Paper 11
WINTER BARLEY — POSSIBILITIES, PROBLEMS AND PROSPECTS

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INTRODUCTION

During the last 15 years the area of winter barley grown in Western Europe has increased dramatically. Many farmers have welcomed this change. They believe that it has brought previously unattainable yields within their grasp and enabled more profitable cropping rotations to be followed. But the upsurge in the area of winter barley has not been welcomed by all. There is no doubt that winter barley brings in its wake some problems. It was not a legal accident that caused the proscription of winter barley growing in the Dutch province of Zeeland in the fifties. It was "because winter barley is an excellent host plant for diseases such as mildew and rust"(Kramer *et al.,* 1952).

This review has four main aims. First, to describe briefly the history of growing winter-sown barley in Europe, with particular emphasis on England. Second, to examine some of the claims made for winter barley, particularly in relation to yield, and to outline some of the problems that can accompany the crop. Third, to describe salient features of the biology and husbandry of winter barley. Fourth, to assess potential yields and the possible place of winter barley in New Zealand agriculture. Throughout the paper some equivalent antipodeal calender months are given in parentheses when months are quoted for the Northern Hemisphere.

HISTORY AND BACKGROUND

First, it is necessary to define the term 'winter barley'. By this I shall mean varieties of barley that are insensitive to frost and cold (i.e. winter hardy), and that need to experience some cold early in their life cycle if they are to develop normally — the so-called vernalisation requirement.

Some winter barley has been grown in Europe, at least since the beginning of this century. Hawkes (1929) reported the practice of growing a small acreage of six-row winter barleys in Essex. This produced grain that could be used only for industrial or feeding purposes, and not for malting (Robinson, 1948). Perhaps more interesting is the sowing of spring varieties or barley in the autumn in the south-east of England (Hawkes, 1933; Bell, 1944; Kirby, 1969). This practice helped to decrease the spring workload and, if successful, produced a heavy yield of good quality grain for malting (Hawkes, 1933; Bell, 1944). The chief criterion of success seems to have been whether or not these spring varieties were winter killed: very cold weather in late winter or early spring can kill many plants of spring barley varieties sown in the autumn and can cause crop failure.

Autumn sowing of barley in England received a fillip around 1944 when G.D.H. Bell of the Plant Breeding Institute, Cambridge released the first winter-hardy, two-row barley with malting potential — 'Pioneer'. This was followed by others, the most successful being Maris Otter, which produced a good grain sample and became a favourite of maltsters. None the less, the area of winter barley remained small, less than 2% of the national barley crop, until the end of the 1950's (Clarke, 1965). By 1970 the area had increased slightly, to about 5% (Parry, 1981). But by 1975 the area had doubled to 10%, and by 1977, 24% of the barley acreage in England and Wales was sown to winter barley. By 1982 the figure had risen to 32% (Anon., 1982).

English farmers have not been alone in their scramble into winter barley; if anything they are the laggards. In France the areas of spring and winter barley were about equal by 1980, with winter barley accounting for 22% of the total cereal area (Anon.,1980). In Western Germany more winter barley is grown than spring barley; in Saxony, winter barley has pushed winter wheat into second place; and in Schleswig — Holstein winter barley occupies nearly 80% of the total barley area (Anon. 1977;1980;1981). Some of the reasons for this dramatic shift to winter barley will now be considered.

POSSIBILITIES

Several possible advantages associated with growing winter barley are regularly suggested.

Better Yield.

Winter barley is commonly believed to be better yielding than spring barley, particularly on light soils which are prone to drought. The bigger yields should bring better profits. These claims are examined in detail below.

More Even Workload.

Where large areas of barley are grown, sowing in the autumn reduces the pressure on spring sowing. It can be a frustrating experience trying to drill spring barley in England when the weather is wet, especially as on most soils each week's delay from the beginning of March brings an increasing yield penalty. Because winter barley matures early, harvesting can start sooner, a larger area of cereals can be cut, and expensive combine harvesters better utilised.

Early Harvest.

This feature of the winter crop means that it provides a good entry for other crops, particularly winter oilseed rape (an important crop in Western Europe) which should be sown in August to obtain the best yields. The earliness is also an advantage if the barley is to be followed by another cereal; it gives room for weed control by cultivation, and still allows the following crop to be drilled early, a practice favoured by most specialist cereal growers. In addition, direct-drilled leys and stubble turnips can be sown early and make good growth before winter. In some areas of Germany the early harvest is important on pig farms, where it lessens the dependence on bought feeds.

Early Sales.

With early harvest, an early sale is also possible, especially if the cultivar can be malted. In the 1970's sale at a premium for malting was one of the great attractions in growing Maris Otter in England, and more than compensated for the lighter yields of this ageing variety. Early sales can also ease storage problems and can improve the cash flow to a farming business.

YIELD POTENTIAL

The most important question governing the decision about whether to grow winter barley is often: How much more will it yield than spring barley? Unfortunately, research in Western Europe was overtaken by farm practice and few direct comparisions of the two crops have been made. Popular opinion is that yields of winter barley are much greater, particularly on light soils and in dry seasons. These opinions seem to find their origin in several remarkable success stories.

For instance, Peter Lippiatt, farming a light soil in Gloucestershire, rarely harvested more than 3.5t/ha before the mid 70's. But with a shift to winter sowing and an almost continuous cereal rotation he now aims to average more than 5t/ha over his farm, and expects his best barleys to yield more than 7t/ha (Lovelidge, 1977). Mr Lippiatt is, however, an exceptional farmer and an innovative and meticulous crop husbandman. Though there are many like him, winter barley does not always yield better than spring barley (Anon.,1978).

To be certain about yield differences, experimental comparisons are needed. Regrettably, there are few. However, in England the National Institute of Agricultural Botany (NIAB) conducts trials each year at several centres where both winter and spring barley cultivars are grown, but not always in the same field. The results of these trials are published annually in the NIAB Journal and enable the performance of spring and winter barleys to be compared. In what follows it is important to remember that the trials are not designed for the purpose of this comparison, and the results can be considered as being only indicative. But to provide some information on comparative yield I have made an analysis of the results of NIAB trials in which both spring and winter cultivars were grown between 1960 and 1980. In this analysis the average yield of all winter varieties grown at any site was compared with the average yield of all the spring varieties. In all trials there were more spring than winter varieties grown.

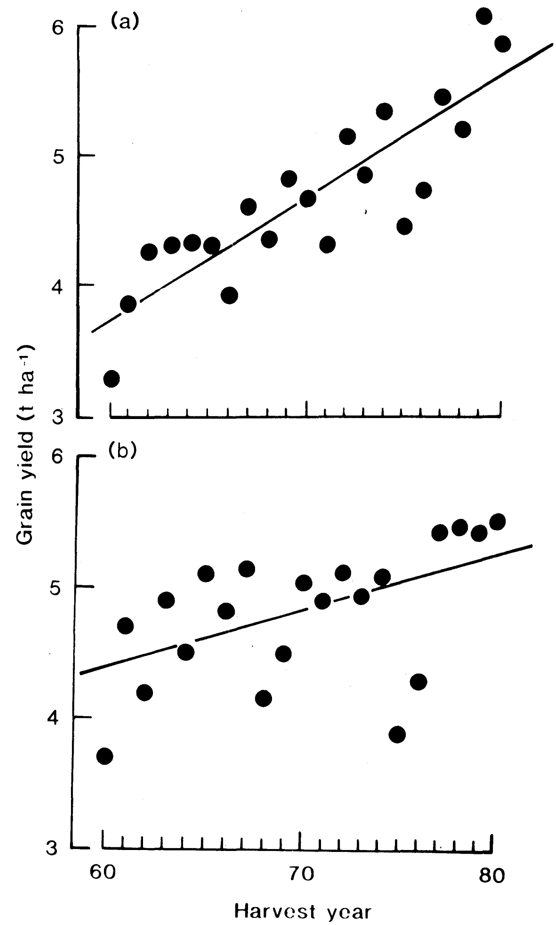

Figure 1: Temporal trends of yields of (a) winter and (b) spring cultivars in national list trials in England. The equations of the fitted lines are: y = 0.094x - 1.92 ($p < 0.01$); and y = 0.044x + 1.72 ($p < 0.02$), respectively. See text for further details.

Figure 1 shows that the average rate of increase of yield with time has been greater for the winter cultivars (94 kg/ha/yr, s.e. 12.5) than for the spring cultivars (44 kg/ha/yr, s.e. 16.7). However, these slopes are significantly different only at $p<0.1$, and together with the other restrictions on this analysis, Figure 1 hints, and no more, at a higher rate of increase. Some support for this comes from Mr W. Fiddian, until recently head of the NIAB cereals section, who is reported as saying, "The new winter barleys Igri and Athene have outyielded Astrix (an older variety) by much larger margins (than new spring varieties), so perhaps the increased breeding input for winter barley is beginning to show the crop's true potential" (Anon., 1978). This sentiment was supported by Rumsey (1979), who cited a study by the Plant Breeding Institute, Cambridge, which showed from five years of results an average 0.24 t/ha advantage to winter over spring cultivars.

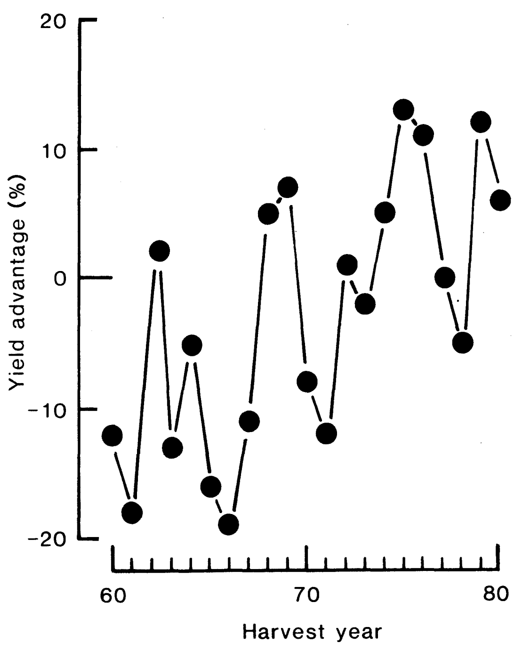

Figure 2: The relation between the yield advantage of winter barley over spring barley and harvest year.

To examine the belief that winter barley will outyield a spring crop in dry seasons, the yields shown in Figure 1 have been plotted to show the advantage of winter barley over spring barley in different seasons (Figure 2). This provides a more sensitive comparison by eliminating many of the seasonal effects common to both crops. There are three points to note. First, there is a reasonably significant ($p<0.05$) trend with time such that winter types were yielding about 15% less than spring types in the 60's but about 10% more in the late 70's; a trend already noted from Figure 1. Second, in some seasons winter barley gave markedly better yields than spring barley: 1968, 1969, 1975, 1976, and 1979. Scrutiny of weather records shows that these seasons were in general characterised by low rainfall during May, June and July. However, the third point to note about Figure 2 is that the mean figures presented mask a massive variation between sites. For instance, in 1976 at Cambridge, within the region of acute summer drought, the winter varieties yielded about 60% more than the spring ones, but in the same year at Morely (just south of Leeds) the winter barleys yielded 20% less. Similar variation between sites existed in other seasons, so that the average standard deviation in the same percentage units as Figure 2 is about 20. Farm surveys have also shown a wide range in yields obtained within any season. There is an urgent need to identify the causes of such variation.

Further evidence of the variability of yield with site and factors other than the weather is provided by results of a regression analysis. In this, the yield advantage of winter barley relative to spring was investigated in relation to weather in May, June and July at eight of the NIAB sites for which weather records could be obtained from the library at Lincoln College. A sample of 50 comparisons was available. Two measures of drought best explained the variability present. The yield advantage of winter barley was positively correlated with the maximum potential soil moisture deficit experienced, and negatively with the total rainfall for May, June and July. This result supports the idea that winter barley does well relative to spring in dry years, but the two variables explained only about 12 and 14% of the variation respectively. Adding other climatic variables to the regression did not account for significantly more of the variation. The yield advantage of winter barley in a dry year is, therefore, by no means guaranteed; other factors of site and husbandry must be of crucial importance.

More direct evidence for the advantage of winter barley in a drought comes from the work of Bainbridge *et al.* (1980) at Rothamsted. They found that early-sown winter barley yielded about 8.0 t/ha (a near record yield in the station's 140-year history) in 1976, the driest spring and summer ever recorded at Rothamsted. This yield was almost double the yield of unirrigated spring barleys and late sown winter barleys (Day *et al.*, 1978; Bainbridge *et al.*, 1980). Similarly, results from Gleadthorpe Experimental Husbandry Farm on sandy, drought-prone soils show a consistent advantage to modern winter barley cultivars sown early in the autumn, over spring cultivars sown at the conventional time (Hart, 1980; Selman, 1980). The importance of early sowing which consistently emerges from these experiments will be considered later.

The yield advantage of winter barley seems to be similar in most countries of Western Europe. Statistics for West Germany give an advantage of about 30% to winter barley nationally. In the province of Schleswig — Holstein this yield advantage rises to nearly 50% (Anon., 1981). National statistics for the two crops are not available for Britain as the winter and the spring yields are pooled.

All that glitters is not gold and some of the problems that can attend the growing of barley are now considered.

PROBLEMS

Increased Autumn Workload

This can cause difficulties if a large area of winter cereals has to be drilled. Most English farmers who indulge in intensive cereal growing tend to start drilling early and use big machinery, or direct drilling techniques, or both, so that sowing is finished by the end of October (April).

Weeds

An increase of winter cereals in a rotation can cause the spread of annual grass weeds as well as most broad-leaved weeds which germinate in the autumn. There is no doubt that weed control has to be good and that chemical control, where used, must be cost effective.

Volunteers

A problem associated with weeds in winter barley/wheat rotations can be an increase of volunteer wheat in barley and barley in wheat. Scrupulous cleanliness is necessary.

Higher Costs

Winter barley is usually more expensive to grow than spring barley because of additional costs for fertiliser, fungicide, and herbicide. This is nearly always true for disease control, as winter barley is susceptible to many diseases. Herbicide and fertiliser costs will depend more on the rotation and the general quality of weed control. In addition to these extra absolute costs, it must be remembered that if a large area of winter barley is grown, it will tie up money in variable costs six months before a spring crop would.

Seed Supplies

In England, where the winter barley is usually harvested from late July to early August (January — February), and where some farmers are wanting to sow from 1 September (March) onwards, there are problems for seed merchants. By and large, these problems have been tackled and solved. But farmers who wish to sow their crops early usually order their seed very early. In New Zealand this should be less of a problem because it is doubtful if sowing in March would be wise due to problems with pests and diseases. Before looking at husbandry practices, some details of crop biology are needed.

CROP BIOLOGY

Development

Winter barley has to pass through exactly the same stages of development as does spring barley (see Scott, this volume). But as mentioned previously, winter barley has to experience a certain amount of cold — the vernalisation requirement — if it is to reach maturity at the usual time. Temperatures between about 5 and 10 °C promote the fastest vernalisation of winter barley (Trione and Metzger, 1970). There is therefore little chance that the requirement for vernalisation will not be met within the usual span of sowing dates in either England or New Zealand.

Time of sowing has some influence on the chronology of the various developmental stages and in the account that follows a late September sowing on a lowland site in England is assumed. A November sowing would be about ten days later to maturity.

The appearance of leaves in October (April) is fast. By the end of the month several leaves and tillers will be present, and the apex of the mainstem will at least be about to initiate spikelet primordia. Development continues slowly throughout winter providing the temperatures are above freezing point. The double ridge stage is usually reached some time in November (May) or December (June) — much sooner than for winter wheat crops sown at a similar time (Barling, 1979a). Anther primordia are visible on mainstem apices in March (September) and awn primordia in early April (October) (Barling, 1981). Ear emergence and anthesis occur around the end of May (November) and crops are usually ready to harvest by late July (January).

To predict the time of occurrence of each of the development stages from weather data would require much knowledge about the influence of weather on the duration of the various phases. However, a crude but fairly accurate estimate of the duration from sowing to the end of grain growth (hereafter called the growth duration) can be achieved by treating winter barley like spring barley. The photothermal duration (see Gallagher *et al.*, Paper 3) between sowing and the end of grain growth for spring barley is about 900 °Cd; to account for the extra time needed before winter crops are fully vernalised this duration was increased to 950 °Cd. This value for the photothermal duration of growth predicts the end of fast grain growth in the middle of July for a crop sown on 1 October (April) in the English Midlands. This corresponds well with the phenological records of Barling (1979a; 1979b) for Gloucestershire.

Growth

The factors controlling the photosynthesis, respiration, and dry matter (DM) growth of winter barley appear to be the same as for spring barley, and are dealt with elsewhere in this volume. In winter barley, however, there are marked differences in the number of leaves formed and of individual leaf sizes, depending on sowing date. Crops sown in early September (March) will produce up to 15 leaves, whereas those sown in February (August) produce only about 10 (Kirby, Appleyard and Fellowes 1982). Warmer temperatures associated with early sowing also appear to favour the formation of larger leaves (Van Dobben and Hoogland, 1954).

Two-rowed cultivars of winter barley usually tiller prolifically. Barling (1979a) reported that 6 tillers per plant were present in January (July), and with 290 plants/m^2 this gave a total of about 1,700 stems/m^2. Gallagher and Widdowson (1980) reported that over 2,000 stems/m^2 were present in the spring on a crop of Sonja winter barley sown in mid-September at Rothamsted. The net effect of the profusion of tillers and leaves is that full crop cover is achieved well before December (June) with an early-sown crop, and this is associated with about 2.5 t/ha of DM. This means that when temperatures warm up in the spring most of the sunlight falling on the crop is absorbed and used for photosynthesis. The crop cover also has the effect of protecting the soil from the effects of radiation frosts — albeit at the expense of some leaf burn and shedding from the plants. Barling (1981) believes that the good crop cover associated with early sowing is important in preventing winter damage in his upland, and sometimes harsh, environment. It is certainly true that late-sown crops of true winter barley can suffer badly from winter killing (e.g. Bainbridge *et al.*, 1980; Phillips, 1981).

Six-rowed barleys tiller less than two-rowed barleys (Barling, 1981). This is probably due to diversion of resources within the plant to enable the growth of a larger ear (Kirby and Riggs, 1978). The consequences of this behaviour are irrelevant to most New Zealand farmers as six-rowed cultivars tend to lose their ears in strong winds.

Growth rates in late spring and early summer are fast, often close to 200 kg/ha/day (Barling, 1981). The ratio of grain to total crop DM, the harvest index, is about 0.46 — similar to spring barley. Grain yields bigger than 8t DM/ha, equivalent to 9.5/ha at 15% m.c. have been recorded (ICI 1981, 1982; Barling, 1981).

Model

For later discussion and predictions, a model describing the response of crop growth and yield to climate will be needed. The simple model for spring barley developed by Gallagher *et al.*, (Paper 3) was modified so as to be relevant to winter barley. The average crop growth rate was left at 95 kg/ha/day but the photothermal time needed for development was increased to 950°Cd., and growth was assumed to stop from 1 November to 1 March due to cold and weak sunlight. Harvest index remained at 0.47.

This model predicted that the maximum yield expected from a mid-September sowing in central England should be about 9 t/ha (15% m.c.); a figure which agrees with the best yields reported by Selman (1980) and Gallagher and Widdowson (1980). For a November sowing in Scotland, the predicted yield was 6.9 t/ha (DM) using climatic data for Northumberland (Smith, 1976). This agrees tolerably well with a yield of 6.2 t/ha for a disease-free crop of Video winter barley sown in November at Edinburgh (Russell *et al.*, 1982). With a limiting potential soil moisture deficit of 50mm, appropriate to sandy soil, the model predicted that a crop of winter barley sown in early October should outyield a crop of spring barley sown in mid-March by about 30%. This accords well with Hart's (1980) figure of 29% from a comparison between Sonja and Goldmarker, but is a larger yield advantage than might normally be expected from the winter ecotype. These calculations suggest that this simple model is useful in interpreting gross differences arising from site, season and sowing date for well-husbanded crops. The calculations also support the idea that winter barley behaves like spring barley but needs a little more photothermal time for development.

YIELD COMPONENTS

Plants Per Unit Area

There is no doubt that it is desirable to come through winter with 200 or more plants/m^2 of ground. Farm surveys show that about 80% of the seeds sown will produce a plant in the autumn and that about 90% of these established plants will be present in the following spring (Wibberly, 1978; ICI, 1980; 1982). Severe frost lift can kill many plants. Cox (1979) reported an example of frost lift which left a plant population of only about 121 plants/m^2; this was associated with a yield depression of about 40%. In general, better yielding crops are associated with higher plant populations but this is probably not causal and may simply indicate better husbandry from the start of growth.

Ears Per Plant

Two-rowed barleys which yield well often produce around 900 ears/m^2 (Wibberly, 1978; Barling, 1981; ICI, 1980; 1983). Early sowing is often associated with good tiller survival and high ear number (Barling, 1979; Bainbridge *et al.*, 1980). This may be because growth is fast relative to development in early-sown crops, resulting in plentiful assimilate to support the growth of many tillers in the spring. Applying nitrogen early in the spring can increase ear numbers but this need not be associated with increased yields.

Grains Per Ear

Within individual experiments the number of grains per ear is frequently inversely proportional to the number of ears per unit of ground area. Gallagher and Widdowson (1980) found that early sowing gave nearly 1,000 ears/m^2, compared with only 650 for later sown treatments, but the numbers of grains per ear were 17.4 and 23.2 respectively. There is widespread belief that such yield component compensation is inevitable. It is not — at least between farms. A survey of 610 commercial crops showed that the better yielding crops not only had more ears/m^2 at harvest, but also slightly more grains per ear and heavier grain than the lower yielding crops (ICI, 1982).

Kernel Mass (1,000 grain weight)

This is an important yield component as it governs **what the product looks like to the maltster or the compounder. Many winter cultivars produce good bold** grain with a kernel mass of about 50mg, providing that conditions in early summer are good for growth (Russell *et al.*, 1982). These large grains are usually associated with large ears bearing many grains. However, Barling (1981) noted that a "disappointing feature" of heavy yielding crops grown on the thin soils of the Cotswolds was their small kernel mass. This was associated with a small specific weight of 61 kg/hl. This is of little disadvantage if the grain is to be consumed on the farm but neither maltsters nor compounders like small grains. Neither does the EEC which has strict intervention standards for percentage of screenings, and will only accept loads of grain with a specific weight equal to or greater than 67 kg/hl. To summarise: if there are many grains/m^2 the grains will tend to be smaller than if there are few; if the ears in a population bear many grain, the individual grains will usually be heavy.

HUSBANDRY

Cultivars

Until recently the rate of change of winter barley cultivars in the British recommended lists was markedly less frantic than the comings and goings of their spring counterparts. The European plant breeders have not, however, been idle and the products of their crosses are now jostling to get into 'the list'. There are three points of interest and relevance.

First, six-rowed cultivars such as Athene and Gerbel often yield best. But the compounding industry does not favour grain from six-rowed ears, though evidence that grain size has much influence on feeding quality as measured by metabolisable energy appears weak (Bayles, 1976). The other disadvantage of six-rowed barleys, as mentioned previously, is that their peduncles tend to break in strong winds. But if fields are well sheltered and the grain is fed on the farm, six-rowed barleys may be worth considering.

Second, an increasing number of new two-rowed cultivars capable of heavy yields are becoming available. These are less prone to ear loss than the six-rowed types, early to ripen, and can give good yields in Western European conditions.

Third, until recently, Maris Otter was the only winter cultivar which maltsters accepted. Indeed, they welcome it as it is harvested early in the season when their stores are empty. But the yields of Maris Otter are usually 10-15% below those of new two-rowed cultivars. Some of these such as Sonja are malted on the European mainland but extract is low and there can be other problems in processing. I believe that a replacement for Maris Otter with both good malting quality and yield will appear within the next two years. If so, the autumn sowing of barley will probably receive another fillip.

Sowing Rate

As mentioned above, a sensible aim is to establish about 250 plants/m^2. To achieve this under English conditions it is necessary to sow about 350 seeds/m^2. This assumes that 75% of the seeds sown will produce plants which survive until harvest.

Sowing Date

In England there is much controversy about sowing date. One school, lead by the Cotswold farmers, favours early sowing, September (March) if possible, as they believe that later sowing gives poorer yields in their upland environment. The more traditional school favours sowing between mid-October (April) and mid-November (May). There is probably little to be gained from joining into the controversy, for the best sowing date will depend on season, soil, area to be drilled, aspect, altitude, latitude, and climate. Season governs factors such as pests and diseases as well as weather. November (May) will not be a good time to drill if winter and heavy frosts set in early. Conversely, with early sown crops great attention must be paid to pest and disease problems if they are not, on occasion, to damage crops severely. Unless specific attention is paid to these and other factors, no optimal sowing date is likely to emerge from empirical experiments no matter how multitudinous they may be.

Despite the many factors governing their outcome, several experiments clearly show that a large yield advantage can be gained from early sowing (e.g. Sage and Roffey, 1980; Bainbridge *et al.*, 1980; Hart 1980; Selman 1980; Harris 1982). As an example, Figure 3 shows that the delaying of sowing from mid-September until November decreased yield by about 20% on lighter land at Cambridge and near Nottingham. The absolute yields from the mid-September sowing, and averaged over all cultivars grown at two sites, were 6.6 and 8.0 t/ha respectively. The loss in yield between the earliest and the latest sowings was therefore about 1.5 t/ha. The line in Figure 3 was derived by estimating yields expected from sowing on a range of dates between September and November, using the model described above with climatic data for the Midlands of England. No restrictions on yield due to drought were assumed. The fit of the calculated line to the data is adequate. This suggests that later sowing decreased yield mainly because development is faster and there is less time for growth, just as was found for spring barley (Gallagher *et al.* Paper 3). The measured yields for the best yielding cultivar at the Nottingham site and at 15% m.c. were: 9.1; 8.4; 7.5; and 7.1 t/ha. The predictions of yield from the model were: 8.9; 8.6; 7.9; and 7.3 t/ha respectively. This helps substantiate the claim that the model can be used to make fairly accurate estimates of the yields of well-husbanded crops.

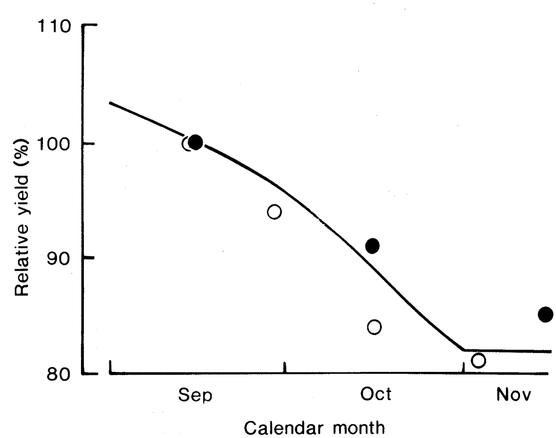

Figure 3: The response of yield expressed as a percentage of the mid-September sowing to sowing date: data of Selman (1980) (o) and Sage and Roffey (1980) (●). The line is derived from estimates made using a model described in the text.

In Canterbury barley yellow dwarf virus, carried by aphids, may be a reason for avoiding early sowing. The earliest acceptable sowing date may therefore be as late as mid-May.

Weed Control

The main problems encountered in England with a high proportion of winter cereals in rotations arise from an increase of grass weeds, in particular blackgrass, wild oats, barren brome, meadow brome, and annual meadow grass. Both farmers and weed scientists favour the practice of controlling these and broad-leaved weeds in the autumn, although a 'herbicide sequence' is sometimes needed (Lovelidge, 1977; Cutting, 1979; Barling, 1981; Dewing, 1982). Many chemicals are available for weed control, but the most expensive of these can cost more than $100/ha (ADAS 1981). Some farmers therefore prefer a combination of rotation, cultivation and herbicide for control (Dewing, 1982). This would surely be so in New Zealand.

Fertiliser

Fertiliser needs vary with soil type, rotation, winter weather, and expected yields. However, the most controversial issue in England with respect to nitrogen is not how much to put on, but when. Many farmers apply fertiliser at specific developmental stages, even if this means going on the land in January or February (July/August). This partly arises from an understandable desire to 'get things moving in the spring' (Barling, personal communication). Be that as it may, there is little experimental evidence to support the practice of applying nitrogen so early. In my opinion there is little point in applying fertiliser to crops when temperatures are too cold to allow much growth — February is, after all, the coldest month in most of England and Wales. In addition, if winter rains are heavy then much nitrogen fertiliser may be leached or denitrified before it can be taken up by the plants. Most advisers would accept the best compromise as being to apply 25-30% of the nitrogen requirement some time in March (September) and the remainder in mid-April (October). The question of when to apply fertiliser is again not easy to determine experimentally; discerning experiments need to be done which take into account the various confounding factors such as season, soil type, and mineralisable nitrogen, sowing date and quality of disease control.

Pests and Diseases

Winter barley is susceptible to many fungal diseases, including such rarities as snow rot, and to barley yellow mosaic virus (spread by the soil fungus *Polymyxa graminis).* Most of these diseases can be controlled by fungicides but constant vigilance by the farmer is needed to ensure that chemicals are used profitably. In a brief review like this, the array of diseases cannot be treated in detail. Suffice to say that if the outbreak of disease or pest is severe, then yields suffer badly (Finney and Hall, 1972; Jordan *et al.,* 1979; Martin and Morris, 1979; Cutting, 1980, 1981; Harris, 1982; Palmer, 1982). Useful handbooks on diseases and their control are published regularly in Britain (ADAS, 1981; 1982).

A specific practical problem has been the profitability of controlling mildew attacks in the autumn. Official advice recognises that such attacks can substantially decrease yields and recommends spraying "as soon as the mildew affects 10% of the area of the lower leaves" (ADAS, 1981). The importance of good disease control is hard to overemphasise. In a year when infection was severe, Harris (1982) obtained a 25% yield increase from full disease control compared with none. Yields were increased from under 6 t/ha to over 7 t/ha, with early sown crops requiring three applications of fungicide.

Growth Regulators

Barley tends to lodge when grown on fertile soils or if it receives heavy dressings of nitrogen. Plant breeders are producing varieties with stiffer straw but there are several reports that growth regulators which shorten straw will increase yields when untreated crops lodge (Petrie, 1981; Knittel, *et al.,* 1981). Growth regulators can certainly shorten barley straw if applied at the right developmental stage and when the weather is favourable, a 10-15% reduction in straw length being common (Gallagher and Widdowson, 1980; Knittel *et al.,* 1981). However, yield responses to growth regulators are often variable and sometimes they appear to damage crops slightly (Petrie, 1981; ADAS 1982). The best advice seems to be to consider using a growth regulator where there is a real risk of lodging. In Canterbury, growth regulators which shorten the upper two internodes may also find a use in preventing neck break.

Some manufacturers, notably Mandops UK, claim that their growth regulators will increase yield in the absence of lodging by decreasing the dominance of the main stem and allowing more tillers to develop. Perhaps the use of chemicals in this way should be distinguished by referring to their effects as growth 'manipulation'. The manipulators in question have not been widely tested but barley growers should be aware that such compounds exist.

Targets For Yield Components

I am not entirely convinced of the value of setting up yield component targets for farmers to aim at. But for what they are worth, here are my suggestions. First decide whether it is just grain quantity (A) or both quantity and quality (B) that are wanted. Then:

- A.1 Sow seed to establish 300 plants/m² by the spring.
- A.2 Identify factors likely to limit the growth of your crop and remove restrictions as cheaply as is possible. This should make the remaining yield components as big as possible, which is the target.
- B.1 Sow seed to establish around 200 plants/m² by the spring.
- B.2 Try not to produce too many ears/m² (600 seems a nice round number). This may mean that sowing date should be delayed and that nitrogen fertiliser should only be applied after peak tillering has been reached.
- B.3 As for A.2 above but be niggardly with nitrogen.

Financial Returns

In the 1920's the output from spring barley crops sown in the autumn, and which survived the winter, was worth about 12% more than that from a spring-sown barley crop (Hawkes, 1933). This advantage derived chiefly from better grain quality though the yields from the autumn-sown crops were slightly greater. Recent data from farms in England recorded by ICI in 1978 and 1979 showed that the value of the output from true winter barley crops was about 13% greater than for spring barley crops, i.e. almost identical to Hawkes' figures for 60 years ago. However, the greater value of the autumn-sown crop in the 70's was derived entirely from bigger grain yields; the price per tonne was less than for spring barley. The 13% better value for output from winter crops produced a gross margin only about 10% greater than for spring crops. This was because, as mentioned above, the variable costs associated with growing winter barley are large (Parry, 1981).

PROSPECTS

The prospects for winter barley hinge on three main questions: What will it yield in different climatic regions and on various soil types and at what cost? Who will buy the grain? Will the crop fit into farming systems?

In an attempt to answer the first question the model developed in this chapter was used to predict what well-husbanded winter and spring barley crops should yield in Canterbury. To adapt the model to the Canterbury climate, growth was assumed to stop from 1 June to 1 September due to cold temperatures and weak light. The equivalent period of stoppage in England was four months. The average rate of potential evaporation was set at 4.5 mm/day. An uncertainty associated with the estimated yields was derived by assuming errors of 10% applied to estimates of growth duration, average crop growth rate and harvest index.

Table 1 shows that the model estimates the yield of spring barley grown either in deep soils or with irrigation to be about 6.4 t/ha. This is close to the best yields reported at Winchmore under irrigation (Drewitt and Smart, 1981) and slightly less than the best yields achieved in recent crop husbandry competitions in New Zealand. The calculations suggest that winter barley could yield 40% more than spring barley (Table 1). This increase arises from the longer growth duration of winter barley.

Without irrigation the model predicts that the yield advantage of winter barley could be even greater, somewhere between 70 and 90% (Table 1). The extra advantage is because winter barley matures earlier and does not lose so much time to drought as do the spring-sown crops. The calculations were also made for **spring** barley sown in the autumn (Table 1). This was not difficult; a spring variety is simply expected to mature about six days earlier than a winter one. Spring barley behaves, therefore, like an early maturing winter type. Because of this it will avoid drought still better than a true winter ecotype and should yield about the same if drought occurs. It must be remembered, however, that a severe winter can kill off spring barley sown in the autumn. In this respect the relation between development stage and sensitivity to cold in spring barleys is important. Kirby and Appleyard (1980) showed that if a spring variety is sown early in the autumn development proceeds — albeit slowly in cool temperatures — because there is no vernalisation requirement. These workers also showed that the advanced stages of development which may be reached during winter if a crop is sown early in the autumn are more sensitive to cold than the earlier stages. Thus spring barley sown too early in the autumn will be at risk if a cold snap occurs in late winter or early spring. This means that there may be an 'earliest safe sowing date'. If spring varieties were to be sown in the autumn before such a date, the risk of winter kill would be unacceptably large. Bearing this possible restriction in mind, it may be that spring varieties cannot be sown early enough in the autumn in New Zealand to enable full crop cover to be reached in early spring and to profit from the faster growth rates which this brings. This problem might be overcome by grazing early-sown crops so that they enter the winter with little top growth.

The question of susceptibility to cold and time of sowing needs researching before recommendations can be confidently made. None the less, it would seem that in regions where the climate in winter is mild there is an advantage to be gained from sowing spring barley in the autumn. In harder climes, the winter hardiness of true winter genotypes will be needed.

As to the question "who will buy the grain?", the marketing of the crop is dealt with by others in this volume.

TABLE 1: Estimated yields of spring and winter barley grown in Canterbury (see text for details).

Irrigation/Soil	Yield (t/ha) Spring Barley Sown 1st October	Spring Barley Sown 1st May	Winter Barley Sown 1st May	Advantage of Winter Over Spring Sown Barley (%)
Full Irrigation (or deep silty clay)	6.4 (±1.1)	8.5 (±1.5)	8.8 (±1.6)	38
No Irrigation Limiting deficit 50 mm (light sandy soil)	3.3 (±0.6)	6.2 (±1.0)	6.3 (±1.1)	91
No Irrigation Limiting deficit 100 mm (clay loam)	3.9 (±0.7)	6.8 (±1.1)	6.9 (±1.2)	77

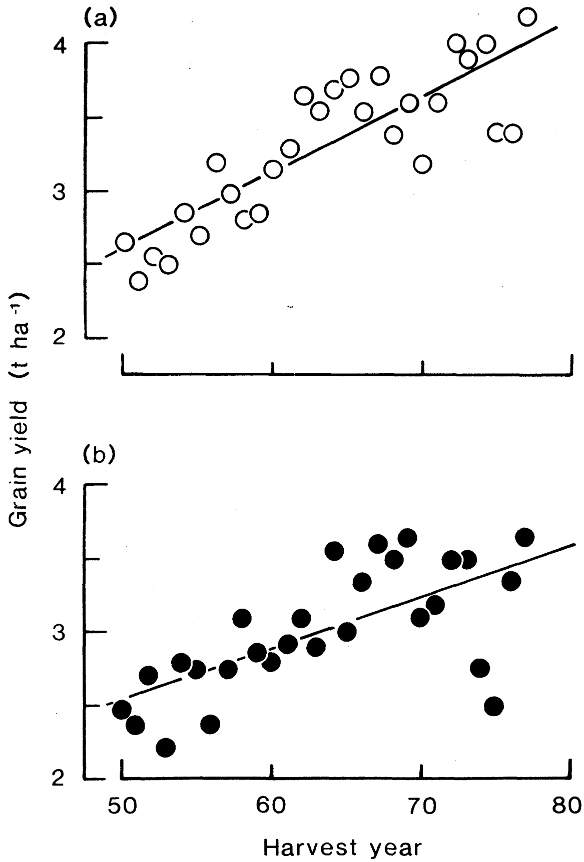

Figure 4: The yields of barley from 1950 to 1977 for (a) England and Wales and (b) New Zealand. The equations of the fitted lines are:
(a) $y = 0.052x + 0.008$ ($p < 0.001$)
(b) $y = 0.035x + 0.779$ ($p < 0.001$)

The answer to this question largely determines whether the crop will fit into farming systems. The short answer must be that winter barley will be fitted into a farming system if it is profitable to grow and if the farmer has the skill to grow it well. Profit may come from large yields, or lucrative export or malting contracts, or both.

With respect to yield, the comparison of the rate of increase of the national barley yields between England and New Zealand is worth comment (Fig. 4). The rate of increase in England and Wales is about 52 kg/ha/yr, nearly 50% faster than the rate of increase in New Zealand. More interesting still is the rate of increase of winter barley yields in Schleswig — Holstein. Between 1965 and 1981 a fairly stable increase of 120 kg/ha/yr was achieved, taking yields from 3.6 to 5.4 t/ha (Anon. 1981). The farmers in this region of Germany are skilled and the climate and soils generally favourable; but could it be that the high and stable price for grain within the EEC affects yield trends more than hot summer days in Canterbury?

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REFERENCES

ADAS 1981. Winter Barley. London: Ministry of Agriculture Fisheries and Food, Agricultural Development and Advisory Service.

ADAS, 1982. Use of Fungicides and Insecticides on Cereals. 1982. London: Ministry of Agricultural Fisheries and Food, Agricultural Development and Advisory Service.

Anonymous. 1977. Die Ernten und ihre Verwertung. Kiel, W. Germany: Ministerium fur Ernahrung, Landwirtschaft und des Forsten Landes Schleswig-Holstein.

Anonymous. 1978. Time for a new look at winter barley. *Arable Farming, 5 (2):* 41.

Anonymous. 1980. We need to know a lot more about winter barley. *Arable Farming, 7 (3):* 103-107.

Anonymous. 1981. Die Ernten und ihre Verwertung. Kiel, W. Germany: Ministerium for Ernahrung, Landwirtschaft und des Forsten Landes Schleswig-Holstein.

Anonymous. 1982. Record cereal drilling. *Farmers Weekly, March 5.* 43.

Bainbridge, A., Finney, M.E. Jenkyn, J.F. 1980. The influence of cultural factors and mildew on yield of winter barley. *Journal of Agricultural Science, Cambridge, 94:* 389-397.

Barling, D.M. 1979a. Development of Sonja winter barley. In: The Yield of Cereals (Ed. Cereal Unit), National Agricultural Centre, Stoneleigh, Warwickshire, England, Cereal Unit, 65-69.

Barling, D.M. 1979b. Winter barley study. National Agricultural Centre, Stoneleigh, Warwickshire, England: Cereal Unit.

Barling, D.M. 1981. Winter barley development work on the Cotswolds. *Journal of the Royal Agricultural Society of England: 142,* 156-164.

Bayles, R. 1976. Poorly filled grain in the cereal crop. II. The relationship of poor grain filling to processing quality. *Journal of the National Institute of Agricultural Botany 14:* 241-249.

Bell, G.D.H. 1944. The breeding of two-row winter-hardy barley. *Journal of Agricultural Science, Cambridge, 34:* 223-238.

Clarke, G.J. 1965. Cereal Production in East Anglia. *Journal of the National Institute of Agricultural Botany 10:* 341-343.

Cox, A.E. 1979. Frost damage to winter barley. *Plant Pathology 28:* 25-26.
Cutting, O. 1979. New ways with cereals bring new weed problems. *Arable Farming, 6 (8):* 49-51.
Cutting, O. 1980. Virus poses serious threat to winter barley. *Arable Farming, 7 (9):* 22-24.
Cutting, O. 1981. Getting organised to combat BYDV threat. *Arable Farming, 8 (10):* 24-28.
Day, W., Legg, B.J., French, B.K., Johnston, A.E., Lawlor, D.W., Jeffers, W. De C. 1978. A drought experiment using mobile shelters: the effect of drought on barley yield, water use and nutrient uptake. *Journal of Agricultural Science, Cambridge 91:* 599-623.
Dewing, R.T. 1982. Light land cereal growing. Reduced labour, cultivation, seedbed preparation and weed control. *Aspects of Applied Biology 1:* 21-24.
Van Dobben, W.H., Hoogland, R.F. 1954. De invloed van de temperatuur op de bladlengte va granen. Verslag van het Centraal Instituut voor Landbouwkundige Onderzoek over 1953, 97-101.
Drewitt, E.G., Smart, J.G. 1981. Effect of irrigation and nitrogen fertiliser on the yield and malting quality of barley. *Proceedings of the Agronomy Society of N.Z. 11:* 23-28.
Finney, J.R., Hall, D.W. 1972. The effect of an autumn attack of mildew (*Erysiphe graminis*) on the growth and development of winter barley. *Plant Pathology 21:* 73-76.
Gallagher, J.N., Widdowson, F.U. 1980. Winter barley: effects of sowing date, timing of nitrogen and a growth regulator. *Report, Rothamsted Experimental Station for 1980.* 23-24.
Harris, P.B. 1982. Pointers on winter barley husbandry. *Arable Farming, 9 (1):* 26.27.
Hart, R. 1980. Which way with winter barley? *Arable Farming, 7 (1):* 75-76.
Hawkes, F.C. 1929. Varieties of cereals for autumn sowing. *Journal of the National Institute of Agricultural Botany 2:* 124-131.
Hawkes, F.C. 1933. Cereal crops in Essex, 1927-1929. *Journal of the National Institute of Agricultural Botany 3:* 236-257.
I.C.I. 1980. Pointers to Profitable Winter Barley. Billingham, Cleveland, England. Imperial Chemical Industries Limited. Technical Services Group.
I.C.I. 1982. Pointers to Profitable Winter Barley. Billingham, Cleveland, England. Imperial Chemical Industries Ltd. Technical Services Group.
Jordan, V.W.L., Tarr, H.S., Baines, C.R. and Miles, D.M. 1979. Barley leaf blotch (*Rhynchosporium secalis*). Disease control trials. *Annual Report of Long Ashton Research Station for 1979.* 134-135.
Kirby, E.J.M. 1969. The effect of sowing date and plant density on barley. *Annals of Applied Biology 63:* 513-521.
Kirby, E.J.M., Appleyard, M. 1980. Morphogenesis. Annual Report of the Plant Breeding Institute, Cambridge, for 1980: 99-100.
Kirby, E.J.M., Riggs, T.J. 1978. Developmental consequences of two-row and six-row ear type in spring barley. 2. Shoot apex, leaf and tiller development. *Journal of Agricultural Science, Cambridge, 91:* 207-216.
Kirby, E.J.M., Appleyard, M., Fellowes, G. 1982. Effect of sowing date on the temperature response of leaf emergence and leaf size in barley. *Plant, Cell and Environment, 5:* 477-484.
Knittel, H., Behrendt, S., Schott, P.E. 1981. Einflus eines Wachstums-regulators auf Wachtsum und Ertrag von Wintergerste bei unterschiedlichem Lagerdruk. *Zeitschrift fur Acker und Pflanzenbau 150:* 50-61.
Kramer, C., Post, J., Wilten, W. 1952. Brouwgerst en Klimaat. Mededeling van het Nationale Comite voor Brouwgerst, No. 18.
Lovelidge, B. 1977. Precision cereal growing pays off with high yields. *Arable Farming, 4 (8):* 52.53.
MAFF. 1960-1980. Agricultural Statistics, England and Wales. (Published annually). London: Ministry of Agriculture, Fisheries and Food, H.M.S.O.
Martin, T.J., Morris, D.B. 1979. The development of the systemic fungicide Bayleton for the control of foliar diseases in spring and winter barley in the U.K. *Pflanzenschutz Nachrichten Bayer 32:* 31-79.
N.Z. 1961-1980: New Zealand Official Yearbook. Published annually. Wellington: Department of Statistics.
Palmer, M. 1982. Winter barley treatments. *Big Farm Management.* January, 23-24.
Parry, J. 1981. All change in spring barleys. *Big Farm Management.* January, 21-22.
Petrie, E. 1981. The trouble with barley growth regulators. *Big Farm Management.* March, 13-15.
Phillips, M.C. 1981. Mixed results with winter barley. *Arable Farming, 8 (1):* 58-61.
Robinson, D.H. 1948. "The New Farming" London: Faber and Faber.
Rumsey, G. 1979. Winter barley: a winner if we can master the art of growing it. *Arable Farming, 6 (1):* 43.
Russell, G., Ellis, R.P., Brown, J., Milbourn, G.M., Hayter, A.M. 1982. The development and yield of autumn- and spring-sown barley in south east Scotland. *Annals of Applied Biology 100,* 167-178.
Sage, G.C.M., Roffey, A.P. 1980. Winter barley. *Annual Report of the Plant Breeding Institute Cambridge for 1980,* 29-32.
Selman, M. 1980. Ways of increasing the yield of winter barley. *Arable Farming, 7 (9):* 82-85.
Smith, L.P. 1976. The Agricultural Climate of England and Wales. Ministry of Agriculture Fisheries and Food, Technical Bulletin 35, London; Her Majesty's Stationary Office, pp. 147.
Trione, E.J., Metzger, R.J. 1970. Wheat and barley vernalization in a precise temperature gradient. *Crop Science 10:* 390-392.
Wibberley, E.J. 1978. A Discussion of the Cereal Unit's Winter Barley Project. National Agricultural Centre, Stoneleigh, Warwickshire, England: Cereal Unit.

DISCUSSION

Malcolm: New Zealand used to grow a relatively large amount of winter-sown barley in Marlborough; Canterbury round Dunsandel, Southbridge; Central Otago round Hawea Flat. There were 2,000 ha of winter barley grown round Hawea Flat until after World War II; 600 ha in Marlborough and another 4-600 ha in Canterbury. Hawea Flat grew the best quality barley in NZ but it was the old Plumage Archer winter sown.

Yield wise round Dunsandel, Pioneer barley, a PBI winter barley, averaged 2.5 t/ha with little fluctuation from year to year; spring barley would yield 1.5 t one year in five up to 3.5 t/ha one year in five; the rest of the time it was about the same as the winter barley. On average the spring barley yielded better but was less consistent.

Gallagher: That is extremely similar to what happened in the U.K. Plumage Archer was an autumn-sown spring barley with a high quality sample. One year in 10 it might be winter killed badly and it would have to be resown in the spring. Pioneer never really yielded as well as the spring cultivars. An early sown spring cultivar in a good season can out-yield easily a late sown winter cultivar, but give both the cultivars a good chance and the winter sown nowadays will out-yield the spring sown.

Malcolm: Birds can be a problem.

Gallagher: At NIAB they have to have cages for their winter barley trials.

Scott: If farmers are interested in sowing winter barley now what should they use?

Stolk: Pyne Gould Guinness have two winter barleys on the National List, a six row and a two row, but there is no seed left.

Coles: I would suggest an erectoid type such as Gwylan, Goldmarker, Magnum or Universe. These are late starting in the spring and would benefit from the earlier sowing. They have the yield potential when spring sown so should be even better autumn sown.

Stolk: We have compared autumn sown Ark Royal with true winter barley and Ark Royal did not perform as well, with greater disease.

Gallagher: We should get some seed of two row winter barleys from Western Europe and try them.

Patchett: We have some experience with winter barleys. This year we sowed Sonja, and Maris Otter in the first week of May and they looked like 10 t/ha crops, until between Christmas and New Year a severe nor'wester reduced the crops to 4 t/ha. In my opinion the conventional types of winter barley have some very serious deficiencies.

Gallagher: That was a "necking" problem with the ears falling off?

Patchett: Right off.

Gallagher: That is a problem in Scotland as well with high winds. One of these compounds like "Cerone" can solve this problem. It shortens the stem; although I'm not generally in favour of chemicals they may be useful for this problem.

Robertson: Later sowing winter barley in the U.K. had a detrimental result: should we be considering sowing in March-April?

Gallagher: There is probably more growth in May and August in N.Z. than the equivalent months in the U.K. and therefore sowing can probably be later in N.Z. than the U.K.

Newton: Given that the barley in the Manawatu is later anyway would you think that winter barley could be sown there too.

Gallagher: When I went to the Manawatu it rained every 4 hours — I guess you drill it between the showers. There may be a vernalisation problem for true winter barley but I doubt it.

Kearney: What stage is winter barley at when spring sowings are being made, especially with reference to frost.

Gallagher: Frost is a problem. Anthesis will occur in early November. The possibilities of frost still exist. The aim would be to have flowering occur late enough to avoid frost but early enough to avoid drought. The true winter barleys are pretty frost hardy.

Coles: In a nursery of about 100 lines of winter barley all headed late October - early November, about a week earlier than autumn wheat, but flowering is protected by more plant tissue than in wheat. This added protection should be enough.

Gallagher: I have that feeling as well: ground frost is not the problem but air frost.

Gaunt: Pathologists would be concerned about the use of winter barley; however we will accept the challenge if it does occur and will work to minimise disease problems.

Smart: Maltsters having been accused earlier of being conservative, I would point out that I can see a real advantage in a malting quality winter barley — early harvest. Most years the best quality crops are the early harvested ones.