mid West U.S.A. breeders who use groats in all quality determinations, McKenzie uses whole oats. Bendelow, who is the cereal chemist associated with McKenzie) believes that the Neotec is very good for wheat flour but there are problems assessing husked grains such as barley and especially oats He is doubtful that milling technology can overcome the problem when using whole grain. The age and make of the grinder will also affect the reflectance. They now determine protein using a modified Kjeldahl and analyse the digest in a Technicon Automated analyser. NH_4+ is read in the colorimeter section. There are 4 modules in the appartus - a proportioning pump, water bath, colorimeter and printout. Approximately 50 samples per hour can be analysed (40 unknown + standards). The apparatus can be used for 17 other analyses but it is very expensive.

Several comments on the likely uses of improved nutritional quality oats were collected.

1) Quakers can't sell oat products for human consumption on protein content, but don't want to see it drop. This is the fault of the market place not Quakers as they heavily support the development of high protein lines. Quakers have a scheme where growers are contracted to grow high protein varieties under management conditions which favour high environmental protein.

2) High fat content is not desirable in milling oats. Quakers used to prefer oats with less than 4% oil but are now processing Dal (high protein, 6-7% oil) without too many problems. It is only after physical damage such as rolling that the high fat content can be problematical i.e. rancidity can then develop.

3) Need increased energy content for ruminant nutrition. There are no digestive or digestibility problems with high fat oat diets.

4) There are no digestibility problems with high protein oats in monogastric diets.

The following papers are useful in discussing the utility of high protein/high fat oats.

SIBBALD, I.R. and PRICE, K. (1976) Relationships between metabolizable energy values for poultry and some physical and chemical data describing Canadian wheats, oats and barleys. Can. J. Anim. Sci. 56: 255-268.

DEVLIN, T.J., INGALLS, J.R. and SHARMA, H.R. (1977) Evaluation of high fat oats in rations of growing and finishing ruminants. Can. J. Anim. Sci. 57: 735-743.

WAHLSTROM, R.C. and LIBAL, G.W. (1975) Varying levels of high protein oats in diets for growing-finishing swine. J. An. Sci. 41 (3) 809-812.

In summary, it seems that oats of better nutritional quality are unlikely to attract a premium per tonne in either the human or stockfeed markets. Rather, it will enable oats to compete better with other cereal grains. Further it would be of special benefit to a farmer who produces and feeds his grain on the same property.

III (f) SELECTION FOR KERNEL %

Breeders were generally aiming in the range 75-80% for groat percentage. Many of the Mid West and Canadian varieties have better groat percentages than Australian varieties. However grain and groat size is generally smaller. McKenzie has used Kent extensively in crosses to improve the kernel size of Canadian oats. Kernel conformation receives attention in several centres.

Most breeders had a Quaker Laboratory dehuller - (impact type). Operators complain of excess noise and dust. Ron McKenzie had two small sample dehullers. One had two contra-rotating files and the other used compressed air. The compressed air dehullers used by Jan-Bert Brouwer (Vic.) and Peter Portman (W.A.) would be superior to all three.

III (g) SELECTION FOR STEM RUST RESISTANCE (SRR)

Stem rust is considered to be of less importance than crown rust in the mid-West of the U.S.A. The relative importance of the two diseases changes in Northern U.S.A. This is reflected by a change in breeders priorities - Iowa and Wisconsin and Minnesota concentrate mainly on crown rust whereas North Dakota and Manitoba work on both equally. Stuthman also has a breeding programme in Mexico - stem rust occurs severely and frequently in nurseries there. In fact, stem rust occurs so severely in this area that Stuthman has collected wild oats (A. fatua) from the area in the hope of finding new resistance genes, without success thus far.

Frey often finds stem rust pustules on space planted or late maturity lines late in the season but there has not been a serious epidemic in Iowa since the late 1950's. Browning collaborates with Wahl, Sztejnberg and Manisterski (Tel Aviv, Israel) on the study of the rust resistance in wild oats (*A. sterilis* and *A. fatua*) from the Mediterranean basin. They have discovered several slow stem rusting genes in *A. sterilis* accessions which they believe are race non-specific. There is a dearth of major gene stem rust resistances in the *Avena* genus - virulence exists on most of these genes in North America. The position can be summarized as follows

Disease / Species	Major genes for resistance to: Crown Rust	Stem Rust
A. sativa	many	few
A. sterilis	very many	1

It is hoped that the Israeli studies will shed some light on the reasons for the different host-pathogen relationships.

Most of the popular North American lines have Pg 2 and 4 (e.g. Dal), Pgl and 4 (e.g. Stout) or less complex resistance. Some Canadian varieties have Pg2, Pg4 and Pg9.

Vernon Youngs (Wisc.) and Marr Simons (Iowa) have undertaken a collaborative study of the effects of rust on grain quality - their findings will be available shortly.

The U.S.D.A. has its National Oat Rust Laboraotry in St. Paul Minnesota. Dr. Paul Rothman and colleagues work intensively on both stem and crown rust. Monitoring of stem rust races for all the U.S.A. is performed in St. Paul.

Rothman is involved with interspecific crosses in an attempt to transfer rust resistance from diploid and tetraploids into hexaploid types. Selected accessions of *Avena magna* (4x) and *Avena longiglumis* (2x) have seedling and adult plant resistance to crown and stem rust respectively. These species have been crossed, the resultant progeny 'doubled' and the synethetic hexaploid "Amagalon" CI9364 formed. Amagalon can be crossed with cultivated hexaploids. Stem rust resistance, identified in *A. abysinnica* and *A. barbata*, is also under investigation.

Deon Stuthman has collected many ecotypes of *A. fatua* from Mexico. Stem rust is common and severe in certain areas of Mexico. 300 stem rust isolates have been typed - all 300 isolates were race 31. It was hoped that there would be directional selection pressure for stem rust resistance in the Mexican wild oat populations. However no useful resistance has been discovered. Stuthman has a winter nursery for his Minnesota lines and a breeding programme for Mexico in Mexico. Mass selection for seed weight in oat populations infected with Race 31 is one approach to stem rust resistance breeding employed in Mexico. Thus stem rust resistance is selected in Mexico and crown rust resistance in Minnesota.

Rothman recommends progeny of Rodney/Omega for good rust resistance and grain type. Omega is derived from the cross *A. sterilis*/Kyto-Kyto has Pg12 and *A. sterilis* is an Israeli accession that exhibits the "slow rusting" characteristic. Crosses which incorporate 'Omega' and 'Alpha' (a sister line) have been introduced to S.A. CI3034 (Pg1 + Pg11) has excellent S.R.R. but 2 characters (golden leaf and weak straw), which are pleiotropic or very closely linked to the S.R.R. loci, limit the usefulness of these genes.

The stem rust resistance genes found in the diploid oat "Saia" are effective against all stem rust isolates found in Minnesota. A synthetic octoploid "Obee" formed by crossing Saia with a hexaploid has the rust resistance of Saia and is the first step in transferring rust resistance into hexaploid background. Hexaploid S.R.R. lines have been developed. Rothman was surprised to find that virulence on Saia existed in the Australia SR flora.

McMullen is investigating *A. longiglumis* as a source of S.R.R. and *A. magna* as a source of C.R.R. *A. longiglumis* has a 'factor' which decreases homoeologous pairing - this increases cross over frequency and also gene transfer likelihood.

1977 was a severe rust year in Manitoba. The most common races were C23 (US 61) and C10 (US31). The variety Hudson (Pg2, Pg 4 and Pg 9) is moderately resistant especially as an adult plant. Pg 11, 12 and 13 are effective in most of Canada but there are problems in their utilisation. Pg 11 is closely associated with golden leaf and tall weak straw. Rodney - pg 11 was crossed with 20 varieties and examination of F7 lines saw no break in the linkage. McKenzie has also used mutagens, without success, in an attempt to break the linkage. Thus it does not appear that Pg 11 will be useful in the short term. Pg 12 (ex Kyto) is associated with "freckled" leaves and post-heading bronzing. Lines carrying Pg 12 are currently in yield trials. Pg 13 (ex Tunisian *A. sterilis* accession) is effective over much of Canada although virulent strains were detected as long ago as 1971.

Martens and Harder (Winnipeg SR and CR specialists) use large plots of rust differentials (6 row x 100 feet) to detect rare virulent races. The aim is to avoid releasing a supposedly RR variety into a situation where there is (rare) pre-existing virulence in the pathogen.

The Canadian workers have made extensive collecting trips to the Mediterranean region and have discovered useful RR especially CRR genes in some accessions.

III (1) SELECTION FOR CROWN RUST RESISTANCE (CRR)

Crown rust (*Puccinia coronata* f.sp. *avenae*) is regarded as the more important of the two rusts affecting oats in most of the states of Mid-West U.S.A.

The race monitoring of CR for U.S.A. is provided by Marr Simons at Ames, Iowa. Frey, Browning and Simons co-operate to produce the famous Iowa CRR Multilines. There are 2 commercial milti-lines - an early and midseason multi-line. The former have been based on Clintland, CI7970 (Clintland x Garry-5) or CI8044 (Clintland x Garry-5) and the latter on CI7555 (Clintland 5 x Victoria 2 x Hajira x Banner 3 x Victory x Hajira 4 x Roxton). They are now generating a multi-line based on Lang and the CI8044 CRR isolines. Two backcrosses will be used. It is hoped that Lang's high yield will be retained whilst the superior grain type and CRR from the CI8044 isolines are incorporated.

Browning has recently studied the proportion of a mixture which needs to be CRR to "effectively" control a CR epiphytotic. He has concluded that as little as 1/3 of the mixture is sufficient. Browning uses large plots physically isolated by a resistant pure line in both Iowa and Texas (in association with McDaniell) to perform his experiments.

The Iowa multi-lines, especially the Early series, are popular with farmers and Frey and Browning believe they have effectively controlled CR with them. Pure seed of each isoline is produced by the breeders and multiplied till 1-2t is available. The isolines are then composited and distributed to farmers for further multiplication. 1-2 t of seed is enough to composite for 3-6 years. The proportion of each isoline and tolerance to variation from this proportion in certified seed is specified in variety registration papers. The E isolines based on CI8044 are awaiting quarantine in S.A.

CRR has high priority in the Wisconsin programme. Selections are inoculated with a syringe into the whorl at the tillering stage. Wisconsin lines are entered into the International Oat Rust Nursery - heading date and rust data is returned.

A feature of the CRR work in Minnesota is the "buckthorn nursery". Buckthorn hosts the sexual stage of *Puccinia coronata* f.sp. *avenae*. Oat selections are grown amongst hedges of buckthorn.

The genes PC 38 + 39 and PC55 + 56 give very effective CRR in Canada. Harder is also using PC 57-61 although he believes that there is inadequate genetic data and a lack of suitable "hot" races to fully differentiate these genes.

III (i) SELECTION FOR BARLEY YELLOW DWARF VIRUS (BYDV) RESISTANCE

Frey has not included BYDV resistance as a selection criterion in his programme but believes that he may do in the near future. Tolerant lines from Illinois yield very well in Iowa. He believes that BYDV may therefore be an important yield determinant, even though the typical symptoms of BYDV are rarely evident in Iowa. Illinois have a co-operative team which includes a breeder, entomologist and plant pathologist working on the problem.

The Canadian's study the BYDV problem extensively. They have a multi-disciplinary approach and have used the following sources of resistance:

1. ex the Australian varieties Kent and Avon
2. ex the S. Carolina high oil line CI4492
3. ex Winter oats of McDaniell (Texas)
4. ex Illinois programme

Research is underway in Winnipeg and Ottawa. McKenzie believes the available resistance in oats is at least as effective as that found in the Ethiopian barleys.

Many researchers now believe that yield losses occur before the visual symptoms appear and that this can only be detected by yield testing resistant lines with a "known" genetic background.

Youngs (Wisc.) and Ohm (Illinois) have studied the effect of BYDV on grain quality - the results of this work will be available shortly.

IV FIELD EQUIPMENT

This was the area in which the study tour was perhaps most disappointing. Most programmes were below or, at most, equal to the level of technology used in Australian plant breeding projects. This was in stark contrast to the manner in which other facets of the programmes visited were handled.

The mechanical handling of plots at harvest is made more difficult by the need to cut/bind/swathe oats before fully mature. Suzue binders were revolutionizing this process and breeders visited had either just purchased or were hoping to purchase these machines. The one row binders cost approx. $Am2000 and the 2 row $Am2600. The sheaves are then fed into large-very large, portable Vogel thrashers. Special pure seed blocks are necessary in these systems and in the programmes using Hege harvesters.

Seeders generally featured the "stationary outer" type cone or the Ojyord cone. Very few had seen or heard of the belted cone. McKenzie was just in the process of building a Winter steiger based seeder to sow 8 rows, a 6 row plot plus a buffer row each side. The double disc principle was used widely to improve seed placement.

Mike McMullen used plastic bubble magazines for head rows. These are made by Precision Machine Co. Lincoln, Nebraska and looked to be a cheap and effective way of developing a large seeding reserve system.

The barley workers at North Dakota State University have developed blower systems for Hege harvesters to help inter-plot cleaning. McKenzie uses Hege harvesters for both yield trials and seed blocks although much more care is taken in harvesting the latter.

Mike McMullen uses "Max Tapeners" for marking F2 plants and for staking up plants grown in pots in the glasshouse. These instruments staple small rings of plastic tape around the desired object. The size of the ring can be easily varied and the tape is available in many colours. It seems that this would be a better way to mark individual plants than to tie on tags or paint plants.

V LABORATORY EQUIPMENT

An important part of the Iowa breeding effort are efficient electronic seed counters. These seed counters are used to count 30 seeds for seeding hill plots.

Vogel thrashers are the standard laboratory thrasher although push bike tubes were used by some to thrash single heads - a 12 inch piece of rubber tube is rolled between hands and surface whilst the head is in the centre - simple and effective.

The "Alanco" seed aspriator is used by some programmes to clean "trashy" samples. These are simple machines which cost $Am400.

Whilst most breeders used the Quaker Laboratory dehuller, which is dusty and noisy, McKenzie had developed 2 dehullers for very small samples. One used two contra-rotating rat tail files to 'pop' the kernel out of the husk and the other used used compressed air to bounce the seeds against the walls of the container until the hull falls off.

VI HYBRIDISATION TECHNIQUES

Most breeders now use the approach method of crossing. The pollen-proof bag is usually 1" diameter dialysis tubing. Emasculation and pollination are performed the same day, 1-2 heads of the male parent are used and the cut female flowers are not taped erect; rather they are jiggled inside the bag till they point upwards. Success rate is in the order of 70%. The Iowa group find *A. sterilis* makes an excellent pollen parent and my experience with Cc4658, the CCN resistant *A. sterilis* line, and *A. fatua* collections would confirm those findings.

In contrast, Shands (Wisconsin) uses hand pollination. Pollination is performed 2 days after emasculation and the crossed head is not bagged. Pollen supply and quality is critical and Shands estimates success rate at 20%.

McKenzie had an ingenious system for increasing his success rate from hand pollination to 70-90%. Two growth cabinets are used - one for the male parents which is set at 10°C Day and 13°C Night and another for the female parents which is set at a lower temperature. The "male cabinet" is set to switch on 6-7 hours prior to the female cabinet. In this way pollen is shedding in the male cabinet whilst the anthers are still firm in the female cabinet. This system:

1. uses an understanding of the flowering process (e.g. the stigma is receptive well before the anthersdehisce) to decrease the probability of selfed seeds and increase the proportion of seeds set.

2. by virtue of using a controlled environment, the time of the day when one wishes to cross can be selected.

3. 'Normal' hand hybridisation involves emasculation in the early morning and pollination in early afternoon i.e. two operations. This is a one process system

4. The availability of good pollen from glasshouse or field varies according to the temperature and other factors, whereas it is highly predictable under this management regime.

VII WEED CONTROL

Several studies have been made by the Iowa group into the suitability of various herbicides for use in oat nurseries. In the early seventies Ray Shorter (now in Qld.) concluded that propachlor (Ramrod (R) was the safest, effective chemical for the control of green foxtail (*Setaria viridis*). It appears that the activity of a herbicide on green foxtail is a useful guide to its activity on S.A.'s major grassy weed, annual ryegrass (*Lolium rigidum*). Rates of propachlor used were in the range 2.5 lb a.i./acre → 3 lb a.i./acre. The margin between crop tolerance and weed control is small and there was some doubt about differential tolerance of varieties. Propachlor is closely related to alachlor (Lasso R), a widely used herbicide in Australia. Propachlor is safer than alachlor on oats.

Broad leaf weeds could be controlled with bentazon (Basagran R) at rates of 1-2 kg a.i./ha at a wide range of growth stages with very little risk of crop damage.

Several new chemicals are being investigated by Jim Fawcett. Propanil (Stam R) is being tried as an early post-emergent spray for foxtail and broad leaf weeds at rates in the range 1¼ - 1½ lb a.i./acre. DPX4189, a DuPont product, is under scrutiny as a pre-emergent, broad-spectrum herbicide. Application rates are very low (½ - 1½ oz a.i./acre). Bifenox (Modown R) appears to be a good pre-emergent chemical for broad leaf weeds and is used routinely by Dale Reeves (South Dakota).

Marshall Brinkman has studied the tolerance of oat varieties to Atrazine. Atrazine is widely used on corn and the residues are commonly detected in the following year, especially if the season of application is dry. These residues may damage the following oat crop. Useful varietal differences do exist. This is encouraging in my attempts to develop simazine tolerant lines as Simazine is closely related to atrazine. Brinkman has also screened Jensen's "Atracomp", a bulk population which has been subjected to atrazine for many years.

Behrens (Minnesota) has also used propachlor and propanil on oats. His experiences with propachlor show that:

1. rates of 3 lb a.i./acre are suitable
2. Propachlor is safer than alachlor. A third member of the amide group, metolachlor (Dual R) is also worthy of investigation.
3. propachlor is cheaper than alachlor in U.S.A. The opposite is true in S.A. - alachlor is used for field crops whereas propachlor is used as a vegetable herbicide and is consequently more expensive.

His experiences with propanil show that:

1. rates of the order of 1½ lb a.i./acre are suitable
2. contact burn is frequent but recovery usually rapid
3. 2-3 l stage of crop is appropriate time of application
4. cost per acre is low - approx. $5.

Behrens has used DPX4189 in one years trials. Grass and broad leaf weed control was excellent. DuPont apparently do not expect as much activity on grasses as was recorded in the ideal conditions of 1978 and are looking at the chemical as a post as well as pre-emergent. Residue problems associated with DPX4 189 appear to be the only obstacle to the development of major new herbicide.

Trifluralin has been used on oats. Stand reduction is usually slightly more than for wheat but oats appear to tolerate large reductions in stand density before yield is affected - I think oat seeding rates are higher in Minnesota than S.A. The depth to which one incorporates the herbicide has a marked effect on crop damage.

McKenzie uses T.C.A. for control of millet in his oats nurseries. He also tried Basagran (R) but believes that its rainfall requirement for satisfactory activity is a disadvantage.

VIII OAT CYTOGENETICS + MUTATION BREEDING

Bob Forsberg (Wisconsin) has been mainly involved associated with attempts to transfer genes from species of other ploidy levels to hexaploids.

Howard Rines (Minnesota) works full time on cytogenetics, mutation breeding and cell culture techniques. Rines is using a range of mutagens in his programme aimed at detecting male sterile lines. He has studied aneuploids which are male sterile and/or completely sterile to identify characters which will allow rapid detection of male steriles. At present, selection is for low seed setting. Techniques for applying EMS and Sodium azide to oats were described. Rines main other areas of investigation are:-

1. Tissue culture a) nutritional quality mutants - he has several novel approaches to producing higher lysine oat lines.
   b) Herbicide tolerance
   c) pathogen toxin tolerance
2. Anther culture a) Haploids → aneuploids
   b) Haploids → tissue culture
   c) Haploids → double haploids

The Minnesota group have the technology to produce plantlets from callus tissue but not from single cells or protoplasts. Callus culture media for oats are relatively well established.

There are a number of interesting mutations which have been produced - these are described in Cummins *et al.* (1978) J. Heredity 69: 3-7.

IX NAKED OATS

Frey's major interest in naked lines was the associated multiflorous spikelet character which may theoretically offer a path to higher yield. Little or no work with naked oats was underway in any centre visited except Winnipeg.

McKenzie released the hulless variety Terra in the mid 70's. The yield of Terra is usually equal to the groat yield of normal husked varieties. Terra has fewer multiflorous spikelets than other naked varieties yet yields are much higher. Straw strength and shattering resistance is good but it is susceptible to BYDV and both rusts. The problems usually associated with naked oats have been reduced and, in time, McKenzie hopes to release a rust-resistant, naked variety. Terra was given to a seed company and the Saskatchewan Wheat Board. Neither group have been successful in developing markets for naked oats. Thus the poor acceptance of Terra is a problem of breeding and of marketing; these problems are listed below:

1. naked oats are hairy which makes farmers itch and can choke livestock - an airconditioned cab and hammermill would cure both of these problems. An exhaustive search has failed to find a hairless oat.

2. the expression of the naked character is variable - under stress conditions up to 10% of grain can be husked. This is unacceptable to the human food trade. Processors prefer to dehull oats and obtain a 100% hull-free product.

3. storage life is inferior to husked oats.

4. germination and establishment is variable and often poor under field conditions.

5. there is no identified major market for naked oats. Naked oats have approximately 7% oil and 15-16% protein given good growing conditions, which is equivalent to groat analysis of conventional varieties. Pig producers use and pay premiums for dehulled oats in starter rations but this market is already supplied and is of limited size. Human food processors prefer to dehull oats because the hulls offer a "sanitary wrapper" to protect the kernel from dust and spoilage organisms prior to processing. Furthermore, a different system of processing involving aspirators would be required to remove dust etc. from hairs on naked grain. This would entail extra expense to industry and could possibly result in a poorer quality product.

6. there is a market for the hulls produced by oat millers as a source of fibre in stock rations or as the raw material for furfurol synthesis.

It seems a great pity that few people have been able to exploit a potentially valuable new genotype.

SUMMARY

The most important aspects arising from visits to breeders are listed below:

1. The opportunity to examine the various approaches to breeding oats in 5 centres has led me to believe that one must maximise the opportunities for re-combination and incorporate a diverse range of parental genotypes. To this end, I plan to examine recurrent selection methods and to seek introductions from a number of new centres including Rothwell Plant Breeders U.K., University of Wisconsin and DSIR in New Zealand.

2. a belief that an Interstate Oat Trial is highly desirable in view of the success of the North American interstate trial series.

3. a number of new (to me) chemicals for grassy weed control in oats were discussed.

4. prospects for major improvements to the nutritional qualities of oats are excellent; rapid analytical techniques necessary to handle large numbers of selections were inspected, their adoption will be possible shortly in S.A..

5. An excellent system of hand pollination involving the use of different growth cabinets for male and female parents was seen in Winnipeg. The system will be especially valuable for out-of-season (i.e. other than Sept. -Oct.-Nov.) crosses which have proved very difficult using conventional hand pollination and approach methods.

6. problems associated with various stem rust resistance genes and approaches to breeding for resistance to this and other diseases.

7. a realistic appraisal of naked oats.

8. A rapid method of marking F2 selections.

9. an understanding of the oat growing conditions, production and marketing systems encountered over a large area of North America.

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