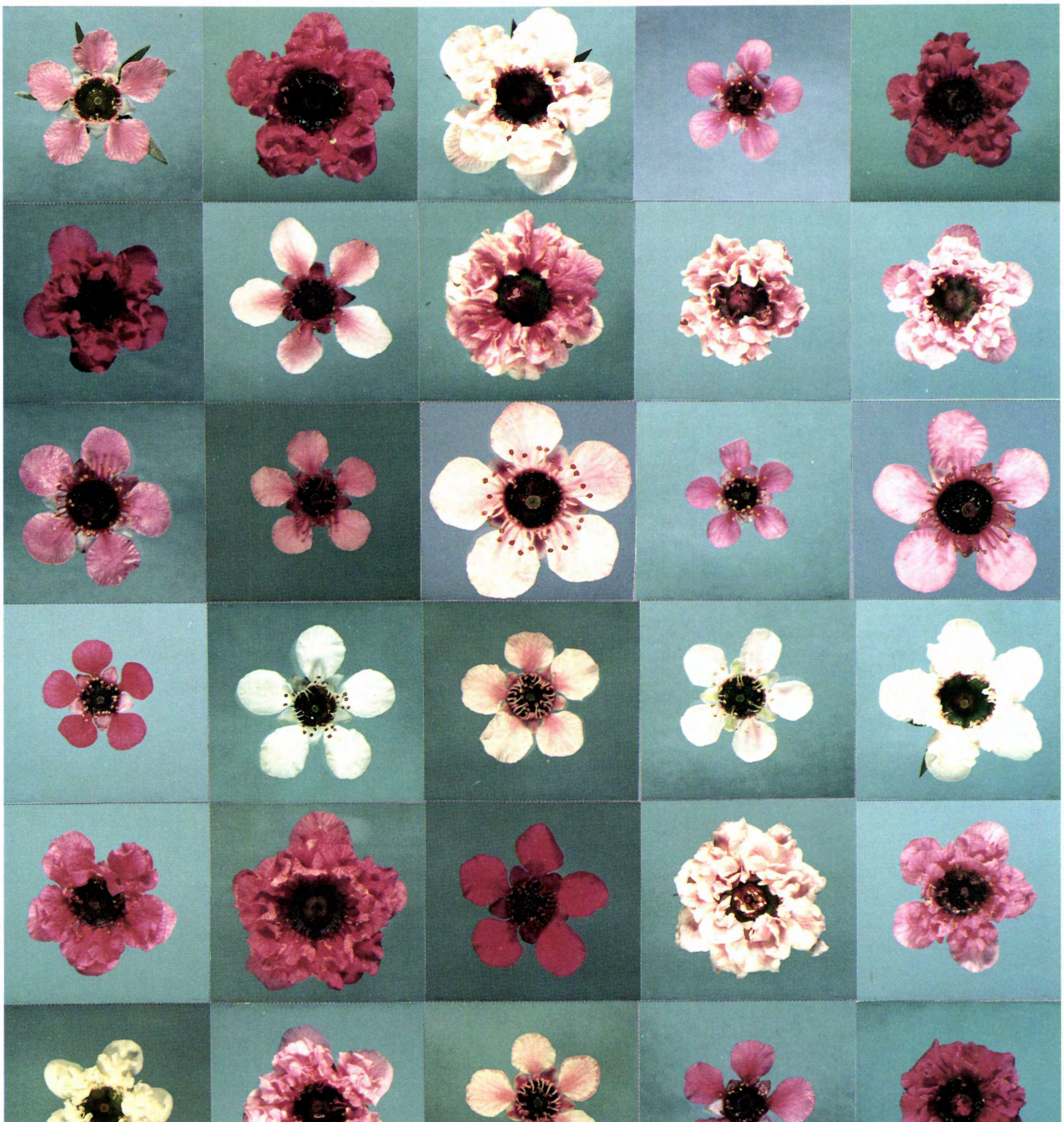
HORTICULTURE IN NEW ZEALAND

Journal of The Royal New Zealand Institute of Horticulture (Inc.)



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HORTICULTURE IN NEW ZEALAND

JOURNAL OF THE ROYAL NEW ZEALAND INSTITUTE OF HORTICULTURE (INC.)

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Horticulture in New Zealand — A new publication?

In early 1989, the National Executive carried out a comprehensive review of Institute publications. This resulted in the replacement of the Bulletin with the Newsletter, and the Annual Journal with this publication, Horticulture in New Zealand.

The change to Horticulture in New Zealand has caused some confusion and for that I must apologise. This confusion was due to the name change and also the change in the ISSN number printed in the contents page. An ISSN number is a unique number used to identify a serial title. When the name of the Annual Journal was changed to Horticulture in New Zealand, a new ISSN number should have been used. In error, I used the ISSN number from the old bulletin which was also called Horticulture in New Zealand.

To put things straight: The name of this publication is Horticulture in New Zealand **not** Journal of the RNZIH. It is a new serial with a new ISSN number (1170-1803) and will be published twice yearly.

Mike Oates

Cover Picture:
Flower variation among *Leptospermum scoparium* (manuka) cultivars. Magnification ×1.4. Photo: R. Lamberts, DSIR.
Row 1 'Aurora'; 'Big Red'; 'Blossom'; 'Boscawenii Minor'; 'Burgundy Queen'. *Row 2* 'Crimson Glory'; 'Elizabeth Jane'; 'Fascination'; 'Fiesta'; 'Gaiety Girl'. *Row 3* 'Helen Strybing'; 'Huia'; 'Keatleyi'; 'Kiwi'; 'Martinii'. *Row 4* 'Nichollsii Improved'; 'Pendulum'; 'Pink Cascade'; 'Pink Champagne'; 'Pink Pearl'. *Row 5* 'Red Damask'; 'Red Ensign'; 'Red Falls'; 'Roseum Flore-Pleno'; 'Rosy Morn' *Row 6* 'Snow Flurry'; 'Sunraysia'; 'Tui'; 'Twinkle'; 'Winter Cheer'.

Assessing The Environmental Safety of Pesticides

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Introduction

The impact of pesticides in the environment has been a matter of increasing public concern ever since the publication of 'Silent Spring' by Rachel Carson (1962). During the intervening years the pros and cons of pesticide use in agriculture have been widely debated. There is no doubt that pesticides are of major benefit to agricultural production but what are the risks to human health and the environment? The public perception of these risks is to some extent distorted by media reporting which tends to label man-made chemicals as 'dangerous' and naturally-occurring chemicals as 'safe'. However, Professor Bruce Ames, a leading authority on the causes of cancer, has pointed out that 99.9% of all the pesticides to which we are exposed are natural. Plants produce toxic chemicals in large quantities to combat the attacks of insects, fungi, viral and bacterial pathogens. An individual plant contains about 40 or 50 toxins, accounting for as much as 5 to 10% of the plant's dry weight. About half of these naturally-occurring chemicals have given positive results in animal cancer tests. The hazards of cancer from current levels of pesticide residues in food and water are likely to be minimal relative to the background level of natural substances that occur in foodstuffs such as mushrooms and peanut butter (Ames *et al*, 1989). Yet society expends much more effort on testing and controlling man-made chemicals than it does on naturally-occurring chemicals.

Similarly, the environmental risks of pesticides should be evaluated relative to other influences on wildlife such as climate, farming practices and loss of habitats caused by changes in land use. Society expends a great deal of effort in the rigorous testing of environmental side-effects of pesticides. A recent report by the U.K. Advisory Committee on Pesticides (MAFF, 1989) puts the environmental problems of pesticides in perspective. During each of the five years up to 1987 about 400 incidents of suspected poisoning were investigated by staff from government research laboratories. About 150 incidents per annum were attributed to the use of pesticides but two-thirds of these were caused by deliberate, illegal misuse, often in an attempt to kill predators of game or livestock. Incidents associated with the normal agricultural use of pesticides were relatively few.

Faced with increasing public concern about "green" issues, industry has worked closely with regulatory agencies to assess and, where possible, to reduce environmental risks associated with the use of pesticides. Tighter controls on pesticide use have been introduced in the form of more stringent legislation, improved packaging, labelling and training of personnel responsible for their application. But some of the most important advances in reducing environmental risks have come from changes in the kinds of pesticides that are now available to the modern farmer. Modern pesticides are more biologically active but are less persistent and more selective towards target organisms than those produced 25-30 years ago, when 'Silent Spring' was published. Thus the quantities of pesticides used by modern farmers are progressively decreasing and they are posing fewer risks to the environment and to wildlife than was the case 20 or 30 years ago. Highly sensitive analytical techniques have been developed to detect pesticide residues in the environment at the parts per billion level. These are now used widely to monitor residues in crops, water, soil and wildlife. Furthermore, with the development of better techniques for the evaluation of hazards in the environment, it is now possible to anticipate and avoid environmental hazards of the kind attributed to older pesticides, such as DDT. In this article the author explains how this is done, using comprehensive testing procedures that are applied to the testing of all new pesticides.

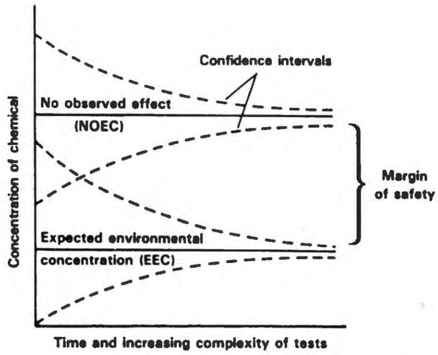

Fig 1 Principle of hazard assessment

Hazard assessment

Hazard assessment is a process designed to determine the nature and magnitude of hazards that may result from the release of chemicals into the environment. The process depends on comparing chemical concentrations that are expected to occur in the environment, the Expected Environmental Concentration, or EEC, with those that are estimated to have no biological effects, the No Observed Effect Concentration or NOEC. The difference between these two concentrations is the margin of safety (Fig. 1).

Most hazard assessment procedures incorporate a series of steps or tiers progressing from relatively simple to more complicated laboratory tests and finally to field tests and environmental monitoring (Fig. 2). An initial or screening stage is based largely on acute toxicity tests, physicochemical properties and rates of chemical degradation. An intermediate stage involves toxicity tests using a wider range of organisms, tests to assess sublethal effects, bioaccumulation tests and studies on persistence and identification of metabolites in water, soil, plants, fish and mammals. An advanced stage of hazard assessment may involve studies in small field plots and outdoor ponds to assess the fate

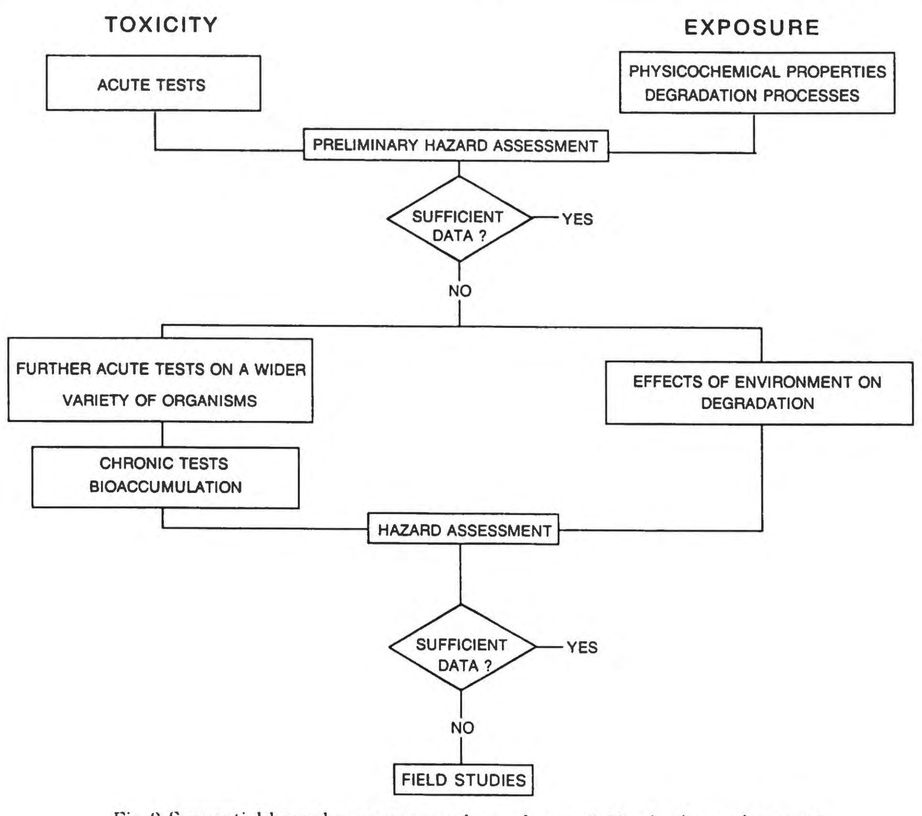

Fig 2 Sequential hazard assessment scheme for pesticides in the environment

and effects of pesticides under conditions that closely simulate the natural environment. Finally, intensive environmental monitoring of pesticides may be carried out during the early commercial marketing of new pesticides to ensure the soundness of the hazard assessment procedures.

There is some uncertainty at each stage of the hazard assessment process. At an early stage the uncertainties associated with estimates of the EEC and NOEC may be relatively great and the associated confidence intervals may be relatively wide. As testing continues and further data are generated the uncertainties become less and confidence intervals become narrower (Fig. 1). Testing proceeds until the margin of safety is acceptably wide and can be defined with sufficient confidence.

The EEC can be estimated from data for chemical release rates into the environment associated with patterns of use, physicochemical properties and environmental parameters (e.g. windspeed, sunlight, pH, temperature) that affect the rates of dispersion and degradation. Mathematical models can be used to couple physicochemical properties with environmental parameters and thus to estimate the EEC for specified environments. The reliability of such estimates depends largely on the reliability of the inputs to the models i.e. on the completeness and reliability of the data for chemical release rates, physicochemical properties and for the parameters of the receiving environment.

There are also uncertainties associated with estimates of the NOEC since these are based on biological data that are themselves subject to statistical variability. Furthermore, there are uncertainties in extrapolating from acute to chronic effects, from one species to another and from the results of laboratory tests to biological effects in the real environment. To allow for such uncertainties, "uncertainty factors" are often applied to a limited set of data to estimate the NOEC. For example, an OECD Working Group (OECD, 1989) recently suggested that an uncertainty factor of 1,000 should be applied to data for acute toxicity to estimate the NOEC, i.e. the NOEC may be estimated as the LC_{50} (the concentration that kills 50% of test organisms in a toxicity test) divided by 1,000. If limited data are available for chronic toxicity a value of 100 should be applied and, if good quality chronic data are available, a value of 10. If data from field tests are available an uncertainty factor of 1 may be appropriate.

Hazard assessment in the aquatic environment

The EEC for aquatic environments can be estimated from data for pesticide use patterns, release rates, physicochemical properties, degradation rates and environmental parameters that affect dispersion and degradation. At an early stage in the hazard assessment process data are obtained that can be used to estimate partitioning of a pesticide between air, water and soil. These data are experimentally-determined values for vapour pressure, water solubility and the octanol/water partition coefficient.

The ratio of vapour pressure to water solubility can be used to estimate Henry's constant, H, which describes the tendency for a chemical to volatilise from water into air. If H is less than 1.0 a chemical will tend to remain in water, whereas if H is greater than 1.0 it will tend to escape into the atmosphere. Values for H vary from around 1×10^{-5} for relatively involatile, water soluble chemicals such as the herbicide 2,4-D up to 10^4 for some volatile solvents. Even involatile organic pesticides can have high values for H if they also have low values for water solubility. For example, the vapour pressure for DDT is 2.63×10^{-5} Pa and its water solubility is 9.36×10^{-6} mol m^{-3}, from which H may be calculated as 2.84 Pa m^3 mol^{-1}. Thus DDT, despite its very low vapour pressure, will tend to escape from water into the atmosphere. This factor, together with its persistent nature and the release of large quantities into the environment, explains the ubiquitous distribution of DDT in places far removed from treated sites.

The octanol/water partition coefficient, K_{ow}, can be estimated in the laboratory using a 'shake-flask' technique. The pesticide is added to a flask containing octanol and water and the flask is shaken using a mechanical shaker. After allowing the two phases to separate the concentrations of chemical in water and in octanol are determined by chemical analysis. The ratio of these two concentrations gives K_{ow}. Alternatively, K_{ow} can be determined using high performance liquid chromatography (HPLC). Values obtained for K_{ow} may be used to estimate the equilibrium distribution of a chemical between water and soil or sediment.

The octanol/water partition coefficient also provides a good estimate of the relative solubility of organic compounds in water and animal fats and is therefore widely used to estimate the potential for bioaccumulation of chemicals in fish and other aquatic animals. It is generally accepted that if K_{ow} is less than 1000 the risk of bioaccumulation is low, because the major route for uptake by aquatic animals is sorption from water into animal fats. On the other hand, if K_{ow} is greater than 1000 the risk of bioaccumulation cannot be ignored.

Early screening of toxicity to aquatic organisms is based on the results of acute toxicity tests using fish, *Daphnia* and algae. Juvenile fish of various species, e.g. rainbow trout or carp, may be used in these short-term tests. They are exposed to a logarithmic series of chemical concentrations for a period of 96 h and mortality is determined at 24 h intervals and at the end of the test. The results are expressed as the 96 h LC_{50}, i.e. the concentration of chemical that is lethal to 50% of the fish after 96 hours exposure. A similar procedure is used to evaluate toxicity to the planktonic crustacean *Daphnia*. These organisms are relatively easy to rear in the laboratory and they reproduce parthenogenetically, i.e. females continually produce female offspring without mating. This feature of their lifecycle means that genetic variation between individuals is minimal and this helps to ensure good reproducibility of results of toxicity tests. New-born *Daphnia* (less than 24 h old) are exposed to chemicals for a period of 48 h and results are expressed as the 48 h EC_{50}.

Toxicity tests with algae are carried out using cultures of unicellular organisms maintained in flasks of nutrient solutions. The numbers of algal cells in each are flask counted at the start of a test and again after 72 h exposure to a series of chemical concentrations. The growth rates and biomass of the populations of algal cells are calculated and the results expressed as the 72 h EC_{50}, i.e. the concentration that inhibits growth rate or biomass production by 50% after 72 h exposure.

The results of these three acute toxicity tests give a good indication of whether a chemical is likely to be toxic to fish, invertebrates or plants in the aquatic environment. From the results it is possible to estimate the NOEC for aquatic environments, using appropriate uncertainty factors as described previously. Estimated NOEC values may be compared with estimates of the EEC to give an indication of the probable margin of safety. If this is sufficiently wide no further tests may be required. Otherwise, it may be necessary to carry out more detailed studies to confirm that the margin of safety is sufficient to provide adequate environmental protection.

Bioaccumulation tests may be required for chemicals where K_{ow} is greater than 1000. They are generally carried out using fish species and their objective is to determine relative concentrations of chemical in fish and water when the fish are exposed long enough for chemical concentrations in fish and water to have reached equilibrium. The ratio of concentration in fish: concentration in water, at equilibrium, is known as the bioaccumulation factor or BCF. For chemicals with a high potential for bioaccumulation, e.g. some organochlorines and heavy metals, an exposure of several months or even years may be required to reach equilibrium. To overcome the problems that are involved in using such long exposures, a shortened method for determining BCF has been developed. This depends on evaluating the rates of uptake and depuration of chemicals in fish. The ratio of these rates is equivalent to the BCF at equilibrium. Batches of fish are exposed to chemicals, generally under flow-through conditions, and concentrations of chemicals in water and fish are determined at various times during the 'uptake' phase of the test. The fish are then transferred to tanks containing water but no chemical and concentrations of chemical in the fish are determined at various times during the 'depuration' phase.

Chronic or long-term toxicity tests may be carried out using various species of fish and *Daphnia*. The objective of such tests is to evaluate effects of chemicals on sensitive biological parameters such as rates of growth and reproduction. Using such sensitive parameters it is possible to define the NOEC for aquatic organisms with greater certainty than is the case with results from acute toxicity tests. Whole life-cycle tests

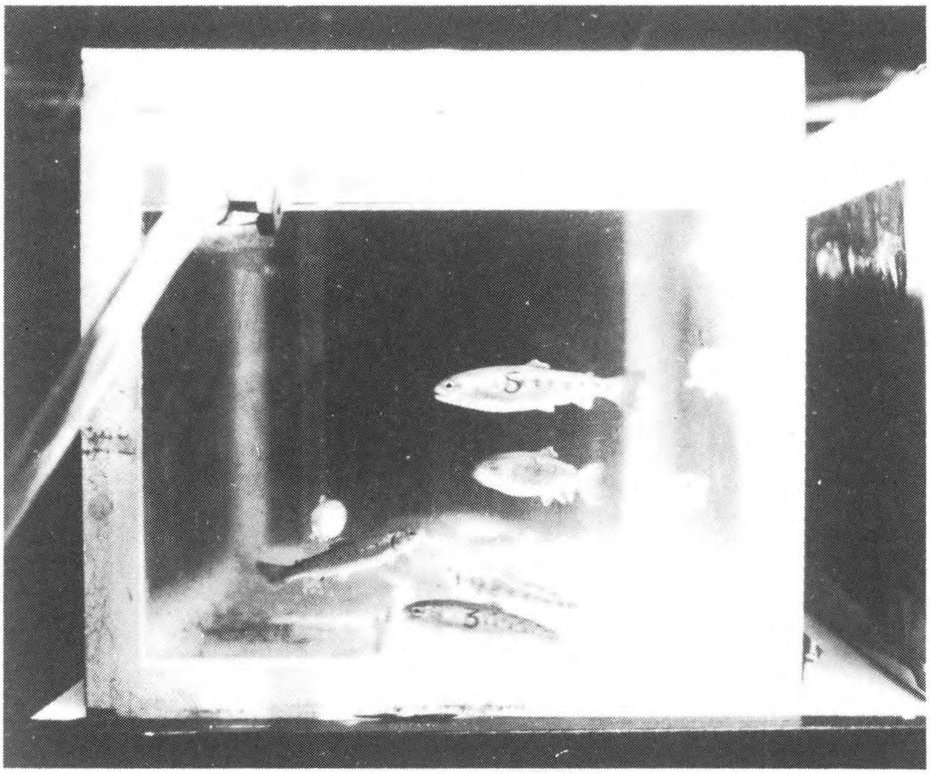

Fig 3 Individually-marked fish are used to evaluate effects on their growth

Fig 4 Outdoor ponds used to evaluate fate and effects of pesticides in aquatic environments

with fish species are sometimes carried out using species that complete their whole life cycle, from egg to egg, during a period of about nine months. However, it has been demonstrated that the embryonic and larval stages of the life cycle are usually the most susceptible and therefore equally valid results can be obtained using a shortened test lasting for only the first 30 days of the life cycle. This so-called embryo-larval test is most often carried out using the fathead minnow, *Pimephales promelas*, a species native to N. America. Batches of eggs are obtained from pairs of spawning adults and placed in chambers containing water and chemical. Water and chemicals are continually provided to the chambers under 'flow-through' conditions. Hatching of the eggs and the growth rate of the fry are monitored to determine the NOEC.

Alternatively, effects of fish growth rates can be evaluated using juvenile rainbow trout. Provided food and space are not limiting, the growth rate of this species is constant and predictable from the fry stage to the onset of maturity. This fact has been used to develop a relatively sensitive and cost-effective method of evaluating effects on fish growth rates. Fish are individually marked (Fig. 3) and exposed in batches to a series of chemical concentrations. They are weighed and measured at the start of the test and again after exposure for 14 and 28 days. From the data obtained for weights and lengths, growth rates are calculated and the NOEC is determined.

While growth rate is generally the most sensitive biological parameter measured in chronic fish toxicity tests, reproduction is generally the most sensitive parameter in chronic *Daphnia* tests. These tests generally last for 21 days, during which time at least three generations of offspring should be produced in control cultures. New-born *Daphnia*, less than 24 h old, are placed individually in beakers containing water and chemical. Every 24 h the *Daphnia* are transferred to freshly-prepared solutions. Effects on mortality, growth and reproduction are monitored daily throughout the period of the test. The organisms reach maturity after 7-10 days and a single *Daphnia* may produce around one hundred young during the 21-day test. The most sensitive stage in the *Daphnia* life cycle is the young embryo that develops in the brood pouch.

On the basis of data obtained from chronic toxicity tests it may be possible to estimate the NOEC with sufficient confidence. However, if uncertainties still exist concerning the NOEC or the EEC, then studies may be carried out under controlled field conditions. Outdoor experimental ponds have been widely used for this purpose (Fig. 4). They are analogous to the agronomist's small field plot, forming a bridge between the laboratory and the natural environment. In outdoor ponds it is possible to study effects of chemicals on populations of various species under conditions of real-world exposure to the chemical rather than under the artificial conditions that are necessary in the laboratory. It is also possible to obtain data for species that are not easily maintained in the laboratory, to study indirect effects such as predator-prey interactions, effects on algal blooms and dissolved oxygen concentrations and to study the rate of recovery of populations from the effects of toxic chemicals.

Replicated pond studies have been carried out to study fundamental relationships between primary and secondary effects of toxic chemicals. These have been of particular value in studies of the indirect effects of insecticide contamination of freshwater ecosystems. Most insecticides are highly toxic not only to insects but also to related organisms such as Crustacea. The Crustacea are important organisms in the plankton of ponds and lakes. Insecticide-induced mortality of planktonic Crustacea can often lead to algal blooms, because the algae are normally an important item in the diet of the Crustacea. An algal bloom and its eventual decay can cause depression of dissolved oxygen concentrations and these can, in turn, cause the death of fish. However, this sequence of events is now well documented and need not be demonstrated for each new insecticide. If it can be shown that effects on planktonic Crustacea are unlikely to occur, it is clear that the secondary effects are also unlikely to occur.

For new pesticides an unreplicated pond study can provide sufficient data to establish the margin of safety. The following case history illustrates this point. The insecticide cypermethrin [RIPCORD, NRDC 149, [R,S] -*α*-cyano-3-phenoxybenzyl (IR, IS, *cis, trans*)-3-(2,2,dichlorovinyl)-2,2-dimethyl cyclopropane-carboxylate] is a synthetic pyrethroid used to control a variety of insect pests. In normal agricultural use recommended dosages are in the range 25-100 g ha^{-1}. The EEC in aquatic environments was assessed by consideration of a 'worst case' scenario, i.e. consideration of the expected concentration in the water of a pond or lake, 1 m deep, that was accidentally oversprayed. Assuming that all of the chemical were to disperse downwards into the water and dissolve the EEC was estimated as 2.5-10 μg l^{-1}. These estimated values were about 10 times greater than LC_{50} values for fish and aquatic invertebrates, indicating that cypermethrin might present a real risk to aquatic life if sprayed near water. However, there were good reasons to suppose that only a small fraction of the chemical would disperse downwards and dissolve into the water. The partition coefficient for cypermethrin is very high (K_{ow} = 2.0 x 10^6), suggesting strong binding to vegetation and sediment. Furthermore, cypermethrin is readily biodegraded, suggesting lack of persistence in water. A pond study was therefore carried out, primarily to obtain a more realistic estimate of the EEC under conditions closely simulating the natural environment.

Two, mature, unlined ponds, 0.7 m deep, were oversprayed with an emulsifiable concentrate formulation of cypermethrin at a dosage of 100 g ha^{-1} using a knapsack sprayer fitted with a 2 m boom held about 1 m above the water surface. Surface water, subsurface water, sediment, aquatic vegetation and fish were sampled and analysed for residues of cypermethrin. High concentrations (>1000 μg l^{-1}) were found in surface water and surface vegetation soon after treatment but relatively low concentrations (0.5-1.5 μg l^{-1}) were found in subsurface water. It was then calculated that only 4-8% of the cypermethrin sprayed over the pond surfaces was found in solution in the subsurface water. Thus, the EEC (0.5-1.5 μg l^{-1}) was much lower than previously estimated (10 μgl^{-1}) and was very near to estimated values for the NOEC, based on the results of laboratory toxicity tests.

Lack of significant environmental hazards under normal conditions of use in agriculture were then convincingly demonstrated by environmental monitoring of the effects of cypermethrin in ponds and streams adjacent to sprayed cropland. Fields of sugar beet and potatoes in the U.K. were treated with cypermethrin using tractor-mounted sprayers. Deposits of spray drift on adjacent pond surfaces were very small and concentrations in subsurface water were near to or below the limits of detection. There were no detectable residues in fish and there were no mortalities of aquatic invertebrates. Vineyards in France were treated with mistblowers. Only very small concentrations of cypermethrin were detected in the water of adjacent streams and these decreased to undetectable levels within a few hours of treatment. There were no fish kills and there were no effects on the population densities of sensitive species of aquatic invertebrates.

Hazard assessment in the terrestrial environment

Whereas aquatic organisms are exposed to chemicals primarily via water, terrestrial organisms are exposed via air, water, soil or food. It is therefore more difficult to estimate the exposure concentration (the EEC) for terrestrial than for aquatic organisms. This has been taken into account by a proposed OECD scheme for evaluating hazards to terrestrial organisms (OECD, 1989). From estimates of pesticide application rates the exposure can be estimated for direct contact of pesticides with plants, animals and soil. Direct contact may cause toxicity to plants, invertebrates and microflora. Indirect uptake via the food chain may cause toxicity to birds and animals.

Recognition of these various possible routes for uptake of pesticides in terrestrial environments has led to the development of numerous test methods for evaluating toxicity to a wide range of non-target organisms. OECD guidelines have been developed to evaluate both lethal and sublethal effects on soil microflora, plants, soil-dwelling invertebrates, insect pollinators, birds and mammals. The International Organisation for Biological Control (IOBC) has developed a range of test methods for evaluating toxicity to about 20 species of beneficial arthropods, e.g. predatory and parasitic insects and mites. Obviously, not all of these tests can or should be used for each and every pesticide. A choice of appropriate tests has to be made depending on the proposed use of the pesticide and estimates of the exposure of non-target organisms, whether through direct contact with spray applications or through indirect uptake via the food chain. The following case history for alphacypermethrin, a pyrethroid insecticide first marketed in 1983, illustrates how these new methods were applied to evaluate the hazards of this pesticide to terrestrial environments.

Recommended dosage rates for alphacypermethrin for control of a broad range of insect pests vary within the range 5-30 g ha^{-1}. At these dosage rates there is no significant hazard to birds or mammals. Furthermore, the insecticide is rapidly metabolised and excreted by vertebrates. In the environment it is biodegradable and therefore is relatively non-persistent. However, because of its broad spectrum insecticidal activity some concern was felt about possible effects on beneficial insects and spiders. Detailed studies were therefore carried out, in both the laboratory and field, to investigate effects on these non-target organisms in a variety of crops.

In the laboratory, toxicity to earthworms was assessed by exposing worms for 14 days in an artificial soil containing various concentrations of alphacypermethrin. There were no effects on the worms even when they were exposed to concentrations many times greater than the maximum recommended dose for control of insects. Further testing against earthworms was therefore unnecessary.

Laboratory tests were also carried out to assess the potential for effects on parasitic wasps (*Trichogramma*), which are important in helping to control caterpillars in various crops. The adult wasps lay their eggs in the eggs of their lepidopterous host. The larvae of the parasite and host develop together. At first the parasite consumes only the non-essential tissue of the caterpil-

Fig 5 A D-Vac suction net being used to collect arthropods from the leaves of wheat

lar but at a later stage, when it is nearing maturity, it consumes the essential parts of the host and kills it. Toxicity to these parasites was assessed by observing effects on freshly-parasitised eggs that were sprayed with insecticide. Effects on the numbers of adult parasites emerging from treated eggs were assessed and also effects on their ability to parasitise fresh eggs of the host. Results showed that effects were relatively minor compared with those of an older, widely-used pesticide. Using guidelines recommended by the International Organisation for Biological Control, alphacypermethrin was classified as harmless.

Field experiments were carried out to assess the effects of alphacypermethrin on parasites and predators of insect pests in cereals, oil-seed rape, orchards and rice paddies. The most detailed study was carried out over a period of five years. Wheat, barley and oil-seed rape were grown in rotation in an eight-hectare field which was divided into two approximately equal areas. One of these areas was treated each year with alphacypermethrin, the other was treated with older organophosphorus and carbamate insecticides. Insects and other arthropods were sampled before and after treatment during each year of the study (Figs 5 and 6). Some of the insecticide treatments had short-term effects on parasitic wasps, predatory flies, beetles and spiders but there were no adverse long-term effects on any of these organisms in either of the treated areas.

During the last 10 years oil-seed rape has been introduced into European farming systems, typically as a 'break' crop in cereal rotations. It is now grown on a very large scale. Insecticide treatments are carried out in the flowering season when oil-seed rape is susceptible to attack by various insect pests. Foraging honey bees, collecting nectar and pollen from the flowers, are often very active in the crop at the same time. Many of the older insecticides are highly toxic to honey bees and during the early 1980s there were frequent incidents of mortality of bees associated with insecticide spraying of oil-seed rape. The developing conflict of interest between farmers and beekeepers is being resolved by the use of new insecticides, such as alphacypermethrin, that are harmless to bees.

In the laboratory alphacypermethrin is highly toxic to bees, whether it is applied directly to the bee as a small droplet containing the insecticide, or whether it is fed to the bees in a sugar solution. On the other hand, when bees are exposed to flowers that have recently been sprayed with alpacypermethrin there is very little mortality. This, together with observations from early field tests, suggests that alphacypermethrin might be repellent to bees and therefore might not be hazardous to bees under practical conditions of use, despite its high toxicity in some laboratory tests.

Detailed field tests were carried out to confirm and clarify this result. Fields of oil-seed rape were sprayed with alphacypermethrin or with an older organophosphorus insecticide, parathion-methyl. Treatments were carried out using either tractor or helicopter-mounted spraying equipment and all applications were timed to coincide with periods of peak foraging activity of honey bees. Colonies of bees were prepared by a professional beekeeper and eight hives were placed in a row at the edge of each field one week before insecticide treatment (Fig. 7). Each hive contained ten brood frames, boxes for storage of honey and an estimated population of 40-80,000 adult bees. Traps were also fitted to the hives to collect samples of pollen from bees returning from foraging.

Numbers of foraging bees in the treated fields were counted and the activity of bees at the hives was assessed by counting the numbers entering and leaving. The older insecticide, parathion-methyl, killed large numbers of bees, had a marked effect on pollen collection and severely reduced foraging activity for a few days after treatment. In contrast, there were no effects of alphacypermethrin on mortality of bees or on pollen collection. There were immediate

Fig 6 A pitfall trap, used to collect ground beetles and spiders

Fig 7 Bee hives next to a field of oil-seed rape

but transient effects on foraging activity of bees in the crops and a decline in the numbers of bees entering and leaving the hives. Results of the laboratory tests show that these effects in the field were caused by the repellency of alphacypermethrin to bees. This repellency reduces the exposure of honey bees to fresh deposits of the insecticide and helps to ensure that bees are not exposed to toxic amounts.

Conclusions

In summary, the environmental safety of pesticides is intensively studied before these products are registered for commercial use. No other class of chemicals is subjected to such an exhaustive and thorough examination of its potential for causing harm to wildlife and to the environment. A broad range of laboratory and field tests encompasses not only the obvious species of concern such as fish, birds and mammals, but also beneficial insects, spiders and crustaceans from a variety of terrestrial and aquatic habitats. Environmental studies are carried out using small field plots and experimental ponds to study persistence and effects at the population, community and ecosystem levels of biological organisation. These tests, and their use by regulatory authorities, have done much to improve the environmental safety of pesticides in agriculture.

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Sir Victor Davies Award

The "Sir Victor Davies Award" is awarded annually to a person under the age of thirty years who has demonstrated an outstanding plant knowledge in New Zealand. This may involve any or all of the following aspects:
— Propagation and production
— Cultivation
— Preservation
— Botanical study and research.

The inaugural award was won by Peter Heenan who is currently Technical Officer at the Canterbury Agricultural and Science Centre at Lincoln.

Citation

Peter Heenan was educated at Otago Boys High School, coming from a family with an enthusiastic and deep interest in horticulture. In 1979 he joined the Dunedin City Council's Parks and Recreation Department as a Horticultural Apprentice, becoming a Leading Hand in 1984. In 1986 he moved to Ashburton as a Foreman in the Parks and Reserves Department, also serving with Waimairi District Council and the Christchurch Botanic Garden, before taking up his present position in late 1989 with DSIR, at the Canterbury Agriculture and Science Centre. His position is currently that of Technical Officer with responsibility for the Canterbury Agriculture and Science Centre landscape plantings and technical assistance for research projects.

Professional qualifications are: Trade Certificate in Horticulture and Gardening (1981), completion of his Apprenticeship (1982), Diploma in Parks and Recreation Management (1985), and National Diploma of Horticulture (1986). He was awarded the Dougal McKenzie Memorial Prize for the best NDH(Hons) thesis presented in 1986.

Peter Heenan's general interests are broadly in native plants and horticulture, with specialist interests in: cultivars and their nomenclature, cultivation and propagation, alpine and rock garden plants, and rare and endangered plants. His interest in the last of these is reflected in his detailed study of rare plant conservation in Parks and Recreation Departments undertaken as part of the course requirements for the Diploma in Parks and Recreation Management. His published paper summarising the findings of his survey is a highly professional study of attitudes, policies and resources; the recommendations in this paper make an important contribution to ongoing rationalisation of *ex situ* rare and endangered plant conservation. There have been very few such studies undertaken anywhere in the world, so that the results have significance not only for New Zealand but for other countries as well.

Peter's NDH thesis was an exhaustive study of propagation and collection techniques and requirements for rare and endangered plants native to New Zealand. Cultivation information was provided for 119 species, including gradings across a range of criteria. This was the first such assessment and includes a great deal of new information which will be critical to the survival *ex situ* of some of our most threatened plant species.

His work on this thesis was not confined to his experimental garden in Dunedin. The project involved considerable fieldwork into remote areas such as the Eyre Mountains, in the course of which valuable observations were made on wild populations; these have subsequently been incorporated into the DSIR threatened plants database. From this fieldwork Peter developed recommendations for collection of living material to be used for propagation.

His interest in threatened species has led to establishment of rare and endangered plant collections, and strengthening of existing collections. This includes his own home garden in Dunedin (where many of the observations and experiments for his NDH study were carried out), the establishment of a collection of rare plants at the Christchurch Botanic Garden, and augmenting and relocation of rare plant collections held at DSIR. An aspect of collections management in which he has particular interest is records maintenance and while at the Christchurch Botanic Garden, particular note was made of his attention to high standards and detail in this area. At all places of work he has studied closely the cultivation of plants native to New Zealand, a field in which he is acknowledged as having wide knowledge and experience. His active fieldwork has allowed him to see and study plants in the wild, so identifying peculiarities to take into account in cultivation, and his experimental horticulture in Dunedin and Christchurch has shown in many ways how plants respond to a range of environmental conditions.

Peter Heenan's input at DSIR includes: upgrading of the nursery operation to utilise modern methods and techniques; layout of the gardens to give a systematic arrangement with 50 plant families represented; further development of thematic plantings; redesign of the computer record system to track origin and progress of plant; design of a permanent label system; propagation and cultivation of plant materials for research, and participation in a range of research programmes with scientific staff.

Publications:

1985 Rare plant conservation in Parks Departments. *Annual Journal Royal N.Z. Institute of Horticulture 13:* 13-21.

1986: The cultivation of New Zealand endangered plants. *Annual Journal Royal N.Z. Institute of Horticulture 14:* 18-30.

1988: *Hebe breviracemosa* — some hardiness observations. *Annual Journal Royal N.Z. Institute of Horticultue 15:* 42.

1989: Threatened natives growing at the Christchurch Botanic Garden, Christchurch, New Zealand. *International Dendrology Society Yearbook.*

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As well, Peter has written various articles on horticulture in New Zealand, for the *Royal N.Z. Institute of Horticulture Quarterly Bulletin,* and while in Ashburton, contributed fortnightly articles on horticulture to the *Ashburton Guardian.* He has appeared on the Television series, "Spot On", and contributed to conferences, including a paper at the Workshop on National Plant Collections (Hamilton, October 1989).

The establishment of a vineyard in the Martinborough district to produce fruit for top quality cool climate wines

Nick Hoskins

Martinborough Vineyards Ltd, Princess Street, Martinborough

Introduction

Vineyard Establishment is a subject that is pertinent to Martinborough as there have been many new vineyards established in the last few years. The total area planted is not large compared with Hawkes Bay or Gisborne but there are many small scale developments with diverse establishment methods. I have been involved with the establishment of two vineyards and am now employed by Martinborough Vineyard who are developing a ten acre block and another five acre block for a Wellington Agricultural Consultant Graham Cleland.

The objectives of this article are to record the processes and decisions that took place and to discuss the rationale behind those decisions that will govern the future performance of the vineyard. In the text there are some comments on the performance of other vineyards in the area. These are included to justify some of the decisions, and to highlight particular problems of vineyard establishment in Martinborough.

History

Martinborough is essentially an agricultural service centre and has had very few commercial growing operations with the exception of cereal and fodder cropping. The planting of vines was a new thing for the Martinborough district. The first plantings were not a haphazard development but rather the result of a scientific soil survey carried out by D.S.I.R. Soil Scientist Derrick Milne who recognised certain soils of Martinborough as having the potential to produce quality wine grapes. Couple this with Martinborough's 700mm p.a. rainfall and low humidity and it should be one of the better areas in New Zealand for producing cool climate wine grapes similar to the Burgundy area of France. The first plantings were in the early 1980s but on a very small scale.

Martinborough Vineyard established a small area in 1980. It was then called Waihenga Vineyards. The partnership was, and still is dedicated to producing top quality Pinot Noir and Chardonnay. To this end they employed ex Delegats Winemaker Larry McKenna. Under Larry McKenna Martinborough Vineyard has produced a gold medal winning Chardonnay and Pinot Noir for the 1986, 1987 and 1988 vintages. A truly remarkable record for a new winery.

At Present

Martinborough produces a very small amount of New Zealand's wine grapes; 1.2% in 1989 (see fig 1) increasing to 2% in 1991. This is an insignificant amount but because the wines have achieved such high recognition for quality, Martinborough has a high profile on the New Zealand and increasingly the International wine scene.

Martinborough Vineyard has contributed greatly to this international recognition and in 1989 exported Pinot Noir and Chardonnay to the U.K. and Australia.

Martinborough Vineyard has been increasing production since its first vintage in 1985. They have purchased grapes from the neighbouring Om Santi Vineyards, and in 1989 crushed 100 tonnes. For the 1990 vintage Om Santi will be making their own wines, although some of the shortfall will be covered by grapes purchased from another vineyard. There will still be a large drop in production. Until now the emphasis has been on developing the winery and consolidating the existing vineyard. Now that this has been achieved and in view of Martinborough Vineyard's successful track record it was a natural progression to develop another vineyard.

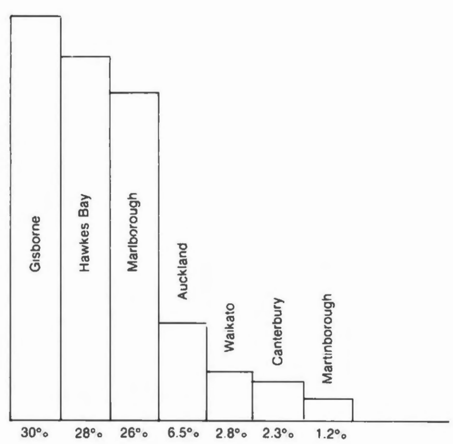

Fig 1 Percentage of area in grapes by region (1989).

Martinborough Vineyard's philosophy on winegrape production

The catchphrase today is that good wines are made in the vineyard, and this is supported by Martinborough Vineyard's philosophy of spending time in the vineyard to ensure top quality grapes are produced, using as little chemical in the vineyard and in the winemaking process as possible, using minimal irrigation to ensure concentration of sugars and flavours in the juice, handpicking all fruit and picking the ripest fruit as possible. Martinborough Vineyard also intends to remain a small scale operation (10,000 cases) to retain control over fruit entering the winery and the resulting winemaking process. It is intended to produce exclusive wines aimed at the more discerning wine drinker.

Reasons for establishing a new vineyard

Control of the fruit in the vineyard is an important part of producing quality wine. It was felt that Martinborough Vineyard would have an assured supply of quality fruit if the vineyards were owned and managed directly by themselves. They had in fact very little Pinot Noir under their control and the Chardonnay had long running problems with poor fruit set. The planting of a new vineyard, along with a select few contract growers would supply the winery with the fruit needed to produce 10,000 cases. It would also give the winemaker a chance to assess some of the more promising new clones and possibly add more complexity to the wines.

The new vineyard would make a better economic unit as far as machinery and staff go, and it would ensure a good supply of quality fruit every year.

History of previous vineyard developments in Martinborough

After deciding to develop a new vineyard, we carried out an assessment of vineyards already established in the area. Many vineyards had been established by field grafting. These vineyards still had vines missing where grafting had not been successful. Some of these vineyards were more than four years old. Numerous vineyards had been established without irrigation. This seemed unsatisfactory especially when planting cuttings as the casualty rate was too high and even if rootlings (one year old cuttings from nursery) were used the growth rate was too slow so that after three or more years there was little or no cane growth to lay down for fruit.

It was also noted that:

1) Shelter was not a priority and that some blocks were suffering from stress

2) Vine and row spacing was varied with little scientific reasoning behind the spacing used

3) There was little or no effort put into obtaining good virus free clones. In fact there were still vineyards being planted in known virused clones.

On the basis of all this information many decisions were made, but the underlying message was clear. If Martinborough Vineyard wanted to produce good crops of quality fruit in the budgeted time frame, there could be no cutting corners in vineyard establishment.

The Sites

The Martinborough Vineyard site and the Cleland site are both situated on the North Side of the Martinborough borough. The Martinborough Vineyard site is 180

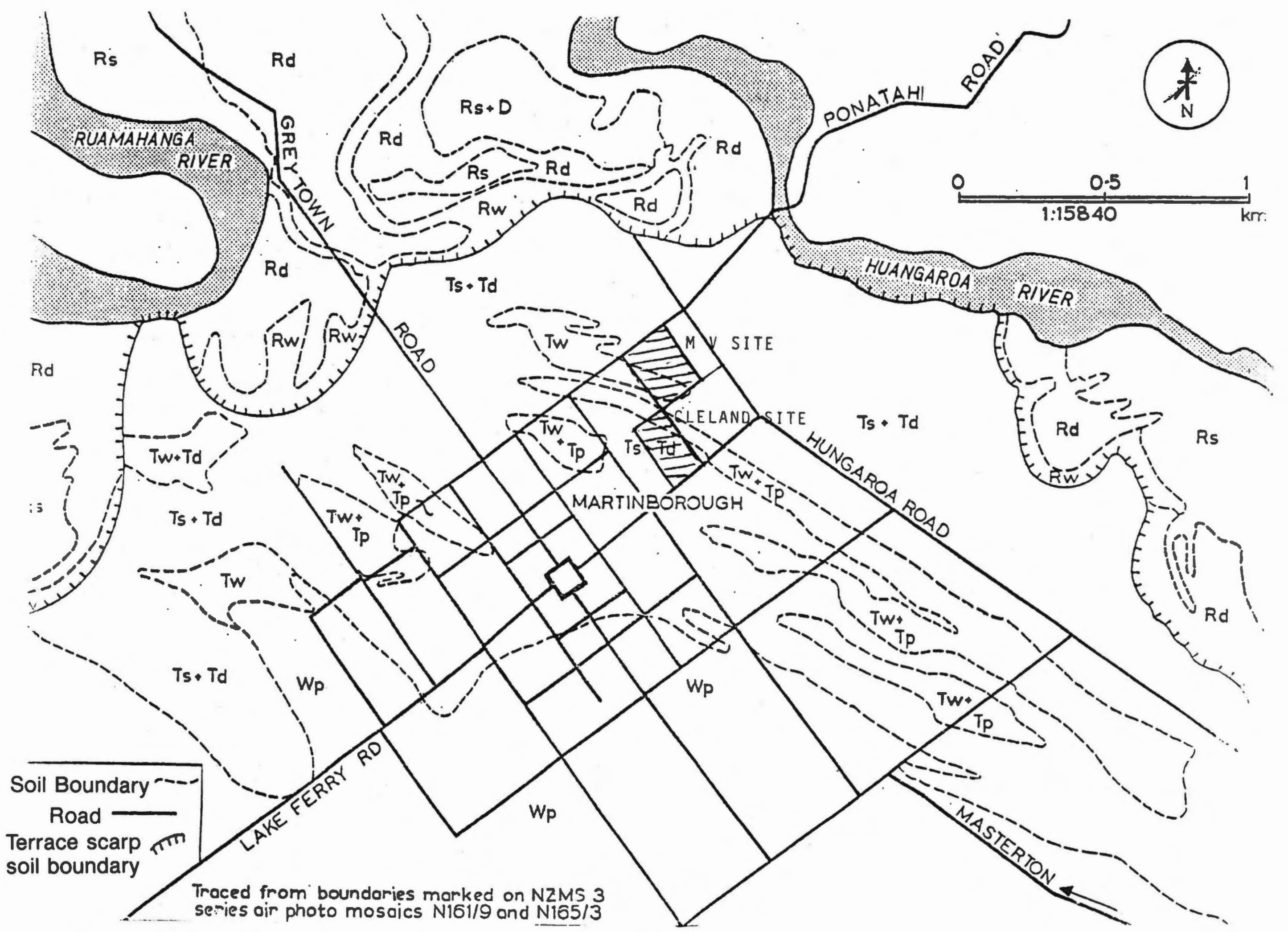

Fig 2 Provisional Soil Map of Martinborough

Legend

Soils of Low Terraces and Floodplains

Shallow and very shallow, excessively drained sandy loam and loamy sand soils — Rs

Moderately deep to very deep, well drained sandy loam and silt loam soils — Rd

Moderately deep to deep, imperfectly to poorly drained sandy loam and silt loam soils — Rw

Soils of Riverine Sand Dunes

Deep and very deep, somewhat excessively to excessively drained sand and loamy sand soils — D

Soils of High Terraces

Shallow and very shallow, excessively and somewhat excessively drained stony silt loam soils — Ts

Moderately deep, somewhat excessively and well drained stony silt loam soils — Td

Moderately deep, imperfectly drained silt loam and stony silt loam soils — Tw

Moderately deep, and very deep, imperfectly drained silt loam and sand loam soils with pan — Tp

Deep and very deep, imperfectly drained silt loam soils with pan — Wp

Soil Map compiled by J. D. Cowie and J. D. Milne, Soil Bureau, September 1979.

Notes:

Depth refers to depth to gravels, not depth to agronomically contrasting layers such as pans or water-tables which themselves restrict root penetration.

Soil boundaries were determined from air photo interpretations, limited ground observations, and discussion with local residents and should be regarded as provisional only.

metres in length and 200 metres wide. The 90 rows are running SW to NE. The Cleland site has 97 rows running NE, the rows are 80 metres long and the block is 220 metres wide.

The soils on the Martinborough Vineyard site are mainly shallow to moderately deep, excessively well drained stoney silt loams (as described by Cowie and Milne).

The Cleland site is also shallow to moderately deep somewhat excessively and well drained stoney silt loams apart from the northernmost corner (see Fig 2) which is moderately deep imperfectly drained silt loam with pan. This corner may prove to be a problem area in controlling vine vigour. Milne (1989) describes a desirable growth pattern as one in which there is initial growth until about eight or ten leaves have formed on each shoot, and shoot length is about 0.8 metres-1.0 metres in length. There is subsequent progressively slowed growth until ripening, at most 12-14 mature leaves have formed and shoot length is 1.2-1.4 metres. He also goes on to say that achieving this growth pattern requires careful balancing of soil, plant spacing, and canopy design in relation to rainfall distribution. Hopefully this will be achieved on the rest of the planted area but no allowances have been made for this corner of the Cleland block.

The blocks have been ploughed and fallowed for a year partly to enhance nutrient status and to decrease weed seed population by letting them germinate then cultivating, and also because it meant fencing around the shelter to run stock to keep the grass down until planting time. An application of lime at one tonne to the acre was applied during the winter.

Shelter

Many New Zealand vineyards have no shelter. Grapevines are not a particularly wind sensitive crop and so in areas where wind is not a problem shelter cannot be justified. However, Martinborough is an extremely windy area especially from October to December when it is not unusual to have 3 to 4 weeks of gale force North Westerlies. The earlier vineyards in Martinborough were all planted with shelter across the path of the North westerlies. When planting the new vineyards there was no reason to discontinue this practice. The planting of shelter belts could increase the risk of frost by reducing air drainage but this had to be weighed against the damage caused by wind, apart from physical damage. Freeman *et al.* (1982) suggests that the closing of stomata together with an inhibition of photosynthesis occurs in vines exposed to strong winds. Kobriger *et al* (1984) further suggests as wind velocity increases the time for recovery of photosynthetic activity lengthens thus potentially reducing the crop level and influencing quality.

The Martinborough Vineyard site is divided by two belts of Alders *Alnus cordata*. The North West and Southern boundaries are planted with Leyland Cypress *Cupressocyparis leylandii*. The alders were chosen for their hardiness, deep rooting, less invasive root system and compact growth. The Leyland Cypress for their quick upright growth habit and tolerance of well drained sites. The shelter was planted one year before the vines. Ideally it should have been three years.

The Alders were planted as 150mm-250mm high, one year old plants in root trainers. They have grown to approximately 500mm to 600mm in their first season. The Leyland Cypress were planted from Pb3.5 planter bags. They were 2 year old plants and are now 700mm-1000mm high. All shelter is irrigated by typhoon driplines. The Cleland block has been planted with 1.5 metre-2.5 metre Alders mainly because of the owners preference. These Alders need extensive staking and some shortening of growth to reduce wind load while they are getting established.

Vine Spacing

The traditional vine spacing in New Zealand is 3 metres between rows and 1.5 metres within the row. Most new vineyards are planted at these spacings. But with the availability of narrow tractors and equipment coupled with high land prices, the grower needs to achieve high yields without compromising quality. Vine spacing appears to be one area in viticulture that has not received a lot of research. However, Shaulis and Kimball (1955) showed that 2.5 metres between rows and 1.8 metres between vines within the rows had consistently higher yields that were stable over time, with higher populations not losing their yield advantage. They also found that a narrow row with a wide within row spacing gave superior yields to the equivalent population with a wide row narrow vine configuration. Shaulis *et al* (1966) also defined between row spacing as significantly affecting yields per hectare with the maximum yields obtained at narrow row, wide vine configuration not necessarily at the highest population. Vine numbers were high but vine density within the row was not excessive.

In deciding the vine spacing for the new vineyard there were three options:

1) Plant at the same spacing as existing vineyard — 3m x 1.5 metres
2) Plant at very high density as a few others in Martinborough are doing 1 metre x 1 metre
3) Plant narrow row (2 metres), wide vine spacing within rows (3 metres).

The first option was dropped because it was felt we could greatly improve yields per hectare and canopy management by adjusting vine and row spacing.

The second option was also dropped because it meant buying all new vineyard equipment to manage the new spacing and there was some doubt as to whether this sort of spacing would be manageable at all.

The third option looked promising as existing vineyard equipment could be used. Good yield and quality could be obtained and hopefully some control over vine vigour which has been giving problems in the existing vineyards.

The strongest argument against this vine spacing was that it required the grower to be totally committed to spur pruning as it would be difficult, if not impossible, to lay canes as long as 1.5 metres to fill the allotted space. There was also some uncertainty as to whether the vines would have enough vigour to adequately fill the trellis space available. The final decision was to reduce the in row spacing to 2.2 metres allowing cane pruning to be carried out. The row spacing was widened to 2.2 metres to facilitate the use of all the vineyard equipment. This spacing produced a square grid pattern giving each vine a 2.2 metre square root area and making the best use of available soil area. This spacing also had the same number of vines per hectare as the conventional 3 metre row and 1.5 metre within row spacing but gave more trellis area for each vine to occupy. The end result is a better balanced vine requiring less trimming and leaf plucking to modify it.

Planting Material

Martinborough Vineyard intends to be one of the top Pinot Noir and Chardonnay producers in New Zealand and is starting to achieve that goal with three gold medals each for Pinot Noir and Chardonnay. Although other wines are produced they are of secondary importance compared to the Pinot Noir and Chardonnay. So the decision of which varieties to plant was not an issue. There were many tough decisions made on how much of each variety to plant, which clones to plant and which rootstocks to use. The decisions were influenced by a number of things. These were the:

— Availability of particular clones
— Virus status of source material
— Need to assess new clones
— Winemakers preference based on his own experience or reports from other winemakers
— Recommendations by Richard Smart, a Viticultural Scientist with the M.A.F.

It was decided to delay the planting of half the Cleland block and half the Martinborough Vineyard block for another year while grafted vines are grown in a nursery. Planting grafted vines would give some buffer against crop losses should phylloxera become established in the district. Almost all other blocks are planted on their own roots and therefore susceptible to phylloxera. Enough rooted Chardonnay plants of clone 15 and clone 6 were available in the district to plant half of the Martinborough Vineyard block. This was a good opportunity as they were the clones of chardonnay that looked the most promising. Martinborough Vineyard also obtained enough budwood to graft 700 Rua 1 chardonnay and 700 2/23 chardonnay. These two clones were recommended by Richard Smart and were certainly worth a large scale trial. When deciding on which Pinot Noir clones to use there was one that appeared to be making a big impact on other winemakers. That was UCD clone 5 and enough budwood was obtained to be able to graft enough plants for 2.3 hectares. Also obtained was enough clone 6 and clone 13 to plant half the Cleland block.

The rootstocks used were selected because of their virus-free status and influence of Richard Smart. The list was narrowed further by availability of material, first choice would be clonally selected material that had been tested virus free. But when not available in large numbers, second choice was the same clone that had not been selected and tested. Those untested clones may not have an entire population that is virus free. The two rootstocks chosen were Schwarzman TK 05051 and Teleki 5BB TK 05048. This material was sent to the nursery to be grafted to the appropriate scion and will be ready for planting in 1990.

Canopy Management

Canopy management is described by Smart and Smith (1989) as deliberate decisions by the viticulturist to achieve some canopy configuration be it in terms of surface area, volume, leaf area per shoot, fruit exposure, shoot orientation or even vine physiological status. Smart (1985) also suggests canopy management is being increasingly recognised as an important tool for manipulating wine grape yield and quality. Improper canopy management can cause shading. Shade depressed fruit bud initiation as is shown by Kliewer and Shaulis (1982). Bunch rot incidence is increased by dense canopies (Rotem and Palti 1969). Shade also affects shoot/fruit composition. Experience at Martinborough Vineyards has shown that improved canopy management produces riper fruit with better flavours, increased brix and decreased acid. Usually decreased acid is associated with higher pH levels but with improved canopy management decreased acid without higher pH levels can be obtained. In general a better balanced juice is produced, this in turn produces wine with more body and better ageing qualities.

Martinborough Vineyards has been evaluating different canopy management systems over the last four years. These are:

1) The four flat canes of New Zealand standard trellis
2) The V frame or lyre
3) The Te Kauwhata two tier
4) The Scott Henry

(see Figure 3)

The standard trellis or four flat canes is a single canopy held upright by foliage wires. The main problem with this is the creation of a dense upright canopy. Large amounts of leaf plucking are needed to expose fruit to sunlight.

The V frame or lyre (see diagram) overcomes this dense canopy by splitting it in two. Although crop loads are good, shading still seems excessive and management of this system requires more time.

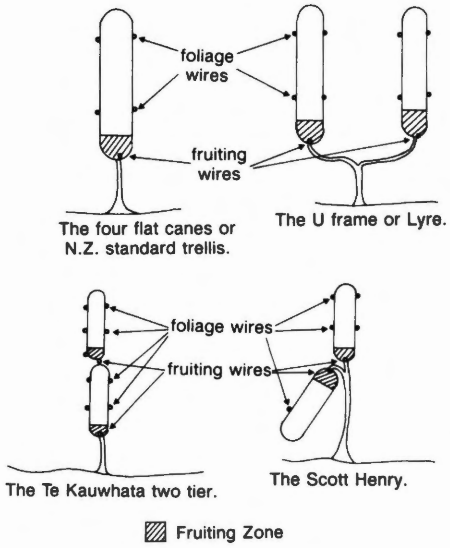

Fig 3 Cross Sections of Canopy Management Systems

The Te Kauwhata two tier also splits the canopies, with two separate fruiting levels. This system is producing good fruit quality and quantity. But there are some minor problems:

1) It is a spur pruned system. There are various arguments for the pros and cons of spur pruning but Martinborough Vineyard is not ready to commit itself to spur pruning in any large way.
2) Experience at Martinborough Vineyard indicates it is a difficult and time consuming system to establish.
3) It is more costly to spray, as early season spraying and bunch line spraying require the use of more than one nozzle per side.
4) I believe it is not entirely suited to windy sites.

The Scott Henry system splits the canopy in two by folding half the shoots downwards about flowering time. This reduces the density of the canopy quite dramatically. It also leaves the fruit exposed and requires less leaf plucking than other systems. The Scott Henry requires very little in extra management. The two levels of fruit are close enough together to be sprayed by one nozzle. It does however require better weed control as no weedspraying can be done after the shoots have been folded down.

We can now say that the Scott Henry canopy management system performs very well in this soil type and climate and is much preferred as far as management goes. After deciding on the Scott Henry system there is still some argument on the initial training of the vines. The two options are shown in Figure 4. The final decision will depend on the amount of growth achieved in the first year. Everything has been done to ensure that this is optimum. If stages one and two can be achieved in the first year then almost a full crop can be expected in the third year.

Irrigation

Early in the planning stages of the new vineyard development, we recognised that a good irrigation system would be needed, especially in the establishment phase, if fruit was to be picked in the third year. Martinborough Vineyard had also been concerned with the water distribution obtained from emitters or drippers. Lateral movement from emitters in well drained soils was less than ideal. Morton Equities had established a large vineyard in the Hawkes Bay using an in-line dripper system called typhoon. A grower in Martinborough had also installed a system using typhoon. The advantages of typhoon are:

— It takes very little time to install
— It can be put underground or under plastic mulch film
— It was cheaper than conventional drippers
— It could be obtained in spacings from 300mm-800mm.

A system was designed for the Martinborough Vineyard and the Cleland block by Paul Landl Ltd of Hastings. They were designed as two separate systems largely because they would be operated with Town Supply water. This meant a common bore for the two properties was not needed and for the price of another water meter and connection fee the two systems could be independent. This could be an advantage if the Cleland vineyard was managed by someone else or sold. It was also decided to install an automated system for the following reasons:

1. It was felt that the Borough Council would be more inclined to grant water rights to a user with a system that was broken into smaller lots and controlled automatically. This is so it could be watered at night and only create a small draw off from the borough supply.
2. In the long term it would save money in water charges as it would cost about $4.35 per hour to run each area. If overlooked for any length of time the cost could accumulate.
3. There would be savings in time spent shutting on and off valves.
4. The vines would perform better with regular programmed watering.

Pest, Disease and Weed Control

Within the constraints of a commercial operation Martinborough Vineyard would like to produce wines from organically grown grapes.

The first step towards this goal is to reduce the amount of herbicide used in the vineyard. To achieve this a plastic mulch film was laid down each row and the vines planted through the film. After some research it was concluded that the mulch film would:

1) Be comparable in price to using herbicides over a two year period
2) Enhance growth of vines by retaining warmth and moisture
3) Reduce the risk of damaging young vines with herbicides
4) Save on water usage.

The idea was to use the plastic mulch film for 2 or 3 years and clean cultivate between the rows. After this time the plastic would be removed and an undervine weeder with an automatic dodging mechanism would be purchased.

There were some major problems in the plastic mulch laying. It is essential to lay the mulch film straight and it has to be laid before the trellis is erected. A small deviation from a straight line meant that the vines could not be planted through the plastic and still be in line with the posts. Much time was spent shifting plastic by hand after the trel-

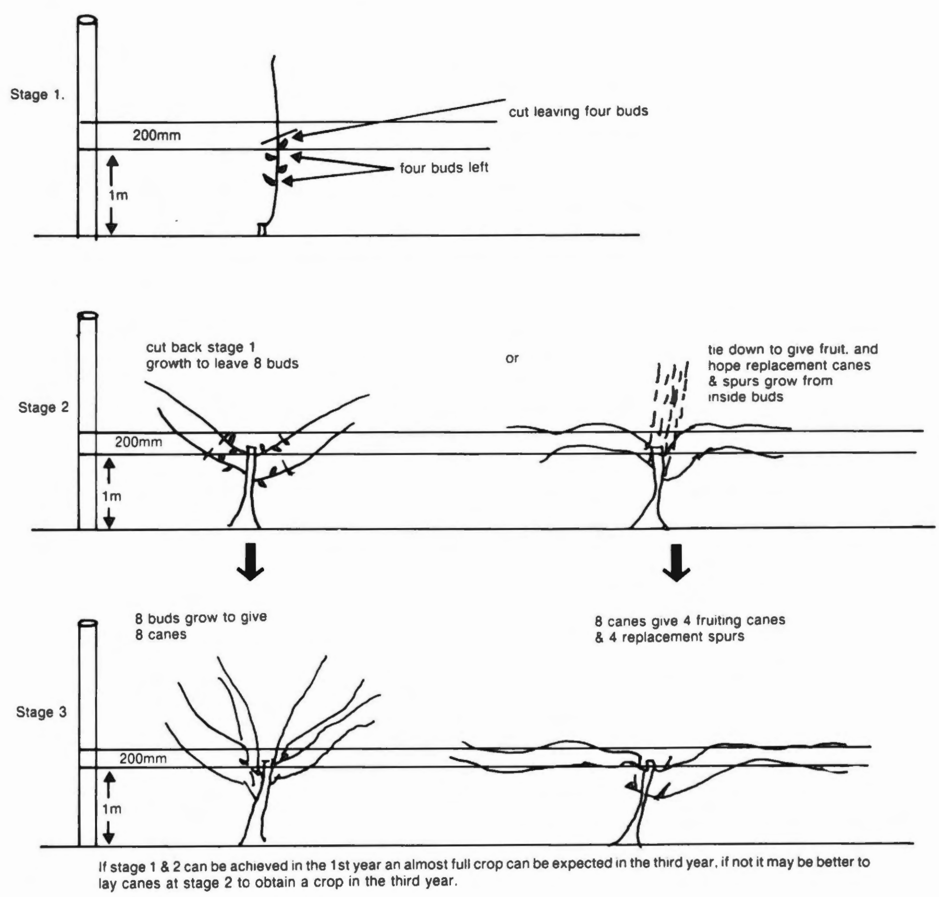

Fig 4 Vine Training

lis had been erected. Ensuring the edges of the mulch film were adequately covered with soil was also a problem. It is important to work the soil into a fine tilth so the plastic laying machine can cover the edges evenly.

For the first two years pest and disease control will consist of keeping powdery mildew at bay using sulphur sprays. Powdery mildew stops growth especially later in the season so it is important to keep growth free of powdery mildew to obtain maximum shoot growth.

Trellising

The trellising is required to be longlasting, strong enough to withstand the crop and wind loads, cheap and easy to erect. Obviously some of these requirements are contradictory, but the vineyard is a long term investment and there is no sense in building it on a second rate trellis.

There were a few options for the intermediate posts: quarter round posts, steel Ag stakes (pressed galvanised steel stakes) or round posts. Quarter round posts have a tendency to warp after they have been put in, they are also more difficult to ram. The Ag stakes are easier to ram but they have very little tractor resistance and if knocked by the tractor or implements usually need replacing. A round post has no sharp edges for implements to catch on. Ag stakes are still a relatively new product and have yet to withstand the test of time. 75 millimetre-115 millimetre small end diameter round posts were used. There was however a very high breakage rate — 13%. There is a possibility of these being replaced. The panel spacing (distance between posts) is 9 metres. This worked in well with the vines spacing 4 vines per panel.

There were also a number of possibilities for the end strainer assemblies but a tieback system was chosen for its high strength and ease of installation. The end strainers were in fact oversized for the length of the rows in these particulars vineyards but we can be sure they will not move.

The tiebacks were constructed from 12 millimetre reinforcing rod and then galvanised. They are an alternative to using screw anchors. The screw anchors cannot be used in stoney soils, and other vineyards in the district have been having problems with them pulling out where they have been put in by a digger. The tiebacks used were comparable in price to the screw anchors but they will not pull out.

2.25 millimetre high tensile wire was used and joined by wireloks. Wireloks are a costly item but justified in years to come as less time spent tightening wires.

Economics

The vineyard establishment costs are high in comparison with other vineyards established in the district. But the initial outlay will be repaid by earlier and higher yields. Some other points to keep in mind when comparing establishment costs are:

1) Half the vineyard will be planted in rooted plants and the other half in grafted plants.
2) The vineyard is on a fully automated irrigation system.
3) The vineyards are planted in some of the best clones of Pinot Noir and Chardonnay available and on the best rootstocks available.
4) The vineyards are planted through plastic mulch film and will need less weed control.
5) The trellis is of excellent quality and should last the lifetime of the vineyard.

Conclusion

There has been an enormous amount of thought and planning put into the establishment of these vineyards. I believe we have made the correct decisions to suit the Martinborough area and to satisfy the needs of Martinborough Vineyard. Costs are high in comparison with other vineyards in the district, but I am sure the initial cost will be offset by earlier yields of better quality and quantity. Martinborough Vineyard is relying on the production of these vineyards to make the whole operation more commercially viable. I am also confident that we are setting an example in vineyard establishment, that others will eventually follow. Gone are the days of poking cuttings in the ground and hoping they grow. Viticulture in the 1990's is a high tech business involving large amounts of investment capital and must be treated as such.

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Acknowledgements

The writer gratefully acknowledges assistance from Larry McKenna and Derek Milne who helped in forming some of the views expressed in the text.

Plant Raisers Award 1990

Mr Jack Hobbs of the Auckland Regional Botanic Gardens was the recipient of the Plant Raisers Award at the 1990 Conference for breeding the following plants:

1. *Hebe* 'Wiri Splash' and *Hebe* 'Wiri Image'
2. *Leptospermum* 'Wiri Joan' and *Leptospermum* 'Wiri Amy'

Hebe 'Wiri Splash' is a *H. brachysiphon* hybrid which is grown for its attractive golden-green foliage, compact habit and early summer crop of mauve flowers. An excellent landscape plant.

Hebe 'Wiri Image' is a compact, disease resistant cultivar with pale mauve flowers produced in summer. It often produces a second flowering in autumn/winter. Raised from seed collected from *Hebe bollonsii.*

Leptospermum 'Wiri Joan' is a tall shrub with attractive green foliage and distinct flower form and colour. The small, bright red, double flowers remain tightly in bud throughout winter and are most attractive at this time. In Auckland peak flowering is usually between June and August. The flowers do not contain stamens and very few seed capsules are formed. Suitable as a garden plant and as a cut flower.

Leptospermum 'Wiri Amy' is a semi-dwarf, conical shrub reaching 1m by 1m in four years from planting. The single flowers are similar in their colouring to *L.* 'Martinii' with rose-red centres and paler petal edges. An abundance of bloom is produced over a long period through winter until late spring.

The cultivars described were developed in a modest breeding programme at the Auckland Regional Botanic Gardens where they have been grown under evaluation for at least four years and have been used in display plantings for several years. Cutting material has been made available to propagators and plants are on sale in local garden centres.

The breeding programme has been developed at Jack Hobb's initiative and the excellent plants which have resulted are a tribute to his skill.

Flora of the Surville Cliffs

A. Silbury
c/- Percys Reserve, Western Hutt Rd, Petone

Sometimes a plant, or group of plants, rare though they may be in the wild, can be found growing in the most prosaic places.

Roadside ditches, rough pasture, weedy coastal sites and even heavily used urban beaches can all harbour remnant populations of formerly more common plants.

At the other end of the scale are those places which even at first glance are "special". Foremost among these are the Surville Cliffs, the most northerly part of the North Island. The serpentine rock of the cliffs and the plateau behind are a mere fly-speck on the map, a speck which is home to as many as sixteen distinct taxa found nowhere else with a further two or three of severely restricted distribution.

An intriguing point about many of the endemics is a peculiar growth form, best described as "prostrate-lianoid". For example, both *Coprosma spathulata* and *Pittosporum pimeleoides* are erect shrubs in their wider distribution, yet on the Surville Cliffs their respective subspecies have long flexuous branches which twine around boulders and through other vegetation, frequently rooting where their nodes touch the ground.

The native jasmines (*Parsonsia spp.*) are well known lianes, climbing high into the canopy of most native forest areas, in both remnant and regenerating vegetation. Not so on the Surville Cliffs. Here the endemic species, as yet without a name, shows no inclination to climb, being content to sprawl over the ground, or to creep through the other low plants in its vicinity. The one thing it does not do is climb to the top of the few small groves of taller vegetation.

Another group of plants are miniatures of their more widely distributed cousins. *Hebe ligustrifolia* grows to the height of a small tree only a few miles from the Surville Cliffs, while its variety on the serpentine rock is a shrub barely a metre tall, a habit which it retains in cultivation on "normal" soils. Similarly, the endemic species of *Pseudopanax* (aff. *P. lessonii*), and *Phyllocladus* (aff. *P. trichomanoides*), are much more compact than the more well known plants. Even these show a tendency to sprawl and to root where they touch the ground, though both species tend to be more erect in cultivation.

The most widely cultivated of the endemics is *Hebe brevifolia*, (formerly included in *H. macrocarpa* as variety *brevifolia*). Even this comes in two distinct forms, often growing together, one being prostrate with purple flowers, while the other, the more well known form, is a rounded shrub with pink/magenta flowers. Interestingly both forms come true from seed and there appear to be no intermediate forms in the wild.

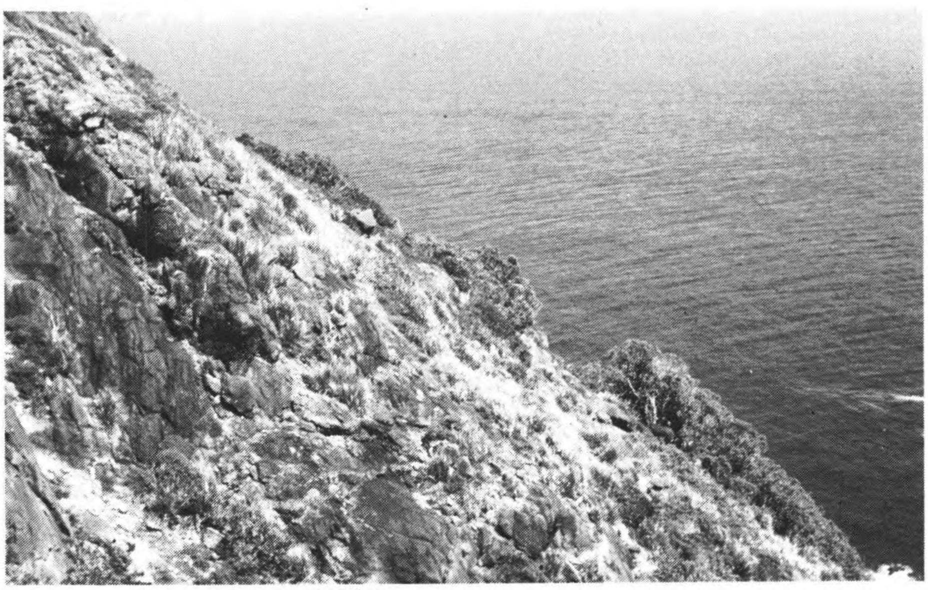
Nowhere else in New Zealand is there a place where such a large group of endemic plants can be found in so restricted an area, thus the value of the habitat to science is reflected in the staus of the Surville Cliffs as a Scientific Reserve.

For horticulture this group of plants holds considerable promise. They are tolerant to wind, salt spray and drought, and despite coming from the most northerly part of the North Island, most appear to tolerate even moderate levels of frost.

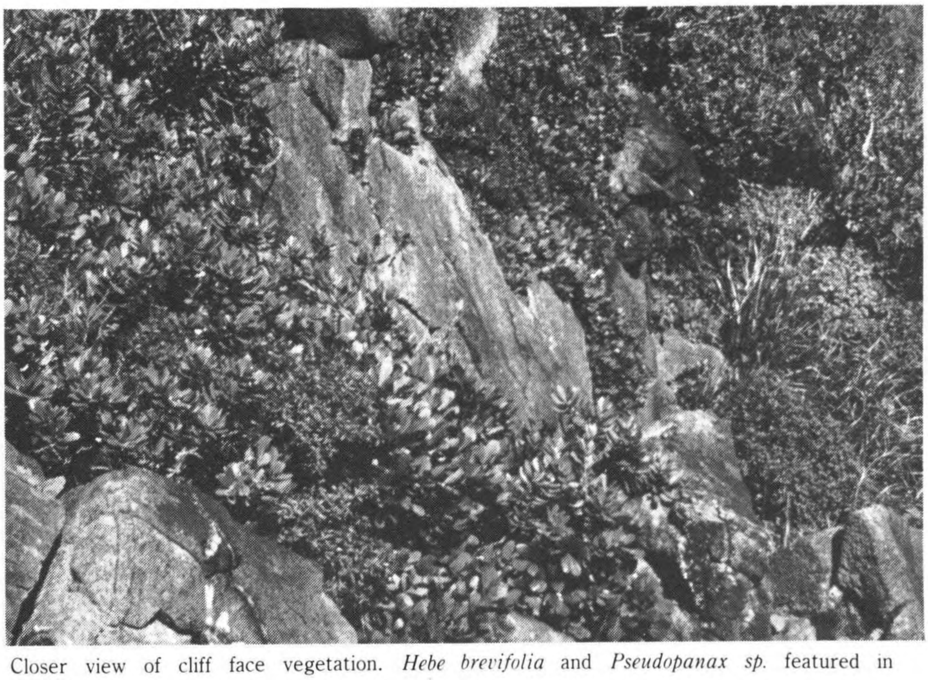
Currently few of these plants are held in cultivation, perhaps two or three of the eighteen endemic or near endemic taxa are held in reasonable number, with a few others being represented by a handful of specimens in scattered collections.

Wider propagation of these plants would not merely provide horticulture with an interesting group of rare, hardy plants, nor science with enough material to study just why these forms are so distinct. (It must be remembered that some are extremely uncommon even inside their tiny natural habitat, being represented by only a handful of individuals). Cultivation of these plants would provide a very real and useful insurance policy against any devastation of their only natural habitat, part of which has already been considerably modified by fire and mining activity, resulting in a considerably poorer vegetation on the plateau as compared to the steep cliff area.

The Surville Cliffs offer a great opportunity for science and horticulture to work together to protect some of the rarest and most interesting plants in the world. An opportunity and, perhaps, a challenge.



General view of slope and rocks of cliff face.



Closer view of cliff face vegetation. *Hebe brevifolia* and *Pseudopanax sp.* featured in centre.

Specimen Tree Pruning — Standards and Styles

Ewen Cadzow

Cadzow Tree Services, 50 Greenhill Ave, Dunedin

During the winter of 1989, while working for the Dunedin City Council, we pruned the trees in the Otago Museum Reserve. A collection of *Acer pseudoplatanus, Fraxinus excelsior, Tilia x europaea,* and *Quercus robur* run round 3 sides of the ground (the museum building runs along the North side) and line a diagonal footpath that is a main student route from the shops to the Otago University. Most of the trees range from 18 to 23 metres tall, are around 80 years old, and form a dominant part of the landscape. We had to remove all dead, damaged and diseased wood, adjust the height of lower limbs to suit pedestrian and vehicular requirements, and remove epicormic branches to improve the appearance of the trees. Our job was not easy as we had to fence off each tree daily to ensure a safe working area below. This was because the area was densely populated with students travelling to and from the university.

We removed ½ to 1 truckload of prunings for every tree and you might wonder whether it was possible to remove so much without affecting the shape of the tree. In fact we enhanced the shape by drawing the eye to the individual character of each tree. Before pruning there was a general impression of a scruffy, dense canopy. The before and after photos of one of the trees illustrates this.

These photos illustrate a particular style or feel for pruning. If another tree firm, or suitably experienced person had undertaken the work, while keeping to the basic pruning rules, perhaps a slightly different end result would have occurred. There are 3-4 tree firms in Dunedin with a high pruning quality, and as a trained observer I usually know who pruned which tree as each have their own style — like handwriting.

Fig 4 Museum Reserve trees the summer after pruning

Even with the advent of natural target pruning and non use of wound sealants, with everybody following the same pruning standard or rules, I can assure you no two people prune trees identically, and therefore pruning becomes a question of style and individuality once certain standards are followed.

Ewen Cadzow
Cadzow Tree Services

Fig 1 Before pruning

Fig 2 After pruning

Fig 3 Summer after pruning

Leptospermum scoparium (manuka) — Chromosome variation of cultivars

M. I. Dawson

Botany Institute, DSIR Land Resources — Private Bag, Christchurch, New Zealand

Introduction

To most New Zealanders *Leptospermum scoparium* (family Myrtaceae), commonly known as manuka or tea-tree, is a familiar sight. It is a very widespread shrub or small tree growing wild in lowland to subalpine areas throughout the country from North Cape to Stewart Island.

There is much natural variation within this species, and forms with desirable characters have been selected by various enthusiasts and brought into horticulture. Through such introductions from the wild and crosses done notably by Messrs. Duncan and Davies (New Plymouth), Mr E. F. Jenkin (Victoria, Australia), and Dr W. E. Lammerts (California, USA), over 70 cultivars are presently grown in gardens here and overseas. There are cultivars with erect or prostrate ("dwarf") growth forms, and showy flowers that are single or double, with colours that range from pure white to various shades of red.

Despite the large number and diversity of cultivars in existence, no chromosome study has previously been undertaken on this group. Chromosomes are tiny, thread-like structures present in the nucleus of a living cell, which can be seen during cell division through a light microscope. They are composed of chromatin (a complex of proteins, DNA, and small amounts of RNA) and hence carry the genetic information of the plant.

Chromosome studies provide a means of distinguishing and investigating relationships between plant groups. Changes in chromosomes, either structural or numerical, can produce different plant forms, and cause reproductive isolation leading to speciation. Numerical changes include deletion or addition of chromosomes, or polyploidy. Polyploidy is a condition in which there are three or more complete sets of chromosomes within the plant cells. The prefixes tri, tetra, penta, hepta, octa, etc. are used to denote the level of ploidy; for example, a triploid plant has three times the haploid number of chromosomes. Therefore, the size, shape, and number of chromosomes are characters which are important taxonomically and can be of use to the plant breeder.

A chromosome preparation is obtained by using actively growing material, such as root-tips which are diploid (2n) tissue, or by using pollen-mother (sex) cells, which are haploid (n) tissue possessing only half the chromosome pairs.

Materials and methods

Plants of wild origin (seed grown) and some cultivars were raised in the Botany Institute experimental gardens at Lincoln. Cuttings were taken from this material and from cultivars growing at the Christchurch Botanic Gardens and Lincoln University, and raised in pots at the DSIR, Lincoln glasshouse in preparation for chromosome counts.

Root tips were pre-treated with a cyclohexamide-hydroxyquinoline mixture, fixed in methanol-chloroform-propionic acid, hydrolysed in HCl, macerated in pectinase, and stained with Feulgen. The meristematic portions were tapped out onto a slide and squashed in lactic-acetic-orcein. The chromosomes were studied using an oil objective (x 1000) on a light microscope.

Flower diameter was measured, and anthers taken from plants growing at the above localities. Pollen was tapped out onto a slide with Alexander's differential stain (Alexander, 1980). Normal pollen grains (non-aborted, presumed viable) stain dark red whereas aborted (inviable) grains stain light green. Percentage of "viable" pollen was assessed by counting 1000-3000 grains.

Pollen size was obtained by measuring the maximum diameter of 50 normal pollen grains using a drawing tube.

Table 1 Documented chromosome numbers of *Leptospermum scoparium* (Myrtaceae)

Wild Forms	2n	Original Source	CHR
	22	North Cape, N Auckland	461235
	22	Motutangi Swamp nr. Houhora, N Auckland	437898
	22	Okahukura Peninsula, Kaipara Harbour, N Auckland	437899
	22	Cape Colville, Coromandel Peninsula, S Auckland	437900
	22	Cape Colville, Coromandel Peninsula, S Auckland	437901
	22	Puatai Rd., E Cape, Gisborne	437902
Cultivars	**2n**	**Source**	**CHR**
Diploid			
'Aurora'	22	Cultivated, DSIR, Lincoln	461241
'Fascination'	22	Cultivated, DSIR, Lincoln	461242
'Nichollsii'	22	Cultivated, DSIR, Lincoln	461243
'Pink Champagne'	22	Cultivated, DSIR, Lincoln	461244
Triploid			
'Helen Strybing'	33	Cultivated, DSIR, Lincoln	461239
'Martinii'	33	Cultivated, DSIR, Lincoln	461240
Tetraploid			
'Keatleyi'	44	Cultivated, DSIR, Lincoln	461236
	44	Cultivated, DSIR, Lincoln	461237
'Keatleyi' Seedlings	44	Cultivated, DSIR, Lincoln	461238
	44	Cultivated, DSIR, Lincoln	461245

Results and discussion

1. Chromosomes

The chromosomes of *L. scoparium* measured 0.7-1.8 microns (μ) in length, too small for detailed karyotype analysis, but a predominance of metacentric (chromosomes with arms of equal length) and fewer sub-metacentric chromosomes were observed. Chromosome numbers are provided in Table 1.

Diploids

The chromosome number obtained from plants originally growing wild at several North Island localities is $2n=22$, which is in agreement with South Island representatives counted in a previous paper. In Dawson (1987) all species in the 6 genera of the New Zealand Myrtaceae (*Kunzea, Leptospermum, Lophomyrtrus, Metrosideros, Neomyrtrus* and *Syzygium*) had the same chromosome count of $2n=22$.

The *L. scoparium* cultivars 'Aurora', 'Fascination', 'Nichollsii' (Figs. 1 & 5), and 'Pink Champagne' were also found to be diploid.

Triploids

L. 'Helen Strybing' (Fig. 2) and *L.* 'Martinii' (Fig. 3) have a chromosome number of $2n=33$, so are both considered to be triploids (Figs. 6 & 7). These cultivars have arisen through separate crosses between *L.* 'Keatleyi' ($2n=44$) and a diploid cultivar ($2n=22$), the resulting progeny having an intermediate chromosome number.

L. 'Helen Strybing' originated as a seedling from *L.* 'Keatleyi' in the Golden Gate Park, San Francisco. It was introduced into cultivation by the Strybing Arboretum, and from there L. J. Metcalf obtained propagation material in the late 1950's or early 1960's, and introduced it into New Zealand (Metcalf, pers. comm.).

L. 'Martinii' is apparently a cross between *L.* 'Keatleyi' and *L.* 'Nichollsii'. The cultivar was named after its raiser, Mr. Martin, a nurseryman of Aramoho, Wanganui (Harrison, 1974). It received the Award of Garden Excellence for 1965.

In his book "Handbook of trees and shrubs", Harrison (1974) comments that *L.* 'Lambethii', a widely grown cultivar in Australia appeared there at the same time as *L.* 'Martinii' and seems to be the same cross. A

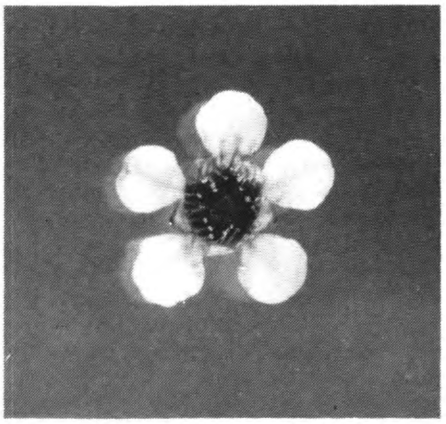


Fig 1 *L.* 'Nichollsii' flower x 2

Fig 5 *L.* 'Nichollsii' chromosomes 2n=22, x 3000

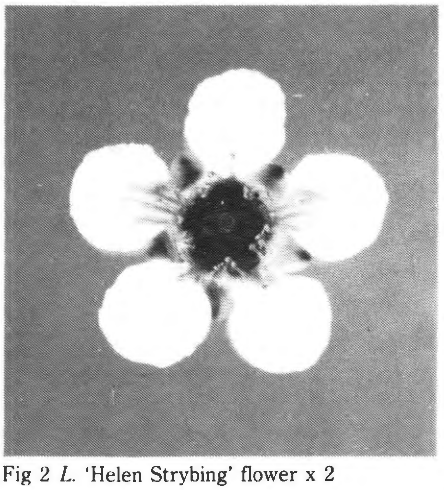


Fig 2 *L.* 'Helen Strybing' flower x 2

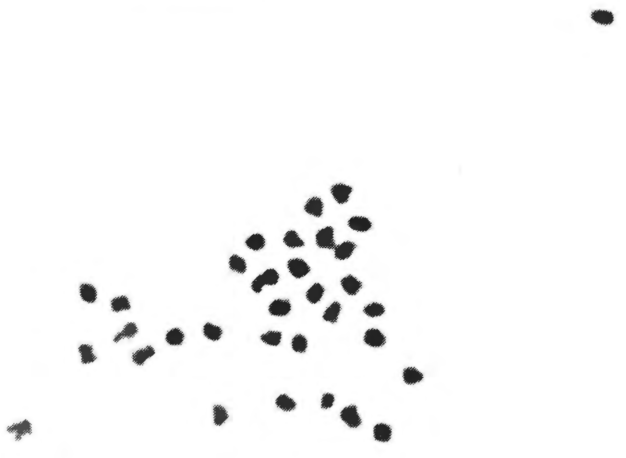


Fig 6 *L.* 'Helen Strybing' chromosomes 2n=33, x 3000

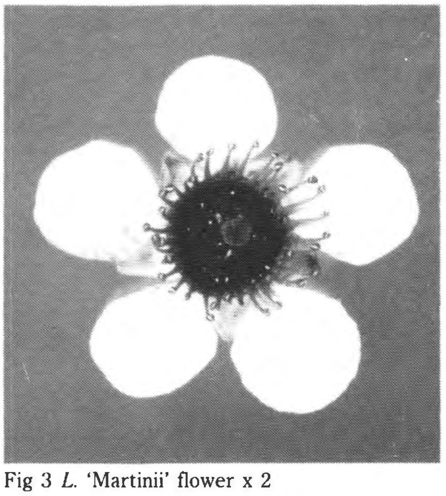


Fig 3 *L.* 'Martinii' flower x 2

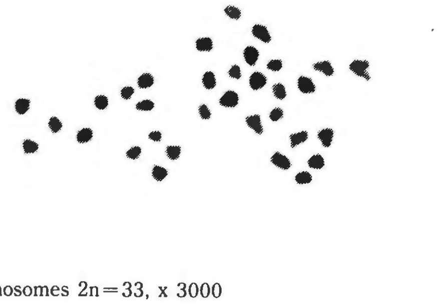


Fig 7 *L.* 'Martinii' chromosomes 2n=33, x 3000

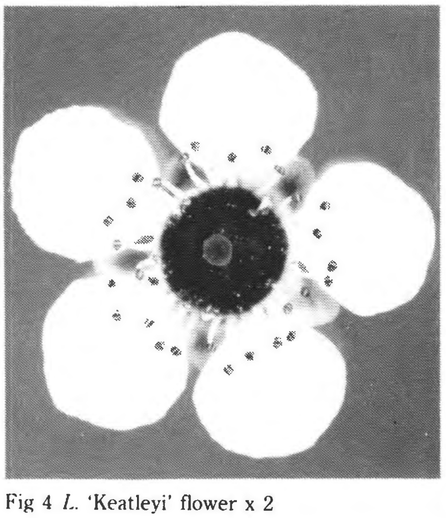


Fig 4 *L.* 'Keatleyi' flower x 2

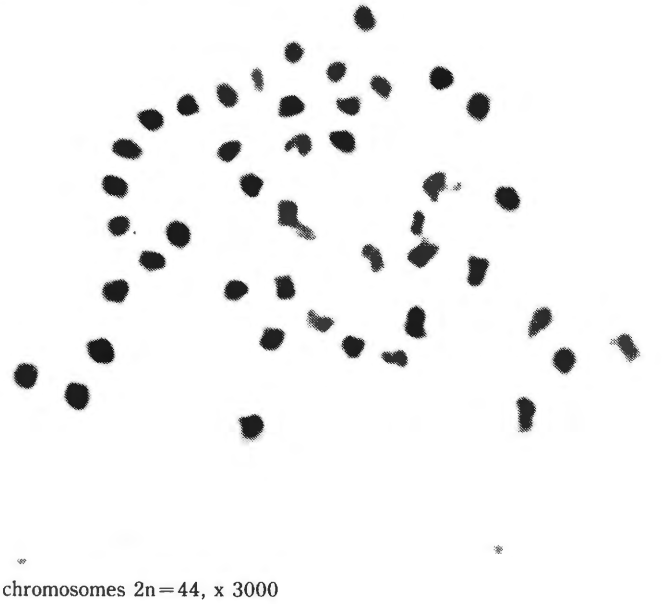


Fig 8 *L.* 'Keatleyi' chromosomes 2n=44, x 3000

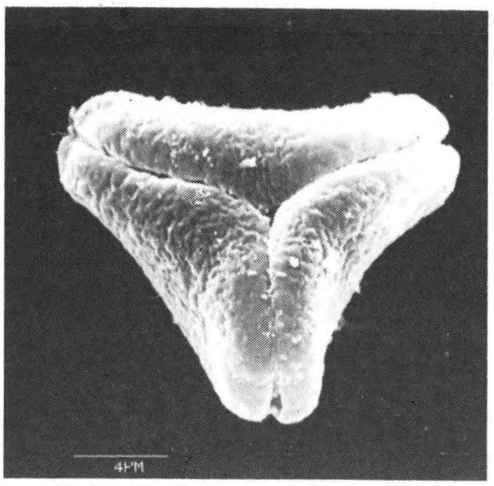


Fig 9 *L.* 'Keatleyi' pollen grain x 3000. Common pollen grain with 3 apertures

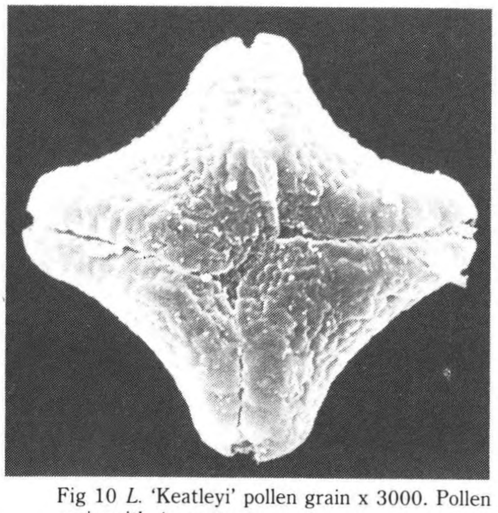


Fig 10 *L.* 'Keatleyi' pollen grain x 3000. Pollen grain with 4 apertures

chromosome count would help verify this opinion.

Inviable seed is often a characteristic of triploid plants, due to the inability of the chromosomes to pair evenly. However, both triploid *L. scoparium* cultivars set seed, some of which germinated. The new cultivars *L.* 'Wiri Lesley' and *L.* 'Wiri Clare' produced by Jack Hobbs (Auckland Regional Botanic Gardens, Manurewa) have both arisen from *L.* 'Martinii' as the seed parent (Hobbs, 1989).

Table 2 Pollen size and fertility of *Leptospermum scoparium* cultivars

Cultivars	Abbrev.	Source*	Mean Pollen Diameter (μ)	Pollen "Viability" (%)
Diploids/Presumed Diploids				
'Aurora'	A	2	18.8	49.78
	A	4	19.6	95.50
'Big Red'	BR	1	18.2	81.54
	BR	2	19.3	29.98
'Blossom'	B	1	17.6	77.60
'Boscawenii Minor'	BM	2	17.4	86.37
	BM	4	18.4	95.10
'Burgundy Queen'	BQ	1	17.2	31.82
'Crimson Glory'	CG	2	18.7	64.71
	CG	1	19.2	35.71
'Elizabeth Jane'	EJ	1	18.2	48.12
'Fascination'	F	1	18.0	60.19
	F	4	18.8	57.78
'Fiesta'	Fi	1	18.4	29.88
'Gaiety Girl'	GG	2	17.2	35.10
	GG	1	18.5	55.71
'Huia'	H	1	17.7	82.41
'Jubilee'	J	2	17.7	83.01
'Kiwi'	Ki	1	18.4	70.73
	Ki	4	18.4	95.57
'Nana Rosea'	NR	4	18.1	93.65
'Nichollsii'	N	2	—	0
'Nichollsii Improved'	NI	1	15.4	43.20
'Pendulum'	P	2	17.0	92.08
'Pink Cascade'	PC	1	18.1	78.82
	PC	2	18.4	61.92
'Pink Champagne'	PCh	4	18.6	97.60
	PCh	2	18.7	73.87
'Pink Pearl'	PP	1	17.7	55.53
'Princess Anne'	PA	2	17.0	79.14
'Red Damask'	RD	1	17.0	66.83
	RD	3	18.2	79.28
'Red Ensign'	RE	1	18.5	48.12
'Red Falls'	RF	1	17.4	71.88
	RF	2	18.1	89.12
'Roseum Flore-Pleno'	RFP	1	18.5	62.78
'Rosy Morn'	RM	1	17.4	78.74
'Ruru'	R	2	17.7	87.45
'Snow Flurry'	SF	1	18.1	44.17
	SF	3	18.8	53.91
'Sunraysia'	SR	1	16.4	55.56
	SR	3	18.9	47.64
'Tui'	T	3	18.4	86.51
'Twinkle'	Tw	2	17.2	52.64
'Winter Cheer'	WC	1	16.6	28.72
Triploids				
'Helen Strybing'	HS	2	19.1	38.07
	HS	4	21.0	45.48
'Martinii'	M	3	20.0	63.86
	M	1	21.0	47.04
	M	4	21.0	41.35
Tetraploid				
'Keatleyi'	K	2	23.2	45.72
	K	3	23.3	52.91
	K	1	25.0	49.10

***KEY FOR SOURCE:**
1: DSIR Plots
2: Christchurch Botanic Gardens
3: Lincoln University
4: DSIR Glasshouse

Tetraploid

L. 'Keatleyi' (Fig. 4), has 2n=44 chromosomes (Fig. 8). This cultivar is a tetraploid, more specifically an autotetraploid, because it presumably originated from the duplication of the chromosome pairs within the same species, amongst a diploid population.

Because of the extra set of chromosomes, tetraploidy invariably affects the size of cells and hence the form and size of the plant structures. *L.* 'Keatleyi' has larger flowers and pollen, and also seems to have larger capsules, seed, leaf and stomata size than its diploid counterparts.

This cultivar was named after a Captain Keatley, who discovered it in the region between Parengarenga Harbour and North Cape in 1917 (Stevens, 1945). It is derived from a pink-flowered form (var. *incanum*) from Northland. The tetraploid plant was probably recognized by the discoverer as distinct, having larger flowers than the other presumed diploid plants in the area. Alternatively, the tetraploid condition may have arisen spontaneously once the cultivar was brought into cultivation, through subsequent selection.

Although polyploid individuals rarely occur within a natural population, they can be induced artificially by using chemicals such as colchicine, a technique used by plant breeders.

Polyploidy can be an important evolutionary factor in plants; individuals with an increased chromosome number may have different adaptive properties. A New Zealand example is *Poa* (a genus of grasses); the taxa constitute a polyploid series of 2n=28, 42, 56, 84, 112, and 266 (Hair, 1968) all arising from a diploid ancestor with 2n=14.

In Australia, where most species of *Leptospermum* occur, only *L. minutifolium*, *L. myrtifolium*, and *L. parvifolium* are tetraploid, other species investigated (about 20) are all diploid (Smith-White, 1948; Dawson, 1987). Polyploidy therefore has

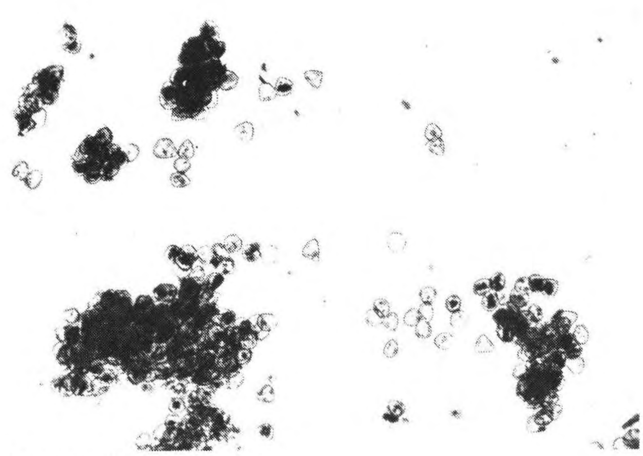


Fig 11 *L.* 'Nichollsii' pollen x 250

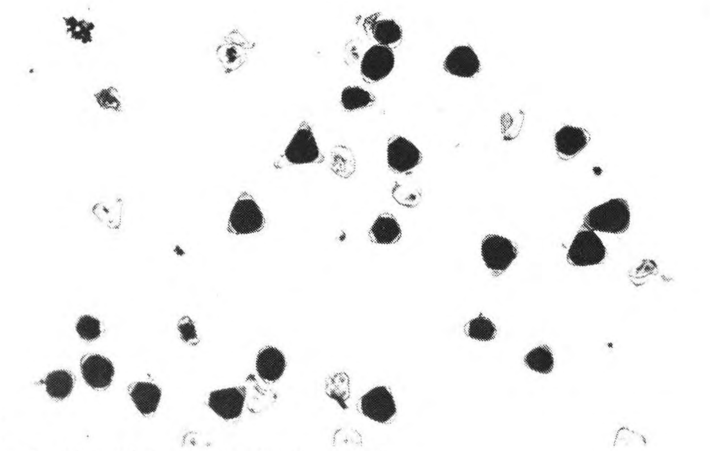


Fig 12 *L.* 'Helen Strybing' pollen x 250

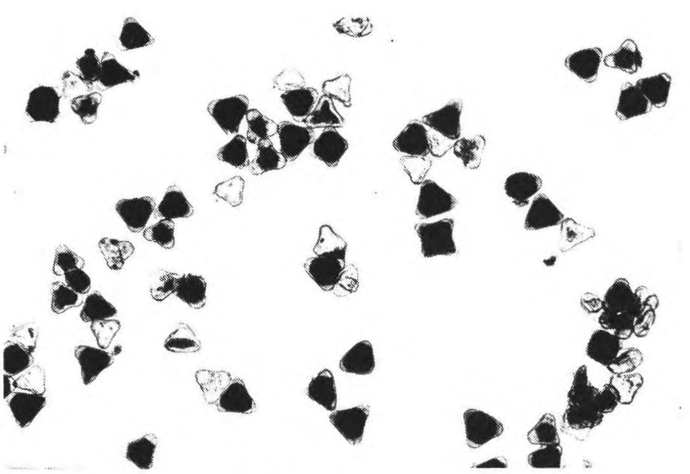


Fig 13 *L.* 'Martinii' pollen x 250

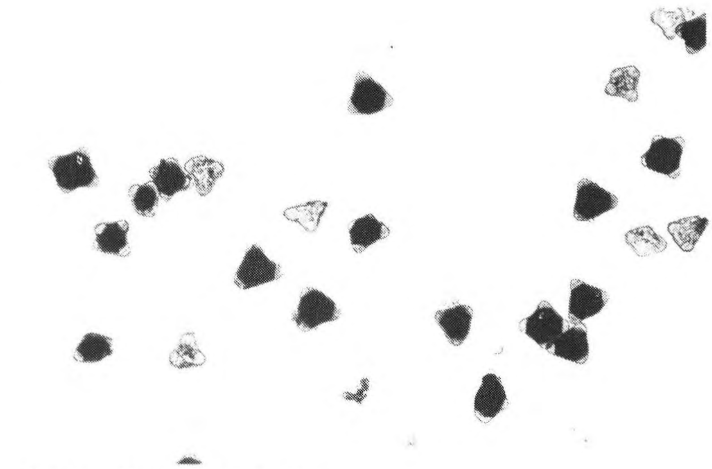


Fig 14 *L.* 'Keatleyi' pollen x 250

not been a major factor in the evolution of this genus.

Germination of *L.* 'Keatleyi' seed was poor; from a batch of seed only two plants resulted, which were also tetraploid, suggesting the parent selfed. One seedling examined had fairly large flowers (19.2-24.1 mm), but they were smaller on average, and a deeper shade of pink than *L.* 'Keatleyi' flowers. The other seedling was not seen in flower, but had very large capsules, indicative of large flowers.

2. Flower and pollen size of cultivars

Pollen of *L. scoparium* usually has three apertures (Fig. 9), although some cultivars also had a few pollen grains with four (Fig. 10). The diameters of these were not measured, but because some were viable they were included in the pollen fertility counts. A larger proportion of pollen grains with four apertures occurred with each increase in ploidy level (Diploids 0-3.33%; Triploids 3.48-10.46%; Tetraploid 16.14-36.6%).

Because of the associated increase in cell size, pollen grain size is often a reliable indicator of polyploidy.

Pollen diameter was measured initially of *L. scoparium* cultivars with known ploidy levels. Because the range in pollen size between ploidy levels overlapped, a statistical analysis of variance was necessary.

Some variation occurred in pollen size and fertility (Fig. 15, Table 2) of a given cultivar between sites. This is presumably due to differences in local climate, and flower or plant ages. Cultivars should be comparable genetically between sites as they are propagated vegetatively through cuttings and have the same origin.

Average flower diameter was plotted against the average pollen size between sites for 34 cultivars. Measurements of flower diameters are in general agreement with the figures cited in Metcalf (1987). The graph (Fig. 16) suggests there is a general relationship between increasing flower and pollen size.

Pollen from the tetraploid *L.* 'Keatleyi' is significantly larger than the diploid or triploid cultivars with no overlap at the 95% Confidence Interval (C.I.; Fig. 15). This cultivar is also distinct with the largest average flower diameter measured. No other cultivar examined is likely to be tetraploid.

L. 'Helen Strybing' and *L.* 'Martinii' have generally larger pollen than the diploid cultivars sampled, but there is some overlap at the 95% C.I. These triploids also have fairly large flower sizes, but are less distinct than *L.* 'Keatleyi'.

Of the remaining cultivars, those whose chromosomes have not been counted are probably also diploids, on the basis of pollen grain and flower size. The possibility of one or two undetected triploid cultivars cannot, however, be rejected.

The cultivar with the smallest average pollen size was *L.* 'Nichollsii Improved'. *L.* 'Nichollsii Improved' is derived from *L.* 'Nichollsii', originally discovered near Kaiapoi, Canterbury in 1898 (Harrison, 1974; Metcalf, 1987). *L.* 'Nichollsii' has an even smaller flower size (12-14 mm) than *L.* 'Nichollsii Improved', but no pollen measurement was possible from the plant growing at the Christchurch Botanic Gardens, because all of the pollen was distorted and inviable (Fig. 11).

The diploid with the largest average pollen size was *L.* 'Aurora', which belongs to var. *incanum*, from which *L.* 'Keatleyi' is also derived.

The smallest average flower size belonged to *L.* 'Kiwi'. *L.* 'Kiwi', *L.* 'Boscawenii Minor', *L.* 'Huia', and *L.* 'Nana Rosea' are all very free-flowering cultivars with dwarf growth form; this group represented in Fig. 16 shares intermediate pollen size and reduced flower size. Other dwarf cultivars sampled such as *L.* 'Red Falls' and *L.* 'Ruru' are not as floriferous, and do not exhibit a reduced flower size. All dwarf cultivars sampled had high pollen fertility.

The largest average flower size in the presumed diploid group was for *L.* 'Blossom'. This cultivar, along with *L.* 'Big Red', *L.* 'Fascination', *L.* 'Jubilee', *L.* 'Red Ensign' and others, are of recent origin, and have been selected for their large, double flowers.

Pollen is scarce, but still obtainable, in all double-flowered cultivars examined except

L. 'Fantasia' in which it seemed all the anthers had been converted into petals.

Generally, flower and pollen size of the wild populations sampled was small, but pollen fertility was high compared to the cultivars.

Summary

Chromosome number variation occurs among *L. scoparium* cultivars. All wild populations sampled had a uniform diploid number of 2n=22. Most of the cultivars of this species share the diploid count, but *L.* 'Keatleyi' was found to be a tetraploid with a chromosome number of 2n=44. *L.* 'Helen Strybing' and *L.* 'Martinii' are both triploids with 2n=33, and have arisen by crossing the tetraploid *L.* 'Keatleyi' with a diploid cultivar.

Acknowledgements

I wish to thank L. J. Metcalf, Invercargill and P. J. Garnock-Jones, W. Harris, P. Heenan, T. R. Partridge and R. F. Zyskowski of the Botany Institute, DSIR Land Resources, for helpful comments. Plant material was kindly provided by G. C. Platt, Albany; W. Scadden, Christchurch Botanic Gardens; and W. Harris, D. Percy, and P. Wardle, of the DSIR. D. J. Purcell maintained the collection of living plants.

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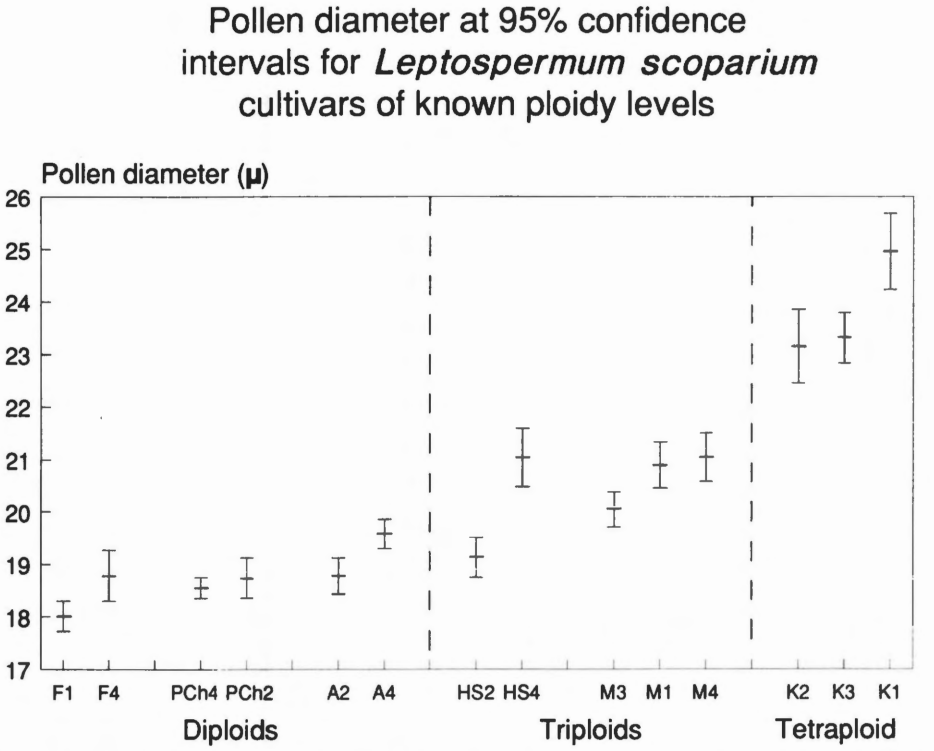

Fig 15 Pollen diameter at 95% confidence intervals for *Leptospermum scoparium* cultivars of known ploidy levels

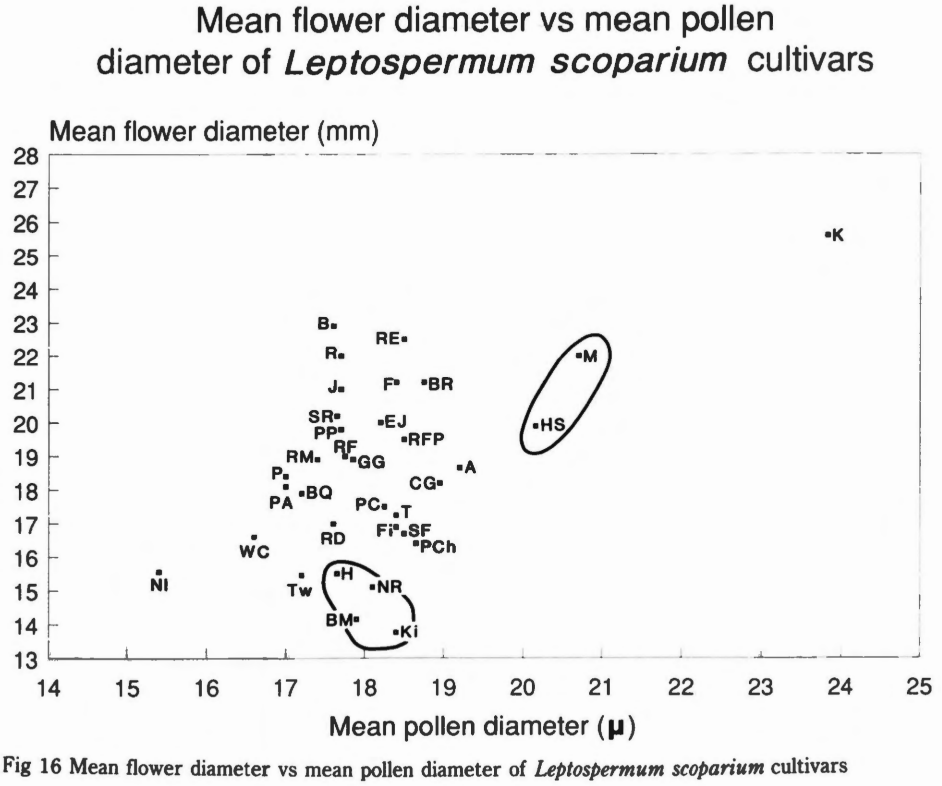

Fig 16 Mean flower diameter vs mean pollen diameter of *Leptospermum scoparium* cultivars

Wellington the Detectable Web

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I feel very honoured in being asked by the Royal New Zealand Institute of Horticulture to deliver the Ian Galloway Memorial Lecture 1990. I knew and worked with Ian for a period of four years. I intend to be outspoken in this lecture about the city of Wellington that Ian loved. I intend to be blunt and do not wish to give offence but I have a passion for this city I live and work in.

The subject of my talk is about the human experience map that lies within our city. I have called this map of human use — the Detectable Web. It is strong. Its strength is as an entity — demolish part and the whole will collapse ultimately. To discern this web is to observe and acknowledge its existence. The realisation of this human web is the guide and opportunity to design cohesively and see the city as a whole entity. The city is not just a set of buildings and streets that we have to put up with. Chermayeff and Tzonis in their book — The Shape of Community state that — "Objects, events and vistas are beginning to look like leftovers from a vanishing world rather than convincing evidence of a new one in the making".

We have an incredibly interesting city unlike any other. For instance in 1855 some early town development proposals were changed not by man but by nature in the form of an earthquake. An example is the land which is now Cambridge and Kent Terrace. This land was lifted several feet during that earthquake which changed the proposal at that time for a canal to the Basin Reserve.

As a city we have continued to build and pull down in a cavalier manner of unparalled optimism. Although we have this optimism and acceptance of change natural or manmade, we should not lose those fragments of the past which are our heritage and which should not be left abandoned or mouldering in some archival basement. For instance I refer to the Royal Albert Hotel which originally stood on the site of the St Georges Hotel. The original hotel was called the Old Identities Hotel. The reason for this was that some window recesses were adorned with the carved heads of old identities. The heads, which were last heard of in the basement of the City Library, were carved by a well known immigrant Italian woodcarver. These reference points should be preserved and cared for. There is an Art of Relationship which is to take all the elements that go to create an environment, buildings, artifacts, trees, nature, water etc and then weave them together. I would like to think that this search and recognition could be termed the Wellington Treasure Hunt 1990 which should form an important part of that relationship.

At this point I would like to honour the man of this memorial lecture — Ian Galloway an outstanding administrator and great supporter of horticulture and landscape architecture in New Zealand. His endeavours in the cause of humanising the urban environment can never be fully assessed.

I remember Ian Galloway telling me of his arrival in Wellington at an early age with his parents. The family had travelled from Dunedin to set up house in Wellington. No sooner had they settled down than the city was struck by an earthquake during which his mother's prized collection of china was shattered. Despite this early shock in his life about the nature of Wellington he retained his optimism and this characteristic was his hallmark. His love of this city is clearly etched in my memory and that of others who worked with him. He has left countless memories to his achievements throughout Wellington and its environs.

He was always reluctant to speak of his highly developed administrative and strategic skills. I remember being asked by Ian to attend a meeting of visiting councillors from another city. Their purpose was to find out how he was able to achieve so much through his Parks and Recreation department for the city. His reticence prompted me to suggest that his strategy was:- should a pothole be left unrepaired he would fill it by planting a tree. The following year a seat would be placed adjacent the tree. The following year a few shrubs would be added. Once this small island had been established and the public had used it no one would dare to require its removal. Small and opportune outlays but a major humanising influence in our city streets. His view was that grand schemes invite long delays. The development of these small green islands ultimately would lead to the greening of a whole street. Lambton Quay today is a perfect example of Ian Galloway's skill. His early establishment of small pockets of vegetation led to others seeing the potential of this major pedestrian thoroughfare. Careful traffic management gradually discouraged the use of the street by traffic. The widening of the footpaths followed and this has now given us a street to be proud of and the opportunity for us to enjoy the vastly improved environment Lambton Quay. I like to remember that Ian always had a bottom drawer which he would require me to keep topped up with designs for any space in the city which could become open space.

That was how, overnight, Midland Park was born. We had a design at the ready. Stage 2 of that design exists, which includes converting the Police building site into a car park as well as extending Midland Park.

Today 5 years on from Ian's last work, I believe that we are growing to understand the importance of the benign urban environment for the well being of its citizens. I quote from the British Landscape Journal Feb. 1990: "A growing public environmental awareness has led to a greater realisation of the value of green spaces in inner city areas. There is now a public will to improve and humanise life in the city by green planning for new developments as well as by re-designing small unused spaces and creating larger green areas from suitable vacant sites. This new attitude has brought with it the need for a re-appraisal of the role and form which plants should take in the city. Plant material must be used as a fundamental part of the urban structure rather than in a cosmetic function."

This has been a firm conviction of the Royal New Zealand Institute of Horticulture's Wellington District Council and they have pursued their cause diligently.

We are in a period of economic restraint and therefore we should be more concerned with rehabilitation of our existing environment rather than developing major new ones. I believe that land claims are a symptom of a growing dissatisfaction with the way our land is being handled both in urban and rural situations. This together with the growing shortage of open land and the concern for the environmental degradation of our way of life, is leading to an inevitable downhill trend in our human relationships. This problem is indirectly ours, but our professional experts have also been slow to anticipate these symptoms.

We must broaden our outlook and anticipate change. For example: European cities have always had Saturday shopping. With the advent of Saturday shopping in New Zealand more families are beginning to use the city on that day. It is urban entertainment. Should Sunday shopping become the norm it will induce even more people to use the city during weekends. Again we have a change in the pattern of public use of the city. The preparation for this change should be assessed now. This short sightedness can be shown by a recent report which was pleased to recommend a programme for traffic management and car park accommodation for the year 2009. It appears that there was no thought of the coincidental prediction that in 2009 we will be experiencing a noticeable change in the water level in the harbour. The report should also have a plan for the use of gondolas!

The question is who is going to anticipate these changes?

We must have a design overview of the city not just a plan for the ward whose councillor is more vocal than other councillors.

At this point we should examine the role of professionals in our existing situation. The planning world has been shuffling its feet to the tune played by architects. Meanwhile engineers have had the unenviable job

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**The Ian Galloway Memorial Lecture was established in 1987 by the Wellington District Council of the RNZIH as a tribute to Ian Galloway, Director of Parks for Wellington City from 1965-1986.*

of simply putting all our dirty problems into the nearest body of water.

The fundamental issue in our urban complexes must be what happens to people. Should we be closing one road and turning it into a mall and then widening the next road to such an extent that other pedestrian routes are severed forever? This presents a fixed and static dictate which creates unnatural boundaries. There is a need for anticipation and flexibility in these changes.

Two weeks ago I was in Melbourne and was fascinated by the traffic management in a city of approximately 3 million people. There is no doubt that the pedestrian is given far more privileges than vehicles. The streets are full. By this I mean they have large trees, trams, vehicles, bicycles, roadside stalls and pavement cafes.

All these activities work in harmony with high rise buildings that would make any of ours look insignificant. Another striking feature was the number of roof top gardens and trees. My impression was that most buildings were welcoming because they were set within a verdant framework.

This must be attributed to strong planning and engineering considerations of the needs of people.

The architectural world is fortunate. They have cleverly buried opposition by their loud advertisement of their right to judgement and style. Very often crude and vulgar. People have to have shelter and architects make it stylishly modular by including whatever trend is current overseas. I quote Kirsty Robertson in the Editorial NZ Home and Building Feb. March 1990.

"After a decade in design where anything goes and superficiality rears it ugly head in the guise of pastiche, facadism — and all things post modern, what can we expect in the 90's."

I don't believe we will continue to accept this treatment.

Fortunately many buildings today are apparently not built to last and they won't if the people that have to use them tragically fall out of them by accident through no fault of their own.

And so another profession gives us an environmental problem.

Whether or not you agree with my examples the conclusion must be that so far planners and architects have not served us well.

They have overlooked the fundamental patterns of human needs and tried to redirect and reshape those needs into a numerical mould. This cannot be accepted anymore. The engineer meanwhile has had to make the best of the situation. Given their head, the engineers would have had a milliscreening plant in place by now which would have been far better than the existing situation. Grand plans invite long delays.

Re-examination of the training of professionals uncovers one profession we have not looked at closely and that is the landscape architect. Their basic ethic has always been a conservationary one of wise stewardship of all resources whether human or physical. No other profession can claim to be so diverse and yet so collective in the practice of it's historical ideals and it's actions towards protecting the health of the environment as a whole.

They do not distinguish about what is urban and what is rural.

The patterns of human need are the same.

Everything is interrelated and cannot be separated by numbers or styles.

The human race depends on the environment whether it is for food or for fresh air.

Landscape architects are trained to recognise the patterns of the past and anticipate the future by designing with flexibility. Cities are organic and areas less favoured now become favoured at a future date. A well developed city incorporates it's history and it's open space as the fundamental elements in the making on an interesting and healthy environment for it's citizens.

These elements are the detectable web and landscape architects respect them and use them to achieve good design within the art of relationship.

I am talking of urban living which has a detectable web if we care to look for it. I would like to quote Sir Geoffrey Jellicoe a world famous landscape architect in his address to the 25th International Federation of Landscape Architects World Conference in Boston 1988 on International Perspectives Collaboration and Communication. I quote: "Uniting us all — we in this hall, our countrylands, the planet earth, the cosmos — are invisible particles that are neither ordered not geometric. They are undisciplined individuals and amorphous like clouds".

Ths significance of this is that we know scientifically what previously we only felt emotionally — that the balance of man's subconscious relation to his environment has permanently changed from hard edge to no edge at all.

From this it seems clear that in due time perhaps even in the next 40 years, landscape design will transcend architecture as the mother of the arts. It will enfold architecture."

I believe that together with engineers we will develop the true combination of the art and science of living.

In closing I would like to remember Ian Galloway as a man who would never have been party to a Sesquicentennial Funfare for 6 million dollars. He would rather have bequeathed for posterity the development of a true commemoration of the 150 years of our city in the form of public open space for our resident citizens. Their daily need is greater within the main streets which does not mean on the foreshore or in the hills. Thank you.

Mitsuba and Shungiku — Two Traditional Japanese Vegetables

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Introduction

The Japanese eat a great many foods unfamiliar to the western palate. Two vegetables that fall into this category include Mitsuba and Shungiku. This article outlines production techniques used in Japan for these vegetables based on a visit the author made to Japan.

Mitsuba (*Cryptotaenia canadensis*) is a perennial member of the Umbelliferae family, which also occurs in North America where it is called Honewort or stone parsley. It has long slender stems topped with three small leaves and is used in clear Japanese soups, as a boiled green vegetable and in chawan-mushi, a hot egg and vegetable dish. The blanched stems are also used in salads.

Shungiku (*Chrysanthemum coronarium*), Garland or Spring Chrysanthemum is a member of the Asteraceae (Compositae) family and is a popular green vegetable used in sukiyaki and similar dishes.

Fig 1 Mitsuba ready for harvesting.

Mitsuba

Production in Japan

Commercial production of mitsuba is widespread throughout Japan. The main production areas are Hokkaido, Ibaragi, Chiba, Shizuoka, and Aichi. These prefectures each produce over 1,000 tonnes of mitsuba per year (see Table 1). In 1983 over 17,000 tonnes of mitsuba was produced from 1379 ha. Although the area under mitsuba production has remained constant since 1978 yields have risen significantly from 13,700 tonnes in 1978 to 17,289 tonnes in 1984, this being largely due to the introduction of hydroponics.

Production methods

There are four production systems for mitsuba:

1. Kirimitsuba (cut mitsuba) obtains the highest price on the wholesale market (see Table 2) but it is the most demanding to grow. Seed is sown in the open as a field crop in April-May (Spring). The crowns are lifted in early October-late December (early winter) and either placed in storage cabinets or healed in to prevent dessication. As required the crowns are removed and planted in troughs in a greenhouse. The troughs, 80-100 cm deep, have electric cables along the bottom to maintain the soil temperature at 25°C to force the mitsuba. Rice husks are placed over the cables, and then the mitsuba crowns are planted in a layer of soil. The crowns are planted densely and watered liberally to aid establishment and growth.

Shading is placed over the trough to produce a white or blanched plant but prior to harvest the shading is removed to allow the leaves to become green. The stalks must remain white.

Harvesting is carried out 20-30 days after transplanting with three harvests possible from each crown. Generally quality standards require the mitsuba stem to be

Table 1: Mitsuba Production in Japan 1983

Prefecture	Area (ha) Glass House	Area (ha) Trough	Area (ha) Open	Area (ha) Total	Yield (t) Glass House	Yield (t) Trough	Yield (t) Open	Yield (t) Total
Hokkaido	28	41	76	145	390	219	439	1048
Aomori	—	<1	8	8	—	6	67	73
Imate	2	46	6	58	21	471	69	561
Miyagi	17	2	15	34	218	45	240	503
Akita	1	1	7	9	2	4	31	37
Yamagata	—	1	1	2	—	1	3	4
Fukushima	4	13	63	80	76	170	661	907
Ibaragi	1	330	91	422	14	1717	835	2566
Tochigi	2	2	6	10	75	40	38	153
Gumma	1	1	48	50	11	6	518	535
Saitoma	14	—	28	42	273	—	370	643
Chiba	10	108	57	175	489	963	894	2346
Tokyo	—	5	9	14	—	59	91	150
Kanagawa	—	2	15	17	—	24	171	195
Nagano	1	—	—	1	32	—	—	32
Shizuoka	58	—	<1	58	1324	—	1	1325
Niigata	1	1	1	3	19	5	24	48
Ishikawa	—	1	1	2	—	2	10	12
Fukui	<1	—	—	<1	18	—	—	18
Gifu	3	—	—	3	65	—	—	65
Aichi	86	—	20	106	2463	—	304	2767
Mie	3	—	1	4	315	—	10	325
Shiga	3	—	—	3	132	—	—	132
Kyoto	1	<1	5	6	32	1	34	67
Osaka	20	—	13	33	317	—	242	559
Hyogo	4	—	1	5	42	—	1	43
Nara	1	—	2	3	14	—	14	28
Wakayama	2	—	—	2	395	—	—	395
Toltori	1	—	1	2	3	—	3	6
Okayama	1	—	9	10	15	—	115	130
Hiroshima	<1	<1	1	1	3	2	8	13
Yamaguchi	<1	—	8	8	4	—	105	109
Tokushiwa	<1	—	—	<1	48	—	—	48
Kagawa	1	—	1	2	13	—	12	25
Ehime	<1	3	<1	3	5	9	4	18
Konchi	1	<1	1	2	17	9	4	30
Fukuoka	30	—	—	30	700	—	—	700
Saga	<1	—	—	<1	11	—	—	11
Nagasaki	—	—	1	1	—	—	7	7
Kumamoto	4	—	—	4	107	—	—	107
Ohita	21	—	<1	21	486	—	2	488
Miyazoki	1	—	—	1	25	—	—	25
Kogoshima	2	—	1	3	25	—	10	35
TOTAL	325	557	497	1379	8199	3753	5337	17289

approximately 25 cm long before harvesting.

There are several varieties of kirimitsuba and several different production methods depending on what final product is required.

2. Ne mitsuba (root mitsuba) is similar to kirimitsuba in appearance in that a white stalk with green leaves is produced. With this method mitsuba is sown outside in rows and as the plant grows soil is mounded up to blanch the stem. Mounding is generally carried out twice.

3. Ito mitsuba (Green mitsuba). Both the stalk and leaves are green. The green mitsuba is sown as a field crop with harvesting carried out when the mitsuba reaches a marketable size. The time required to produce a marketable product depends on the season.

4. Ao mitsuba is similar to Ito mitsuba except that the crop is produced hydroponically in glasshouses. Seed is sown thickly onto foam pads placed in trays of water in growth cabinets. When the mitsuba has germinated the foam is cut into 2 cm^3 blocks with each block containing several plants. The blocks are then fitted into holes in large polystyrene sheets that float on large troughs containing nutrient solution.

When the plants reach marketable size the stems are cut to remove the foam and roots then packaged into plastic bags and then into cardboard cartons.

Yields and Crop Returns

Mitsuba grown under glass on average produces 25.23 tonnes/ha with an average wholesale price of 591 yen/kilo.

Mitsuba grown in the open on average produces 10.74 tonnes/ha with a wholesale price of 591 yen/kilo. While the yields are lower the costs to the grower are also less.

Kirimitsuba yields only 6.74 tonnes/ha however there is a premium paid at the wholesale market with an average price of 963 yen/kilo.

Research

Past research in Japan on mitsuba has concentrated on developing a satisfactory technique for growing the crop hydroponically. This has been achieved with excellent results. Currently there is little work being carried out in Japan on the crop.

Possibilities of growing mitsuba in New Zealand

Ito mitsuba is easy to grow and is in steady demand by Japanese consumers for use as a green vegetable. Good supplies were produced throughout the year by Japanese growers resulting in no market gap. The price throughout the year also denotes a common everyday vegetable. At no time during the year would Ito mitsuba be economical to grow in New Zealand for export to Japan. In addition it has a very poor shelf life.

Kirimitsuba on the other hand, while being more difficult to grow, does have a price premium. There was also a market gap from July to October (see Table 2). This was associated with a price premium in 1985 of between 3,000 to 5,000 yen/kilo. New Zealand could grow kirimitsuba to fill this gap. However production is labour in-

Fig 2 Mitsuba production under glass. The polystyrene floats in the foreground have recently been harvested.

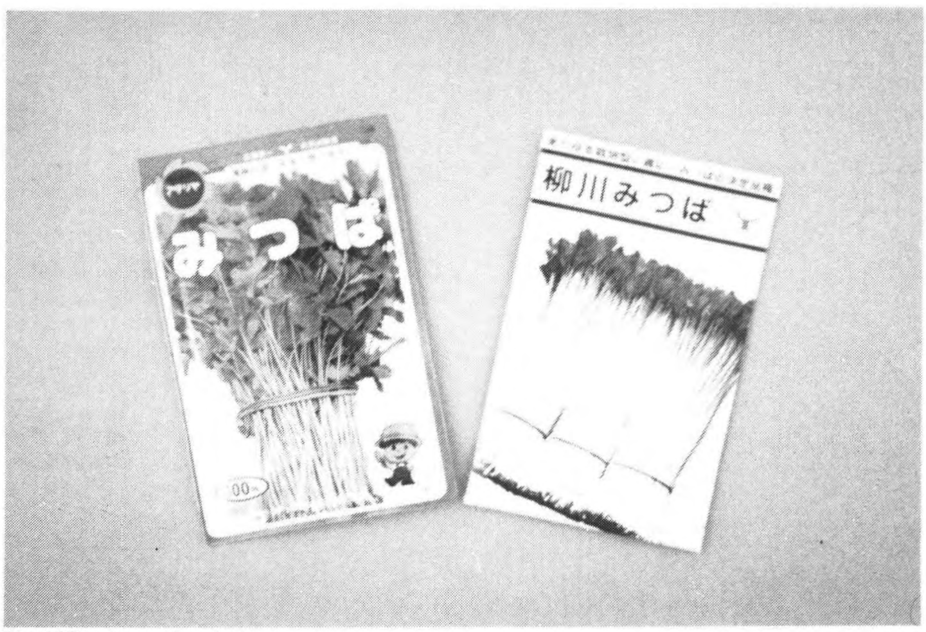

Fig 3 Mitsuba seed packets.

Table 2: Wholesale Prices and Volume of Mitsuba at Tokyo Central Wholesale Market 1985

Month	Kirimitsuba Price (Yen/kilo)	Kirimitsuba Quantity (t)	Ito Mitsuba Price (Yen/kilo)	Ito Mitsuba Quantity (t)
January	1164	176	635	94
February	1324	120	458	100
March	1196	121	458	113
April	1815	54	329	147
May	2890	28	359	151
June	2528	19	418	134
July	3440	18	696	141
August	4750	14	657	120
September	5012	20	969	118
October	3345	35	842	137
November	1822	82	541	128
December	1885	277	774	140

Table 3: Shungiku Production in Japan 1983

Prefecture	Area (ha) Glasshouse	Open	Total	Yield (t) Glasshouse	Open	Total
Hokkaido	11	18	29	126	236	362
Aomori	1	13	14	13	167	180
Imate	12	18	30	144	223	367
Miyagi	18	18	36	457	235	692
Akita	0	51	51	7	529	536
Yamagata	6	11	17	52	80	132
Fukushima	77	94	171	1046	874	1920
Ibaragi	16	62	78	284	761	1045
Tochigi	19	7	26	517	106	623
Gumma	68	98	166	2057	1753	3810
Saitoma	57	65	122	1036	979	2015
Chiba	269	84	353	6850	1629	8479
Tokyo	3	36	39	32	468	500
Kanagawa	5	48	53	109	821	930
Yamanasahi	—	3	3	—	45	45
Nagano	1	16	17	5	105	110
Shizuoka	8	5	13	100	49	149
Niigata	9	22	31	114	210	324
Toyama	2	20	22	35	282	317
Ishikawa	—	4	4	—	61	61
Fukui	3	1	4	41	7	48
Gifu	8	0	8	205	3	208
Aichi	52	7	59	835	263	1098
Mie	2	1	3	41	4	45
Shiga	29	7	36	864	159	1023
Kyoto	8	6	14	105	75	180
Osaka	95	202	297	1689	3707	5396
Hyogo	40	78	118	744	1410	2154
Nara	13	32	45	184	423	607
Wakayama	1	5	6	37	114	151
Toltori	2	1	3	20	7	27
Shimane	8	20	28	127	240	367
Okayama	6	24	30	127	233	360
Hiroshima	32	59	91	514	547	1061
Yamaguchi	3	21	24	37	257	294
Tokushiwa	1	3	4	22	52	74
Kagawa	2	3	5	43	52	95
Ehime	4	20	24	47	254	301
Konchi	5	3	8	102	10	112
Fukuoka	145	50	195	2140	500	2640
Saga	5	6	11	60	63	123
Nagasaki	2	17	19	23	182	205
Kumamoto	2	18	20	24	225	249
Ohita	1	9	10	24	109	133
Miyazoki	9	13	22	120	160	280
Kogoshima	21	35	56	286	387	673
Okimowa	—	15	15	—	273	273
TOTAL:	1081	1349	2430	21445	19329	40774

Fig 4 Recently harvested Shungiku.

tensive and with a shelf life of 3-5 days there are inherent difficulties in suggesting kirimitsuba could become a viable export crop for New Zealand.

Shungiku Production in Japan

Shungiku is produced throughout Japan with over 40,000 tonnes being grown in 1983 (see Table 3). Although large amounts of Shungiku are grown the demand has remained static with no notable increases in production since 1978 when almost 39,000 tonnes were produced. The wholesale markets are well supplied throughout the year with only a slight shortfall in July and August when the crop is flowering in most parts of the country (see Table 4). Shungiku harvested from flowering plants is poor quality and this may be why there was no price premium at this time even though only limited quantities are available.

Climate

Although Shungiku is produced throughout Japan (see Table 3) it prefers cool temperatures and above 30°C it is prone to bolt. Much of the breeding work carried out in Japan is to develop high temperature resistant cultivars.

Production Methods

There are two production methods for shungiku:

1. In the single harvest method the plant is harvested when it has developed a form similar to endive or an open hearted lettuce. Production and harvesting methods are similar to endive and lettuce.

2. With the multiharvest method leaves are picked after the shungiku has produced an elongated stem. This method allowed for several harvests.

The preference for either method depends on the market. Tokyo for example prefers the multiharvest type whereas in Tochigi the single harvest is preferred.

It is possible to produce shungiku all year

Fig 5 Leaf shapes of three common Shungiku cultivars. From left to right, long leaved, medium leaved and nan tai.

under glass. The use of hydroponics has also helped to guarantee a continuous supply. Seedlings take 25 days to mature in summer and up to 35 days in winter.

In the open shungiku can be produced from May to November with the use of tunnel houses extending the season through until March. Shungiku seedlings are usually transplanted when they have 4-5 leaves into formed beds 100-120 cm wide with 4 rows/bed with plants spaced 15-20 cm within the row.

Cultivars

Little distinction is made between varieties with many growers relying on local selections. One of the main characteristics between varieties is the leaf size and shape with a medium leaf size preferred.

Research

Much of the research on shungiku in Japan has been directed towards the understanding and manipulation of flowering. Delayed flowering would result in high levels of production throughout the year.

Possibilities of growing shungiku in New Zealand

Shungiku is easy to grow and is grown extensively by the Japanese. Good supplies are produced throughout the year with only a small market gap in July-August. This market gap was not associated with a price premium, perhaps because produce sold at this time was of poor quality. New Zealand growers could produce good quality shungiku at this time. However, the maximum price paid for shungiku at the Tokyo central wholesale market at any time was only 696 yen/kilo (Table 4). Shungiku is labour intensive and has a short shelf life, and consequently would have to be air freighted. This cost would make the profit margin relatively small and consequently the likelihood of shungiku being a viable export crop at the present time appears unlikely.

Conclusions

Although the short shelf life of these vegetables may make them unsuitable to grow in New Zealand for export to Japan, they have proved easy to grow as summer vegetables in the Waikato. If the public awareness of these vegetables was to increase they could prove to be popular in the local market as specialty crops.

Fig 6 Shungiku seed packet.

Table 4: Wholesale Prices and Volume of Shungiku at Tokyo Central Wholesale Market 1985

Month	Price (Yen/kilo)	Quantity (t)
January	573	696
February	326	651
March	344	525
April	349	274
May	304	211
June	332	189
July	493	138
August	384	102
September	562	211
October	435	533
November	220	846
December	364	996

Book Reviews

Colonial Landscape Gardener. Alfred Buxton of Christchurch, New Zealand, 1872-1950. Rupert Tipples. Lincoln College, Canterbury 1989. ISBN 0-86476-033-7. $40.

I should say at the outset that I found this a difficult book to review. It is by no means easy reading and I believe that it could have been much improved by more rigorous editing — and yet, it contains much of interest and, like any good book, encourages wider reading and stimulates further thought.

Alfred Buxton's family emigrated to Canterbury in 1886 when he was 13. After serving a nursery apprenticeship with Thomas Abbott, the leading nurseryman in Christchurch, Alfred Buxton started his own nursery in 1893. He must have developed an early interest in landscaping because his first nursery catalogue of 1899 claimed that landscape gardening was a speciality, a claim adduced to by published testimonials. Buxton was not New Zealand's first landscape gardener nor, despite the main title of this book, do I believe that he can really be considered a colonial landscape gardener as his professional career began only at the turn of the century. He was, however, undoubtedly one of the most successful and influential landscape gardeners in New Zealand during the first part of this century. Landscape gardening is an expensive discipline and Buxton was fortunate that for much of his professional life, New Zealand enjoyed great prosperity.

Buxton laid out many of the finest gardens, both public and private, in Canterbury and other parts of the South Island. In 1912 his business expanded to the North Island and over the next twenty to thirty years he was to be responsible for many of the gardens at the great country stations in the Wairarapa and along the East Coast. At his busiest, Buxton employed up to 80 men. Large teams were required because there was no heavy earthmoving equipment and landscaping therefore depended on "pick and shovel and horse and dray". It is clear that for many of his clients, money was no problem. One of his most splendid gardens at 'Panikau', Tolaga Bay, cost more than £8000 at a time when an unskilled labourer earned only about £100 a year. At 'Homewood', Karori, the property of Benjamin Sutherland and now the residence of the British High Commissioner, between twelve and twenty men worked for several years. Of course, not all owners were that extravagant but many commissions seem to have involved gardens of at least two to three hectares. It is the scale of the work that is now astonishing.

Why owners were prepared to spend so much money is not made clear. Dr Tipples refers to Miles Fairburn's suggestion that for the colonists, gardens played a part in counteracting the effects of loneliness. However, Fairburn is, I think, really referring to a considerably earlier period. The reminiscences of Buxton's contemporaries or clients indicate that he was a very good salesman and I suspect that an element of "keeping up with the Joneses" may have been involved. This may be why so many of Buxton's early gardens look so similar, almost stereotyped, as if there was very little input from the client. Indeed, many landowners apparently wanted their properties landscaped exactly as in the model of a farm used by Buxton for advertising. I also wonder whether many clients really knew what they were getting. The photographs used by Buxton to advertise his work show gardens only a short time after planting, and the model does not seem to give a good impression of the likely density of the plantings when they reached maturity. This is why some of the photographs indicating the changes in Buxton's gardens over the years from first establishment are now so interesting.

Buxton designed and constructed gardens for almost 40 years and it is therefore probably inevitable that his design approach varied over the years. Few gardens survive sufficiently well to give a good indication of the original design and it is now difficult to separate the contributions of Buxton himself and those of his staff, particularly his son, Trevor, and Edgar Taylor who worked with him for nearly twenty years. Dr Tipples has been able to identify four phases in Buxton's career, largely according to the people associated with him. I find the later gardens the most interesting, possibly because of their greater formality and their heavy reliance on architectural features such as extensive terracing, massive stonework and walling and solidly constructed pergolas. Such gardens resemble those of the Surrey School in Edwardian Britain. A good example is 'Panikau' constructed in 1918 and still well maintained with comparatively few changes, although the original house was destroyed by fire. ('Panikau' is described and illustrated in the *New Zealand Gardener* of February, 1989). Other features of Buxton's work I find less appealing and some of his gardens appear rather fussy — some elements, indeed, sound suspiciously like kitsch. Dr Tipples described how "rustic" bridges were constructed out of reinforced concrete which was poured into moulds in the ground, the soil giving the rough finish required. He quotes a description of an even worse example at 'Homewood', Karori: "At the entrance is a most charming scene. Disposed in carefree attitudes around five tiny fountains are grouped several gnomes, watching with delighted attention balls kept in play by jets of water on which are played varicoloured lights. Architectural features in stone, brick or concrete often remain, even if in poor condition, but Dr Tipples points out that it is more difficult, without documentation, to evaluate the original plantings. Even so, I would have liked more discussion on the range of plants that Buxton used and how much variation there was from garden to garden. The plantings at 'Wharanui', in Marlborough, are analysed in detail but it would be interesting to know how typical it was in, for example, the high proportion of natives planted. The photographs throughout the book make it clear that Buxton was particularly fond of cabbage trees.

In his preface Dr Tipples describes this account of Alfred Buxton as being, according to the definitions of Antony Alpers, a "primary biography", one that establishes the historical facts. There is no doubt that Dr Tipples should be congratulated on the assiduity with which he has undertaken his research. The lengthy bibliography indicates both the detail and the comprehensiveness of his reading. Occasionally, I felt that Dr Tipples was excessively concerned about the information he didn't have rather than that which he had been able to establish — that he indulged too much in conjecture, especially in the first chapters.

A more fundamental problem is my uncertainty as to Dr Tipples' intentions. This uncertainty is probably prompted by Dr Tipples himself when, in the very first paragraph of his preface, he recounts how a colleague, asked to review an early draft of part of the manuscript, questioned whether it was a "family history, a social history, a trade evolution study or a record of New Zealand's first landscape gardener and his landscape firms." To me this is a problem that has not really been resolved and the result is a book which I found quite a challenge. What could be considered a wealth of information can also be viewed as a surplus and I believe that the book is overloaded by too much barely relevant information. An example would be the over-detailed account of Buxton's antecedents, an account which is probably of very limited interest to all except family members. Too many extraneous themes are developed and although some of these may be of more general interest and others are quite illuminating, the consequence is that what I thought was the main intention of the book — the recording of the life and works of one of New Zealand's first landscape gardeners — becomes obscured. Even Buxton himself does not emerge as an individual person until late in the book and his wife remains at best a shadowy figure. What I considered to be most interesting, Buxton's landscaping work, has to be extracted from a number of chapters. Buxton's involvement with professional organisations such as the Association of Nurserymen and the Institute of Horticulture is likewise not brought together.

Colonial Landscape Gardener is very generously illustrated with over 180 maps, drawings and photographs. Most of these add greatly to the text and the views of Buxton's various gardens. R. P. Moore's panoramic views, are particularly useful. The photographs are so good and so well chosen that it is a pity that many seem to have suffered in reproduction ending up dark and decidedly murky. I have not been able to make comparisons with the originals but at least two — the view of Thomas Abbott's nursery and the photograph of Thomas George Abbott — are better reproduced with greater clarity in papers by Challenger. There are also colour plates and two in particular are delightful. These are reproductions of landscape plans painted in water colours and designed to sell the landscaping jobs. It is especially interesting to be able to compare one of these coloured plans with the working plan drawn on linen.

The book shows signs of over-hasty preparation. There are too many literals and although I did not check the bibliographic notes I did notice in passing at least several incorrect or incomplete references. There is an index of places and organisations, an index of names and a subject index. These likewise show signs of hasty preparation. For example, Buxton appears under the separate entries of Buxton, Alfred William and Buxton, A.W.; Buxton, Joseph refers back without discrimination to A.W. Buxton's uncle, grandfather or great grandfather; Mrs Buxton (A.W.'s wife) has only one entry under her maiden name and subsequent mentions in the text do not appear to be indexed; Trevor Buxton (A.W.'s son) has no index entries but is discussed in the text.

When *Colonial Landscape Gardener* was published late in 1989, newspaper publicity recounted how it had been completed during Dr Tipples' rehabilitation after a serious car accident. This publicity, although doubtless well meant, has probably done Dr Tipples a disservice. Although the considerable difficulties under which the book was written should be acknowledged, it would be wrong and, indeed, most unfair even to consider assessing *Colonial Landscape Gardener* simply as a rehabilitation exercise. That would be demeaning to Dr Tipples for his book can be judged on its own merits. I consider it to be a most useful addition to the history of horticulture in New Zealand. It certainly establishes the historical facts and it provides many interesting ideas worthy of further examination. It should be read by all those who are interested in the development of New Zealand landscape architecture or horticulture. Social historians too will find much of value. This is a book that will reward careful reading.

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The Brightest Jewel. A History of the National Botanic Gardens, Glasnevin, Dublin, by Charles Nelson and Eileen McCracken with original watercolours by Wendy Walsh. Published by Boethius Press Kilkenny Ireland 1987. ISBN 0-86314-083-1

This 268 page, well produced book, is a welcome addition to the histories of Botanic Gardens now considered a sub-discipline of Garden History. Charles Nelson needs no introduction to members of the R.N.Z.I.H. for two articles of his were published in the Annual Journal No. 16 1989. Moreover this same Journal features a section entitled "Focus On Botanic Gardens". The story of the Glasnevin Garden links very well with this theme and draws attention to the role Botanic Gardens might be expected to play in the 21st century and particularly our N.Z. botanic gardens.

The two articles of Dr. Charles Nelson demonstrated a high quality of scholarship. The Brightest Jewel which he has co-authored with Eileen McCracken reaches a similar high standard. The first two chapters — "The origin of Botanical Gardens" and "The early history of Irish Botany and the first botanical Gardens" are as well written and researched as any that I have read on these subjects.

Development of the Dublin National Gardens emphasises the difference between European Botanic Gardens and those which developed in the British colonies in the 19th century. The science of Botany and the skill of the gardener go hand in hand but in Glasnevin this culminates in the Garden becoming the home for Ireland's National Herbarium which houses a most important assemblage of native flowering plants, gymnosperms, and cryptograms, as well as extensive collections of specimens from Great Britain and all round the world. The Australian Gardens at Melbourne and Sydney, like Glasnevin, hold national collections but New Zealand botanic gardens did not follow the same path. In Glasnevin the entire running of the garden reflects this scientific background and expertise of their staff but even so the skill of the gardener is not forgotten and the public can still admire colourful bedding displays and well presented plant collections. Glasnevin functions both as a research centre and a teaching garden and therein lies the difference with our N.Z. Gardens.

As the authors tell the story of Glasnevin, emphasis is directed to the successful 19th century introduction of plants to cultivation. From our point of view it is satisfactory to know that some plants and seeds sent by N.Z. collector, Henry Travers, were successful and that some still survive today at Glasnevin. Under Director David Moore there was an association with the Sydney Botanic Garden where David's brother Charles Moore was its Director. This was an important link in the early distribution of plants as both men strove to improve the collections in their respective gardens.

Illustrations for the book have reproduced well except for some of the early documents. This is unfortunate for their impact and meaning is lost on the reader. Apart from this criticism The Brightest Jewel is thoroughly recommended, placing on record the importance of this Irish Botanic Garden as a world centre for botanical research, teaching and horticulture. The authors have done an excellent job in bringing this garden to our attention.

Winsome Shepherd

Early Importations of *Pinus radiata* to New Zealand and Distribution in Canterbury to 1885: Implications for the Genetic Makeup of *Pinus radiata* Stocks. Part II

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Canterbury Plantations, The Domain Board, Canterbury Nurserymen

Plantations — Private and Public

The history of both public and private plantations is the key to much of South Island radiata seed sources. Known Canterbury recipients for GS seed were Sir John Hall, Edward Richardson, T. H. Potts, William Rolleston, John Enys, the Hon. Col. Brett, the Canterbury Domain Board and D. Nairn[60]. There could well be others[61]. The composition and age of trees in Richardson's Albury Park stand which was felled in 1986 can be explained when original source information is re-examined and with the knowledge that Richardson was a regular recipient of GS seed[62]. Sir John Hall, a recognised pioneer of tree planting in Canterbury, was also a recipient of GS seed, certainly for the first 1870 shipment and in 1879, and probably like Richardson on a regular basis. It seemed desirable therefore to examine Hall's property "Terrace Station" at Hororata and search papers still held there.

In April 1988, both on "Terrace Station" itself, and on the properties around, extant 1870/1880s radiata confirmed Hall's statement that he gave seed to his neighbours[63]. These occur outside the 1885 Terrace Station boundaries shown in Fig. 10. It illustrates the plantations established by 1885 and although today the size of the station is considerably reduced, the majority of plantations illustrated are still in existence. The relationship of Terrace Station Plantations to Provincial Plantation reserves is not clear as the Station diary shows —

19 April 1883

"I believe the Planting Board will plant the strip at McDonald's"...

15 June 1883

"The Planting Board are going to plant the 80 acres at McDonalds."

7 Sept. 1883

"I have got the 2,000 pines up for the Planting Board for planting in McDonalds."

2 Nov. 1883

"Powell and Barson have finished the fence at the County Plantation. The Plantation at McDonalds cost the Board £109. I

Fig 9 C.1870s radiata at Hororata, on roadside skirting 'Terrace Station'. R. W. Shepherd 1988.

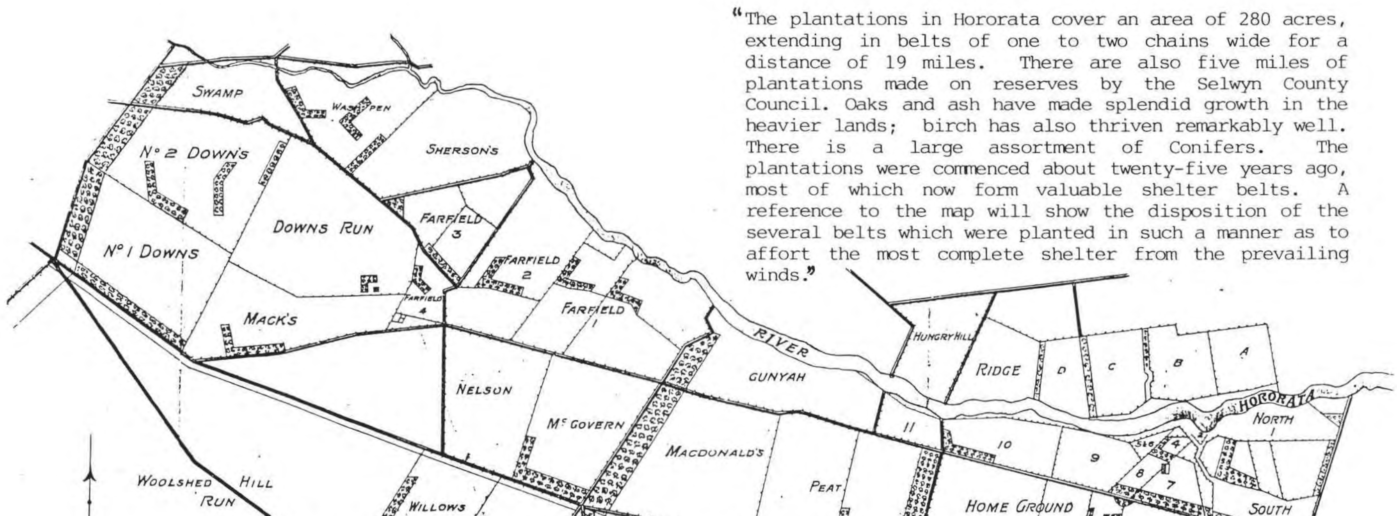

Fig 10 J. Hall "Planting for Shelter" 1898.

charged them 12/- per chain for the end fences and bought material for their share of the division fences charging for putting up and also for the men's time planting and digging holes."

6 Dec 1883

"There is no other tender for your plantation reserves... they can take the ground for planting anytime... Mr Stevens says he will try and get Mr Baker to have them (plantations) surveyed and lay off your roads and water race reserves."

11 Sept. 1885

"Turner, contractor for planting the 88 acres at McDonalds is working at it and I have got the strips filled up over at Hororata with 2 yr insignis. It took 600."

Clearly "the Board" refers to the Canterbury Plantation Board established in 1879 to administer 32,000 acres of crown land set aside for plantation reserves, primarily in Selwyn, Ashburton and McKenzie Counties. These reserves were typically in elongated strips from 200 to 300 yards across. Initially many ran north to south, but these were superceded by east-west strips which proved to be more effective shelterbelts[64].

Today a few radiata pine, topped many year ago, are close to the homestead itself, while there is an interesting triangular planting, probably experimental, which features several mature conifers including *Pinus coulteri, P. radiata* and *Cupressus macrocarpa.* Unfortunately no reference in Station papers was found to the 1870 or any other conifer seed sent by Sir James Hector[65]. An envelope, no date, marked *Pinus laricio, P. coulteri, P. ponderosa* and Wellingtonia and giving the address James Veitch and Sons, Kings Road, London, may indicate that Hall imported some seed from Veitch. The first reference to pines is for 1872 when a further fifteen acres of the homestead's "Hill Paddock" was planted, a "*few*" pines being used. Their source is obscure. They could have come from the 1870 GS seed sent to Hall, but equally they could have come from the Christchurch nursery firms Kerr & Barnett and Greenaway which are mentioned in the records. Increasing use of pines particularly radiata came after 1872. In 1876, 200 two year old radiata as well as first year seedlings were planted at Hall's "Bluff Station". These came from the nurseryman Greenaway and cost 40/- per hundred. It was evident too that by 1876 Hall saw radiata and macrocarpa as "nurses" to more desirable plantings, but by 1883 entire belts were in radiata. "White and Ontario" poplars were the only trees ordered from the Government Gardener. Extensive plantations on his property were at first supplied and carried out under contract by the above two nurseries. Later Hall found it preferable and cheaper to raise radiata plants from his own seed e.g. 2,000 were "got up" for planting in "McDonalds" in 1883. Some of these could have been raised from GS seed.

In August and September 1885, Kerr & Barnett were contracted to do the plantation plantings — nine feet apart for 40/- per acre.

Gums and wattles did not fare as well as pines, and at Terrace Station Hall had the plantation strips on his property filled up with 2 year radiata. Although other pines were used - *Pinus sylvestris, P. maritima, P. austriaca, P. ponderosa, P. tuberculata, P. sabineana, P. torreyana, P. jeffreyi* and *P, benthamiana,* clearly *P. radiata* was the most successful. In 1898, Sir John Hall's reputation in the field of tree planting was widely known and he was invited to give a paper entitled "Planting for Shelter" to the Agricultural Conference[66].

The following extracts from this paper give a valuable insight to late ninteenth century plantings for Terrace Station and the exposed Canterbury Plains.

... In Provincial days the Provincial Government of Canterbury, instead of selling all the land, made Plantation Reserves of many thousands of acres for ensuring planting on our treeless plains. Management of these lands was at first vested in a Plantation Board, but more recently in the County Councils. The Reserves not intended to be planted at once, have from time to time, been leased by public tender and the rental has provided a fund out of which considerable portions of the remainder have been gradually covered with trees... Some belts on the Plains, 10 and 11 chains in width, have been made by the County Council." Hall found belts of 1-2 chains in width were ample and when shaped like the letter L the angle formed by the two sides of the letter gave shelter to stock from prevailing winds.

Describing the failures or advantages of the many tree species he had experimented with Hall concluded that "the one tree which is conspicuous for rapidity of growth and abundance of foliage, and which by its strength and constitution is enabled to resist frost and drought and to thrive in the poorest soil is the *Pinis insignis*... It is an abundant seeder, and is easily grown from seed... After letting contracts for planting I have found it more satisfactory to grow my own trees and do my own planting... The plantations in Hororata cover an area of 280 acres extending in belts 1-2 chains wide for a distance of 19 miles. There are also 5 miles of plantations made on reserves by the Selwyn County Council." With the section of a seventeen year old tree on the table he found it "difficult to believe that for such timber many useful purposes will not be found". Nineteen years later the position was unchanged. The Selwyn Plantation board distributed a report by Mr K. Wilson

Fig 11 Historic Monterey Pine. C.1863 Christchurch Botanical Gardens. Photo John Johns. Sept. 1987.

which said "the number of species of pines used in plantings was very limited, *Pinus insignis* being the principal one used, and thrives better on the Plains than any other, but its timber can only be used for a few purposes." Gums, Oregon pine, macrocarpa, oaks and poplars were among the trees recommended[67]. The sources of supply to the two nurseries used by Hall will be looked at more closely when examining other Canterbury nurseries.

The Christchurch Domains Board

In Christchurch the Government Gardener reported to the Christchurch Domains Board who controlled interalia the Botanic Gardens. Adjoining this was the Acclimatisation Society's garden. In the early days a close liaison existed between the Society and the Domains Board. A proportion of all plants and seeds presented to the Acclimatisation Society were given to the Domains Board[68]. Both the Acclimatisation Society and the Domains Board appear to have received 1871 GS seed, the latter coming through Superintendent Rolleston[69]. Planted in the Nursery gardens they had by Jan. 1872 "come up and were doing well."

By that time radiata was established in the Garden, one plant having been donated by W. Hislop in 1865. W. Wilson recorded two earlier plants in the Domain near Deer Park. See Fig. 11. In 1868 von Haast gave the Acclimatisation Society seed sent to him by Joseph Hooker. It may well have included radiata[70]. In 1870 pines (unspecified) "were planted on the angle of the river opposite the sandhill in the Domain and on the waste ground north (sic) of the road near Carlton bridge[71]." Pines generally were not listed in 1871 Domains Board circulars to roads boards and school committees although sycamore, ash and native plants were[72]. However, by May 1872, 2000 plants of various pines were available for distribution. Some of these may have come from the Acclimatisation Society and included therefore some plants raised from GS and von Haast seed. In 1872 the Domain Board received a packet of seed which contained radiata from Californian nurseryman E. C. Moore, the same nursery which supplied William Martin in Dunedin in 1869.

By 1873 local demand for trees from the Domain Board was so great that a request for forest trees for Invercargill was turned down. Table I, extracted from Domain Board minutes lists trees sent out for the years 1870-1881. The distribution peak for 1877 was matched in Auckland[73].

Table 1

No. of Plants		No. of Plants	
1870	4,437	1876	128,146
1871	9,050	1877	184,265
1872	11,250	1878	105,673
1873	13,353	1879	75,520
1874	27,470	1880	36,319
1875	33,585	1881	63,944

Total: 693,012

The Otago Daily Times 10 Jan 1874 reported:

"The Canterbury Government are planting out trees on Government reserves on a much more extensive scale than has been attempted in Otago. We read of avenues around Christchurch being planted with the lime, Spanish Chestnut, *Pinus insignis*, and *Pinus radiata*, and of terraces being "clumped" with a variety of Californian pines and cypresses; also of an avenue of Californian pines and cypresses; also of an avenue containing an area of five acres being planted entirely with *Cupressus macrocarpa*. On the Northern line of the railway, near Kaiapoi, about 8000 young trees have been planted this year with a view to protecting the line from sand. . . . About 5000 trees were planted at the same place last year".

Fig 12 C.1902. Prebbleton Church framed with radiata. In 1872 250 trees were sent to the school at Prebbleton. Trees in this photograph could well have come from the Domains Board about this time.

Extracted also from Domain Board records Table 2 shows their distribution list of 37,075 plants for 1874.

The proportion of radiata trees in Table 2 is uncertain but a distribution list dated May 1876 indicates that 8.6% were pines of various sorts[74]. Approximately 11,000 pines were sent out that year. Oak and sycamore still predominated while birch, ash and gum made up the remaining. Between the years 1870-82 a total of 763,034 trees were distributed to public bodies in Canterbury. (Fig. 12). It can be presumed that most, although not all, of the radiata and other conifers distributed for the years 1872 to 1881 were raised from GS seed particularly so after 1874. Distribution of 1871 seed sent to the Canterbury Acclimatisation Society is unknown. Provincial Government in May 1876 reserved one-third of Domains Board seed for forwarding to Timaru. In 1876, 2000 young trees were sent from the Domain Board to the New Plymouth Recreation Grounds[75]. The foregoing information confirms a distribution pattern of GS seed similar to that for Wellington although Canterbury nurserymen are not mentioned. Early photographs and postcards confirm this distribution. Timaru was exceptionally rich with radiata shelterbelts around Caroline Bay. (Figs. 13-16). Winchester Domain today is interesting in that it contains two completely different races of Douglas fir. In 1875 a pinetum was established in the Christchurch Botanic Garden[76]. One hundred and fifty species were planted out, grouped according to their country or

Table 2. Domain Board Plant Distribution for 1874

	No. of plants		No. of plants
Railway Plantation	17,860	Templeton School	363
Domains and Parks	2,052	Rangiora Park	2,462
Kaiapoi-Stationmaster	136	Mrs Miles	118
Mr Howlings	50	Rangiora School	950
Lyttelton-Public Cemetery	200	Mrs Davies	74
Lyttelton Bor. Council	619	Addington Gaol	1,043
Convent-Christchurch	165	Kaiapoi Domain	1,000
Waimakariri Conservation	100	Police Dept	182
Courtenay School	165	Mr Hopkins	672
Dunedin Asylum (mulberries)	600	Springston Cemetery	560
Dunedin Asylum (trees&shrubs)	1,746	Timaru Park	180
Kaiapoi Cemetery	450	Mr Lewis, Timaru	146
Temuka Park	2,500	Royal Soc. Hobartown	124
Ashburton Cemetery	200	Ven. Arch. Davies	48
Indust. school (mulberries 100)	1,941	Captain Southern Cross	29
Killinchy school	340		

Total: 37,075

Fig 13 C.1905. Radiata at Caroline Bay, Timaru, possibly planted by Parks and Reserves under the direction of W. Hislop. They could be from GS seed sent to Timaru in the 1870s.

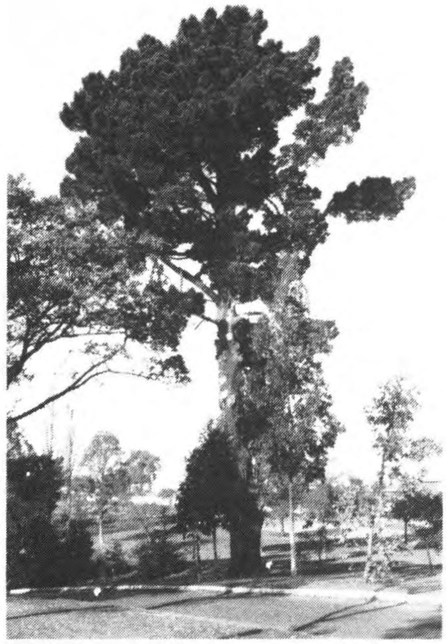

Fig 15 Timaru Gardens. A mature radiata, possibly from 1870s. GS seed, distributed through the Superintendent for Canterbury or from Christchurch Domains Board. R. W. Shepherd 1986.

Fig 14 C.1905. Band rotunda and Park Timaru. (A.A. Ware Series).

Fig 16 C.1902. The young tree, seen centre back, is now a very fine old radiata possibly raised from GS seed sent directly to the Ashburton Domain from Wellington.

source of origin — Europe and Africa, Asia, Canada and the U.S.A., California, Australia, New Zealand and South America. It is easy to see now why Rolleston, Superintendent for Canterbury, recommended this approach to the testing of all conifers in New Zealand botanic gardens and domains[77]. By 1875 in the Wellington Botanic Garden, 127 species representing twelve genera were recorded by Buchanan.

Canterbury Public Plantations — Summary

Government Railway Plantations were managed by the Canterbury Domains Board and in 1874 (Table 2) these were supplied with 17,860 trees. Of these possibly one-twelfth were pines. Domains Board resources were obviously strained by supplying such large numbers of trees and in 1878 they sought a government grant for this work[78]. The Canterbury Plantation Board on the other hand, formed in 1879 to administer some 32,000 acres of Crown Land Reserves, came under the Department of Crown Lands, itself administered by a Board. Domains Board representative on the Canterbury Plantation Board was T. H. Potts[79]. In 1885 when the Canterbury Plantation Board went out of existence 2000 acres had been planted under its auspices. The Reserves were now vested in the Selwyn and Ashburton County Councils respectively. Plantings were mainly eucalypts and *Acacia dealbata* with some conifers[80]. Negotiations with the Selwyn County Council involving the sum of £3,000, are referred to in Domain Board minutes for Dec. 1878[81]. Discussions were still proceeding in 1881 but it is unclear what these were about. Clearly more needs to be known about the source of trees used to afforest those 2000 acres of the Canterbury Plantation Board for the years 1878 to 1885 but it may be, as was shown for Sir John Hall's Hororata property, that it was general to use contract nurserymen such as Greenaway and Kerr & Barnett. In 1881 the Domains Board, on the recommendation of T. H. Potts, appointed a forester named Gray[82] but unfortunately no initials are given (refer Shepherd & Cook, The Botanic Garden, Wellington). In conclusion it would appear that in the 1870s and 1880s the Christchurch Domains Board administered and planted the Canterbury Railways Plantations and some other public plantations. They included trees raised from GS seed. The Canterbury Plantation Board plantings were supplied, under contract, from nurseries, or from locally grown seedlings as Hall provided at Hororata. Plantations like those of Terrace Station initially may have been planted with trees raised from GS seed but by the 1880s, radiata seed harvested locally from trees planted in the early 1870s was being used for private plantings and those of the Plantation Board.

Canterbury Nurserymen

Early Christchurch nurseries have been well researched by S. Challenger[83] who concludes that the years 1863-67 were critical years in the increasing awareness of the value of conifers. Particular acceptance of American and Indian conifers is reflected in nursery catalogues after this date. Greenaway, the nurseryman used by Hall, exhibited conifers at Canterbury Horticultural (C.H.S.) shows for the 1863-64 season. On 3 March 1865 Hislop exhibited 84 "varieties" of conifers. Greenaway also staged an exhibit of unspecified conifers,[84] while in 1866 he was awarded an extra prize for his collection of conifers at the C.H.S. show. A C.H.S. lecture in 1865 makes no reference to the possible use of conifers for planting on the open plains[85]. Two years later however, in 1867, it was said that limited use could be made of some species of Coniferae for planting of Town Belts[86]. The giant Californian redwood or *Wellingtonia gigantea* as it was called appears to have been introduced to Canterbury shortly after Lobb's 1853 collection of it in California. Challenger also remarks on this early introduction. Nurseryman Hislop in 1863 had a 9-year-old tree and by 1864 was advertising seedlings for sale[86A]. There is some mystery here since 1853-54 is the date given for its first planting (unsuccessful) in England at Killerton. Gerd Krussman says in his manual of Cultivated Conifers -

"In 1853 W. Lobb sent huge quantities of Wellingtonia seed to Veitch & Son in Exeter. Some months before, a Scottish plant collector, John D. Matthew was collecting seed in the same region which reached Scotland before that collected by Lobb. It has been presumed that the old specimens in Scotland were grown from seed sent by Matthew and those in England from Lobb."

Dec. 1853 was when it was first described by W. J. Hooker. One would expect a nine-year-old Wellingtonia to exceed 4'6" in height in 9 years so there may be some inaccuracy in the Torlesse report. Did Hislop have a very early contact with California or with Veitch? In 1873 Hislop went as Park Ranger to Timaru Parks & Reserves. His experience with conifers benefited Timaru and in 1875 he requested and was sent a donation of seeds from the Christchurch Domains Board while in 1876 one-third of Domains Board GS seed was reserved for Timaru.

Nurseryman Wilson, in 1865, according to Swale[87] said "newly introduced trees, shrubs, evergreens and conifers would always meet with a fair trial", This would have included specimens of "handsome *Pinus insignis*"[88]. In 1869 Greenaway, now also secretary for the C.H.S., advertised "A fine stock of *Pinus insignis* and other choice conifers". In 1870 Andrew Duncan (referred to Hector by Professor Kellog in 1874)[89] listed 80 varieties of conifers[90]. An executive member of the C.H.S., he was also a Provincial Council member for 1868 to 1873, when Rolleston received the first GS seed sent to Canterbury Province. Acceptance, but not yet the dominance, of radiata and macrocarpa was now evident. In 1872, Wilson, now vice President of the C.H.S., lectured on conifers to the Society. Of radiata he said "it is rapidly raised from seed either from England or California but it is a comparatively recent introduction and little is known about its timber"[91]. Of macrocarpa he said

"The province abounds in beautiful specimens of this tree. Two planted in 1863 are near the deer park in the Government Domain. One is coning. A tree grows in Mr Steven's lawn (President C.H.S.) — height 28'; two are in the garden of Mr Jenkins, Ferry Rd — slender and upright compared with the two previous examples. There are a large number of specimens on the peninsular hills behind the residence of Murray Aynsley. The tree is readily raised from seed which is now being produced in great abundance in the Province."

At Kew in 1867, the oldest macrocarpa in Europe, a 50' high tree, was killed by frost and snow. *Pinus lambertiana* was the only other American conifer referred to by Wilson[91]. Wilson, Duncan & Son, and Greenaway all exhibited at the C.H.S. show that year — species shown did not centre specifically on American conifers[92].

In the early 1870s remarkably high stock numbers were advertised by some Canterbury nurseries. For 1873 Wilson lists 500,000 "insignis" (represents 25kg seed approx.) but this is reduced to 100,000 for 1876. Challenger was unable to reconcile Wilson's nursery acreage with these figures. He raises the question "was there an overstatement of stock in the newspaper advertisements?"[93] Did Wilson taken an entrepreneurial 'punt' on the impact of the Forest Tree Planting Encouragement Act in his 1873 advertisement? As conifer stocks in Wilson's 1876 catalogue were twice that for hardwoods, they must have become accepted as being easy to establish in Canterbury. GS radiata seed imports for the successive years 1871 to 1874 were 1lb, 5lbs and 9lbs respectively.

Quantities and the origin of radiata seed obtained by Canterbury nurserymen are still far from clear but Australian and New Zealand sources can be discounted since it seems unlikely that radiata coned much before 1867 in Australia and even later than this in New Zealand. Strong evidence exists for early 1860s importations of seed from England possibly from both the Exeter and London branches of Veitch's Nursery. London nursery firms cannot be discounted. Gold mining activities and establishment of the Mail Service between California and New Zealand could have furnished the first addresses for seed distributors in California. Once that first initial information became known it would not take long for this to come to the notice of all those in public affairs and certainly Canterbury nurserymen were linked to the C.H.S., the Provincial Council and Town Council, while men like Hall, Rolleston, Duncan, Potts, and others were members of the New Zealand Institute. Unfortunately the Christchurch Domains Board records are not detailed enough to say whether GS seed, as in other centres, was sometimes distributed to nurserymen e.g. Wilson or Greenaway.

By 1871 the 1,300 acres of private land which had been planted would have had little or no conifer contact but of the 20,000 acres planted by 1898, radiata and macrocarpa would have formed a large part[94]. Add to this the planting of the 32,000 acres of Crown land in McKenzie, Selwyn and Ashburton counties[95] which followed the 1879 amendment to the 1871 Forest Trees Planting Encouragement Act, we can get some idea of the areas planted in radiata. Hall used the nurseryman Greenaway who in 1876 supplied 250 "insignis" for his Bluff Station. Greenaway died in 1880 which accounts for Kerr & Barnett, nurserymen, Stanmore St, being contracted to plant 25 acres for Hall in 1885. Unfortunately, Challenger does not discuss this firm in detail although he notes that Wm Kerr in 1864 advertised as a "Landscape Gardener"[96]. The two other nurserymen mentioned by Hall, Duncan & Hislop were used to supply other plant material for Station use.

We may conclude therefore that up until 1886 Canterbury nurserymen planted extensive areas in conifer plants raised from at present unknown American or English seed sources. Besides this, there was also a wide distribution of plants raised from GS seed. Cooney[97] gives no figures for the acreage of conifer or radiata forest planted on Selwyn County Reserves land between 1880-1890. He takes no account of reserves on properties like that of Hall (Fig. 10), yet it is obvious that areas like Hororata and Darfield, with early radiata still extant, benefited from this afforestation. Perhaps it is significant that the Selwyn Plantation Board's nursery was established at Darfield.

The 'Old Boy' network and early GS radiata distribution appear to go hand in hand, e.g. Hall's first manager at Hororata was John W. Buller, son of the Rev. W. Buller and brother of the ornithologist. In 1869 John Buller left Hororata, moving to Wanganui where his brother Walter was Resident Magistrate. In 1871 GS seed was sent to Buller at Wanganui — the initials and address are not stated[98].

A similar "network" may uncover the origin of Geraldine's "Grey Pine", and even link together some early Christchurch radiata. The "Grey Pine" C.1860 in Geraldine grows on a bend in State Highway

Fig 17 "The Grey Pine" Geraldine. C.1860. Photo: John Johns 1989.

Fig 18 C.1910 Although radiata and macrocarpa were predominantly successful among 48 conifer species introduced 1870-1885, Wellingtonia and Douglas fir as shown in this postcard of the Blenheim Memorial fountain did very well.

72 on the outskirts of the town. The property is presently owned by D. N. Godsiff. It is a magnificent tree circ. 314 inches at breast height, diam. 100 inches[99]. Fig. 17. Originally the tree had a big companion but this was felled 40 years ago when it became thin in the crown[100]. The property "Blackfoot Station", as it was then called, was bought by Hall's brother Thomas W. Hall in 1858. A year later it was sold to Albert Henry Grey[101]. The "Grey Pine" in age, coincides with expected germination of Acland's 1859 radiata seed from Veitch and raises the question as to whether Acland gave his nearby neighbour these two plants. Did he distribute any in Christchurch to, for example, the Christchurch Botanic Garden where the radiata tree like the Grey Pine is a substantial tree? (Fig. 11) Newly returned from his home in Devon, Acland could be expected to enthuse about the Californian conifers Lobb was sending back to Veitch. In treeless Canterbury he could have passed this knowledge, Veitch's address and a few plants raised from his 1859 seed to neighbours, friends and nurserymen in Christchurch. It is an intriguing thought, Lobb's continued residence in California until his death in 1863 and Acland's link with Veitch may have provided direct seed supply sources for those in Canterbury.

Radiata Seed Sources Important Regions additional to that for Canterbury

Nelson

Nelson is an important source of radiata within N.Z., and possibly for Australia. About 1950, according to Burdon[102], the firm of H. G. Kingsland is reputed to have sent large quantities of bulk seed around N.Z. and to (at least) Australia. In 1925 358lbs of seed was collected from trees circa 1875-1885 for export to South Africa[103]. Challenger [104] infers that the nurseryman Hale had radiata by 1865 but the species is not shown in Hale's 1865 catalogue. However from the Californian species mentioned, (*Pinus sabineana, P. muricata, Wellingtonia gigantea* and a number of *Cupressus* species), it seems likely that he received *Pinus radiata* around this time.

Burstall gives C 1850 as the estimated age for a radiata and *Pinus wallichiana* at Nelson's Isel Park originally formed by Thomas Marsden [105]. Evidence used by Burstall to support this early date is obscure. It may be linked to misinterpretation of an entry in the Saxton Diary 11 Sept. 1849.

"They gave me 3 pine cones picked by her mother (Mrs Marsden's mother) on New Year's Day. They got me out a seed. One bed was filled with forest tree seeds and I was promised seedlings." [106].

The cones clearly were not locally grown, and probably were harvested in Cumbria (Marsden's home) as possibly was the seed for the "Forest Tree" seedlings. With the first Californian seed collected by William Lobb being sent to Veitch in 1850/51; to date the first record for radiata from Veitch to Australia being 1 plant in 1854[107]; the commercial unavailability of the species in Australia before 1860[108]; and that Hale does not list it for 1865, it appears that a review of the dating of radiata and other American and Indian conifers at Isel Park is necessary.

No evidence is yet available as to where nurseryman Hale, sometime after 1865 received American and Indian conifer seed prior to the release of GS seed in 1871. Canterbury nurserymen, Wilson and Hislop, may hold the key here as both had radiata by 1865 and were well known to Hale.

GS seed was sent to the Nelson Superintendent in 1871 and probably from then on a regular basis until 1876, when with the abolition of the Provinces, GS seed was given to Dr Boor, Nelson hospital superintendent, for distribution to certain nurserymen and others in Nelson[109]. Plants too were sent from the Wellington Botanic Garden to public bodies and others in both Blenheim and Nelson[110]. Postcards and early photographs of Nelson and Blenheim churches, schools, cemeteries, the orphanage and old homesteads support a conifer distribution pattern similar to that found for Canterbury and Wellington. (Fig. 18). No examination of Provincial records has yet been made. It would be helpful to find the source of seed to nurserymen such as Hale. It should be noted here that Marsden of Isel was at one time a member of the Nelson Provincial Council.

Manawatu

Large quantities of radiata seed sent to Kaingaroa were collected at Aokautere, Palmerston North by a Mr Oxam[111]. Old radiata resembling those in the Wellington Botanic Garden are in this area and may well derive from GS seed. Only a further search of Botanic Garden records and a knowledge of the 1870/85 owners of the land can decide this.

Waikato

No analysis of Auckland Domain Boards (Acclimatisation Society) distribution of seed and/or plants raised from GS seed has been undertaken. Some seed was certainly distributed to Waikato and Tauranga. In just one year, in 1876, N.Z. received a quantity equal to over one half of the total amount of GS radiata seed imported for the period 1870-1885 — 4lbs of GS radiata seed came from Miller and Sievers, while in response to Major Jackson's order 24lbs came from Professor Kellogg[112]. Upon its arrival Major Jackson who was a Member of Parliament for Waikato did not want all the order. The Wellington Botanic Garden took 12lbs radiata seed, the balance being divided among the 9 superintendents. What proportion of radiata seed was taken and distributed by Jackson is unknown but a considerable amount of radiata seed could have been distributed in the Waikato for that year.

Matamata is an area which seems to have furnished forestry with radiata seed. In this vicinity C. W. Firth first planted radiata C. 1869/70[113]. These would have coned about 1880 and could therefore have provided early seed for the area. Unfortunately the source of Firth's seed is unknown. The high yield of radiata timber as compared with that of other pines was evident when Firth's stand was felled in 1919[114].

Summary

Given the very localised natural populations of radiata, and information covered in this literature review, the theory that radiata spread is linked to Californian miners moving around the Pacific basin is discounted. Likewise is the view that Australia was the main source of seed for N.Z. Pivotal to the species first introduction to both Australia and N.Z. is the English firm of James Veitch in Devon. The provenance was Monterey. A similar provenance would have been applied to any English grown seed derived from Douglas's 1833 introduction, which may have been on stream about the same time as Lobb's first seed (1850-51) was sent to Veitch. Around 1869 any American and Indian conifer seed supplied by Joseph Hooker and purchased at auction in London or sent to him from the U.S.A. Department of Agriculture is of unknown provenance. Only in the late 1860s did importation start to come direct from California. Importations of GS seed followed for the years 1870-1885, a small proportion being forwarded across the Tasman to Australia. Early GS seed supplied by Professor Kellogg may have had a Monterey provenance although as yet this is by no means sure. Later seed supplied by commercial firms in San Francisco could be either Monterey, Anõ Nuevo or both.

Source of radiata seed sent to von Mueller in Australia is still central to an understanding of its distribution in that country even though a previously unnoticed import of pines (unspecified) to Sydney as early as 1851 is now documented. In 1858 shortly after his appointment as Director of the Melbourne Botanic Garden, Mueller acknowledged a first parcel of unidentified seed from American Harvard University botanist Asa Gray[115]. A further letter in 1859 infers Gray was to send more seed[116] but with the destruction of the Melbourne Botanic Gardens archives nothing further is known. A brief examination of archival papers of N.S.W. nurseryman Thos. Shepherd, indicated a possible American link by 1861-62[117]. Supplying radiata to Acland as Shepherd did in 1859, before most other Australian nurserymen stocked it recommends further study be undertaken on this nurseryman.

The GS seed distribution noted by Shepherd and Cook is confirmed for Canterbury and possibly for Nelson/Blenheim regions. However, additional to this general distribution pattern GS seed provided trees for some public plantings such as Highway Board plantings in Auckland and Railway Plantations in Canterbury. Also in Canterbury some private plantation belts planted in the 1870's contained GS seed. Use of radiata for all plantings increases from 1871, the earliest date one could expect to see GS plants. In Hororata, trees in the private plantations coned and supplied some seed for the Canterbury Plantations Board plantings of the 1880's. It would be helpful to ascertain the exact localities and ownership of properties used for collection of seed in the 1880's.

Radiata C.1850 at Isel Park, Nelson is discounted and it is recommended that early dates in Burstall's mensuration reports be re-examined. Acland's 1859 importation of one three year old radiata from N.S.W. nurseryman Thos Shepherd, a tree still extant, stands as the first record for radiata in N.Z. Equally important is Acland's 1859 introduction of seed from Veitch probably collected by Lobb in Monterey. Returned from his home in Devon that year Acland would well have been enthusiastic about the success of Lobb's seed there. If he returned via Sydney it could account for his purchase from Thos. Shepherd. It raises an interesting question as to whether this enthusiasm may be central to early Canterbury radiata introduction.

A major query rises from Challenger's analysis of figures for nursery production in Canterbury. While the importance of GS seed relative to undocumented imports is still open to question, enough is known of the GS distribution to give a general picture of the spread of the ubiquitous pine from California. A series of relatively large seed lots, with complex and strongly overlapping distributions around N.Z. would ensure that the local stock was quite broadly based genetically, and of fairly similar origins among N.Z. localities. Further information may yet pinpoint collection areas for both California and N.Z. radiata seed from which our commercial forests derive. Monterey was the main seaport before the rise of San Francisco. Douglas and Lobb collections were from Monterey. The general appearance of some of the earliest N.Z. plantings seems to converge on Monterey dominating the early, small-scale seed introductions. On the other hand Anõ Nuevo appears to predominate in the overall ancestry of New Zealand stocks, which suggests that this provenance must have figured very prominantly in the GS seed. Thus from its introduction to New Zealand gardens last century stem today's commercial radiata forests. A synthesis of historical investigations into its introduction together with genetic studies is, according to Forest Research Institute scientist Dr Rowland Burdon, likely to be highly productive.

Rowland Burdon's invaluable contribution to this article is gratefully acknowledged as are the splendid photographs contributed by John Johns.

*Error in Fig 5, Part I of the article published in Horticulture in New Zealand Volume I Part I. 'Veitch to Australia? unknown' should read 'Veitch to Australia 1854'.

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Abstracts of Theses presented in partial fulfilment of the requirements for the National Diploma in Horticulture (with Honours)

The effect of physiological age, cultivar, and soil pH on nutrient concentrations in asparagus

J. M. Follett

There has been a great deal of research on the field response of asparagus to various fertiliser applications. However, little work has been done to evaluate how factors other than fertiliser affect the nutrient concentrations in asparagus. This project evaluated the effect of physiological age, cultivar and soil pH on nutrient concentrations in asparagus fern and spears. Sampling was carried out over a three year period.

Results indicated that the physiological age of the fern had a large effect on the nutrient concentrations in the fern. Because concentrations in the fern were most stable eight to fourteen weeks after closeup this time was recommended for sampling fern for diagnosing nutrient disorders. As there were fewer significant differences between nutrient concentrations in the spear, sampling for nutrient diagnosis could possibly be carried out during the spear stage. However, there are no critical nutrient concentrations available for spears, making interpretation difficult.

Nutrient concentration for all nutrients except nitrogen varied between cultivars, however, these relative differences varied from year to year making interpretation of the results difficult.

Except for calcium, boron and molybdenum, soil pH had little effect on nutrient concentrations in the fern.

All three trials showed variations in nutrient concentrations from year to year. This was thought to be due in part to environmental factors.

Effect of seed quality on subsequent seed germination and growth of radiata pine in the nursery

Vicki Hodder

Seed orchards now produce sufficient seed for all of New Zealand's *Pinus radiata* seed requirements. These orchards have been established with grafts and cuttings of the best clones following extensive tree breeding.

It is important that seed from these orchards has high viability, germinative energy and growth in the nursery to maximise the number of seedlings raised from each kilogram of seed. There have been complaints about seed orchard seed quality from nurserymen, particularly about small seed size and poor, uneven germination.

There are many potential causes for seed quality problems in seed orchards, and special seed collections were organised to examine some of these.

Results from laboratory germination and nursery bed sowings gave the following results:
There were no significant differences in germination and subsequent growth between seedlings produced from seed collected off trees grown from seedlings, cuttings or grafts. This is an encouraging result, since seed orchards are established with cuttings and grafts from selected clones.

Similarly, there were no significant differences between seedlings produced from seed collected from healthy and unhealthy cuttings. This indicates that the resin bleeding noticed in unhealthy cuttings has not affected the seed quality.

However, while there was no difference between seedlings produced from seed collected from healthy and unhealthy grafts, seed collected from very unhealthy grafts was smaller, and had poorer germination. Seed from very unhealthy grafts also produced a poorer percentage of plantable seedlings. Therefore, seed should not be collected from very unhealthy grafts.

The effect of time of seed collection was not consistent. Seed collected in June and July from an open-pollinated seed orchard at Kaingaroa gave good germination and produced high quality seedlings. The earlier seed collection in May from Kaingaroa resulted in poor germination and later seedling growth. However, with seed collected from a control-pollinated seed orchard at Amberley, the best germination and better seedling growth came from the early May collection, while the later June and July seed collections gave poorer results. The effects of time of seed collection and open-pollinated compared with control-pollinated will need further study, using seed collected from only one site to avoid possible environmental effects.

Seed from mature crop cones germinated very well and produced high quality seedlings. However, seed from first cone crops were smaller, germinated poorly and produced fewer and poorer quality seedlings. This experiment indicates that cones should not be collected for commercial use from small trees just coming into cone production.

The Effect on Survival in Dry Site Plantings of *Metrosideros excelsa* by the use of Hydrogels in Nursery Potting Media and at the Transplanting Site

Robert Nisbet Smith

Abstract

The influence of the hydrogel Broadleaf P4 on the survival of transplanted pohutukawa (*Metrosideros excelsa*) in a dry planting site on the Gisborne foreshore was examined. The hydrogel was incorporated either at the time of potting on, at transplanting or both.

The results demonstrate that the incorporation of Broadleaf P4 into the potting media at the time of the final potting on has a negligible effect on the survival rate of the transplanted trees. They also demonstrate that the incorporation of the hydrogel into the backfill soil at the time of transplanting gives positive results in terms of the survival rate of the transplanted trees under the conditions of this trial.

N.B. All theses listed above are deposited in the Lincoln University Library and are available through the N.Z. Libraries Interloan Service.