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RESOURCE ALLOCATION AND INSTITUTIONAL ARRANGEMENTS FOR FOOD AND FORAGE CROP BREEDING IN NEW ZEALAND

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ABSTRACT

Past contributions of plant breeding to the New Zealand economy are outlined and the case for continued plant breeding is established. Criteria for determining allocation of effort to particular crops are discussed and the present allocations are compared using these criteria.

Inputs into some crops are not sufficient to meet the goals of the industry; fruit breeding and kiwifruit in particular being the most under-serviced. There is need for some re-allocation of resources between projects and for more and better directed contributions from non plant breeding units within DSIR. Co-operation between DSIR and private breeders has developed on an *ad hoc* basis and needs rational planning.

Plant breeding needs a foster body to guide these developments.

Additional Key Words: Plant breeding, research benefits, research organisation, research allocation

PAST CONTRIBUTIONS TO NEW ZEALAND PRODUCTION

By the 1940's, cultivars bred in New Zealand were displacing imported cultivars or local ecotypes. The displacement has continued until now, as shown in Table 1.

Local cultivars have supplanted foreign cultivars of many crops. In the pasture species, and with swedes, there has been an element of government regulatory control involved in the change but local cultivars have mainly replaced foreign cultivars because farmers and their customers preferred them.

For some crops were have data on the comparative performance of new cultivars and the cultivars they displaced. The best set of data is from comparative field trials of wheat which show that wheat breeding has added about 35%, or 100,000 tonnes of wheat, to New Zealand's crop each year.

There may be quibbles about the validity of the derivation of these figures (Palmer, 1981) but they probably very seriously under-value the contribution of wheat breeding to the New Zealand economy. Wheat breeding was started in New Zealand because the old cultivars were not suitable for factory production of bread while good bread-making foreign wheats did not grow well here. Cultivars bred in New Zealand have given an acceptable combination of yield and quality not available in foreign cultivars.

If we did not have a local wheat breeding programme, we would not have satisfactory bread-making wheat to grow in New Zealand. If we did not use our wheat to make bread we would not grow any. If we did not grow wheat, we might not still have a local flour milling industry.

This chain of reasoning leads to the conclusion that New Zealand wheat breeders have added the value of the whole New Zealand wheat crop, and perhaps the whole of the added value of flour milling, to New Zealand production. If you think that this reasoning is rather fanciful, recall that in the fifties, before the advent of Arawa and Aotea, the New Zealand wheat area had shrunk to only 25,000 hectares. We can also credit the whole of local hop production to hop breeding.

TABLE 1: Percentage of crop area sown in New Zealand cultivars*.

	1940	1960	1980
Apples	0	0	10
Barley	0	50	25
Clover**	10?	100	100
Hops	0	0	100
Kale	0	0	0
Kiwifruit	—	—	100
Lucerne	0	80?	25
Maize	100	0	0
Oats	0	0	90
Onions	?	100	100
Peas	0	20	40
Potatoes	40	40	90
Rape	0	100	100
Ryegrass**	10?	100	100
Swedes	0	40	30
Tobacco	0	0	90
Turnips	0	50	50
Vegetables	10	10	10
Wheat	40	95	98

* New Zealand bred cultivars are defined as cultivars which have originated or been significantly changed by selection in New Zealand.

**The figures are of the percentage of area sown each year, not of total area in pasture.

By the 1940's, New Zealand breeders had produced cultivars of ryegrass and white clover which were world leaders. They formed the basis of a seed industry which produced up to 2% of our export income.

Disease resistant peas have maintained the local processing industry and the seed export trade in the face of increasing incidence of disease and competition from foreign breeders and seed producers. Improved potato cultivars have extended the production and storage seasons for potatoes, aphid and virus resistant brassicas eliminated these troubles of the brassica forage crop. These are examples of benefits which are not easily measured. Breeders should be doing more to measure them if they are to attract the support that is warranted.

The verifiable cases of economic gains from New Zealand bred cultivars and their general acceptance give evidence of the past value of local breeding. They do not demonstrate the need for its continuance, that effort is best deployed for economic gains or that our institutional structure foster the best deployment and integration of resources. These are the questions I raise here.

NEEDS FOR LOCAL PLANT BREEDING

Historical success is not sufficient justification for continuing a course of action. Plant breeding is needed in New Zealand to improve and maintain our efficiency of production. It is still necessary to produce plants better adapted to our physical environment; to our peculiar and changing farming, processing and marketing systems, and to the deterioration in our crop environment caused by spread and increased incidence of disease. Increasingly it is needed because breeders in other countries are producing improved cultivars for their growers, so our growers must have improved cultivars to keep up, or hopefully, to keep in front.

TABLE 2: Percentage of work force in agriculture and tonnes of grain or numbers of animals per farm worker. Source: FAO Production Year Book.

	NZ	Aust.	USA	UK	France	Netherlands
% workers in agriculture	9.0	8.1	2.1	2.0	8.2	5.1
Grain per worker (tonnes)	7	50	152	37	16	5
Cows per worker	66	60	50	25	8	18
Sheep per worker	540	309	6	63	4	3

To the extent that our environments and production systems are unique, we must do our own breeding. If some of you are unaware or have forgotten, Table 2 will remind you how different our production systems are.

Plainly we will have to do most of our own sheep research, pasture research and kiwifruit research. Who else is there to do it? It must be done if we are to maintain our efficiency in relation to the rest of the developed world's grain producers and farmers feeding animals on grain. On the other hand, we should be able to import much of our cereal research.

With what sort of effort are our breeders competing? There are some figures available on inputs in the UK to compare with our own (Table 3).

TABLE 3: Numbers of state employed plant breeders with BSc or higher degree. Sources: Annual reports of Welsh Plant Breeding Station, Plant Breeding Institute, Scottish Crop Research Institute.

	Cereals	Forages
New Zealand	6	7
UK	30	23
Australia	40	?

The other developed countries have similar public sector breeding inputs to the UK and all of them have similar or greater private sector input. A good deal of this breeding is interchangeable between countries. Corn hybrids in Europe are partly based on US inbreds, the European rape seed industry on French cultivars, 30% of British barley area grows continental European cultivars.

Our cereal breeding programmes cannot hope to match these sorts of inputs. Nor is it necessary, for northern hemisphere cereal cultivars are increasingly becoming adapted for growing and use in New Zealand. But our pasture-based industry and its plant breeding base does have to compete with the northern hemisphere grain system. Is this possible in the long term, or have we already slipped?.

PURPOSE OF PLANT BREEDING

It is generally well understood that plant breeding aids efficiency of production by increasing product output in relation to inputs. It also contributes very significantly by producing qualitatively different products. Zero-erucic acid rape seed has created a new market for rape seed and a new industry for Canada in the last 10 years. Triumph barley, Royal Gala apples, the red sports of Delicious, uniform F1 hybrid cabbages from Japan have all become, within a few short years of their release, the standard of excellence for other breeders to meet. The best breeding does not aim to meet standards but to set them.

Akaroa cocksfoot, Huia clover and New Zealand ryegrass have been this type of standard-setting cultivar in the past. Hayward kiwifruit is one now. Konini, the purple grained hexaploid wheat bred by Les Copp could be one with progressive marketing. We must keep these cultivars coming.

Producers with the first access to such novel cultivars have an immense advantage. Industries relying on up-market sales must be based on breeding which keeps its quality standards ahead of world competitors. While we may produce a little less efficiently than our competitors and survive, if our quality is not the best we will have no industry at all. Our export fruit industry will succeed or fail on this.

CRITERIA FOR RESOURCE ALLOCATION

New Zealand plant breeders have a considerable responsibility and a formidable task. We have a limited plant breeding resource and we commonly cultivate more than 100 food and forage plants. How should the resource be allocated among them?

The present value of the crop must be considered but it is only one consideration. A low value crop with no prospects needs no consideration.

The increase in value which can be expected from breeding is really the vital point. The likely biological response and the time and effort needed to achieve it are questions for the professional breeders of the crop and it may take considerable breeding investment to establish this. It is important to remember that other breeders will also be improving competitive crops so that projected increases in value may not give the local crop a relative advantage but may be necessary to maintain the *status quo*. The soyabean/corn comparison is a good New Zealand example.

Over the past 20 years new soyabean cultivars have been hailed as the breakthrough which would make growing soybeans competitive with growing maize. In the meantime maize yields have been increasing steadily and today soyabenas are relatively no more profitable than they were.

These questions can be best answered by breeders who are thoroughly aware of what breeders of other crops are up to. This awareness is one of the major benefits coming from co-operative breeding programmes.

The other important component of response to breeding is the extent to which new cultivars embodying biological improvements will be taken up by industry.

Processing industries are reluctant to change cultivars. Brewers have cautiously changed barley cultivars, new pea cultivars have been slowly accepted by processors. Acceptance standards for current cultivars may be inappropriate for new ones. Oroua, a wheat with superior baking quality, was effectively discounted because its grains were smaller than the arbitrary standard set for the current larger grained cultivars.

Seed production and seed distribution channels must be adequate. New lucerne and lotus cultivars have failed because of deficiences in these departments.

Can increased production or higher quality be profitably sold? Private and social gain from the adoption of new cultivars do not always coincide so it is not always clear who benefits.

On saturated markets, more production does not result in higher grower profits. The first growers of an improved cultivar benefit until it is widely grown when the increased production will reduce prices and benefit consumers. Of course, growers who stay with the older cultivars will make lower profits so growers must change and the breeder of the new cultivar sells more seed.

To evaluate commercial or social gains to be expected from a plant breeding project involves considerations outside the field of expertise of most plant breeders.

PRESENT PLANT BREEDING ACTIVITY

In Table 4 I set out, as well as I am able, the effort devoted to breeding individual crops.

How do these inputs tally with the prospects as determined by the criteria discussed above? The discussion is best made crop by crop.

TABLE 4: Numbers of people* concerned with breeding or introducing crops in New Zealand.

	Public		Private	
	Breeding	Intro.	Breeding	Intro.
Wheat	9	2	2	2
Barley	5	1	2	2
Maize	3			1
Peas	3		4	4
Potatoes	5			
Onions	1		5	
Squash	1		1	
Asparagus	2	2		
Kiwifruit	7			
Pip fruit	3			
Stone fruit	1	3		1
Strawberries	1		1	
Rubus	2			
Herbs	1			
Subtropicals	4			
Ryegrass)			9	
White clover)	20			
Other pasture)				
Forage brassicas	2		2	
Lucerne	4			

* Scientists and science technicians engaged through selection and evaluation stages. Figures have been supplied by research directors and interpreted by me. The figures may not be exactly comparable between crops. Kiwifruit inputs may be comparatively exaggerated and pasture plant inputs under-stated. DSIR science and technology programmes prepared for the 1984 science and technology plan co-ordinated by NRAC lists 66 pasture plant breeders in DSIR.

Wheat

Local breeding has been necessary to maintain the local industry. Foreign wheats of high baking quality have not given adequate yields in New Zealand while high-yielding European wheats have been very prone to shatter and have had very poor baking quality. This situation is now changing. The entry of stripe rust into New Zealand has given resistant European wheats an immediate temporary advantage. New cultivars bred in Europe have short straw and good grain retention and European breeders are now seriously breeding for high baking quality. Increasing use of irrigation for wheat production will boost the potential of the later maturing European cultivars. There are already excellent exchange schemes with northern hemisphere breeders in both the public and private sectors. All these changes point to the probability of our importing a greater proportion of our wheat cultivars and to the possibility to switch some state breeding effort to other crops.

Barley

Local breeding has never been crucial to the survival of local barley production. Malting barley production and export strongly influence the local industry. Foreign maltsters prefer to buy from New Zealand, out of season, the same cultivars as their northern hemisphere growers supply in season. European cultivars of spring barley perform well in New Zealand. These considerations are reflected in the increase in the proportion of the crop sown in foreign cultivars from 50% in 1960 to about 90% today. New Zealand companies with good contacts with European breeders can be expected to continue to serve the industry well. Public involvement in barley breeding in New Zealand is a wasteful luxury.

Maize

The local maize industry has been served entirely by hybrids of U.S. origin ever since the introduction of hybrid cultivars. Local conventional maize breeding by the State is unlikely to produce any significant new cultivars.

The incorporation of cold tolerant genes into inbreds for production of commercial hybrids should be continued to allow evaluation of what might be a valuable project for New Zealand and world agriculture.

Peas

Pea breeding has been one of the notable successes of New Zealand plant breeding. The local process, produce and seed export business, worth $25 m annually, depends on the local cultivars resistant to fusarium wilt and virus diseases. Most foreign cultivars lack sufficient resistance to these diseases for profitable culture here.

Processing quality of our adapted cultivars is not as good as customers prefer and some quality requirements for dried peas are not adequately defined. Soil disease problems, partly undiagnosed, are increasing with continued pea growing and more virus diseases are becoming important as new aphid vectors become established in New Zealand. These New Zealand problems must be solved by New Zealand breeders.

DSIR has capacity for quality and disease resistance breeding which is not available in the private sector. Private firms have been maintaining cultivars and breeding peas in New Zealand since the thirties. This private sector capacity could be used more fully in co-operation with DSIR breeders. In co-operation with European breeders, we may be able to re-capture seed markets we have lost in Europe.

Potatoes

Almost all the New Zealand crop is planted in local cultivars. Local cultivars with nematode resistance and better culinary and processing quality are required by the industry. At present, the local market is fully supplied by local production and increases in efficiency of production will result in a smaller area in potatoes rather than in greater sales. The local breeding programme could provide cultivars better suited for growing in lower latitude countries than are now supplied from northern Europe. This would increase the prospects for seed exports from New Zealand.

Vegetables

About 1950, Crop Research Division set up a vegetable breeding section in response to the unsatisfactory state of imported seed. It was considered that many cultivars were not adapted, there was considerable critical variation between stocks within cultivars and some stocks were very variable. There were problems in continuity of supply.

This is certainly not the picture today. Vegetable breeding has been developed to a high science by Dutch, Japanese and American breeders. Generally, most cultivars are of uniformly high quality with high yields well adapted to mass culture. The New Zealand market is small and with little scope for expansion. Only in exceptional cases is breeding for the local market warranted or likely to be profitable.

Onions

During the past few years onions have increased steadily in importance as an export crop. This success has been based on the excellent storage quality of the Pukekohe Longkeeper cultivar and its derivatives. Improvements to the crop must proceed from this and should be done in New Zealand. State involvement in onion breeding has been ineffectual until now and should be improved and increased. Private breeding has increased considerably.

Squash and Pumpkin

Local consumption has been adequately supplied by local cultivars. The recent development of exports is based on foreign cultivars with indifferent keeping quality. Exports and export value could be increased by development of cultivars suitable for export markets and with better keeping quality.

Tomatoes

One local glasshouse tomato cultivar has a significant share of the market. Foreign outdoor cultivars are not well adapted to our cool erratic season. The local processing industry is not likely to survive without better adapted cultivars. These will not come from foreign breeders who are not breeding for conditions as marginal as ours. It is not certain that the present, or any, local breeding will be successful.

Asparagus

In New Zealand, asparagus suffers from stemphylium leaf disease which reduces yield and from root and crown rots which reduce longevity. These may be problems peculiar to New Zealand.

Breeding is slow and expensive but improvements in yield and disease resistance are certain. There are problems with quality and supply of foreign cultivars.

The future of the crop for export is uncertain. But it is certain that it is much more likely to be successful with locally bred cultivars.

Fruit Breeding

Many projections give fruit a major place as a future export earner. The realisation of these projections depends entirely on New Zealand produce being the highest quality available in the market. This points to the need for a continued flow of new, high quality cultivars being available to our producers before they are available to our competitors. Stone fruit growers are well aware of the importance of new cultivars and apple producers are becoming so. Kiwifruit producers have been reluctant to accept the concept.

Orchardists and nurserymen have demonstrated their ability to select winning cultivars. They should be encouraged, by a share in cultivar royalties, to select cultivars from segregating populations produced by professional breeders. Centralisation of breeding within the Division of Horticulture & Processing will hinder progress.

Apples

Private breeders have produced several leading cultivars. The State breeders have produced root-stocks but have not released any dessert cultivars yet. The New Zealand industry should aim to have a new improved cultivar taking a major part of the market about every five years. If it is to do this, two or more candidate cultivars should be entering extensive production runs for shipping and market tests every year. New Zealand breeding is not geared to this sort of out-put.

We cannot look to foreign breeders for new cultivars without losing some of the advantage of novelty but we must ensure very early access to foreign cultivars at the testing stage. This will be best done by having co-operative arrangements with most foreign breeders.

There are two main bottle necks in apple breeding. The long generation time makes recurrent improvement projects unattractive and the pre-release testing of the requisite numbers of candidate cultivars hinders progress. Increased input from plant physiologists may help with the first problem and a bolder approach the second.

Given all this, the programme needs considerable expansion to serve the industry effectively.

Kiwifruit

The arguments for increased kiwifruit breeding are the same as those for apples but apply with much greater force. The future of the industry depends on the supply of new cultivars with better dessert quality. We must be the first to produce them.

The New Zealand industry is based on a very small number of introductions which presumably included a very limited and un-representative sample of the genetic variation available and should be augmented by considerable collections within the species and genus.

The plant is dioecious so male plants may not be selected for fruit characters except by progeny testing, or more adroitly, by successive back-crossing to chosen females. Programmes to produce hermaphrodite plants will involve wide out-crossing or close in-breeding to disrupt the genetic balance which determines sexual expression, preferably carried out in contrasting and marginal environments. Consequently efficient breeding schemes will involve several sexual generations.

Clonal and somaclonal selections may give immediate response and a breathing space.

All these programmes require considerable effort in kiwifruit breeding, carried out at several stations. "Every kiwi a kiwi breeder" should be the slogan and a budget of $1 million dollars per year is appropriate, when compared with the $500,000 spent on wheat breeding. The industry and the research establishment is slowly awakening to the challenge.

Stone Fruit

The need for local breeding may not be as great as for kiwifruit and apples. We are slotting into gaps in northern hemisphere production and not competing directly. Northern hemisphere breeders are producing very high quality cultivars and we would find it hard to do better. There are particular disease problems, such as blast, which may warrant local breeding.

It is essential, however, that we get the first bite of the new cherry and other stone fruit cultivars as they are produced. Co-operative arrangements with northern breeders to ensure this are filling the role adequately. Quarantine procedures need streamlining to speed up cultivar importation.

Berry Fruits

New Zealand is equal to, or second only to the USA, in boysenberry production. This is a fruit of fine flavour and appearance when picked ripe but as it must be picked for export it is deficient on both counts — too ripe to keep its shape, too green to eat. Cultivars with a better combination of fruit characters on more tractable vines could form the base for a large export industry. The present breeding programme is exploratory.

Strawberries are worth about $15 m annually, with $3 m worth of exports. Yield, season of production and fruit quality can all be improved by breeding which may increase local sales and give expanded export opportunities. Long storage life is more important to New Zealand producers than to any others. Close liaison between private breeder, foreign breeder and DSIR seems a rational way to handle this crop.

Subtropicals

There are a number of these being surveyed and promoted at present. There may be prospects for breeding the more promising. This should not divert effort from the more important kiwifruit or apple breeding.

TABLE 5: Area (,000 ha) of forage brassicas. Source: New Zealand Farm Production Statistics.

	1960	1970	1980
Rape	50	20	20
Kale	50	30	20
Swedes	80	50	40
Turnips	90	70	50
Mixed	20	10	10
Total	290	180	140

Forage Brassicas

There has been a steady decline in the area of forage brassicas since about 1960 (See Table 5).

Much of the decline has resulted from increased productivity of better managed pastures. Part of the decline has resulted from the disease susceptibility of the crops. Breeding for resistance has been successful, though not completely so. I hazard no guess as to what increases in animal production efficiency could result from increased forage brassica breeding.

New Zealand is a major world user of brassica forage crops, especially of swedes and turnips. Local problems of high aphid, virus, clubroot and dryrot infection are peculiar to New Zealand. There is little foreign input into breeding these crops, so advances must come from local breeders.

Pasture Breeding

Pasture provides most of New Zealand's exports. The contribution pasture plant breeding is making to New Zealand pasture or animal production is not so clear. Unknowns include the area of pasture which has been sown to bred cultivars, the extent to which bred genotypes survive in pastures and the advantage of new cultivars over the populations they have replaced. The cultivars of ryegrass and clovers introduced during the thirties were a very significant advance over what was generally available then. However, the recent success of what are essentially natural ecotypes of ryegrass (Nui & Ellet) suggests that progress since then has not been great. The 1982 drought in the East-Coast North Island provided the best — first? — opportunity in fifty years for re-sowing new cultivars but farmers did not see introducing new cultivars as important. Management systems are geared to the needs of existing cultivars which hinders change.

In contrast with this lack of evidence of genetic gains in pasture productivity, foreign meat and milk producers have had a very considerable genetic gain in animal feed production efficiency. Duvick (1984) has produced good evidence for a genetic gain of more than 50 kg per hectare per year in corn yield with the increase accelerating. There is similar evidence for grain production in Europe (Austin *et al.,* 1980). Animal producers in New Zealand are working from a relatively deteriorating genetic base for feed production and also the genetic progress in meat production in sheep and cattle does not match the progress in chicken and pigs. Freezing workers and inflation are not the only problems.

There is a very great need for genetic improvement in pasture production. But this need, by itself, is not justification for maintaining or increasing pasture plant breeding. Nor is the growing input from private breeders. There is no evidence to show that private breeders' cultivars are better than state cultivars though it may be early days to judge. Perhaps the decentralised private sector effort may be able to deliver more than the centralised DSIR programme. There is considerable evidence that proprietary cultivars are very profitable to their breeders.

It is not that our pasture plant breeders have fallen down in the job. The problems of pasture plant breeding, both in incorporating genetic improvements and converting them to more animal products, are known world-wide to be intractable. The whole rationale of pasture plant breeding in New Zealand needs close, unbiased examination.

Lucerne

If pasture production has had no genetic boost in the past forty years, lucerne is now less well adapted to its New Zealand environment than it was then. There has been progress in breeding or introducing resistance to some of the more prevalent pests and disease but not enough to maintain lucerne's productivity or longevity in a deteriorating environment.

Cultivars with a satisfactory package of resistances are not available from foreign breeders which is a *prima facie* case for local breeding. Local breeders can almost certainly produce the needed cultivars. If agronomists are right, improved lucerne cultivars could contribute significantly to national production efficiency (Dunbier and Easton, 1982). Local seed production and seed distribution channels have not been adequate to multiply and distribute seed of local (Rere, Oranga) or introduced (Washoe) cultivars.

Pasture Seeds

In the twenties and thirties, cocksfoot seed was a considerable New Zealand export. In the mid-forties ryegrass and clover seeds provided 2% of New Zealand export income or almost double the present contribution from kiwifruit. Grass and clover seeds are now worth about 0.3% of total exports. The decline is due, in part, to lack of genetic tailoring to the customers' requirements. All producer groups should heed this lesson.

In the forties, we had the market because ours were the first commercially available cultivars which had been bred for sustained pasture production. Competing seed suppliers had been selecting for seed production. Now our cultivars are competing with local cultivars selected for pasture production in the market area.

Co-operative breeding arrangements may once again give local seed producers access to premium cultivars.

The market in Europe has been static and is not likely to return to its former high importance to New Zealand. Retention and development of markets outside Europe will also depend on development in conjunction with breeders from the customer countries.

RESOURCE ALLOCATION

This short review has indicated that our plant breeding effort is small in relation to the needs of our primary producers and in comparison with the plant breeding output available to our competitors. Extra inputs are unlikely to come from government.

Private investment has been concentrated in areas where competition is already greatest, and need probably least, such as cereal and pasture plant breeding. It has been an excellent vehicle for importing cultivars.

There is a small but growing commitment from producers. There may be room for some re-allocation of resources away from well serviced areas such as cereals, or perhaps from non-responsive areas such as pastures, to more promising areas.

SUPPORT SCIENCES

Plant breeding efficiency can also be augmented very greatly by contributions from other biological sciences.

Wherever scientists of different disciplines interact, the association must be symbiotic to be productive, and intimate to be symbiotic. A plant breeder and a scientist from another discipline must work together for some time to develop an understanding of what they can achieve together and how to achieve it. There can be no question of one scientist working for another. Both must have the production of superior cultivars as their objective. To achieve this, the scientists' directors should be similarly motivated. It is not always the plant breeder who has the greater dedication to the cause. Within DSIR there have been administrative problems as several biological divisions are structured around a discipline and not a product.

Applied Mathematics Division and Plant Diseases Division have had a long productive association with plant breeders. The statisticians pushed the breeders into using new techniques. There was no question of the breeders going to them with their problems. They were established early at Lincoln and Palmerston North and eagerly looked for ways to help. Since Calder and Gibbs produced Club Root Resistant rape in the forties, to the present day (Menzies and Falloon working on root-rot resistant and stemphylium resistant asparagus, Hawthorne and Dunbier on root-rot resistant lucernes, and Ashby, Fletcher, Musgrave, Jermyn and Scott on legume viruses and root rots), Crop Research Division breeders and Plant Diseases Division pathologists have been producing cultivars together.

Plant breeders have benefitted from the association by more efficient production of resistant cultivars. Pathologists have gained by a better understanding of life histories and epidemiology and in tools for assessing the effects of disease. Genetic studies have given important insights into the physiology of disease expression.

The early posting of Plant Disease Division pathologists at Lincoln has greatly facilitated this productivity. During most of the time, the directors of both divisions have had the production of resistant cultivars as a top priority.

With insect and animal pest resistance breeding there has been little fruitful interchange. Generally, entomologists have been concerned with elucidating mechanisms of insect resistance and the good work in this field has not lead on to resistant cultivars.

The proximity of Applied Biochemistry Division, Plant Physiology Division and Grassland Division at Palmerston North has not been productive of cultivars. Oestrogenic content of clovers and differential uptake of trace elements by ryegrass genotypes seemed worthwhile co-operative projects. Perhaps the elusive non-bloating clover has diverted effort from more amenable projects.

There are many projects on which biochemists and plant breeders can combine. There has been a long productive association between flour chemists and wheat breeders who have both had higher flour quality as a major objective. Co-operative work aimed at better quality cultivars is developing between breeders of onions and aromatic plants and Applied Biochemistry Division biochemists and in cereals between breeders and Plant Physiology Division biochemists.

In many crops, the chemical composition which determines quality is not well known. Biochemists can define standards of excellence to be obtained and help devise methods suitable for selection. They profit from the large range of genetic diversity which the breeder offers them for study. The New Zealand breeder and producer could profit from offering the first objectively described produce; then our standards would become the international standards, an immense commercial advantage.

Plant physiology and crop physiology can contribute in several fields. Crop modelling studies by Wilson and Jamieson (Wilson *et al.*, 1984) are showing what sort of new cultivars are needed for new management systems. These models are well rooted in empiricism and theory and I expect they will be valid. In crops where genotype and environment interactions are large, physiological studies may reduce the necessity for extensive, expensive cultivar evaluation trials. Asparagus is a crop ripe for such treatment.

Long generation time imposes limits on progress in many breeding projects. Using growth chambers, breeders of spring cereals have shortened the generation time to three months. Contrast this with the 20 years McKenzie (1983) suggests is common in apple breeding, or the several years typical of kiwifruit breeding or even the two years for onions. Research aimed at advancing sexual maturity, or by-passing it by vegetative hybridisation, should be a priority of plant physiology research.

Modification of sexual expression, inducing and stabilising male sterility, suppressing cross fertilisation or self-sterility barriers would all bring dividends. Embryo culture, use of irradiated pollen and somacloning are standard breeding techniques.

Facilities and people for using and developing these techniques must be available at breeding centres and people capable of using them must be part of plant breeding teams. There is a lesson to be learned from the low productivity of the highly sophisticated and expensive phytotron unit at Palmerston North compared with the high productivity of the humble growth chambers at Lincoln. Large centralised units do not stimulate interactive research.

GOVERNMENT OF PLANT BREEDING

We see that there should be re-allocation of resources between current plant breeding projects. We also see that there are many other strands from New Zealand science which can contribute to plant breeding. But how are all these strands to be twisted into a good strong rope?

The Dutch system is often quoted as a model to emulate. The co-operation between government research stations, universities, private breeders, seed producers, seed merchants and regulatory authorities is highly productive and profits are shared equitably. Science aspects of the development of this system over the past forty years are outlined by Hogenboom (1983). Scientists, businessmen and administrators will each see something different in the Dutch system. We should study it but recognise that the New Zealand industry has different resources, problems and objectives, and may require different institutional arrangements.

Already, strong links have developed between private and state breeders. The very efficient New Zealand plant selectors rights system, the envy of European breeders, has been hammered out by public and private breeders acting to further their common interests. Similarly, the cultivar testing system is a model of co-operative development. The impetus for this co-operation has come from professional breeders in both camps, acting under the aegis of, but advisory to, the New Zealand Plant Breeding and Research Association and DSIR directors.

But the professionals can only accomplish so much. They can point out the need for re-allocation of resources and the deficiencies of present institutional arrangements but do not have the authority to implement the changes. In the New Zealand Plant Breeding and Research Association, the private breeders have a body for considering the objectives and organisation of their sector of the industry and for politicking to achieve these aims. We need a similar parliament for the whole industry, with terms of reference to further New Zealand's primary production by fostering plant breeding. Smith first seriously mooted the formation of a New Zealand plant breeding institute in a report to the Director General of DSIR in about 1979. It is time this proposal was dusted off and activated. Without some central guiding hand, New Zealand plant breeding will fail in its duty to the nation.

CONCLUSION

I have surveyed some aspects of plant breeding resources. I have found them to be meagre for the task in hand. I have suggested how they may be re-deployed and augmeted. I have suggested institutional changes which may further these ends.

I have raised several debatable points. I hope that this talk will induce both the professionals and administrators among you to think about the subject and to use this as a basis for a thorough critical review of the subject.

Let us take the dry bones of contention I have dug up. Let us examine them and articulate the sound ones into a strong skeleton. Let us put some flesh on these dry bones to make a body beautiful and useful. Let us do it now.

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