THE COURSE OF RESEARCH AND DEVELOPMENT OF ALTERNATIVE ARABLE CROPS IN NEW ZEALAND

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ABSTRACT

Arable farming in New Zealand is based on a very limited range of crops: wheat, barley, oats, peas, maize, and potatoes. In the last forty years three crops have disappeared (mustard, linseed and linen flax), and although thirteen alternative crops have been grown commercially, three are now no longer in commercial production and of the remainder only durum wheat occupied 1000 ha or more in 1984/85.

This paper reviews the course of research and development of 23 potential broad-acre crops with particular emphasis on the apparent reasons for their commercial success or failure or for their abandonment during research and development.

INTRODUCTION

New Zealand's arable cropping is currently based on only six food crops and there is no significant production of any oil or fibre crops (Table 1). The range of arable crops produced in New Zealand has diminished in recent times with the disappearance of three crops, linen flax, linseed, and mustard.

TABLE 1: Arable crop areas (ha) harvested in New Zealand from 1980-1984.

Crop	Mean area 1980-1984	% of Arable crop
Barley	85910	37.5
Wheat	75650	33.1
Peas	20720	9.0
Maize	18300	8.0
Oats	17715	7.7
Potatoes	8750	3.8
Others *	1740	0.8

* Includes lupins, linseed, soybeans, oilseed rape, sunflowers, lentils, and "other crops" but excludes tobacco and hops.

Linseed (*Linum usitatissimum* L.) was a significant oil crop until 1979 with up to 10,000 ha being grown in the early 1950's. World-wide the demand for linseed oil dropped with the introduction of acrylic paints and substitution of vinyls for linoleum.

Flax was also an important fibre crop in the 1940's with up to 8,500 ha grown. There has been a recent resurgence of interest in the production of linen flax fibre using chemical retting and 200-400 ha are likely to be sown in 1985/86 (B. Bisdee, pers. comm.).

White mustard (*Sinapis alba*) and black mustard (*Brassica nigra*) produced for culinary purposes were significant arable crops in the early 1940's reaching 1000 ha in one year (Claridge, 1972), but mustard is no longer produced on a large scale.

Cropping farmers need a wider range of crops to spread financial and climatic risks and provide break crops in rotations. Diseases are also limiting farmers' options. For example, take-all (*Gaeumannomyces graminis*) in wheat and root rot in peas caused by *Aphanomyces euteiches* cannot be economically controlled using chemical methods and no known genetic resistance exists.

This paper outlines the research objectives and the problems encountered in the development of 23 arable crops in New Zealand. The contribution that alternative crops are making to arable agriculture is examined and the time span from initiation of research to commercial crop production detailed. The crops have been defined as arable on the basis of their broad-acre scale of production. Forage crops, pasture and forage seed crops, and herb and vegetable crops have not been considered. Commercialisation is defined as the stage at which the product is produced for financial return. Prior to this stage on-farm evaluation and/or seed production may have taken place for some years.

CEREALS AND FLOUR PRODUCING CROPS

Buckwheat (*Fagopyrum esculentum*)

Buckwheat probably originated in Central Asia and is a crop suited to cool moist climates and short growing seasons. It is related to dock (*Rumex* spp.) and is well adapted to poor soils.

Dalgety Agresearch have investigated buckwheat since 1972/73. Problems include the indeterminate habit of the crop resulting in shedding and harvesting losses. The triangular seed is enclosed in a hull and the dehulling process results in seed loss. Crop Research Division (CRD) at Gore in 1977/78 compared buckwheat and wheat (cv. Takahe) and obtained 1.2 and 4.0 t/ha respectively. Post emergence weed control was a major problem but, by using trifluralin, good control was achieved and buckwheat yielded up to 60% of wheat (D.S.C. Wright, pers. comm.).

There is a very small, local demand for dehulled buckwheat as a health food. Apparently only 90 ha are required to satisfy the current market.

Durum Wheat (*Triticum turgidum* var. durum)

Pasta products, such as spaghetti and macaroni, are best made from durum wheat but until recently pasta was produced from bread wheats (J.W. South, pers. comm.). Research to develop a durum wheat for New Zealand began in 1957 with trials by MAF in South Canterbury. In the mid 1960's some short-strawed durums were imported by CRD from CIMMYT (Mexico) but little commercial interest was shown until 1974 when a cooperative trial with the Timaru Milling Company and MAF was set up using CRD lines. From this work the cultivar Tara was released in 1982 and gave acceptable pasta by world standards. Since then about 3000t of Tara have been produced annually in mid- and south-Canterbury for the Timaru Milling Company. This company also contracts for about 1000t of the durum cultivar Aldura (J.W. South, pers. comm.), which provides a desirable yellow pigmentation in pasta.

Until recently, the yields of durum wheats were well below those of bread wheats but now they are similar.

Input from the major producer was the key to the commercial development of a durum wheat in New Zealand. Although the need for a durum wheat was perceived and research was initiated in the late 1950's it was not until about 15 years later that commercial interest developed, and a further 8 years before pasta was made from 100% durum.

Grain Amaranth (*Amaranthus cruentus, A. hypochondriacus, A caudaus*)

Grain amaranth is a native of Mexico and South America where it has been used as a food grain for centuries. The very small seed is highly nutritious with a well-balanced content of amino-acids. It is a C4 plant which grows well under low fertility and high temperature.

Breeding objectives overseas are related to harvesting; reduced height and resistance to lodging, increased harvest index, increased seed size, uniformity of ripening and resistance to shattering.

In 1982/83 MAF conducted two trials on grain amaranth in South Canterbury. Yields from the only site harvested ranged from 0.3 to 1.6 t/ha (McLeod, 1985). A subsequent trial in 1984/85 yielded 1.5-1.8 t/ha. McLeod considers the crop has a yield potential of 1-2 t/ha and that more work is required on planting density, harvesting methods and seed shedding. No pests or diseases were observed in these trials. Amaranth may have a place as a crop in the warmer areas of New Zealand. There is commercial interest in any new 'grain' which can increase the range of bread products available to the consumer.

Quinoa (*Chenopodium quinoa*)

Quinoa, a close relative of fathen (*C. alba*), has been grown in South America for centuries but is new to modern agriculture.

In 1978/79 CRD grew several accessions from INIA Peru but further research was not carried out until 1983/84. Plots were sown at Pukekohe, Palmerston North, Riwaka and Lincoln. Only crops at Palmeerston North and Riwaka were successful where plants grew to heights of 1.6 and 1.4 m and yielded 2.3 and 3.1 t/ha respectively. A processer found the flavour of products produced from quinoa flour to be unacceptable but this may have been caused by the high saponin content of quinoa grain which can be washed out prior to processing. No further trials have been conducted.

Rice (*Oryza sativa* L.)

New Zealand imports rice and rice products which, in 1983/84, totalled some 8,500 t and were worth $NZ6.3 million c.i.f.

Research on rice started in 1958 at the Rukuhia Soil Research Station to determine the most suitable cultivars, appropriate agronomic techniques and the place of rice in existing farming systems (Gerlach and Southon, 1971). Initial results were encouraging and after 4 years a larger scale trial was established on a farm near Te Puke. Several other rice trials were also set up in other parts of New Zealand. From this work suitable long and short-grained cultivars were selected from those grown overseas in areas with soils and climate similar to those found in New Zealand. A combination of dryland and wetland cultural techniques was found to be best suited to the New Zealand situation. Satisfactory weed control and harvesting methods were also identified.

A commercial company, Rice Growers of New Zealand Ltd., was formed in 1965 and began operations with a planting of 5 ha in the Te Puke area. Later commercial plantings increased to 45 ha. The short-grained rice produced in Te Puke was of better quality than the short-grained rice then imported from Australia and received favourable reports from the International Rice Research Institute and the New Zealand public. However, in 1971/72, unseasonal floods reduced yields and commerical rice growing stopped because of a lack of finance to expand production to an economic level (about 120 ha) on less flood prone land (J.C. Gerlach, pers. comm.).

Subsequently Gerlach showed that three Italian long-grained cultivars could be grown in Northland with an average yield over three years of 5.5 t/ha on soil of medium fertility, applying the wetland production method modified to suit New Zealand conditions. This yield was considered to give an acceptable profit margin to the grower at 1974 price and demand levels in New Zealand. Despite this, rice has not been produced commercially in New Zealand since 1971/72.

Triticale (*Triticosecale*)

Triticale is a man-made cereal resulting from crossing wheat with rye. The first wheat-rye crosses were made more than 100 years ago but stable fertile lines from these hybrids were not produced until the 1930's. Triticale is resistant to many diseases affecting wheat and is better adapted than wheat to light or acid soils and cold climates. It can be used as a forage crop or in grain-based animal feeds and also for milling for human consumption. About 1 million hectares are grown annually world-wide, mainly in USSR, North America, Europe and Australia. Commercial cultivars have only recently become available in New Zealand.

CRD began evaluation of imported triticale lines in the mid 1950's. Initial results were not promising however because of sterility problems and tallness. The first introduction of dwarfing genes to reduce lodging caused grain shrivelling and poor germination.

New material from Canada was tested at CRD in 1969/70. These lines were more fertile and this material and lines from other areas, including Eastern Europe and Australia, have since been further evaluated. Two cultivars selected from the best of the material tested were released as Aranui and Karere in 1985 (McEwan, 1984).

Two further triticale cultivars Lasko and Salvo were introduced from Poland in 1981 and released in 1985. Subsequent trials in Canterbury have shown they can outyield top wheat cultivars and about 250 ha of the two cultivars were grown in 1984/85. Lasko is suited for use in flour and speciality food products, with the higher yielding Salvo suitable for stock feed.

Successful commercial development of triticale will depend on the establishment of methods for using the product in the milling and baking industries and in the stock food industry. Milling trials on triticale have shown that 70/30 and 60/40 mixtures of Lasko flour and Oroua wheat wholemeal have baked satisfactorily and small quantities of bread containing triticale are now commercially available.

Triticale is at the threshold of becoming a commercially viable crop in this country. The development time has been long, partly as a result of technical problems in selecting cultivars which yielded well under New Zealand conditions and partly because of the lack of strong interest from grain processing industries.

GRAIN LEGUMES

Adzuki Beans (*Vigna angularis*)

The adzuki bean has long been grown in China, Korea and Japan. It has been introduced successfully into USA, S. America and West Africa. The beans, especially the red ones, are popular in Japan where they are boiled, fried or ground and used as flour in small cakes and sweets. They may also be split, sprouted for use as a vegetable or used whole in soups or for feeding livestock. Japan is the major producer and consumer of adzuki beans and is virtually the only country importing them, the demand fluctuating with domestic production.

Research on adzuki beans in New Zealand began at CRD in 1968 and showed that although they are probably better adapted to a more continental climate with higher summer temperatures than are experienced in New Zealand, good yields of up to 2.6 t/ha were obtainable experimentally in the south Auckland area (Palmer, 1972). Initial problems with weed control and harvesting techniques were solved and suitable lines for growing in New Zealand conditions were selected. In the early 1970's small areas of adzuki beans were bulked up under contract to Japanese buyers but no further contracts were available however as cheaper supplies from China became available. (J. Palmer, pers. comm.).

Chick Peas (*Cicer arietirium*)

The chick pea is an annual grain legume which has been grown for many years in Asia, the Mediterranean region and parts of Africa. It has also been introduced successfully into Mexico, Argentina and Chile where it has become an important crop. Chick peas are drought tolerant and the seeds have a protein content of about 29% which compares favourably with that of lupins and beans.

There are two main kinds of chick peas. Smaller seeded coloured chick peas are known as desi and the larger cream or salmon-coloured types are known as kabuli or garbanzos. India produces about 75% of the world chick pea crop.

Commercial awareness of the possibility of growing chick peas and the other pulse crops for export was aroused in the late 1970's. Evaluation of chick peas began at CRD in 1977/78, the lines being from ICRISAT were mainly of the high yielding desi-type. By 1981, grain firms had established that the larger seeded kabuli-type were required for export. From ICRISAT material, seven promising kabuli-type lines were selected and trial yields reached 1.5-2 t/ha. Further agronomic work was carried out but these lines still do not meet industry size and colour standards for top grade, and price (D.S. Goulden, pers. comm.).

In 1982, some commercial cultivars of kabuli-type chick peas were imported from the United States but problems with seed set and quality occurred. Current research at CRD aims at determining if these problems are related to climatic or disease factors.

Providing the quality standards for top grade crops can be reliably met commercial interest in producing chick peas in New Zealand is likely to remain strong. There is currently a world shortage of chick peas as a result of India's embargo on exports of pulse crops.

Faba Beans (*Vicia faba*)

Faba beans (also known as field, tick or horse beans) were grown in the early 1900's for horse feed. Small scale commercial production was renewed about 10 years ago.

Evaluation of faba bean production began with trials by CRD and Dalgety New Zealand Ltd using four cultivars from the United Kingdom. These preliminary trials suggested that faba beans could be produced in New Zealand and provide valuable high-protein supplement for stock.

Agronomic work commenced at CRD and Lincoln College in the 1970's and a small breeding programme was begun in 1975 as most overseas bred cultivars were not well adapted to New Zealand conditions. However, cultivar release is still some years away because of difficulties with breeding an outcrossing plant.

Faba bean production began on a small scale in mid and north Canterbury in the mid 1970's using overseas bred cultivars. The area has remained small, at around 350 ha, because of relatively high input costs, yield uncertainty, and low prices. The major defect with the crop is susceptibility to *Ascochyta* blight which markedly reduces yield and quality. This seed borne disease may be partially controlled by seed treatment and later use of fungicides but these treatments are not economic at present prices. Newton and

Hill (1978) considered that header losses were large and contributed to low commercial yields in Canterbury.

Most of the harvest has been exported, mainly to Australia. However, this market is limited by volume and price.

Lentils ***(Lens culinaris)***

Until recently New Zealand imported about 100t of lentils annually, about two thirds of which were red lentils. Commercial production of lentils in New Zealand began in 1982 and is still small scale.

Interest in lentils as a crop was aroused in the late 1960's but lentil trials in the South Canterbury were abandoned because of crop failures and low rpices. CRD began to evaluate the crop in 1972 and, because of a lack of suitable cultivars, research switched from work on crop management to evaluating germplasm to obtain cultivars with suitable plant and seed type, maturity, and reaction to local diseases (Jermyn *et al.*, 1981). By 1981, the regions and agronomic practices suited to lentil cropping were defined and a red cultivar, Titore, was released.

Commercial production began with 100 ha grown in 1982 and the area has increased to an estimated 700 ha in 1985/86. Two yellow cultivars imported privately became available in 1985 and DSIR will probably release a further yellow cultivar in 1986. The lentils produced are being marketed in both New Zealand and overseas by Lentil Marketing (NZ) Ltd. Prospects for further development of the crop are encouraging however the international market for lentils has been volatile in recent years so careful marketing and production planning will be needed to maintain good prices. The domestic demand for lentils is expected to increase and could be supplied entirely by New Zealand grown lentils.

Navy Beans ***(Phaseolus vulgaris)***

In 1983/84, New Zealand dry bean imports totalled about 1500 t and cost $2.6 million. At present most are navy beans used for canning as baked beans.

Various types of dry beans were investigated sporadically and unsuccessfully between 1940 and 1970. CRD began an evaluation of navy beans as a crop in 1969. Sanilac was imported from U.S.A. and reselections of it have been made to obtain types better adapted to local conditions. A small breeding programme was established at CRD in 1969 to develop high yielding disease resistant cultivars capable of direct harvesting. Emphasis was placed on producing cultivars suited to a wide range of conditions. This programme will soon release a higher yielding cultivar than the standard Sanilac. Agronomic work has also been carried out to determine the crop's innoculation and irrigation requirements and to establish a management package for growing the crop.

Canning of navy beans by J. Watties Canneries began about 1945 and Watties first started growing navy beans in Hawkes Bay in 1953. They were also tried in Gisborne in 1955 and from the early 1960's have been grown in the Wairarapa and Marlborough. Small quantities of navy beans were grown under contract to Watties between 1974 and 1979 but poor quality and unreliability, and indifferent returns, lead to a decline in local production. A major problem has been the lack of interest in locally produced navy beans from seed merchants to act as agents between growers and the processor when there was little financial incentive.

Average yields of navy beans in Marlborough have been about 1.4 t/ha but these can be expected to increase to 2-3t/ha with additional research and extension input. This would make production of the crop for the local market more profitable.

Peanuts ***(Arachis hypogaea)***

Peanuts, a crop of South American origin, are grown extensively in many tropical and warm temperate regions of the world. The possibility of growing peanuts in northern New Zealand has been investigated but the crop has not been produced commercially on a large scale.

MAF carried out a number of trials on peanuts in 1967/68 and concluded that yields were too poor for viable commercial production. Highest yields of 0.9 t/ha were achieved in Northland (Gerlach, 1973). In 1978 CRD tested 73 lines from Canada, USA and Australia in Northern areas and 42 were retained for further evaluation in 1979/80 (Anderson and Piggot, 1981). In 1980/81, 12 of the most promising cultivars, mostly early maturing types, gave yields over 3 t/ha on sheltered sites with early sowing and good week control. Further research is needed on weed control and fungal diseases, primarily *Sclerotinia*. The high yielding selections appear adequate for establishing a peanut industry on sheltered sites in the northern North Island.

There is interest in commercial production of peanuts and some small areas (under 0.5 ha) have been harvested in recent years. The major factor limiting the area is the lack of suitable harvesting machinery and importation or development of this equipment will require significant financial input by a developer (J.A.D. Anderson, pers. comm.).

Soybean ***(Glycine max)***

Soybeans are the world's most important grain legume and soy meal and oil are major commodities in world trade. USA and Brazil are the major producers. About 15 million litres of soybean oil and 5,000 t of meal are imported annually for food and animal feeds respectively. Soybeans have been grown on a very small scale in New Zealand for about 15 years, mainly in the Gisborne region.

Experimental work on soybeans began in New Zealand in 1914 and considerable interest in the crop existed in the 1920's and 1930's (Gerlach *et al.*, 1971). This early work did not lead to commercial production of the crop however because of unsuitable cultivars for the climatic conditions and a very small domestic market More success with the crop may have been obtained if the research has also included a study of crop phenology and climatic adaptability in this country (J.C. Gerlach, pers. comm.).

Interest in soybeans revived in the late 1950's with trials conducted by CRD, MAF, Lincoln College and commercial interests. These trials, in which about 70 cultivars were tested by CRD alone, showed that if was unlikely that soybeans would yield enough to become a profitable oil crop in Canterbury (Blair *et al.*, 1966). Yields

in some northern districts were more encouraging but were still insufficient for commercial production. Weed control was a major problem.

Subsequently, further trials by a number of agencies established improved crop management methods. Small scale commercial plantings of up to 2.5 ha were made, encouraged by Fletcher Industries.

In 1969, CRD terminated research on soybeans in the South Island but a small genetic improvement programme was continued at substations in the North Island. Available cultivars performed well in good seasons but very poorly in cooler seasons. Soybeans with a combination of cold tolerance and earlier maturity are required. With this aim a cooperative programme was developed with Agriculture Canada in 1977.

Dalgety NZ Ltd took up an interest in soybeans and began contracting for soybeans in 1971. In the Poverty Bay area yields averaged 3t/ha (Manning *et al.*, 1974). By 1973/74 over 500 ha were grown but average yields were lower than those obtained in previous years and the prices were insufficient to attract a large enough area to warrant establishment of an oil extraction plant. Recently the soybean area has declined to about 100 ha.

In 1982, Matara, a CRD selection from Canadian material was released as well as a Canadian cultivar, Maple Arrow. These cultivars are better adapted to New Zealand conditions than the two standards Amsoy and AMT19.

Soybeans are relatively easy to grow and are a very good rotation crop with maize and other cereals. The area produced could increase in the future, particularly if there was sufficient confidence in the crop to establish an oil extraction plant but at the present time the returns to farmers do not equate with what can be obtained from other crops.

OIL CROPS

Meadow Foam (*Limnanthes alba*)

Meadow foam is a winter annual from the pacific north west of the United States which is being developed in the USA as an oil crop. The waxy oil is a potential substitute for sperm whale oil. In 1978/79 CRD Lincoln grew a plot of meadow foam but seed yield was very poor partly because of harvesting difficulties. Massey University in 1982/83 began to investigate the general adaptability of the species, harvesting, oil processing techniques and development of suitable cultivars. Progress to date indicates likely seed yields of 2 t/ha and oil yields of 0.5 t/ha (I.Gordon, pers.comm.).

Accelerated research and commercial development are unlikely until sperm whale oil becomes unobtainable.

Oilseed Rape (*Brassica napus*)

There are two types of rape grown for oil: spring sown annuals and autumn-sown biennials of both *B. napus* and *B. campestris*. Work in New Zealand has concentrated on autumn- and spring-sown *B. napus*. The biennial type has been grown in Canterbury and Otago for many years for the production of seed for sowing as a forage. However, research on growing the crop was limited and the number of growers with significant experience of the crop was small. Research requirements were therefore in basic agronomy, development of cultivars suitable for oil production and attainment of much higher yields because of the low value of the product.

CRD began investigating rape oil production in 1964 by looking first at autumn sowing in Canterbury. Observations on commercial crops suggested that yields were limited by insufficient cultivation, weed control and nitrogen and by aphid infestation (Lammerink, 1973).

Work on spring-sown oilseed rape by CRD began in Southland in 1968/69. The objectives of the breeding programme were development of types with low erucic acid and glucosinolate content and aphid resistance. Dalgety Agresearch conducted a series of trials from Waikato to Canterbury from 1972 to 1974 and concluded that as a spring-sown crop, oilseed rape appeared to be economic (Manning *et al.*, 1974). Yields ranged from 1.1 to 2.2 t/ha. Lammerink (1973) concluded that spring-sown crops were unlikely to be economic in Canterbury because of the high costs of weed control, irrigation and aphid control.

CRD released a low erucic acid, low glucosinolate ("double zero") cultivar Oturu, in 1982 as a replacement for Canadian-bred Tower. However, Oturu was only grown on a limited scale before being outclassed by European-bred Bullion.

When the demand for linseed oil dropped Fletcher Agriculture turned to oilseed rape to utilize its Dunedin plant. In 1969/70 they grew three crops in Southland with yields of 1.6-2.3 t/ha but the average yield over three years was only 1.3 t/ha. By 1974/5 they were growing over 500 ha of Tower in Canterbury, Otago and Southland. Yields in Canterbury and North Otago were greatly influenced by aphids and restrictions on the use of pesticides under the Apiaries Act proved a problem in controlling aphids in flowering crops. Yields in Canterbury-North Otago averaged 1.1 and 1.9 t/ha and in Southland 1.6 and 1.8 t/ha in 1974/75 and 1975/76 respectively (Davidson, 1976). Fletchers stopped oil production in the late 1970's but for a limited period they extracted oil for farmers to use as a diesel substitute and kept the meal as payment.

In 1981 a growers cooperative, South Oil, bought Fletcher's oil extraction equipment and grew 120 ha of Tower in 1982/83 to produce oil as a diesel substitute. Subsequently the oil became too valuable for this use and production has expanded, for producing cooking oil, from 400 ha in 1984/85 to a planned 2000 ha in 1985/86.

Yields in 1984 and 1985 averaged 2.2 t/ha. Growers consider the returns economically attractive (basic price is to be $396/t in 1985/86), and as a break crop it is claimed rape increases wheat yields, especially in the second crop after rape (W. Wilson, pers. comm.).

Clubroot (*Plasmodiophora brassicae*) is a major problem with oilseed rape (W. Wilson, pers. comm.). Double zero cultivars are all clubroot susceptible which limits rape production to every fifth year in a rotation. The cooperative has been frustrated by a lack of Government

research and has had to conduct its own with limited resources.

The South Island Barley Society is also contracting areas for oilseed rape in Southland for 1985/86, adding to the renewed interest in the crop.

Safflower (*Carthamus tinctorius*)

Safflower is a thistle-like plant from the Near East which was initally grown as an alternative to saffron for its yellow dye. More recently it has been grown for its seed oil which is rich in polyunsaturated acids.

Investigative work on safflower began at CRD in 1962/63 although the crop had been grown experimentally in the 1930's by CRD and in 1954 by Massey University. In 1964/65 eight trials were sown from Seddon in the North to Hawea in the South. None of the trials, except Seddon, produced seed because of botrytis (*B. cinerea*) infection. At Seddon losses were about 33% of the crop which yielded 1.3 t/ha. This work showed that the crop was relatively easy to grow but botrytis head rot at flowering was a major problem. In 1969/70 leaf curl caused by potato aphid (*Aulacorthum solani*) was a problem. Experimental seed yields up to 3.0 t/ha have been obtained (Manning *et al.*, 1974, McCormick and Thomsen, 1978). Selections with tolerance to botrytis were made but CRD scaled down the work in 1970 in favour of sunflower development. A small amount of work continues at CRD and Plant Physiology Division, Palmerston North.

In 1972/73 and 1973/74 Dalgety Agresearch grew CRD selections at a number of locations (Manning *et al.*, 1974). It was concluded that the major factor limiting commercialisation of the crop was the availability of cultivars which combined botrytis resistance, high oil content and low hull to kernel ratios.

Sunflower (*Helianthus annuus* L)

Originating in the United States of America, this now valuable crop plant has been markedly improved by breeding and selection, especially by Russian workers. Oil content has been increased from 20-30% to 40-55%.

Sunflowers were grown by CRD from 1943 to 1945 with yields of 1.6-1.6 t/ha and oil contents of 25-30%, but a concerted effort to develop the crop did not begin until 1964/65. Initially overseas cultivars and accessions were tested but later a breeding program was undertaken selecting for earliness, disease resistance, yield, and oil content. Experimental yields ranged up to 5.0 t/ha with oil contents of 38-48%. Sclerotinia (*S. sclerotiorum*) and botrytis proved to be major problems.

In 1964/65 20 ha of sunflowers grown in Northland yielded 2.3 t/ha with an oil content of 48%. Subsequently 40-60 ha has been grown annually in the North Island to supply the local bird seed market using low oil content cultivars. Over 200 ha of sunflowers were grown in North Otago in 1971/72 at an average yield of 1.9 t/ha. From small scale commercial plantings over the 1972 to 1974 period Manning *et al.* (1974) concluded that sunflowers were uneconomic because of poor yields and bird damage. They concluded that the future of sunflowers in New Zealand depended upon the successful development of hybrids. Yields from 8 districts and 34 ha averaged 1.0 t/ha in 1972/73, and from 7 districts and 152 ha, 0.7 t/ha in 1973/74.

Lammerink and Stewart (1974) concluded commercial production had been disappointing because of late, slow and variable ripening which induced diseases and necessitated premature harvesting and artificial drying and caused heavy seed losses to birds.

DRUG AND OTHER CROPS

Evening Primrose (*Oenothera biennis*)

Evening primrose, a South American plant long grown in temperate regions of the world as an ornamental has recently been grown for its seed oil which has medicinal properties. The oil is high in linoleic acid and gamma linolenic acid, the later giving the oil its apparent medicinal properties (Palmer, 1985).

In 1979/80 a small quantity of evening primrose seed was multiplied by CRD for re-export. Since then Yates Research at Courtenay and growers themselves have investigated the crop. Major problems arise with establishment, weed control and harvesting. In early accessions germination was irregular but lines and cultivars recently grown in New Zealand have been selected for improved germination. Establishment is more uniform where sowing is shallow (15 mm) and the soil warm (16-25 °C).

Harvesting is difficult because flowering is indeterminate giving a large range of maturities at harvest. The oil content of full size but immature seeds can be only 8% compared to 26% for mature seeds and mature pods shatter easily. Harvesting may be further aggravated by weeds, exacerbated by a lack of reasonably priced herbicides. Under experimental conditions, seed yields have ranged up to 1.5 t/ha.

There is considerable commercial interest in the crop from a number of local and overseas companies. Details on areas and yields are not available but 80 ha were believed to have been sown in Canterbury in 1984/85 and yields up to 0.8 t/ha achieved. Establishment difficulties probably results in less than half the area sown being harvested in the first year.

It is believed that all the seed is for export, with oil extraction being carried out overseas. Prices are currently about $12/kg for seed and $100/kg for oil.

Gauyule (*Parthenium argentatum*)

Gauyule is a hardy rubber producing plant which originated in the Chihuahuan desert of Mexico. Wild plants were first used for rubber production in Mexico and the USA in early 1900's. Guayule is grown as a cash crop in Mexico, its potential is being re-examined in the USA and Australia.

Research of gauyule in New Zealand is still at a very early stage. Evaluation began at Lincoln College in 1983 where seed of five cultivars imported from USA was planted to see if the plants suited the Canterbury environment. The plant survived a frost of − 9.6 °C in May 1984 and subsequent cold winter temperatures. One cultivar produced high dry matter and rubber yield (J.O. Taylor, pers. comm.).

There is a strong industry interest in this research which is being funded by Skellerup Industries Ltd. Processing facilities would be needed in the growing region if guayule was to be grown commercially for rubber production.

Peppermint (*Mentha piperita*)

Peppermint is a sterile plant which is thought to be a natural interspecific hybrid. It is grown for the oil that is synthesised in glands in the leaves. Plant propagation is by broadcasting root material. The crop is daylength responsive and growing is concentrated about latitudes 40-45°.

The cultivar Micham was imported from Oregon by CRD in 1968/69 and trialled. In 1969/70 further trials followed at Riwaka, Invermay and Lincoln. Research concentrated on weed control, fertiliser management and cutting times and on methods aimed at maximising yield and quality. The oil contains many components but the major aim is to maximise menthol and minimise menthone and menthofuran. Management trials showed that although topping reduced the undesirable elements in the oil, highest yields with acceptable quality could be obtained by harvesting, without prior topping, at full to later flower (Lammerink and Manning, 1971). Experimental oil yields averaged 40 kg/ha in first year crops and 60 kg/ha in older crops.

No major pest or disease problems were encountered during the research phase although the mint aphid (*Ovatus crataegarius*) and the orchard leafroller (*Plantotortrix excessana*) were observed on crops (Lammerink, 1974).

In 1970/71 the Dominion Yeast Company (DYC) encouraged small commercial plantings at three sites (Broadfield, Lincoln College, North Otago). In 1971/72 DYC began commercial production and areas increased slowly in the Christchurch region to 150 ha in 1978/79. The wilted plant material was trucked to Christchurch, the oil removed by simple steam distillation and the residue trucked back to the farm.

In 1978/79 an epidemic of a new race of mint rust (*Puccinia menthae*) caused severe leaf loss and a reduction in oil yield (Beresford, 1980). DYC stopped a planned expansion of the contracted area to 1500 ha pending satisfactory control measures. Then in 1980/81 DYC abandoned the crop for a number of reasons related to the economic viability of processing it. The world peppermint oil price fell and processing costs, especially diesel fuel, increased, with rust proving to be expensive to control. These factors and the marginal economics of the crop because of poor yields (30-40 kg/ha), coupled with the high costs of weed control, fertiliser and irrigation, resulted in DYC ceasing production (J. Rainey, pers. comm.). Two farmers in the Rangiora area continued growing and distilling oil from 30 ha until 1983/84

Both Japanese mint (*M. avensis*) and Scottish spearmint (*M. cardiaca*) were also grown by CRD at Lincoln but problems with rust and the closure of the peppermint project stopped research on these less promising species.

Solanum (*Solanum aviculare*)

Solanum, or Poro poro, is a native New Zealand plant developed as a crop for solasidine for pharmaceutical purposes. The previous main source of the steroidal alkaloid was from the Mexican yam (*Dioscorea* spp.).

Research on solanum was begun by Ivan Watkins-Dow in 1964 and continued until 1982. It was grown initially as an annual with establishment being a major problem. Both *S. laciniatum* and *S. aviculare* were experimented with but *S. aviculare* was found to be agronomically more suitable although the berries contained less solasidine. Research showed that growing the crop as a perennial was more practical. Lack of persistence in the third year and beyond was overcome by defoliating less completely, allowing regrowth to recover more before further defoliation and by timing harvests carefully especially in the autumn. Cucumber mosaic virus and potato blight (*Phytophthora infestans*) proved troublesome. Stem borer and cut worm could be controlled. Research has resulted in at least a two fold increase in solasidine production over the 18 year period.

Experiments at CRD began in 1969/70 with *S. laciniatum* grown as an annual in the expectation that disease would be less of a problem in the South Island and in crops replanted each year. However, Davies and Mann (1978) concluded that this system was not competitive with methods used in the North Island. CRD also began a breeding programme which included as objectives increased solasodine content, disease resistance and earlier maturity.

In 1976 the crop production technology was sold (with a 10 year secrecy clause) to a consortium of Biosynth BV. of Holland and Fletcher Agriculture. The consortium grew and processed in excess of 800 ha of the cultivar NA38 in Taranaki from 1977. Commercial yields exceeded 250 kg solasidine per hectare.

Production ceased in 1981 because of cheaper alternative sources of supply. The steriod was being produced synthetically and China was selling solasidine from *Dioscorea batatas* on the world market at half the New Zealand break-even price.

Sprouting radish (*Raphanus sativus*)

Sprouting radish is a brown-seeded non-bulbing radish grown for use in Japan as a salad vegetable after sprouting.

Commercial seed production for export began without any local research base although some research has previously investigated a Japanese radish for forage production. This work showed the propensity of the radish to bolt without bulbing and the effect of sowing date. In 1984/85 unacceptable lesions on the cotyledons of the sprouts were investigated by MAF and they concluded that the problem was associated with insect damage allowing entry of bacteria and fungi, and with bruising during harvesting (I. Harvey, pers. comm.).

Nine small areas were spring-sown in Canterbury in 1982 to have the quality of New Zealand-grown seed assessed by Japanese buyers. Drilling the small seed at low rates proved difficult and establishment was uneven. The best of these crops yielded 2 t/ha.

In 1983/84 250 ha were grown but problems with harvesting and marketing resulted in only 75 ha in 1984/85.

Threshing has proved difficult because the pithy nature of the pods requiring harsh treatment which may have resulted in damage to the soft seeds. Unacceptabe black marks or lesions on the cotyledons of the sprouts, which may have resulted from physical damage during harvest has been a major marketing problem (B.J. Patchett, pers. comm.).

Sugar beet (*Beta vulgaris*)

Approximately half the total world production of refined sugar is from sugar beet grown in temperate regions. Government support has been essential for the establishment and maintenance of beet-based industries.

Research on beet for sugar production has been carried out in New Zealand for over a century with a considerable research input by MAF and DSIR and most other agricultural research agencies. In the 1940's DSIR commenced a breeding programme at Lincoln. Perhaps the largest effort was in the 1960's and the 1970's when research was conducted in several regions to answer questions on soil, sowing date, weed, pest and virus control, cultivar and irrigation requirements. This research concluded that sugar yields of 10-16 t/ha could be obtained in cropping districts from Northland to Canterbury.

Lobbies to establish the crop at various times in different places such as Waikato in the 1980's, South Canterbury in the late 1930's, South Otago in the 1960's, Mid Canterbury in the 1970's all used the same arguments — saving overseas funds, independence of supply and employment. Reports seldom stated that the crop could be justified on economic grounds.

Generally reasons for the final decision not to establish an industry included the inescapable fact that beet sugar could not be produced cheaper in New Zealand than imported can sugar, disruption of trade with the established suppliers and insufficient farmer interest.

DISCUSSION AND CONCLUSIONS

This review covers a sample of the alternative arable crops investigated in New Zealand. Although other species have also been investigated, a number of conclusions can be reached from a study of this sample.

From the record of alternative arable crop development in New Zealand (Table 2) it is apparent that the probability of successful commercialisation is not clearly related to either the amount of processing involved or to whether or not the crop is major, minor or newly domesticated in world terms. Satisfactory development of new crops is dependent on climatic suitability, agronomic

TABLE 2: Record of alternative arable crop development in New Zealand.

Category in N.Z.	Status in the world*	Crop	Year Research began in NZ	Year Commercial crop in NZ
commercial	major	durum wheat	1957/58	1981/82
		lentils	1972/73	1982/83
		oilseed rape	1964/65	1969/70
		soybean	1914/15	1970/71
		sunflower	1964/65	1964/65
	minor	buckwheat	1972/73	1974/75
		faba beans	1975/76	1975/76
		sprouting radish	1982/83	1983/84
	new	evening primrose	1979/80	1984/85
		triticale	1955/56	1985/86
commercial failures	major	rice	1958/59	1965/66-1971/72
	minor	peppermint	1968/69	1972/73-1983/84
	new	solanum	1964/65	1977/78-1981/82
research continuing	major	chick peas	1977/78	-
		peanuts	1978/79	-
	minor	safflower	1962/63	-
		navy bean	1969/70	-
	new	grain amaranth	1983/84	-
		guayule	1983/84	-
		meadow foam	1978/79	-
research abandoned	major	sugar beet	1873/74	-
	minor	adzuki beans	1970/71	-
	new	quinoa	1983/84	-

* Major: greater than 5m ha grown worldwide
Minor: less than 5m ha grown worldwide
New: not yet commercialised or new to developed agriculture this century.

TABLE 3: Most likely single factors limiting research, development or commercial expansion of 23 species as at 1985.

Commercial Factors		Agronomic Factors		
Market	Finance	Yield	Disease	Quality
durum	rice	soybeans	safflower	radish
lentils	peanuts	primrose		quinoa
triticale		navy beans		
adzuki beans		amaranth		
buckwheat		gauyule		
meadow foam		peppermint		
solanum		sugar beet		
faba beans		sunflower		
		chickpeas		
		oilseed rape		

performance, internal or external demand, commercial interest, availability of special processing plant and, for the grower, a satisfactory gross margin relative to established crops. All these components are required for successful commercialisation and although single reasons for a crop's success or failure cannot always be identified because of the relationship between yield, price, quality and the influence of growing costs on them, an attempt has been made to do this in Table 3. Some factors such as market and yield are almost inextricably linked. For example, if the price is high enough then agronomic problems such as poor yield can be accepted and conversely if the yield is large enough, the potential lower price makes marketing easier. Low and variable yields and market factors appear to be the dominant factors limiting further expansion of the development of the 23 crops examined.

Enthusiastic involvement of suitably experienced industry personnel at an early stage is essential. Innovative farmers willing to try a new crop have seldom been limiting although farmer reluctance was cited on more than one occasion as being a reason for the failure to establish a sugar beet industry. This may have been justifiable scepticism by farmers about the economics of growing the crop rather than a reluctance to be innovative. In fact farmers have, on more than one occasion, grown the first areas of a new crop without local formal research input.

Estimation of likely commercial farm yields and quality is a major problem in commercialisation of a new crop. During the early stages of research, experimental yields are usually below likely farm yield. This can mean that a potential crop is discarded unjustifiably at an early stage. But as Palmer (1981) has pointed out, later in a research programme, experimental yields may remain up to 50% above that which can be achieved under good management on a field scale. This can result in unrealistic yield expectations and unsound commercial decisions. For example, yield was crucial in peppermint commercialisation but experimental yields were seldom achieved by growers. Growers appreciate the uncertain and often variable returns from new crops and generally expect gross margins considerably above established crops to compensate for the risk involved.

Scale is often a problem for crops requiring special processing equipment. Robb (1973) for example, in discussing incentives and barriers to a viable edible oil and protein industry in New Zealand considered a minimum of 6-8000 ha/annum of crop would have to be grown to support an industry. The expansion of soybeans has been limited by the lack of processing equipment which in turn has been limited by the small area grown.

Evaluation of some crops goes beyond simple agronomic and economic considerations and has social and political implications. This may result in accelerated development as in the expansion of the linen flax industry during the 1939-45 period.

In reviewing the literature the almost random nature of new crop introductions and development was apparent. A notable exception was the systematic search for a suitable oil crop by Dalgety Agresearch and Fletcher Agriculture in the 1960-1970 period. However, apart from triticale, grain amaranth and quinoa, all the crops examined were or are being assessed for specific established markets, mainly the internal market. Of the 23 species five (solanum, peppermint, adzuki beans, sprouting radish and evening primrose) were export oriented. Only 3 crops have 'failed' in the commercial phase (solanum, peppermint and rice) two of these being for export. This supports the view that success is more likely if commercialisation is based first on an established local market then expanded into the export area.

Time from the start of research to the first commercial crop was, not unexpectedly, related to the world status of the crop. Excluding soybean which was for many years being tried outside its climatic range, the new crops, triticale and solanum, averaged over 20 years in development with the remaining crops averaging about 6 years in development (Table 4).

Of the alternative crops which have been grown commercially, only durum wheat has reached 1000 ha (Table 4) and then it has simply replaced an equivalent area of bread wheat in mid and south Canterbury. There are prospects for expansion in 1985/86 of the oilseed rape area in Southland to 2000 ha, the lentil area to 700 ha and the triticale area to 450 ha. Alternative crops were grown on approximately 2800 hectares in 1984/85 and their contribution to arable farming was small, especially when related to the area of the major crops, the area of linseed once grown or to the recent expansion of the barley area. It

TABLE 4: Alternative crop development time and estimated 1984/85 area or estimated highest area (ha).

Crop	Years*		Area
durum	24		1000
lentils	10		500
oilseed rape	5		400
faba beans	0		350
triticale	30		150
soybeans	56		100
buckwheat	2		90
evening primrose	5		80
sprouting radish	1		75
sunflower	0		50
solanum	13	1981/82	800
peppermint	4	1978/79	150
rice	7	1971/72	45

* Years from when research first began in NZ and when the first commercial crop was grown. Research may not have been continuous or at a high level of inputs and often intensified as commercial sowings increased.

seems likely that if expansion of the arable crop area does occur, it will mainly be of the current main arable crops.

There is a need for alternative crops which can be grown on a large scale in a cropping rotation and new crop development must continue with increased effort and in a more systematic and coordinated way to meet this need. New crop commercialisation is very vulnerable to market forces in the first few years and the availability of development finance for this purpose should be considered.

ACKNOWLEDGEMENTS

The authors are grateful to the following for unpublished information and helpful discussions: J.A.D. Anderson, B. Bisdee, J.C. Gerlach, I. Gordon, D.S. Goulden, I.C. Harvey, J. Lammerink, B.J. Patchett, J. Palmer, T.P. Palmer, J. Rainey, J.W. South, J.O. Taylor, W. Wilson, D.S.C. Wright.

REFERENCES

Anderson, J.A.D., Piggot, C.J. 1981. Peanuts a possible crop for warm northern areas of New Zealand. *Proceedings Agronomy Society of N.Z. 11:* 73-75.

Beresford, R.M. 1980. Peppermint growing set back. *Field Crop News 4:* 25-26.

Blair, I.A., Tan, C.F., Palmer, T.P. 1966. Soyabean trials in Canterbury. *N.Z. Journal of Agricultural Research 9:* 894-908.

Claridge, J.H. 1972. "Arable Farm crops of New Zealand." A.H. and A.W. Reed, Wellington.

Davies, D.J.G., Mann, J.D. 1978. Solasodine production from *Solanum laciniatum* in the South Island of New Zealand. *Proceedings Agronomy Society of N.Z. 8:* 69-71.

Davidson, D.M. 1976. Oilseed rape: agronomic experiences problems and potential. *Proceedings Agronomy Society of N.Z. 6:* 57-60.

Gerlach, J.C. 1973. The potential of oilseeds in the North Island. *In* Proceedings Oilseed Symposium 12-13 March 1973. Crop Research Division, DSIR, Report No. 3: 121-129.

Gerlach, J.C., Cottier, K., Cumberland, G.L.B., Nixon, G., Bilnler, K., McCormick, S.J. 1971. Studies on the cultivation of soyabean (*Glycine max* (L.) Merill) in New Zealand. *Proceedings Agronomy Society of N.Z. 1:* 129-137.

Gerlach, J.C., Southon, T.F. 1971. Rice in New Zealand. *Proceedings Agronomy Society of N.Z. 1:* 225-233.

Jermyn, W.A., Goulden, D.S., Lancaster, I.M., Banfield, R.A. 1981. Lentil evaluation in New Zealand. *Proceedings Agronomy Society of N.Z. 11:* 77-81.

Lammerink, J. 1973. The potential of oil crops in the South Island. *In* Proceedings Oilseed Symposium, 12-13 March 1973. Crop Research Division, DSIR, Report No. 3: 89-95.

Lammerink, J. 1974. Peppermint; Guide to growing in Canterbury. Crop Research Division, DSIR. Report No. 19.

Lammerink, J., Manning, T.D.R. 1971. Yields and composition of oil from peppermint grown at Lincoln, New Zealand. *N.Z. Journal of Agricultural Research 14:* 745-751.

Lammerink, J., Stewart, D.A.C. 1974. Effects of varying sowing date on sunflower cultivars. *Proceedings Agronomy Society of N.Z. 4:* 9-12.

McCormick, S.J. Thomsen, C.L. 1978. Development and yield of safflower in relation to sowing date and plant population. *Proceedings Agronomy Society of N.Z. 8:* 15-18.

McEwan, J.M. 1984. Triticale: here to stay? *DSIR Cereal News 11:* 13-15.

McLeod, C.C. 1985. Assessment of grain Amaranth in South Canterbury. *Australasian Field Crops Newsletter 20:* 53-54.

Manning, S.H., Mortlock, C.T., Young, H.T. Investigations into the development of oil seed crops in New Zealand. *Proceedings Agronomy Society of N.Z. 4:* 19-23.

Newton, S.D., Hill, G.D. 1978. A survey of commercial field bean (*Vicia faba* L.) crops in Canterbury. *Proceedings Agronomy Society of N.Z. 8:* 31-35.

Palmer, J. 1972. Some problems with the introduction of a new bean crop to New Zealand. *Proceedings Agronomy Society of N.Z. 2:* 65-71.

Palmer, J. 1985. The evening primrose as a source of gamma linolenic acid. *N.Z. Agricultural Science* 19(3): 119-121.

Palmer, T.P. 1981. Promise and performance. *Proceedings Agronomy Society of N.Z. 11:* 1-4.

Robb, A.J.D. 1973. Incentives and barriers to a viable edible oil and protein industry in New Zealand. *In* Proceedings Oilseed Symposium 12-13 March, 1973. Crop Research Division Report No. 3: 134-141.