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Breeding better rape and linseed for Western Australia

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Rapeseed and linseed—the main oil seed crops grown in the south-west of Western Australia—have both been beset by problems which have limited farmers' interest in them.

Rapeseed was first grown commercially in 1970, when wheat quotas and low prices for other cereals forced farmers to seek alternative cash crops. The area sown to rapeseed increased rapidly, but disastrous outbreaks of the disease blackleg caused rapid decline, and little rapeseed is now sown.

Linseed has been grown in W.A. for more than 30 years. Linseed rust proved disastrous but was overcome by the introduction and breeding of rust-resistant varieties. In recent times the industry has been beset with a run of poor seasons, wind-blast damage of seedlings and contamination of seed with weed seeds. This has led to a decline in sowings.

Prices for both crops have been attractive since 1973 and a revival in interest can be expected if some of their problems can be overcome.

The best long-term answer to these problems may be through breeding and this article outlines the Department of Agriculture breeding effort with the two crops.

Rape

Rapeseeds (Brassicas) are becoming increasingly important for production of essential fats and proteins. Improved varieties developed in Canada and Europe produce high oil yield and nutritionally desirable fatty acid levels (zero erucic acid). In some varieties the glucosinolate content of rapeseed meal has been reduced to a level that allows it to be safely used as a protein source in livestock and poultry feeds. There is also a continuing demand for high erucic acid rapeseed oil for industrial use.

It was not surprising, therefore, that in 1970 when wheat and wool faced a severe slump, the search for an alternative source of income led to this “cinderella” crop, as rape is called in Canada where it came to the rescue of the Prairie farmers in a similar situation. When rapeseed

Stages in cross-pollination of rapeseed—
1. bud selection; 2. Emasculation (removal of anthers) of the flower bud; 3. pollination, in which anthers selected from another plant are used.
cultivation was introduced in W.A. in 1970 it came amid high expectations based on Canadian experience.

At first rapeseed had a good start, being "easy to grow" and "a profitable crop", particularly in the cool, long wet season of the south. Over the next few seasons the area sown grew rapidly. A number of Canadian and European varieties were tried and found promising.

But in 1972 the disease blackleg (*Leptosphaeria maculans*) virtually wiped out the rapeseed industry. From an estimated 41,566 hectares in 1972, the area under rapeseed fell to 2,225 hectares in the following year.

It soon became obvious that if the rapeseed industry was to survive in this State it would be necessary to develop adapted varieties resistant to blackleg.

In 1973 the Department of Agriculture therefore established an intensive rape breeding programme.

Breeding objectives and priorities

Breeding objectives were set in the following order of priority:

1. Resistance or tolerance to blackleg disease under the cool, moist conditions of south-western Australia has first priority in the programme. If this can be achieved, the following adaptive and quality characters must also be incorporated:
   - High seed yield, early maturity, synchronous growth habit, shattering resistance, waterlogging tolerance and so on
   - High oil content and yield
   - High quality oil (zero erucic acid and low linolenic acid)
   - High quality meal (low glucosinolates, high protein and yellow or light seed coat with low fibre content)

2. Earliness and drought tolerance are needed to allow an extension of rape growing into the wheatbelt

3. Resistance to white rust is required in *B. campestris*

Next in importance to resistance or tolerance to blackleg is to increase the seed/oil yield per unit area to make the crop economically more competitive.

Production of zero-erucic acid lines has been given priority over other oil quality aspects.

For the dry areas, developing early-maturing varieties tolerant to drought is being emphasised. Blackleg may not be such a problem in these areas and more importance may have to be attached to developing *B. campestris* varieties resistant to white rust (*Albugo candida*).

Genetic variability in rapes

Natural selection and breeding for several thousand years have resulted in a range of crop types in several species of the genus Brassica. The commercial term "rapeseed" covers at least four such species: *B. campestris* (turnip rape), *B. napus*
(rape), *B. juncea* (brown mustard), *B. nigra* (black mustard). *B. napus* and *B. campestris* are the two main species in Western countries.

Almost unlimited resources of genetic variability exist within the various rapeseed species. Genetic characters can be transferred, though with some difficulty, from one species to another by cross breeding. Collection and evaluation of the widest possible range of the species and genetic types within them is therefore a fundamental part of any programme of varietal improvement.

Many developed and primitive rape varieties from several parts of the world are now being introduced into Western Australia, most notably from Canada, Sweden, Japan and India. These will form the basis of a long term, continuing programme in the Department of Agriculture if initial success in overcoming blackleg warrants it.

Fortunately, some of the most immediately required characteristics are already available in high-yielding developed varieties from Canada, Sweden and Japan. These will form the main initial basis for breeding. Use of hardy underdeveloped varieties, such as some from India, could become more important in the long term to develop varieties for drier parts of the agricultural area.

**Blackleg resistance**

Varieties tested so far have all proved susceptible to blackleg at the seedling stage, both in the glasshouse (artificial infection) and in the field (natural infection).

Several late-maturing winter *napus* varieties, including Rames, Major, SV62/371 and Marcus, which European workers have reported to be resistant to blackleg, have turned out to be susceptible at the seedling stage under our conditions. Fortunately, these and some Japanese lines (all of *B. napus*) together with some Swedish lines of *B. campestris*, have been found to be highly tolerant to the disease at the adult plant stage. This is when the main damage occurs.

The European winter varieties showing tolerance to blackleg are all too late maturing for Western Australian conditions. The Japanese tolerant types are not too late for some areas, however, and are undergoing within-variety selection with a view to improving further their resistance and adaption to Western Australian conditions.

Meanwhile, crosses have been made between the tolerant European materials and susceptible but otherwise adapted and high-yielding varieties such as Target, Norin 16, Norin 30 (high erucic), Oro Zephyr, and Midas (zero erucic). The first generation crossed plants were grown in the glasshouse over the 1973-74 summer, using special low temperature (vernalization) treatments to make them flower and set seed normally.

In 1974 F2 (second generation) progenies from the crosses were grown for the first time at Mount Barker under conditions of heavy blackleg infection. From these crosses it has been possible to make large numbers of selections based on earliness in maturity and adult plant disease tolerance. Selection among these for erucic acid (high or low) and oil content was carried out through the 1974-75 summer, using quick laboratory assay techniques, before planting out again in 1975.

Such selections must be carried out through several seasons before the best lines can be finally identified and bulked for field scale yield testing.

The number of genes and the nature of gene action involved in conferring adult resistance to blackleg are not known. Our preliminary study indicates that it may behave as a highly heritable character. In some crosses 25 per cent of the F2 populations have segregated as "resistant" plants. If this is borne out by later studies, it should be fairly easy to select from the crosses early lines with good resistance or tolerance to blackleg disease, combined with suitable erucic acid levels (high or low).

The possibility of finding other genetic sources of resistance has not been neglected. *Brassica juncea*, *B. Napus* and *B. campestris* belong to the leafy fodder type of rape grown in cool, wet regions of the world. The existence of other resistance genes among them would not be unexpected.

The possibility of inducing mutations through radiation and other techniques, particularly in diploid *campestris* (turnip rape with a low chromosome number) and then screening the treated material for resistant genes, is also under investigation.

**Seed and oil yield**

In Europe, winter forms usually have better seed size or weight and better yield than the summer forms. Similarly, *B. napus* varieties have larger seed and higher yield potential than *B. campestris*. However, genetic variation in seed weight exists within each species and this can be exploited in breeding.

Parallel to seed size, oil content is highest in winter rape (47 per cent) followed by winter turnip rape (43 per cent). However, again varietal difference exists within species. One Japanese summer rape variety, Norin 30, has given as high as 54.7 per cent of oil content (dry matter basis).

It is easier to increase oil content in the seed through a repeated ("re-current") selection programme than to raise seed yield, since oil content...
is controlled by a relatively small number of genes. Such increase can apparently be achieved without sacrificing seed yield.

The new laboratory technique “nuclear magnetic resonance” (NMR), now available in the Department of Agriculture, makes it possible to assay large numbers of seed samples for oil content without damage to the seeds or loss of viability.

**Fatty acid composition**

Canadian and Swedish experience has shown that wide variation can occur in the fatty acid composition of rape seed oils.

To the extent that they are genetically based, such differences can be manipulated in breeding. High erucic acid in edible oil, is generally believed to be nutritionally undesirable, although controversy continues as to whether the rat experiments on which this belief is based are directly relevant to human nutrition.

High linolenic acid content causes instability and rancidity, thus lowering the keeping quality—an important consideration in, for instance, use for salad oil and mayonnaise. The breeding aim is for a maximum content of linoleic acid, which is both stable and nutritionally desirable as a polyunsaturated fatty acid.

Genetic variation in fatty acid composition between cultivars is greater than that caused by environmental conditions. In cross-fertilising species such as *B. campestris* this genetic variation can be detected between individual seeds on the same plant. Sophisticated laboratory techniques have been developed in which half of a seed is used for assay and the remaining half sown. This makes it possible to screen for desirable fatty acids before planting.

**Zero erucic acid**

In 1961, Canadian plant breeders succeeded in isolating rape (*B. napus*) plants completely free from erucic acid, and this led to the production of a series of varieties combining absence or low levels of erucic acid with desirable yield and oil content. Subsequently, the same breeders isolated a zero erucic acid line of turnip rape (*B. campestris*), from a Polish variety.

Further work established that the level of erucic acid is mainly governed by two genes in *B. napus* and one gene in *B. campestris*.

Absence of erucic acid does not influence total oil content of the seed.

In our programme in Western Australia we are using the new Canadian zero erucic acid varieties Oro, Zephyr and Midas (*B. napus*) and Span and Torch (*B. campestris*) for crossing with the apparently blackleg-tolerant winter varieties Ramses, Major, Marcus and SV6/2-571 (*B. napus*) and Duro (*B. campestris*) respectively.

Once attained, zero erucic acid is easier to maintain in *B. napus*, which is self-fertile. In *B. campestris*, which is usually self-infertile and where outcrossing is the rule, problems arise in maintaining a pure variety. Self-fertile *B. campestris* types do exist, however, for example, yellow sarson from India, which also has the desirable characters of yellow seed coat and low seed fibre content. Such types are being investigated with a view to use in the breeding programme.

**High erucic acid**

There is still a good demand for high erucic acid oil for industrial use. In the *Brassica campestris* species *trilocularis* (yellow sarson) erucic acid contents as high as 50 to 60 per cent have been reported. Introduction of yellow sarson varieties into the programme, for reasons mentioned above, should make it possible to select adapted very high erucic as well as low erucic varieties with good yield and other desirable agronomic properties.

**Linoleic/linolenic acid**

Most lines selected for zero erucic acid in the Canadian and Swedish programmes have some increase of linolenic acid and approximately double the linoleic content of conventional varieties.

It would be desirable, however, to decrease linolenic acid considerably. This is difficult to achieve due to a considerable environmental effect which makes selection in the greenhouse unreliable.

**Glucosinolates in rapeseed meal**

Rapeseed meal contains glucosinolates, principally glucanapin, glucobrassica napin and progoitrin, which in turn produce, through enzyme action, butenyl and pentenyl-isothiocyanates and oxazolidine-thione respectively. These toxic products can adversely affect the feeding value of rapeseed meal. Research in Canada and Sweden indicates that it is possible to eliminate these compounds through plant breeding.

In *B. campestris*, some cultivars from India and Japan are free of pentenyl and/or oxazolidine-thione. Absence of these is controlled by single recessive genes which can readily be transferred to other *B. campestris*.

In *B. napus*, one Polish summer rape variety (*Bronowski*) was found to have a very low level of all the three glucosinolates. It is now being used in Canada and Sweden for crossing with suitable lines for the production of superior low-glucosinolate varieties.

The level of glucosinolates in *B. napus* is, however, influenced by the genotype of the maternal parent and is subject to changes by environmental factors. Some 11 or 12 recessive genes are said to be involved for the absence of all the three glucosinolates in this species.

Despite these complications there are good prospects for the development of varieties of both rape and turnip rape without erucic acid and without or with only a trace of glucosinolates, as the level of erucic acid and glucosinolates are inherited independently of each other. Canadian workers have recently released one variety (*Tower*) in *B. napus*, combining zero erucic and low glucosinolates.

**Fibre content and pigments of seed coat**

The seed coat contains a lot of fibre but little oil or protein. A reduction of the seed coat percentage can therefore produce an increase in oil content of the seed as well as in the feed value of the meal.

A small seed generally has a higher seed coat content than a larger one, and at least in rape and turnip rape, yellow and white-seeded types have thinner seed coats than dark seeded types.

As the colour of the seed coat is determined by genetic factors (one to three genes are said to be involved), yellow seed coat colour be-
Rapeseed breeding rows at Mount Barker in 1975. The marked row was almost wiped out by blackleg. The good stands in adjacent rows are blackleg resistant.

ing a recessive trait) there seems to be quite a good basis for breeding varieties with high oil content and low content of pigment and fibre.

**Protein**

Rapeseed meal contains about 40 per cent protein and increasing protein content along with oil content would be difficult to achieve. The protein content of rape seeds has only secondary importance and seems to be at satisfactory levels now.

**Drought adaptation**

The possibility of growing a short-duration crop of rape in the Western Australian wheatbelt needs investigation. In this relatively dry region a very low incidence of blackleg would be expected.

Early maturing varieties of *B. campestris*, and their crosses involving the zero erucic acid varieties Span and Torch are being tested in this region for selection of high-yielding zero erucic lines adapted to low rainfall situations.

Trials conducted so far indicate that some high erucic Swedish *campestris* varieties could significantly outyield existing Canadian varieties.

**LINSEED**

Linseed is grown primarily for its oil, a drying oil used in the manufacture of paints, varnishes, linoleum, oil cloth and other products. Oil content of the seed depends both on the variety and on its growing conditions and is usually from 35 to 44 per cent. The active constituents in drying oils are linolenic and linoleic acids.

Department of Agriculture breeding work resulted in the release of the two varieties Gibson and Kamena, which for many years were the only varieties grown in Western Australia. They are now being replaced by Glenelg, more recently developed by the Victorian Department of Agriculture. This white flowered variety is higher yielding and has been used in crosses with Gibson and Kamena in an attempt to produce superior varieties better adapted to local conditions.

For a number of reasons, including the smallness of the industry and drought and insect damage during the last three years, the breeding programme is at present at a low level. It will be expanded with the development of the new Glenelg crosses.

**Objectives in linseed breeding**

The aim in the programme is to produce early maturing, high yielding varieties with high oil contents and satisfactory quality.

Early maturity is an advantage because of the shortness of the growing season. Even along the south coast, and in the Great Southern where most linseed is grown, early maturing varieties usually outyield midseason ones. Glenelg is an early midseason to midseason variety, so theoretically some yield improvement should be possible.

Crossing is carried out in the glasshouse at South Perth. The progeny are then selected in the field at Wongan Hills Research Station. This is followed by initial yield testing at Wongan Hills and Mount Barker Research Stations. High yielders are then more extensively tested in linseed variety trials on research stations and on farmers' properties in the medium to high rainfall areas (annual rainfalls from 350 to 650 millimetres).

Preliminary evaluation for oil content is carried out on seed from individual plants in the first segregating generation (F2 generation). This enables crossbreds with low oil contents to be discarded early, thus increasing the efficiency of later selection.

During yield testing greater quantities of seed become available and more extensive quality tests can be carried out on each crossbred. These are for oil content, iodine number (an indication of the drying property of the oil), and protein content of the mash after oil extraction.

**Diseases**

Diseases affecting linseed are rust (*Melampsora lini*) and pasmo (*Septoria linicola*). Rust has been controlled by the breeding of resistant varieties. It no longer causes serious damage, but is still present in the State because wild flax (*Linum marginale*) is an alternative host plant.

Pasm is common, but usually not serious. It has been difficult to produce resistant varieties. At the time of release Glenelg was resistant to the races of this disease in Victoria and may also be resistant in Western Australia.