Canola breeding in the seventies – a personal look back

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ABSTRACT
Rapeseed was introduced into Australia in the late sixties in response to farmer’s quest for new crops following the introduction of wheat quotas. In 1970 the first rapeseed/canola breeding program was begun in Werribee by the Victorian Department of Agriculture. This coincided with the decision in Canada and elsewhere to rapidly develop “double low” cultivars. Germplasm was introduced from Canada, Europe and Japan, and evaluated for adaptability and quality. Both spring and winter lines of Brassica napus and B. rapa germplasm was evaluated and it was shown that the best adapted material came from Japanese B. napus cultivars. Double low lines were produced by crossing Zephyr (low erucic acid) by Bronowski (low glucosinolate) as there was no double low germplasm available. These lines were then crossed to Japanese varieties to produce the first adapted canola varieties. Blackleg, first noted in 1971, devastated the WA crop in 1972 and became a major focus of breeding. Other breeding programs were started in WA and NSW in 1973 as well as major research led by Noel Thurling at the U of WA. The first ARAB meeting in Perth (1977) was initiated by Noel and me because of the need to coordinate research on phenology, blackleg and yield trials. After attending the 1978 International Rapeseed Conference in Malmo, Sweden, it was clear that future breeding would focus on hybrids with double haploid technology as a breeding tool. The seventies ended with the first local canola variety, Marnoo, replacing the single low variety Midas and therefore the start of the Australian canola industry.

BACKGROUND
In the late sixties Australia was said to be producing too much wheat for the market. The response from Canberra was to limit production by introducing wheat quotas so that each farmer was limited in the area sown to wheat. The response in the cropping industry, farmers and research, was to look at “alternative crops”. There was a flurry of activity in the various Departments of Agriculture, CSIRO, and Universities to introduce and evaluate a wide range of species. Oilseeds were seen by many as having potential. Up until that time the only oilseed widely grown and crushed in Australia was linseed. However the market for linseed oil was decreasing and the main crusher, Meggitt Ltd, was keen to seize the opportunity to move into edible vegetable oils. A wide range of oilseed species were studied and tested in the wheat belt including rapeseed (both Brassica napus and B.rapa), crambe, safflower and sunflower. The challenge was to learn quickly about all aspects of these crops, agronomy, disease, plant breeding, quality, markets and other aspects, to see if they had a fit in the rotation in the wheat belt.

THE START OF RAPESEED BREEDING
In August 1970 I joined the Victorian Department of Agriculture to start the first rapeseed breeding program in Australia. My official title was ‘geneticist’ as in those days this sounded better to some in the public service than ‘plant breeder’. As I had to start from scratch with just a handful of introduced varieties I was handed over the linseed breeding program as well. At the time of joining I had never seen a rapeseed plant so there was some very basic biology to learn about the two species.

There had been an International Rapeseed Congress in St Adele, Quebec, Canada earlier in the year and an agronomist (Tom Patton) from the Dept. of Agric had attended. This was a conference with a crisis. Research was announced that indicated that erucic acid had detrimental effects on a strain of rats and the view of the meeting was that unless high erucic acid rapeseed could be converted to low erucic acid types quickly then the ‘Cinderella’ crop of the Canadian prairies would collapse. Low erucic acid genotypes had already been selected out of the European variety ‘Lino’ and it was known that by introducing the alleles from two...
genes (*Brassica napus*) or one gene (*B. rapa*) it was possible to convert older rapeseed varieties to ‘single zero’ (or low erucic acid) varieties. At the same conference there was discussion about producing ‘low glucosinolate’ varieties by transferring this trait from the variety ‘Bronowski’. In 1968, Jan Krzymanski, working with Balder Stefansson at the University of Manitoba had found that Bronowski – an old land race variety from Poland – had low levels of glucosinolates in the meal. Studies had revealed that the trait was controlled by several genes and that the trait in the seed was controlled by the genotype of the mother plant. The upshot of the St Adele congress was that the way was now clear to produce ‘double low’ rapeseed – and that there was an urgent need to do this.

Meanwhile back at Werribee the new breeder was trying to catch up on the literature and anything else about the rapeseed plant. Two varieties, Target (*B. napus*) and Arlo (*B. rapa*) had been grown in 1969 and 1970 so there was some basic information about the phenology and agronomy of the two species. A few other varieties had been introduced from Canada and some winter varieties from Europe. Variety trials soon indicated that winter varieties vernalized readily but were four to six weeks later to flower in the spring so did not fit the climate. Of course this was not surprising as the same situation had been realized in wheat.

One of the first things to do was to search the literature, get in touch with foreign breeders (the only kind available) and try to introduce varieties and germplasm from different backgrounds. The key introductions were the sources of low erucic acid ‘Oro’ and later ‘Zephyr’ in napus and ‘Span’ in rapa and the source of low glucosinolates, ‘Bronowski’. For agronomic traits the key material was a range of rapeseed varieties from Japan. These were old varieties as Japanese breeding had stopped in the early sixties when Japan opened its doors to imports of rapeseed from Canada. A range of other germplasm was also introduced such as the various rapa types from India (yellow sarson, brown sarson and toria), fodder types from New Zealand (such as Rangi) and the other forms of napus (swedes) and rapa (turnips).

In 1972 Bruce Wightman and I did a trial at Werribee to try to understand the range of germplasm available. We chose six very different genotypes from both species and planted them every two weeks throughout the winter and into early spring. The plots were irrigated so that we could see the potential of each variety. At that time the study of phenology was very popular so we looked at SIAM (sowing, floral initiation, anthesis and maturity) for each variety. We also looked at yield and oil content. This single experiment was seminal to canola breeding in Australia. It showed that the best germplasm for yield came from Japanese background. It also showed the Japanese varieties were early (if their small vernalization requirement was met) and their oil content was good. This study was also the first to show a dramatic influence of temperature at pod filling stage on the oil percentage of the seed (without moisture stress). For every one degree rise in temperature, oil content dropped from 1.5 to 2.0%.

**DEVELOPING METHODS TO BREED “DOUBLE LOW” RAPESEED**

For a breeder with very little resource, starting to breed ‘double low’ rapeseed there was the question of how to select for low erucic acid and low glucosinolate content. Which analytical methods could be used and which generations should be selected for the different traits? This question was being asked around the world but there was nothing in the literature. In hindsight I can see now that each breeder had to make their own decisions based on resources available – and also that breeders are often reluctant to publish their breeding methods for fear of criticism.

Some very timely papers from Germany on screening for erucic acid and glucosinates helped solve the analytical chemistry issue. Lein’s paper on the use of glucose strips (from diabetic testing) for a quick screening method for the low glucosinolate trait and Thies’s paper on screening for low erucic acid by paper chromatography were crucial for rapid and cheap methods of testing a large number of lines for the double low traits. There was no cheap method for screening oil content so the measurement of that trait had to wait until near the end of the breeding process when there were fewer lines to analyse.
Since there was no standard method to develop double low lines from crossing the traits from the donor sources, I had to develop my own procedure. First the cross was made between Zephyr (a low erucic variety from Canada) and Bronowski (the low glucosinolate variety from Poland). Zephyr was a reasonably adapted variety but Bronowski had poor vigour (and purple leaves – but that did not really matter). A large F2 was grown and single plants were selected without bagging. Seed from each F2 plant was screened for glucosinolates using the ‘testape’ method. About two percent of selections were kept. Individual seeds from each selection were then tested for erucic acid using the ‘half seed’ method and paper chromatography. The ‘half seed’ method involved germinating a seed for about a day so that the radical was just emerging. By dissection, the outer cotyledon could be removed for analysis and the remaining embryo with one cotyledon could be left in a Petri dish until the result of the fatty acid test was known. The surviving ‘half seeds’ could then be planted. Because the fatty acids are determined by the genotype of the seed then the resultant plants from selected seeds (and subsequent generations) breed true for the low erucic acid trait. The F3 plants were then checked for the low glucosinolate trait. As there was a degree of outcrossing in the F2 generation this meant that a percentage of the F3 lines (up to 30%) needed to be discarded. The F4 and subsequent generations then bred true for the ‘double low’ traits.

**BREEDING ‘DOUBLE LOW’ RAPESEED**

The results from the cross of Zephyr/Bronowski were disappointing for yield and agronomic traits. Although the lines went through a final evaluation in 1976 it was decided not to release a ‘double low’ variety from this cross as it could not compete with the existing commercial variety ‘Midas’ – a low erucic acid variety from Canada. However the best lines from this cross were used to make crosses to the Japanese lines that had earlier been identified as showing the most promise for yield and agronomic type. At this time the only other sources of ‘double low’ material were the varieties Tower and Regent from Canada. These were very susceptible to blackleg, were tall, late and lodged easily. So a range of crosses were made between the locally bred ‘double low’ material and a range of Japanese varieties. This meant that the pedigrees looked like:

Chisaya//Zephyr/Bronowski

Chikuzen//Zephyr/Bronowski

and so formed the base germplasm of much of the Australian varieties to follow.

This second round of crosses to Japanese varieties were now put through a well developed breeding method.

**Cross** Chisaya x Zephyr/Bronowski

**F1 increase**

**F2** select several hundred plants from each F2 population, screen five seeds from each plant for glucosinolate content using testape. Retain about 2% of F2 packets of seed.

Individual F3 seeds from each packet screened for erucic acid using the ‘half seed’ technique. About half of the packets produce some plants with low erucic acid – the rest are ‘fixed’ for at least one high erucic acid locus. F3 plants are grown, seed harvested and tested for low glucosinolates using testape. About 30% fail this test because of outcrossing in the F2 nursery.

**F4 rows** are then grown in a nursery and selected for agronomic type, blackleg resistance and other traits.
SELECTION FOR “MEXICAN WHEAT” PHENOTYPE
The phenology work of the seventies was often a point of discussion. What was the influence of daylength and temperature on rapeseed and other crops? We soon understood that Canadian varieties were adapted to growing under long days at higher temperatures compared with Japanese varieties which showed little or no response to daylength but many of which had a low vernalization requirement (such as the cultivar Isuzu). In the crosses above I took advantage of this by selecting for earliness in the winter time (daylength neutral) and earliness in summer nurseries (no vernalization requirement). This meant that the material surviving this selection process was analogous to the Mexican wheats just coming into vogue i.e. early and daylength insensitive.

BLACKLEG
In 1971, while looking at my rapeseed nursery in Werribee, I noticed some leaf lesions. Checking the symptoms in a book it turned out to be ‘blackleg’ – the first record on rapeseed in Australia. The Werribee region had been growing cabbages for a long time so it was not surprising to find a Brassica disease. By 1972 the area of rapeseed in Australia had grown dramatically to about 80,000 hectares, with most of it in WA, particularly around Esperance. Blackleg hit the Esperance crop badly; most of the crop was sown to a rapa variety which was particularly susceptible. This devastation of the Australian crop was to become folklore in Australia and the rest of the world. Australia was seen as having the worst blackleg, and when blackleg became a serious disease in Canada in 1976 it was assumed to have come from Australia. With hindsight we can see that we were the only country growing spring varieties as a winter crop and that our varieties from overseas had never been selected for resistance (unlike winter crops in Europe). Rapa varieties were even more susceptible than napus varieties and even though rapa disappeared as a crop the curse of blackleg came up in discussion whenever rapeseed was mentioned.

After the 1972 blackleg disaster the germplasm was screened for sources of resistance. European winter rapeseed had good resistance but the idea of using this source was not very appealing because of the baggage that came with it – poor winter growth and genes for late maturity. Japanese oilseed cultivars had moderate resistance but the Japanese variety Mutsu (sometimes called Mutu) had excellent resistance. Mutsu was a fodder variety, quite different to the range of Japanese oilseed cultivars but more adapted to Australia than the European winter types. The third round of crosses in the Victorian program used Mutsu as a source of blackleg resistance, which led to pedigrees such as:

Chisaya/Zephyr/Bronowski/3/Mutu

Mutsu/3/Haya/Zephyr/Bronowski

Crosses were made to other germplasm such as Chinese lines (historically closely related and derived from Japanese lines) and so if pedigrees are examined from the Victorian program of the seventies the information above can be used to track the logic used in making the crosses.

In 1973 WA (Narendra Roy) and NSW (Neil Wratten) Departments also started breeding programs. The WA program worked mainly on napus and used winter material and juncea for sources of blackleg resistance. The NSW program in the seventies worked mainly on developing rapa lines. Pedigrees from WA show that ‘double low’ lines were derived from crosses such as Major/Tower. By 1973 the first ‘double low’ variety, Tower, was released in Canada and so was a source of quality traits. Roy used this to cross with winter varieties such as Major to bring in a source of blackleg resistance. On request, I sent some of the advanced lines from the Victorian program to NSW to be used in the Wagga program as they were abandoning work on rapa. This led to varieties such as Maluka and other varieties which were derived from crosses between two advanced Victorian lines.

At CSIRO Canberra Rex Oram produced a series of ‘double low’ lines from a three way cross using Bronowski, Oro and Rangi – called the Brongoro lines. Although these lines did not
perform well this experience with napus led Rex to work with John Kirk to develop the world’s first low erucic acid lines of *Brassica juncea* - the ZEM lines.

**ARAB**

There was an International meeting in Canberra in February 1977 (SABRAO) that brought together breeders from the Asia Pacific region. It was extremely hot and the only cool spot was a bar. Noel Thurling (Senior Lecturer at U of WA) and I met there a number of times and discussed the problems of arranging cooperation on rapeseed breeding and other rapeseed research. Noel was the leading rapeseed researcher at the time and had a number of PhD students working on different areas of rapeseed research. We were frustrated because rapeseed research was organized on a state level and it was difficult to have any national research programs that crossed state boundaries. Our most urgent aims were to organize interstate trials in three areas, yield trials, blackleg testing and phenology studies. We decided to form a club of rapeseed researchers so that we could arrange national meetings and have an “official body” which we could use as an excuse to put in grant applications to the Oilseeds Research Council (the forerunner of the GRDC). After returning from Canberra, Noel and I corresponded and eventually settled on the name ARAB (Australian Research Agronomists and Breeders) and decided that Noel would host the first meeting in Perth later that year.

That first ARAB meeting thirty years ago had eleven participants:

Noel Thurling, Richard Richards, Sarah Ryan, Lorelle Cargeeg and Vas from the U of WA; Mick Poole and Narendra Roy from WA Dept of Agriculture; Greg Buzza from Vic. Dept. of Agriculture; Neville Mendham form U. of Tasmania; Neil Wratten from NSW Dept of Agriculture; Terry Heard from SA Dept. of Agriculture.

ARAB 1 was a breakthrough, setting in place a process for conducting interstate variety trials, interstate blackleg trials and setting up a phenology experiment. At the time of the first ARAB meeting the wheat breeders had the Wheat Breeders Assembly. They had a formal document – something like a constitution – and this was something we wanted to avoid. We decided that ARAB should have no rules as an organization but just be a forum for rapeseed breeding, agronomy and other rapeseed research. At each meeting there would be a decision as to which state would hold the next meeting in two years time and it was up to that state to run the meeting as they saw fit – a bit like awarding the Olympic games to a city – but without any stipulations. I think this is one of the reasons that ARAB has worked so well – there are no rules to discuss. The only change has been that at ARAB 7 in Toowoomba in 1989 we decided that the acronym ARAB would now stand for the Australian Research Assembly on Brassicas.

When ARAB 2 was organized in Horsham in 1979 we had enough recognition for ARAB as an organization that it was much easier for participants to get permission and funds to cross state borders. And of course ARAB has gone on from strength to strength and is now an accepted part of the landscape.

**MEANWHILE OVERSEAS**

In 1978 I attended the Fifth International Rapeseed Congress in Malmo Sweden. We had six participants from Australia which showed that we were now joining the rapeseed research world. By this time Canada had made the switch from rapeseed to canola and the European breeders were well on the way to developing ‘double low WOSR’. It would be a number of years before the Europeans would use the word ‘canola’ without choking – as they were reluctant to change the name of their crop - be it WOSR, colza or raps – and this is still an issue!

To me the 1978 meeting had two exciting areas of breeding research – hybrids and double haploid production. It was clear that breeders wanted to move to hybrids as they had seen
the success of hybrid sunflowers and other hybrid crops. The problem was “how to do it”. The discussion had been on CMS systems – Heyn on ogura and Shiga on the ‘nap’ cms system. Others believed SI (self incompatibility) was the way forward. Double haploid lines had been produced by doubling naturally occurring haploids found in the field but research was starting on anther culture and even megaspore culture (which never progressed very far). So this congress set the scene for me on where canola breeding was going – hybrids and doubled haploids. I even wrote this in a report on the trip – in those days overseas trips were a big thing for the public service, needing lots of time and paperwork to organize, and so a thick bound report was required after each trip. As mine was tied to an oilseed exchange to the Soviet Union I needed an official report – which appeared a year later!

In 1979 the results of nearly a decade of breeding were that we now had ‘double low’ rapeseed lines that was at least 20% greater in yield than the commercial cultivar Midas and better blackleg resistance. In the Victoria Department we had four lines that were all at this level and there was debate on which one to release. Despite a decision to wait another year to decide on which of the four to release, I decided to increase one in a spare paddock at Werribee. That one became Marnoo – and along with Wesroona from WA – started the “canola” crop in Australia.

**REFERENCE**

A canola plant showing resistance to blackleg — the disease has not spread from the prick wounds on the cotyledons where blackleg spores were applied. Researcher Liban says that his team has to be able to look at what is available to them in terms of the pathogen population, identify which genes are most effective, and then transfer those into varieties for the marketplace. Liban says that researchers are starting to see companies market more varieties with multi-genic resistance. This gives you a double insurance policy. Check out the video for more on breeding blackleg resistance, and the links below for more on this topic: Canola School: Rotating Blackleg-Resistant Varieties. Organic canola oil: debunking the misunderstandings about organic canola oil, which was NOT genetically modified from rapeseed oil to begin with. We'll explain. These canola plants are the result of the hybridization of the rapeseed plant back in the 70's. Some varieties of canola are hybrid and some are open pollinated; both of these are the result of traditional breeding that happened decades ago, not genetic engineering. This kind of traditional plant breeding is similar to crossing a brown chicken with a white chicken to get a speckled brown-and-white chicken. Then you cross that speckled chicken with a brown chicken, and down through the generations it goes, imparting more and more of the genes that you're choosing to breed.