Paper 1
THE HISTORY OF BARLEY IN NEW ZEALAND

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EARLY HISTORY OF BARLEY

Barley had been domesticated and utilised by man tens of centuries before its introduction into New Zealand. After long study of the botanical evidence Körnicke (1895) considered that *Hordeum spontaneum* is the oldest of our cultivated plants. He quoted from Artemidor that the Greeks recognised this, and according to tradition the Greek god Ceres gave barley to mankind as the first form of food.

Some authorities believe that barley was the cereal crop of Mesopotamia 50 000 years ago. It was certainly the only cultivated crop of the Greeks in the Homeric Age and of the stone-age lake-dwellers in Europe, being used as a staple food before wheat was brought into cultivation. The Greeks lightly roasted the barley and then ground it coarsely. The grist was stirred with water and eaten with the addition of oil and condiments. This preparation took the place of bread as we know it.

In later times barley was baked into bread, and this use continued in Continental Europe down to the sixteenth century, when it was gradually replaced by rye and wheat. Throughout the world cultivated barley is still primarily a feed crop for domesticated animals and humans. Second in importance is its use for brewing and distilling.

Weaver (1943) says, "Barley has a wider ecological range than any other grain. It thrives beyond the Arctic Circle in regions where in summer the soil thaws no more than a few inches below the surface, and also on the tropical plains of India. High on Ethiopian mountain slopes barley grows beside frozen pools of water, and is cultivated beneath the date palm in Saharan oases. It matures on the lower delta of the Nile, where salt water is found at depths of little more than a foot. It provides the native food in the Dangra Yum Basin in Tibet, at an altitude of 15,000 feet, and climbs even higher on the Himalayan slopes, where a form with recurving stalks places the head of grain almost on the ground in protection from the relentless winds. It grows on the plain of the American Midwest, on the high plateaus of Bolivia and Peru, on the South African veld, and on the alkaline soils of Australia."

The famous Russian botanist Vavilov (1950) presented evidence that there were two very widely separated primary centres of origin of barley, one in North-east Africa and the Middle East, and the other in South-east Asia and China. As to the origin of barleys found in North-west Europe, including the British Isles, there is reason to think that the primary forms from which they arose came form South-east Europe and areas bordering on Turkestan.

Early land barleys

All two-row barleys grown or derived in New Zealand have stemmed from Europe, where until early last century only unnamed strains of barley were grown. These were termed "Landgersten", meaning "barleys of the country", or just "land" barleys. In the British Isles evidence of barley in the Neolithic Age (3000 B.C.) occurs as grain impressions on hand-made pottery. The first evidence of two-row barley is the depiction of an ear on a British coin struck about 20 B.C.

No written records on barley are helpful until 1523 when Fitzherbert produced his "Boke of Husbondrye". He described "Sprot barleye" (later called 'Spratt'), "Longe-eare" (later 'Scotch Common'), "Archer", "Old Irish" and "Beare-barley (6 row) that is the worste barleye". Then in 1757 Edward Lisle in his book "Observations in Husbandry" described three sorts of barley on physiological characteristics:

"Rath ripe" (rath = early), with weak straw (represented later by Old Irish and Scotch Common and by 'Hanna' in Europe).
"Middle ripe", equivalent to the mixture from which 'Chevallier' was selected.
"Later ripe", with short strong straw (later called Archer).

These three sorts of unselected narrow-ear barleys were in general cultivation in England until well into the nineteenth century and were known as "Common two-rowed or English barley." Even in the 1950's in small well-defined districts in the British Isles there existed a few unselected sorts of barley, including Old Irish and Scotch Common.

Early selections

The first named cultivar was Chevallier, selected on sight about 1820 by Rev. Dr John Chevallier from a plant growing accidentally in the garden of a farm labourer living in a cottage owned by the Doctor. By about 1825 he had harvested the seed from an acre, and from then on he began to dispose of it. Although no official records of races of barley were available, Beaven (1947) found that 83% of barleys with varietal names were Chevallier in the Barley Competitions of the Brewer's Exhibition between 1887 and 1890.

Fuller information on the history of European barley may be obtained from books by E.S. Beaven (1947) and H. Hunter (1952), the two most famous barley breeders of Great Britain.

These accounts of early barleys indicate the most probable types of barley brought to New Zealand by the early settlers, who predominantly stemmed from the British Isles. Brief early references just mention "barley", without denomination of any type. It must be presumed that the early importations were from the available British pool of types including Scotch Common, Old Irish, Archer, Spratt, and later Chevallier. By the end of the 19th century many selections had been made from these strains, to produce pure lines for use in many parts of Western Europe. These were important in their own right and also because they were the progenitors of many successful hybrid cultivars in the early part of the 20th century. The one which played the largest role in New Zealand was Webb's 'Kinver Chevallier' which, according to Hewlett (1931), was the main cultivar of any importance in cultivation in Canterbury prior to 1920. It remained important until after the Second World War.

To cover the gene pool that has contributed to New Zealand barley production it is necessary to go back to 1889, when a single wide ear, shaped like Spratt, was discovered in a British field of Chevallier barley and was raised to become 'Goldthorpe', a high-quality barley used for its quality in later hybrids. Another cultivar was derived by selection from the Swedish "plumagekorn" by Beaven in England after 1902. 'Plumage', as it was known, was extensively grown in New Zealand in the 1920's.

HYBRID CULTIVARS FROM ABROAD

In the 1930's Plumage was replaced by the Beaven hybrid 'Plumage Archer''. Two hybrid cultivars bred by Hunter were 'Spratt Archer', which played a very important role in New Zealand between 1924 and 1950, and 'Goldthorpe Spratt', which was grown to a limited extent on light land, where it yielded relatively well, with high quality grain. 'Golden Archer' (Beaven) was grown on substantial areas for a few years after the Second World War.

Before 1950 two other two-row cultivars were grown commercially to a limited extent. 'Gisborne' was at one time popular in some districts, with the synonym of 'Wind-resistant', but in trials conducted by the author it did not prove as good as other cultivars in this respect. Its origin is uncertain, but it is probably a New Zealand selection from Spratt. The other cultivar, 'Prior', was an early maturing selection, probably from Archer (Fitzsimmons & Wrigley, 1979), introduced into Nelson and Marlborough in 1937 and grown extensively there for a few years under the name of 'Marlborough Chevallier' although it was distinctly different from Kinver Chevallier in plant appearance and performance.

The first reliable cultivar statistics showed the predominant role the selected or deliberately bred British barleys had played in New Zealand production (Table 1).

TABLE 1: Early cultivars as percentage of barley area.

	Canterbury (Hewlett 1931)		New Zealand (Malcolm 1947)	
	1925	1930	1938	1945
Chevallier	44	16	25	38
Plumage	52	2	—	—
Spratt Archer	4	76	21	20
Plumage Archer	—	4	23	16
Goldthorpe Spratt	—	2	8	5

RESEARCH IN NEW ZEALAND

From 1945 to 1950 barley research was intensified by Malcolm at the Agronomy Division, DSIR, Lincoln. Golden Archer was successfully released in 1946, 'Kenia' in 1950, and a mid-season maturing selection of 'Research' in 1951. Golden Archer came from a cross between Plumage Archer and Spratt Archer. It was released in England in 1932 and introduced here in 1937 for trial by R.A. Calder. Kenia was introduced at the same time, and was from a cross between 'Binder' and 'Gold' made at Abed, Denmark, and released there in 1931. The local Kenia was different from the Danish Kenia in an obvious morphological grain character (teeth on the lateral lemma nerves). Research was the result of an Australian cross between Plumage Archer and Prior, released in 1942 and introduced here in 1943, and reselected in 1946 into early, mid-season and late maturing groups. The early group, sent back to Australia, was released there in 1962 as 'Resibee'. Details of cultivar origins and performance were given by Malcolm (1949,1952,1959).

Two further significant cultivar milestones were the introductions of 'Carlsberg' by Crop Research Division in 1952, superseded by 'Carlsberg II' which was introduced by Malcolm in 1955 and released as Carlsberg in the same year, and 'Zephyr' introduced by a South Canterbury farmer in 1965. Both cultivars contributed substantially to barley production, Carlsberg for feed barley and Zephyr for feed and malting purposes. Carlsberg came from a cross between 'Prentice' (English Archer) and 'Maja' (a sib of Kenia) made in Denmark. Zephyr was produced by M.G.H., Holland, from a cross between 'Heine 2149' and Carlsberg.

The commercial lives of cultivars available since 1946 were remarkable compared with current cultivar development and usage. Golden Archer lasted from 1946 to 1955, Kenia (latterly called Kea) 1950-1970, Research (latterly called Rupe) 1951-1980, Carlsberg 1957-1980, and Zephyr, from 1965, was still providing 54% of the New Zealand barley area in 1980.

The spate of barley cultivars which have entered commerce since 1970 will not be dealt with in detail. They have been described and given regional ranking for yields by Malcolm (1979) and in an updated Recommended List by Thaine and Malcolm (1981). The full impact of potential yield has not been realised because the latest high-yielding cultivars have not fully replaced the older cultivars. Unfortunately reliable statistics have not yet been published for the most recent seasons but figures from the 1980 harvest show the predominance of Zephyr, which still holds an important place in 1983 (Table 2).

TABLE 2: Barley cultivars used in 1979/80 season. (Source: Agricultural Statistics 1979-80).

Cultivar	Area (%)	Average yield (t/ha)
Zephyr	54.2	3.3
Hassan	13.7	3.8
Carlsberg	3.2	3.1
Manapou	3.2	3.4
Rupe	1.4	3.2
Kea	0.9	3.0
Black & Cape	0.1	—
Others	23.3	3.5
Total	100.0*	3.4

*66,461 ha

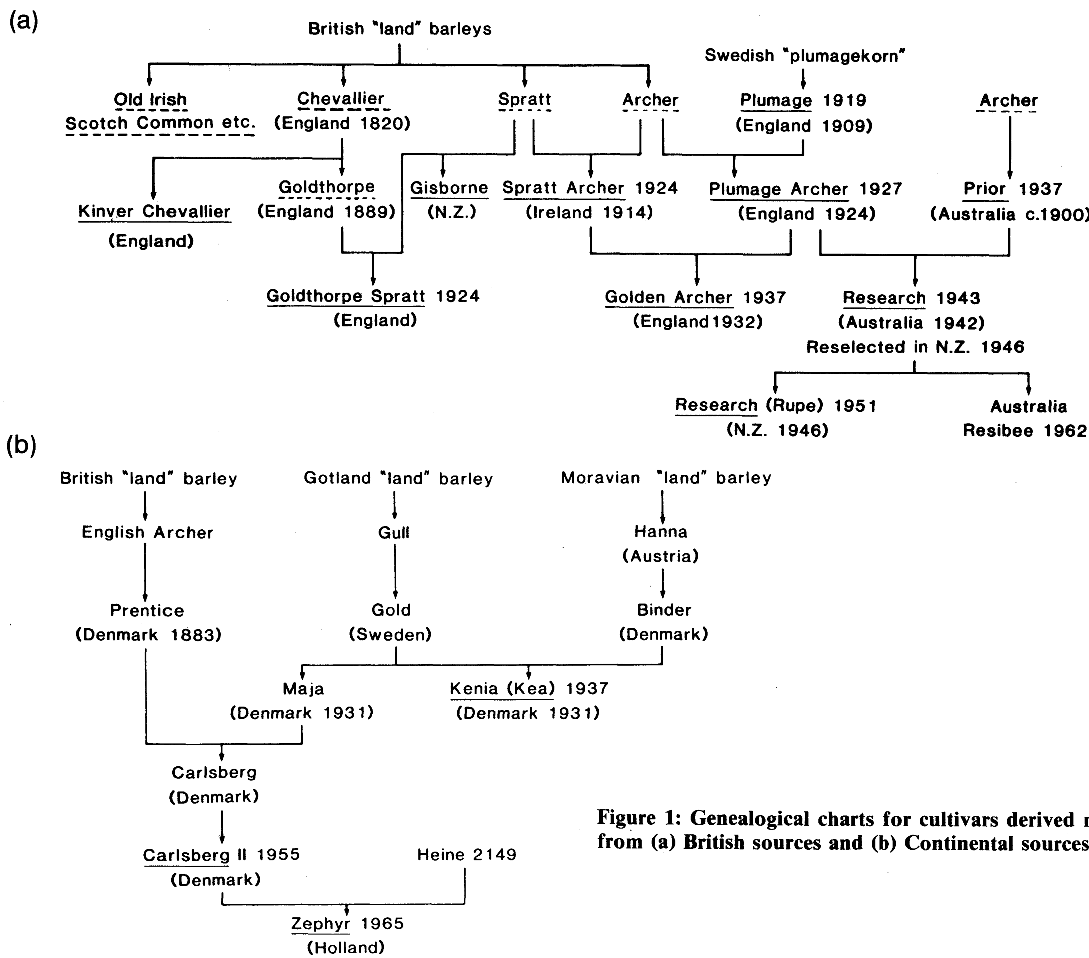

Figure 1: Genealogical charts for cultivars derived mainly from (a) British sources and (b) Continental sources.

SUMMARY OF CULTIVAR ORIGINS

The clearest way to summarise the development and usage of barley cultivars in New Zealand up to the introduction of Zephyr in 1965 is by means of genealogical charts showing descent from British and Continental barleys. When known, the country and year of release are shown in brackets, and the year of introduction into New Zealand without brackets (Fig. 1). Cultivars commercially grown in New Zealand are underlined (those probably grown have broken lines).

SIX ROW BARLEY CULTIVARS

Six-row barleys in New Zealand have been used for fast-growing green-feed crops, with surplus grain production being ground for barley meal. In trial comparisons they have not produced as high a grain yield as two-row barleys in New Zealand, hence the small percentage of the total barley areas in 'Black Skinless', 'Cape' and 'Kakapo', grown and threshed for seed or grain. Jolly (1946), dealing with a total barley area of 13,000 hectares for the 1944 harvest season, showed that greenfeed barley occupied almost 2000 ha, or 14% of the total. The area of barley sown, but not threshed, for the 1979-80 season was 2400 ha, but this was only 3.5% of the total barley area.

Two six-row barleys of long standing are Cape and Black Skinless. Cape originated in the Cape of Good Hope region of South Africa, but the date of introduction here is not known. It was introduced into Australia from the same area early this century. The arrival of Black Skinless is not recorded, and its origin was probably in northern India.

Two other six-row barleys have been grown in restricted areas for shorter periods. 'Wong' was a Chinese cross between Russian 'Orel' (two-rowed) and an unnamed Chinese six-row barley and was developed in the U.S. It was used as a true winter greenfeed barley and as a highly mildew-resistant parent for some early barley crosses at Lincoln in 1947. Commercially it was not of great importance, mainly because its very low seed yields made seed expensive and difficult to obtain. Kakapo (originally called 'Argentine II') was a selection from 'Bordenave Ranquelina MAG', an Argentinian cultivar introduced by Crop Research Division in 1956. It gave very high grain yields in the northern part of the North Island, but suffered from severe loss of grain through shaking in southern regions (Cottier *et al.*, 1971). Kakapo has not been widely grown because provender millers find the grain very hard to grind.

BARLEY PRODUCTION IN NEW ZEALAND

Fragmentary information is available for the early days of barley growing in New Zealand. Statistics of areas and yields were collected and published from the 1860's but cultivar data were not published until 1936. To follow the establishment and development of the crop, Figures 2 and 3 will be used as the bases from about 1870 onwards. Prior to this a few early references will give a sketchy account.

Captain Cook did not bring barley to this country, but on his second voyage he brewed the first beer, at Dusky Sound in 1773. In place of hops for this beer he used "Spruce Fir" (which was almost certainly rimu) and manuka. Instead of malt he used molasses, making a good

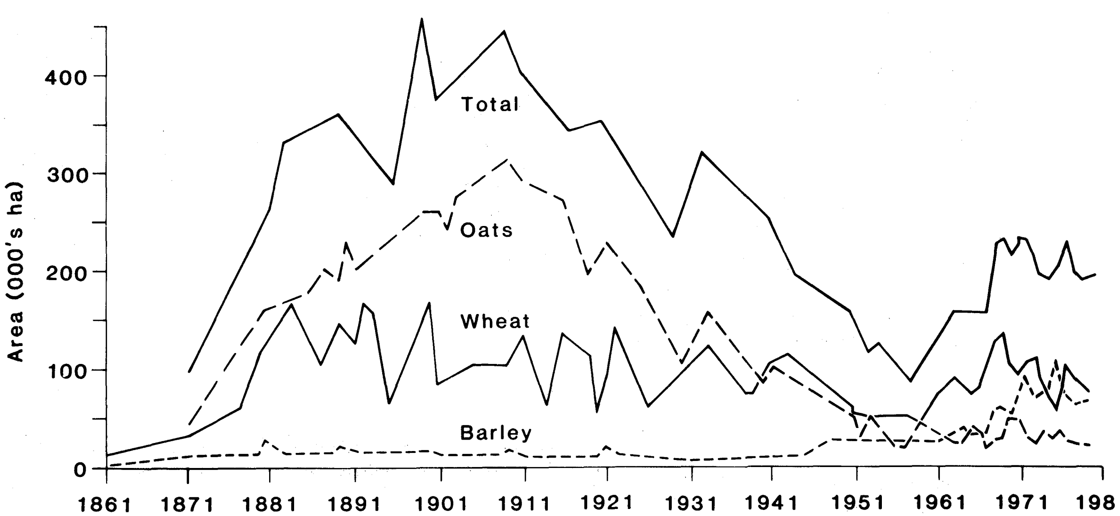

Figure 2: Cereal areas 1861-1981.

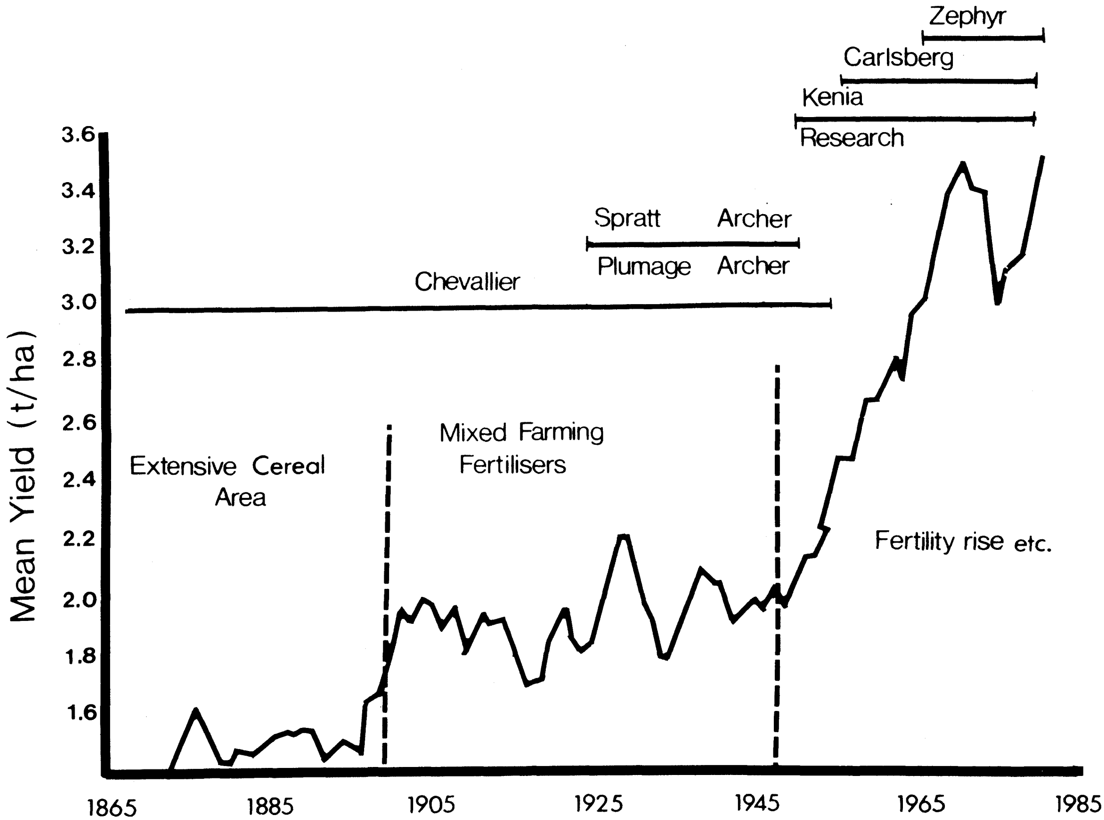

Figure 3: Barley yield (5-year moving average).

and successful beer. Plant introduction by Cook was confined to the establishment of temporary vegetable gardens in Queen Charlotte Sound.

The early traders and whalers did not encourage agriculture, except for Johnny Jones at Waikouaiti and Dicky Barrett in the Sounds, who became successful farmers by the 1840's. However the early colonists had to till the land for grain and vegetables to fulfil their own requirements. The Nelson province was early to produce a surplus of hops and barley, although around Auckland enough of these crops was grown for local needs.

However, planned colonisation did not bring with it an organised brewing industry. Many individuals set up brewing operations, often in association with their hotels. By 1843 Dodson had a brewery in Nelson and in 1844 barley grown in the Auckland fields between Mt Hobson and Mt St. Johns was malted by Hancock to brew beer for his hotel and sell to other hotels. By 1862 he had a brewery built behind the Captain Cook hotel to enlarge the scale of the brewing enterprise successfully developed in the hotel. It is recorded that by 1867 Hancocks Brewery in Auckland was buying 10,000 bushels (225 tonnes) of barley from Canterbury each year for malting (Quigley, 1962). Canterbury and Otago had by then become the granary of New Zealand.

Period of steady production

Until the 1940's the area and production of barley were tied to population numbers and the production of beer. About 80 percent of the barley was malted for brewing and the remainder used for feedstuffs. This is shown in Figure 2; the barley area did not climb, as did the areas of wheat and oats which made us self-sufficient (with export surpluses) from 1875 for about 40 years (Fig. 2).

New uses for barley

The first significant change to the steady state of barley production occurred after 1945. Area and production doubled over the 1945-1960 period, starting from 12000 ha producing about 23000 t of grain. Further increases occurred during the 1960's when the area steadily rose from 27000 to over 60000 ha. During the 1970's the area fluctuated between 71000 and 104000 ha, grain production being between 228000 and 335000 t. In the 1974 and 1975 harvests barley was ahead of wheat as the most important cash crop in New Zealand.

Until 1945 usually 80% of the barley produced was used for malting. With increased production the utilisation is reversed, with approximately 80% being used for stock feed, and in more recent years for export.

The history of production is summarised in Figure 3, which illustrates three distinct phases based on yield levels or patterns, which reflect changes and development of farming systems in conjunction with higher-yielding barley cultivars. The three periods are now described in more detail.

PRE-1900 : PHASE I

Reliable information on agricultural production started to become available during the 1860's. The dearth of barley information before this is not important because of the small demand. The European population had reached about 40000 by 1860, and approximatley two-thirds were in the North Island. Barley, wheat and oats were grown locally to provide the needs of the pockets of populated areas. Barley was grown for the small privately-owned breweries, and for pigs for home consumption.

Within ten years of organised settlement in 1850, Canterbury had become the leading producer of cereals in New Zealand, and has maintained this position. In the beginning, the Lyttelton Times in February 1852 reported that the yield of wheat and green crops was superior to the average of the Old Country (Evans, 1969). The easier, better-drained, ploughable country covered with open grassland and short scrub provided a short-lived initial soil fertility. The clearing of native vegetation to sow crops, followed by English grasses, was done on a large scale during the 1860's on lowland short-tussock grasslands in many parts of the South Island (McLintock, 1959). Figure 2 shows a relatively high yield peak of the five-year moving average barley yield centred on the year 1875, which may be some expression of the "cash-in" on natural fertility.

After this, much of the arable land in the South Island was cropped excessively and the veneer of fertility was seriously depleted. Figure 1 shows the increase in cereal areas from 1870, reaching a peak of 445000 ha at the end of the century. Before 1875 considerable quantities of wheat had been imported from Australia, but after this valuable exports of wheat and oats were made for about forty years. Although the barley area remained steady at some 10000 ha the large areas of wheat and oats for grain and chaff reduced the yields of succeeding crops. This is reflected in the low yield plateau for barley, fluctuating around 1.5 t/ha until near the end of the century.

During this agricultural phase no developments had reached fruition to boost the lowly yield level. Seed was sown broadcast on the furrows of ploughed land, no fertilisers were available, the more fertile heavier soils were not completely drained for cultivation, the short three year pastures with a little unthrifty clover and low stocking rates did not induce much fertility, and the barleys grown were rather rough-and-ready selections from British land barleys.

Apropos of fertilisers, according to McCaskill (1929) the first example of soil rejuvenation was in Taranaki in the 1870's, where swede crops responded in a spectacular manner to locally produced bone dust. Ivey, the first Director of Lincoln College, introduced superphosphate in 1881 and produced increased yields in turnip trial plots. Following these results and trials at Rothamsted in England, a superphosphate works was established by Kempthorne Prosser and Co. in 1882. In the same year the first refrigerated cargo of meat, with a little butter and cheese, left for Great Britain. The establishment of the meat industry produced valuable fertiliser by-products. These innovations in producing fertilisers gave no material benefit until after the turn of the century, when reasonable quantities became available. In addition seed drills with fertiliser boxes were not developed until supplies were adequate.

The constraint of the unavailability of the most fertile soils of the swamps (Acland, 1951) in the Temuka, Longbeach, Leeston, Lincoln and Kaiapoi coastal areas was not overcome for many years. For instance, the survey map of 1863 shows Longbeach to be an impenetrable swamp for most of the area between the Ashburton and Hinds Rivers and extending from near the coast to near the proposed southern railway line (Stevens, 1952). John Grigg commenced the development of a network of open drains about 1867, but much of the land still remained too wet. In 1889 a brickmaker and ten men began making field-drain tiles from a kiln newly erected on Longbeach. By 1900, when the work was almost completed, 240 kms of drains had been laid, involving the use of close on one million tiles and draining approximately 3650 ha. In addition to this, tiles were supplied to farmers who had bought land from the estate. This illustrates the time taken to develop these swamp lands for general cultivation, even with the earliest of schemes which proceeded with well-organised continuous endeavour over a large area. Barley did not become an important cash crop on Longbeach until 40 to 50 years ago.

The time scale was similar for the development of the more fertile land of the swamps in the Ellesmere district, which became the traditional concentrated area of commercial barley production. At the beginning most of the eastern half of Ellesmere County needed draining (Graham and Chapple, 1965). This was started by farmers creating ditches and sod-bank fences. At the end of 1868 the Lyttelton Times published cereal statistics for the Ellesmere district: wheat 3830 ha, oats 1714 ha, and barley 714 ha which was estimated to yield 1.68 to 1.96 t/ha.

1900-1947 : PHASE II

This phase shows an overall yield increase (Fig. 2) and also some wide fluctuations in yield. A number of factors influenced these changes, but their relative importance cannot be determined.

TABLE 3: Barley area by regions (1924/1925)

Region	% of total*
North Island	8.6
Marlborough	21.8
Nelson	2.2
Canterbury**	1.1
Ellesmere***	27.6
Ashburton	1.1
South Canterbury	6.6
North Otago	4.0
Central Otago	17.0
Southland	1.9

* 10500 ha.
** North of Waimakariri River
*** Waimakariri to Rakaia River

One factor difficult to quantify was the establishment of three predominant regions for barley growing, which persisted for most of this period. Taking the season of 1924/25 as representative, in the middle of the period, two-thirds of the Dominion's barley was grown in the Ellesmere district (between the Waimakariri and Rakaia rivers), and in small sections of Marlborough and Central Otago. Compared with the wider distribution of barley growing in recent times the restriction to defined areas in 1924 appears remarkable.

Malcolm (1947) calculated the Dominion average yield for the 21 years to 1946 as 2.02 t/ha, which is 25% higher than for the pre-1900 period. Contributing to this higher yield, the Ellesmere district averaged 2.36 t/ha from about one quarter of the total area of barley. Central Otago was near the average with 1.94 t/ha and Marlborough slightly below with 1.86 t/ha.

Although recently drained and fertile land in Ellesmere was becoming available for spring-sown barley, not all of this yield increase can be attributed to this factor.

After 1900 fertilisers became available in larger quantities from freezing works, and seed drills were developed with fertiliser boxes (McLeod, 1962). From 1900 to 1914 blood and bone, Peruvian guano and Japanese superphosphate and freezing works fertiliser declined, and locally produced superphosphate assumed the main role. McLeod showed a barley yield increase of 16% with the application of 125 kg/ha of superphosphate. This agrees with an increase of about 15% shown by Hewlett (1931), covering several seasons in Ellesmere County. The effect of fertiliser on average yields would be less than this, because not all barley crops received fertiliser.

A third factor in raising barley yields was the decline in wheat and oats, which were gradually replaced by fat lamb and dairy products for export. The total area of cereals (Fig. 1) dropped from about 400000 ha to just over 160000 ha, although there was a short-term rise in area during the economic depression lasting some years from 1929. This increased cropping is a partial cause of the short-term depression in barley yield (Fig. 2). Associated causes were decreased use of fertilisers through financial stress, farmers saving their own untreated seed which resulted in an increase in the incidence of disease (particularly the smuts), and the occurrence of several dry growing seasons. However, the increasing sheep numbers during the whole period, with topdressed pastures of improved quality, created a more desirable rotational system for improving cereal yields on a declining area.

The temporary dip in barley yield during World War I can be largely attributed to lowered input of fertiliser, which was not available from Nauru Island, and the use of inferior seed. Hewlett (1931) stated that all seed lines became mixed and dirty during this period, and the smut diseases in particular took a heavy toll.

The rise in yield level during the late 1920's was caused by four highly productive harvests, from 1927 to 1930 (Malcolm, 1947). The seasonal weather was favourable and the yield level reflected the elimination of smuts from all malting barley crops by 1928 (Hewlett, 1930), following studies of control in wheat (Neill, 1924). Other yield-promoting factors were the more widespread use of fertilisers and the introduction of the new hybridised barley, Spratt Archer. Hewlett (1931) calculated conservative yield increases obtained by the contributing factors of the new cultivar, fertilisers, disease control and climatic conditions during the 5-year period to 1930. Spratt Archer gave an 8.5% yield increase over Chevallier during this period, but in the present author's trials in the 1940's this difference no longer occurred. Superphosphate fertiliser usage gave a 1.5% yield increase over the whole crop, although only about 70% of the crops received fertiliser by 1930. Disease control (mainly the smuts) gave an overall yield increase of nearly 8%, with individual increases up to 34%. The combined total effect of these factors Hewlett calculated as a 19.8% rise in yield for the 1927-30 period compared with the preceding season. The advantageous climatic conditions experienced, especially for the 1927 and 1928 harvests, created a further yield increase of well over 20%.

To end Phase II, the last decade until 1947 showed slight fluctuations in yield above and below the plateau of about 2 t/ha (Fig. 2). The wheat area rose during World War II but the total cereal area declined from 260000 to 160000 hectares. The barley area remained constantly between 10000 and 12000 hectares until after the war. Some of the barley yield depression during the war years was caused by autumn and winter sown wheat taking precedence for the better-drained fertile land, pushing barley onto lighter land, or onto poorly drained land for late spring sowing.

POST 1947 : PHASE III

Following the relatively low yielding plateaus of the first two phases, barley yields rose steeply during the 26-year period to 1973 (Fig. 2). The rise was from about 2 to 3.5 t/ha, a 75% yield increase. The temporary dip after this was caused by two dry seasons, with relatively low yields of 2.8 and 2.5 t/ha from the 1974 and 1975 harvests.

Yields then recovered to re-establish the present 5-year average of approximately 3.5 t/ha.

The factors which caused yield levels to rise progressively during this phase were the utilisation of better cultivars, effective weed control, reasonable disease control, introduction of seed barley certification, better farm cropping rotations with the decline in total cereal area and improved pastures, betterment of land drainage, universal use of fertiliser, and, especially during the last decade, increased use of irrigation.

Cultivars

The first improved cultivar grown in this phase was Golden Archer, released in 1946, which occupied one-quarter of the barley area by the 1951-52 season (Barrer, 1952). Golden Archer had a 10% yield advantage over Spratt Archer in 29 Department of Agriculture trials over three seasons in the South Island. Over four seasons, in 12 Agronomy Division (DSIR) trials in the Ellesmere County, Golden Archer outyielded Spratt Archer, Kinver Chevallier and Plumage Archer by 18%, 8% and 27% respectively (Malcolm, unpublished data, reported in minutes of the Barley Sub-Committee of the Field Crop Committee, 1947-1950).

To estimate the effect of any new cultivar on the national average yield level, the average yield advantage over established cultivars in trials is weighted against the eventual area occupied. In the case of Golden Archer, the trial yield advantage is conservatively taken as 12%, with one-quarter area occupancy by 1952, giving an assessed 3% national higher yield level on a unit area basis.

Concurrent with the release of Golden Archer was the widespread adoption of Australian Research after 1943. In the series of Department of Agriculture trials quoted, Commercial Research (Australian) outyielded Spratt Archer by 22% and Golden Archer by 13%. In the Agronomy Division trials the yield advantage was 26% over Spratt Archer and 8% over Golden Archer. With Golden Archer, Research took over the area in Spratt Archer, Plumage Archer, and other contemporary cultivars. It occupied 44% of the barley area by 1949-50, rising to 59% by 1951-52 (Barrer, 1952). The trial data suggest that when half the area was in Research the nett overall gain in yield over the older cultivars was 12%.

However, Australian Research was not acceptable to the main market, malting, because of its variable development within the plant population, noticeable from the late jointing and ear emergence growth stages. In bulk grain lots individual grain behaviour was diverse during the "steeping and water" and "germination" stages of the malting process. The resultant malt was unsatisfactory, with relatively low malt extract and uneven modification of the starch endosperm. An acceptable degree of uniformity in Research was achieved by 1950, as described in detail later.

Kenia (latterly called Kea) was the next cultivar to arrive on the farm scene. Released in 1950, it occupied 12% of the barley area by 1952, one-third of the area in 1960, and up to 46% in 1963. By 1969 the area had decreased, and it remained at 20% for many years, as one of the two, and later three, cultivars contracted for malting. In a series of trials Kenia outyielded Golden Archer by 13% and was little ahead of Australian Research. The reason Kenia was not released in lieu of Golden Archer was the malting and brewing industry suspicion of unknown continental European barleys, in contrast to the traditional acceptance of cultivars developed in Great Britain. Once this prejudice was overcome Kenia ousted Golden Archer and the older British cultivars by 1960, by which time Kenia and reselected Research were the predominant cultivars. During its 20-year career as a major cultivar it is estimated that Kenia gave a 4% increase over Golden Archer in national barley production.

The first major advance made by New Zealand breeding and selection work was the reselection of a mid-season maturing group from Australian Research. The selection supplanted the Australian line as quickly as possible from 1951, and conferred the benefits of an even-maturing line while retaining the name of Research. Relatively few trials were conducted to ensure that yield and other characters had not been impaired, but in selection trials the mid-season selection outyielded Australian Research by 21%. In extension trials it showed some improvement in resistance to lodging, which occurred frequently when Research was grown on heavy land (Malcolm, 1959). In seven Department of Agriculture trials from 1950 to 1952 the selection outyielded Australian Research by 7.5%, and in five of these trials on lighter to medium soils the yield differential was 10% in favour of the selection (Malcolm, 1952).

From this time Kenia was recommended for good medium to heavy land because of its shorter straw with more resistance to lodging. Research was recommended for medium to light land, where lodging was not usually a problem and a reasonable straw length assisted in harvesting operations, especially on stony land. The yields of selected Research and Kenia in the small number of trials appeared to be equal on heavy soil types, but the selection showed a 21% advantage on lighter soil types. In reality over many seasons both cultivars yielded similarly in the malting barley area under contract, but Research bore the brunt of less favourable conditions on the shallower, drier soils. The selection, with its 10% yield advantage over Australian Research, occupying up to 65% of the barley area by 1960 and surviving for almost 30 years as a significant cultivar, can be given credit for a 6% increase in national barley production over at least 10 seasons.

The cultivar Carlsberg was the next significant advance. It was introduced by Crop Research Division in 1952 as a potential malting barley, but with its reselected line Carlsberg II was not found suitable for brewing purposes because of a tendency to produce a hazy wort, the infusion of malt before fermentation. A similar problem was experienced in Europe, where little Carlsberg malt was used for brewing. Carlsberg II gave a slightly, but not significantly, higher yield than Carlsberg, and both produced large, plump grain suitable for stock feed. The cultivar was agronomically similar to Kenia, but higher in yield. An average yield increase over Kenia of 15.4% was obtained in 33 Department of Agriculture and Crop Research Division trials during the three seasons to 1959-60. In 18 trials Carlsberg outyielded Research by 16.5%. After its release in 1960 Carlsberg spread to occupy nearly half of the barley area five years later, and has survived on 3% of the area in 1980. The advantage to national barley production in 1965 is assessed at 7.5% for Carlsberg over Kenia and Research. Constant monitoring and hot-water treatment of Carlsberg were necessary to suppress loose smut, which could quickly build up in this "open flowering" cultivar.

The next invasion of loose smut came with the introduction of the cultivar Zephyr by a farmer in 1965. The seed from this line was hot-water treated and used for trials and seed multiplication. Zephyr, with relatively short straw, was more resistant to lodging than Kenia or Carlsberg, and far more resistant than Research. Zephyr shows a slight weakness in the straw 2-3 cm below the head but a significant loss of heads only occurs when gale-force winds affect ripe crops, and then other standard cultivars are also damaged. Zephyr was resistant to powdery mildew for its first five years in New Zealand, but some mildew appeared on it at the end of 1970, and it became as heavily infected as other cultivars in the following season. Sixty-three commercial sized split-block trials over six seasons, apportioned equally between comparisons with Kenia, Research, and Carlsberg, showed it to have yield advantages of 19% over Kenia, 16.2% over Research and 6.4% over Carlsberg (Malcolm and Thompson, 1972). The yield difference between Zephyr and Carlsberg corresponds with that obtained in Field Research Section trials in 1965-1971 (Cottier *et al.*, 1971). Zephyr showed better malt characteristics than Kenia or Research and was quickly adopted as a malting and feed barley. By the 1969 harvest it accounted for over 18% of the barley area (cf. Carlsberg 45%). Zephyr rose to 65% by 1978, while Carlsberg had declined to almost 8%. Zephyr was by far the predominant barley for the 1970 decade, and still occupied over 54% of the barley area in the latest available statistics, for 1979-1980. Despite powdery mildew susceptibility from 1972 having some pruning effect on the yield advantage of Zephyr, it is credited with a 3% increase in national barley production by its displacement of Carlsberg and some of the Kenia and Research.

From about the middle of the 1970 decade a host of new barley cultivars, 13 listed by 1981, were offered to growers. The new cultivars were at least nearly equal to Zephyr in yield, and in most districts superior (Thaine and Malcolm, 1981). For the first time since the 1930's the development and release of new barley cultivars was not the exclusive domain of government breeding organisations. Private breeding organisations, based on commercial grain and seed companies, imported and developed 9 out of 13 new barley cultivars as agents for overseas breeding organisations. The yield advantages over Zephyr for all the new cultivars range up to 8% in the North Island, up to 11% in Canterbury/North Otago and up to 12% in South Otago/Southland. New cultivars (other than Zephyr, Carlsberg, Research and Kenia) accounted for 22% of the barley area in 1977/78, 32% in 1978/79 and 40% in 1979/80. The first two new cultivars to be specified separately in statistics were Hassan occupying 13.7% of the area in 1979/80 and Manapou with 3.2%. Hassan has a consistent 4-6% yield advantage over Zephyr, and Manapou, confined to Canterbury, shows 6% higher yield. The full impact of the new cultivars obviously does not express itself in the 5-year moving average yields in Figure 3, which is based on annual yield data up to 1979/80. Assuming that new cultivars occupied one-fifth of the area over the last 5-year period and the yield increase over Zephyr was 5% for the first wave of new cultivars, then the benefit accrued to national production was 1%.

In summary, since 1947 the national yield benefit due to improved cultivars has been 28.2%. This figure was calculated by taking the trial yield percentage increase of each cultivar and adjusting it for the assessed area occupied and utility life span. The adjusted cultivar percentages were then multiplied from base 100 representing Spratt Archer, Chevallier, and Plumage Archer as grown in 1947.

Weed control

The use of selective herbicides in crops was in its infancy at the beginning of this post-1947 phase. The most prevalent weeds which reduced yield by competing for space, light and moisture were tares, wild turnip, fathen, and Californian thistle, and willow weed on heavier soils. Reductions of 25% in grain yield of barley were recorded with only moderate infestations of fathen in a fairly dry season. Now that weeds are controlled by herbicides as an established practice it is estimated that barley yield has been boosted by about 20% during this phase (F.C. Allen, pers. comm., 1982). In addition harvesting operations are expedited and grain is not so contaminated with weed seeds and damp weed material to create grain storage problems or extra expense for drying. Application of herbicides can now be considered as a prophylactic practice, with lower weed populations prevailing in the modern more densely canopied barley cultivars. However, any relaxation in the use of herbicides would result in a resurgence of weeds which could reach their former highly competitive level in three to five years.

To this point a 28% yield increase has been attributed to cultivar improvement and 20% to weed control. This leaves a 27% yield increase to account for to make up to total 75% yield increase which has occurred since 1947, or 14% if we multiply rather than adding. To apportion this remaining increase amongst the following factors cannot be done with any degree of accuracy because information is not available on overall farm practices.

Disease and pest control

No change in yield level can be attributed to the control of smuts or leaf stripe, which have been kept suppressed by seed treatments. The smuts showed up in the crops grown from the small importations of Carlsberg and Zephyr seed but the infections were quelled by hot-water treatment of subsequent seed. Latterly seed-borne diseases have been controlled more conveniently and just as effectively by seed dressing with new systemic fungicides.

Yield suppression by foliar diseases is difficult to estimate. Significant yield increases have been demonstrated in trials using contact fungicides, and more recently systemics, against specified fungal pathogens. However, the application of foliar fungicides has not yet become a generally accepted cultural procedure. Any control of foliar pathogens on an extensive scale has been achieved by resistance or tolerance of cultivars. The effect of this is expressed in their average yield performance.

The insect pests most studied during this phase have been the aphid vectors of barley yellow dwarf virus (BYDV). Lowe (1966) trapped aphids for seven seasons and found higher numbers of the main BYDV vector, *Rhopalosiphum padi,* during November than in September, October or December. Even so the actual numbers of aphids in November may be very low following low populations the previous autumn and an adverse over-wintering period. Most of the barley in November is going through the late tillering or jointing growth stages, which are considered to be late stages for possible secondary infection with BYDV.

H.C. Smith, in a series of papers from 1953 to 1967, studied isolates and strains of BYDV, aphid species in relation to transmission of BYDV, susceptibility and tolerance of cereal cultivars, and dosage rates of viruliferous aphids at early and late stages of growth. Smith (1967) rated Kenia, the most important commercial malting cultivar then grown, as moderately susceptible, with a 45% tolerance to BYDV expressed as grain yield in greenhouse trials. However, susceptible cultivars innoculated at later growth stages gave significantly smaller effects of BYDV on grain yield. Research, the other important malting cultivar, was classed as tolerant to BYDV, and grain yield was affected only when many aphids fed on the plants at a early growth stage.

Burnett and Gill (1976) reported that the yield of infected plants of Herta barley was reduced because the number of fertile tillers, number of seeds per tiller, and kernel weight were all reduced. These effects were more pronounced as the number of aphids increased.

All these experiments of Smith and Burnett were conducted on single plants or small hill units of several plants, all inoculated with viruliferous aphids. In the typical barley crops of the moderately susceptible to tolerant cultivars that have been grown in New Zealand many plants escape being infected. The healthy plants can compensate for the loss in yield from the death or reduced vigour of plants infected between the seedling and jointing stages of growth.

This compensatory effect was recorded by Malcolm in unpublished data obtained from a series of test plots grown between 1958 and 1966 to measure yield components of established and new cultivars. Seeds were sown at 2.54 cm spacings within rows, to correspond with the average seed spacing from a drill coulter at a seeding rate of 112 kg per hectare. However, to allow working space, the rows were 30 cm apart rather than the usual commercial field spacing of 18 cm. The plots were grown on Mount Pleasant, near the Port Hills grazing land containing ryegrass and cocksfoot, grasses which are hosts of barley yellow dwarf virus. They were protected from birds. To illustrate the effect of a very high BYDV infection the results from two seasons are summarised (Table 4). The 1962/63 and 1964/65 seasons had similar climatic conditions for barley growth and development until mid-December and the final yields for Canterbury were similar, being 2.86 and 3.08 t/ha respectively. However, the winter of 1962 was very mild and aphids overwintered in large numbers, causing heavy infections of BYDV throughout Canterbury. In the growing season of 1964 aphid numbers were much lower, as was the incidence of BYDV. The slightly higher yield in the latter season was mainly attributed to late December rainfalls, which did not occur in 1962. The figures in Table 4 illustrate the remarkable ability of barley to compensate for reduced plant density caused by the death of plants from seedling through to the late jointing stage. The main response was an increase in number of ears per plant, in all three cultivars. However, Kenia did not produce an increase in average grain weight with the lower plant density, while Research and Carlsberg both produced much larger grain. The mean yield level of the three cultivars was not reduced by BYDV, in fact it was 4% higher in these plots, heavily infected with BYDV in a dry season.

TABLE 4: Effect of BYDV on yield and its components in seasons with high and low incidence.

	Kenia		Research		Carlsberg	
	62/63	64/65	62/63	64/65	62/63	64/65
plants killed %	34	8	3	10	44	14
grain weight (mg)	42.6	43.3	49.3	40.0	48.9	42.0
grains/ear	20.4	20.7	22.4	22.1	19.9	19.9
ears/plant	4.1	3.1	4.2	3.3	5.2	3.6
yield (kg/ha)	2750	3080	3310	3030	3420	3030
yield reduction		11%		- 9%		-13%

Smith (1963) reported that wide-spread spraying with organo-phosphorous insecticides was advocated in the 1962/63 season, and that increased wheat yields had been obtained by even one spray application where the unsprayed wheat was badly infected with BYDV. Autumn-sown wheat does not have the compensating ability of extra tillering (after spring infection which weakens but does not kill wheat plants) shown by spring-sown barley. For the same season the barley review (contributed by Malcolm) in the 1962/63 Pyne, Gould, Guinness Annual Review mentions that many crops were sprayed with systemic insecticides with profit. More recently aphid levels have been lower and spraying with insecticides has declined, and is not standard practice in barley growing. In the North Island, which now grows about one-fifth of the barley crop, conditions favour the spread and development of BYDV, which is very evident in most seasons, and therefore aphid control can be more valuable.

The overall effect of BYDV may not be as great as it appears nor as some research suggests. The compensatory yield ability of unaffected plants, the greater tolerance of newer cultivars, and the fact that most of the crop has been grown in the lesser-affected South Island all tend to reduce the damage.

Seed barley certification

Barley was included in the official seed certification scheme at the beginning of this historical phase. Smut-free seed has been maintained by hot-water treatment of Breeders (formerly Nucleus) seed (Hewlett, 1927) and recently by systemic fungicide treatment. Purity and trueness to cultivar type are assured by employing the single plant selection method devised by the late J.W. Hadfield, the first director of Agronomy Division, DSIR. The selections are grown and multiplied through three identifiable generations with rigorous inspection and selection procedures. This system prevents any possible decline in performance due to lack of cultivar purity and agronomic standard, and any build-up of seed-borne diseases. Hewlett (1931) reported on the effects of low seed standards during the First World War.

Farming systems

Farm cropping rotations have become more rational, with soil-fertility depleting crops, such as barley, being grown more often after restorative crops, such as clover pasture, lucerne and forage crops. The quality of pastures preceding grain crops has shown a general improvement over the last 35 years, resulting in a fertility rise due mainly to the better clover content.

The total area of cereal crops declined significantly during the profitable pastoral farming period of the 1950's and early 1960's (Fig. 2). The cultivars Kenia and Research held sway during all of this period but yield rose steadily from about 2.2 to 2.8 t/ha (Fig. 3). The effective practice of selective weed control is responsible for much of this rise, but the growing of barley more often after pasture rather than the decrease in wheat area must be a contributory factor.

Further improvements have been made to land drainage, allowing more of the fertile low-lying soils to be utilised for spring cropping rather than for long-term grazing pastures.

Fertiliser usage is now universal, with rates of superphosphate tending to rise from the usual 112 kg/ha to up to double this amount, especially on the more productive soils. Nitrogen fertiliser has been used to a limited extent more recently, and has given payable yield responses when there is no shortage of moisture and when more intensive cropping rotations are practised.

Probably irrigation is becoming the most helpful farming operation to boost barley yields, and it must be credited with some of the yield gain since 1975. An accurate estimate of the added yield obtained by added water is not possible because statistical information has not been gathered on water application to barley. In real life even the most conscientious grower may not be sure that he has applied the optimum quantities of water at the right times. More often growers know that they have not watered adequately, due to limitations in water supply or labour, or prior demands of other crops. White clover seed, peas and potatoes are examples of crops which take precedence for water during the critical periods, usually occurring in November and December. It is known that severe moisture stress during these months has suppressed a seasonal average yield by over 30% compared with a favourable season. One such comparison is shown, between the harvest season of 1962 and 1964, in a report prepared by Malcolm for the Sixty-fifth Annual Preview of Pyne, Gould, Guinness Limited. The same order of yield suppression occurred in 1974-75 compared with 1975-76. On light soil, a Lismore stony silt loam, Thompson, Smart and Drewitt (1974) obtained yield responses from irrigation of 32% and 66% in two seasons at Winchmore.

To sum up, the residual 27% yield increase to be accounted for during this 1947-1982 phase, above that shown due to new cultivars and weed control, can be attributed to the combined effects of some disease and pest control, more rational farm rotations, a somewhat smaller total cereal crop area (therefore a rise in fertility levels), more good land drained, increased fertiliser usage, and the recent increase in irrigation on barley.

CHRONOLOGICAL SUMMARY

Pre-1900 : Phase I

1820-1840	A few traders and whalers established farms.
1840's	Farming operations near centres of population.
1850-1870	Organised settlement in the South Island. Canterbury and Otago became the granary of New Zealand, cashing in on natural fertility of easily cleared well-drained land; no fertiliser used. Land races of barley introduced from Britain.
1860's	Open drainage systems introduced in swamp lands.
1870-1900	Extensive area of cereals grown, rising to 440000 ha. in 1898, with oats about half the area and wheat one-third. Wheat and oats exported. Excessive cropping caused depletion of fertility.
1882	First by-product fertiliser from meat industry. First superphosphate works established.
1889	Field tiles made at Longbeach and used to complement open drains.

1900-1947 : Phase II

1900-1914	Various fertilisers imported, and larger quantities available from freezing works. Seed drills with fertiliser boxes adopted when fertiliser supplies became adequate.
1919	Introduction of cultivar Plumage. Kinver Chevallier selection probably already established.

1920's Locally produced superphosphate became predominant.
Cereal area on the decline.
Topdressing of pastures began to restore soil fertility.
The South Island regions of the Ellesmere district, Central Otago, and Marlborough firmly established as the principal barley areas.
Land drainage work continued.

1924 Introduction of Spratt Archer and Golden Archer.

1925 Commencement of hot-water treatment of seed to eliminate smuts from malting barley; about 80% of the crop.

1927 Plumage Archer introduced.

1937 Australian Prior introduced to Marlborough (grown as "Marlborough Chevallier"). Kenia introduced.

1943 Australian Research introduced.

1946 Golden Archer released, "Mid-season" Research selected.

Post 1947 : Phase III

1950's Selective herbicides began to appear.

1951 Reselected (Mid-season) Research released. Kenia, released in 1950, approved for malting.

1955 Carlsberg II introduced, and released in 1959 as a feed barley. Continued hot-water treatment was necessary to suppress loose smut.

1965 Zephyr imported by South Canterbury farmer; seed from crop hot-water treated. Quickly adopted as a malting and feed cultivar.

1970's Many new cultivars developed by DSIR breeders and private organisations.
Irrigation of barley practised.

1978 First guide to barley cultivars published, as forerunner to a "Recommended List" in 1981.

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