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INTERACTIONS BETWEEN VARIETY AND SOWING DATE FOR WINTER WHEAT AND WINTER BARLEY

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INTERACTIONS BETWEEN VARIETY AND SOWING DATE FOR WINTER WHEAT AND WINTER BARLEY

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ABSTRACT

During the last decade the area of winter wheat has increased considerably. At the same time winter barley has gained popularity at the expense of spring varieties. These trends tended to exaggerate the autumn work peak on many intensive arable farms leading to an increasing proportion of crops being sown during September. Results of sowing date experiments carried out in the 1970s showed that although late September or early October was generally the optimum sowing date for winter wheat, delaying until November generally incurred more severe yield penalties than sowing in mid-September. The increased efficacy of agrochemicals also reduced the weed, pest and disease problems traditionally associated with managing early-sown crops.

Preliminary investigations undertaken during the late 1970s suggested that certain varieties of winter wheat and winter barley were more suitable for early (or relatively late) sowing than others. Consequently, trials were carried out by the Plant Breeding Institute (PBI), and the Agricultural Development and Advisory Service (ADAS) in collaboration with the National Institute of Agricultural Botany (NIAB) to test for varietal interactions with sowing date.

The purpose of this paper is to review data from variety by time of sowing experiments carried out in England and Scotland up to 1987 and to establish which varieties were most suitable for early or late autumn sowing.

Winter wheat

The ADAS/NIAB trial series tested 32 varieties between 1982 and 1987 with the majority retained for three consecutive years. Three sowing dates were compared; mid-September (early), late September (normal) and mid-October (late) using a split-plot experimental design. Trials were managed to ensure that weed, pest or disease attack did not penalise the early sowings. Yield data from each site were aggregated to provide annual and over-years summaries. The PBI trials were undertaken using a similar technique, although sowings continued until January.

Variety by date of sowing trials generally confirmed that late September was the optimum sowing date for winter wheat, but seasonal and site effects were considerable. November and December sowings frequently incurred severe yield penalties, and there were indications of superior performance from spring wheat varieties when sowing was delayed to this extent. This was confirmed by a recent trial series comparing winter and spring varieties sown between late autumn and early spring.

Variations between sites and seasons tended to obscure varietal interactions with sowing date, but despite this clear trends were apparent in most trials. In terms of yield, Longbow, Norman, Brigand and Vuka were the most suitable varieties for mid-September sowings, and tended to perform equally well when sown at any time between mid-, and late September. Other varieties tending to exhibit similar behaviour were Virtue, Rapier, Hustler and Aquila, although for these the data were less conclusive. Conversely, mid-September sowing reduced the yield of Brimstone, Renard, Stetson, Avalon, Galahad, Fenman and Brock, and the optimum sowing date for these varieties was generally late September. Slejpner and Mercia demonstrated a useful degree of flexibility by showing little sensitivity to sowing dates from mid-September to mid-October. Bounty, Mission and Armada performed similarly to Slejpner and Mercia, but these varieties were tested at a time when a high proportion of trial sites included only two dates of sowing making the identification of trends more difficult.

This was especially so for Armada where early sowings were infected frequently and severely by common eyespot.

Straw length was increased by early sowing, and varieties with poor inherent standing power, such as Brimstone, suffered earlier and more extensive lodging. There was some evidence that the relative performance of these varieties could be improved when sown early by the use of plant growth regulators. Brigand, Virtue and Norman with good standing power, were among the varieties most suitable for early sowing.

Variety by date of sowing trials and surveys of commercial crops demonstrated that the severity of common and sharp eyespot, Septoria tritici and occasionally take-all were increased by early sowing. Varieties with a high degree of susceptibility to these diseases frequently gave relatively low yields when drilled early.

Early sowing tended to reduce thousand grain weight and specific weight, often in association with high fertile tiller numbers or early lodging, and occasionally varietal interactions were detectable. At certain trial sites a relationship was observed between early drilling and the size of the plants in winter leading to increased frost damage from mid-September sowings.

Trials have demonstrated that the interactions between variety and sowing date are relatively small for winter wheat, and generally no more than $\pm$ 0.25 t/ha for the normal range of autumn sowings, between mid-September and mid-October. These differences are smaller than the yield variation associated with site or season, and the effects of lodging or disease control. Despite this, however, certain winter wheat varieties suffer economically significant yield losses when sown too late, or too early. These require careful scheduling into the sowing programme to achieve optimum yield. Conversely, some varieties yield consistently over a range of sowing dates and are, therefore, useful for situations where crop sowing date is uncertain, for example, where winter wheat follows cash roots.

Winter barley

The ADAS/NIAB trial series tested 26 varieties between 1984 and 1987 when sown in mid-September and mid-October. At a few sites early-September sowing was also included. The experiments were conducted using a technique similar to that adopted for winter wheat.

Apart from 1985 (when sowing date had little effect), yields were higher from mid-September than mid-October sowing, although the degree of difference varied from season to season.

Halcyon tended to give the greatest response to early sowing with the highest yields achieved from mid-September (or sometimes early September) drilling. The six-rowed varieties Pirate and Gerbel performed similarly to Halcyon but were included in trials for only one year. The majority of other varieties tested also tended to give higher yields from mid-September than mid-October sowing, including Monix, Pipkin, Nevada, Marinka, Concert, Magie, Torrent and Vixen, although for these varieties the trends were less clear than for Halcyon.

Panda responded less to early sowing than other varieties, giving little or no yield increase in favourable years and a reduction in 1985 when early sowings were generally penalised. Maris Otter and Kaskade showed a similar, but less distinct trend.

Sowing in mid-September increased fertile tiller numbers, but although varietal differences were occasionally observed, they were not correlated with yield. Straw length and lodging levels were generally reduced by early sowing, and there was a tendency for weak-strawed varieties such as Halcyon and Pipkin to give higher yields when sown early. Conversely, Panda with strong straw performed relatively well when drilled in mid-October. As with wheat there was a tendency for early sowing to reduce specific weight, but the data were inconsistent. Early drilling tended to give higher levels of foliar disease in the autumn, but these were controlled following fungicide application.

ADAS/NIAB trials conducted between 1984-87 showed that yield variation between trial sites averaged approximately 2.0 t/ha for most winter barley varieties, but the effects of season did not generally exceed 0.4 t/ha. The mean difference between mid-September and mid-October sowing was 0.48 t/ha. As with winter wheat, however, an understanding of interactions between variety and sowing date is necessary because certain commercially important varieties have tended to give the optimum yield when sown slightly later than most others.

Recommendations for further action

Variety by date of sowing trials conducted to date have been affected by considerable variations between sites and seasons, which tended to obscure varietal interactions. In addition, the monitoring of trial sites was frequently insufficiently intensive preventing the interpretation of observed differences between sites, seasons, and experimental treatments. Nevertheless, the data has proven useful and varietal sensitivity to sowing date cannot be determined solely on the basis of characteristics such as standing power and disease resistance observed in other trials. Continued screening of new varieties is, therefore, essential. In order to optimise resources and detect smaller treatment differences than previously, experimental techniques should be revised.

a) Winter wheat

i. All trials should include three sowing dates, and top priority should be given to sowing during the target periods.

ii. All trials should be located on ADAS Experimental Husbandry Farms, or other institutes offering similar facilities. Once established, trials should not be relocated in subsequent years, and consideration should be given to maintaining a similar rotational position from year to year.

iii. Where possible, sowing date treatments should be fully randomised but this would be possible only on lighter, easily worked soils.

iv. A more intensive monitoring regime should be adopted for these trials using techniques developed for validation of the AFRC wheat growth model. Plant, tiller, and ear numbers should be recorded at specified growth stages, together with measurements of above ground dry weight. Winter hardiness, lodging and levels of disease should be recorded, in all future experiments, using uniform assessment techniques.

The technique described above is necessary for a full understanding of the data, but the cost of such work is high, particularly compared with the relatively small interactions between variety and sowing date detected to date. Consideration should therefore be given to alternative experimental designs to obtain the minimum essential data. Wheat varieties could, for example, be sown on unreplicated small plots, at 7 to 10day intervals, over a 70 day period, and yield data interpreted by regression analysis. Minimal recording of crop development would be required. The objective of this experiment would be to establish a relationship between apical development rate and variety/sowing date interactions. If successful, varieties could be screened subsequently by measuring apical development rate only.

b) Winter barley

Previous trials have been less valuable than similar winter wheat experiments, giving fewer indications of interaction between varieties and sowing date. Their continuation should, therefore, be given lower priority. As with winter wheat, however, better data would be obtained by more consistent monitoring of plant and tiller numbers, lodging and levels of disease. Similarly, consideration should be given to the adoption of three sowing date treatments.

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GLOSSARY OF TERMS

Analysis of variance (ANOVA)	- A statistical technique which examines the variation within a whole group of means, and allows comparisons to be made between selected means.
Coefficient of regression	- In this context a relationship between grain yield and sowing date was defined; varieties were examined to determine how closely they conformed to this relationship.
Coefficient of variation (CV)	- Gives an overview of the accuracy of a trial, and generally the smaller it is the more accurate the trial. This is not necessarily so as a high yield can mask relatively high experimental error.
Interaction	- Where the effects of two experimental treatments (in this case sowing date and variety) do not vary independently and are not,therefore, purely additive.
Least significant difference (LSD)	- Pairs of means which differ by more than one LSD may be regarded as significantly different at the level of probability employed (usually P = 0.05; i.e. there is a 95% probability that a difference between two means in a treatment effect, and not due to error).

INTRODUCTION

The aim of this paper is to review work on interactions between date of drilling and variety for winter wheat and winter barley conducted in England, Wales and Scotland up until 1987. Special emphasis has been given to work not published elsewhere, with a view to identifying interactions, and making recommendations on future experimental work.

The area of wheat grown in the United Kingdom increased from approximately 1,231,000 ha to 1,997,000 ha between 1976 and 1986 (Anon, 1976; 1986a). At the same time, winter barley increased in popularity and exaggerated the autumn work peak on intensive cereal growing farms, tending to bring forward the start of autumn drilling from October to September.

Winter wheat

A series of 77 date of drilling trials carried out between 1958 and 1980 were reviewed by McLean (1981) and showed that the optimum sowing date for winter wheat was usually early October. These studies also indicated that yields tended to be higher from September than November drilling. Intensive cereal growers were, therefore, advised to begin work in September to avoid the risk of work being delayed until late autumn, when conditions were frequently unfavourable. Further data reported by Walker (1980) and Rule (1983) confirmed these findings.

In some of the preliminary field trials, September sowings frequently suffered more severely from the effects of weeds, pests and diseases, which obscured potential yield increases from earlier drilling. In more recent experiments these problems were largely eliminated by appropriate management, but could not be entirely discounted.

In commercial cereal production the various agronomic problems associated with early sowing must also be taken into account, because their alleviation by agrochemicals can increase variable costs, possibly negating other benefits. Three years of field trials (Anon, 1986b) showed that September-sown wheat did not respond to extra autumn fertiliser, or agrochemical inputs, unless specific problems were encountered. Routine insurance applications were not, therefore, justified. As experimental evidence accumulated, advisory guidelines on sowing dates and the management of early sown crops were updated by the Ministry of Agriculture, Fisheries and Food (Anon, 1982; 1985a & 1986b).

Detailed studies by Gallagher and Biscoe (1978) demonstrated that crop dry-matter accumulation was proportional to the quantity of solar radiation absorbed by the crop canopy; Green (1985) suggested that yield variations between sowing dates were largely determined by changes in dry matter accumulation. Trials carried out at the University of Nottingham (Green and Ivins, 1985) related these theoretical studies to crop performance in the field, demonstrating that no further yield increases occurred from early September drilling despite greater biomass accumulation, due to high levels of disease.

Many earlier workers suggested that interactions may occur between sowing date and variety, although direct evidence for this was lacking. The effects of varietal characteristics such as standing power, winter hardiness and disease resistance were discussed by Green and Smith (1985), but the first systematic study of modern winter wheat varieties was carried out by Bingham et al. (1986). This study revealed the existence of interactions between sowing date and variety. Consequently, guidelines were given on the relative suitability of different varieties for earlier, or later drilling.

A more extensive trial series on variety by sowing date interactions was initiated in 1982 by the Agricultural Development and Advisory Service (ADAS) in collaboration with the National Institute of Agricultural Botany (NIAB). The results of these experiments have not been published, and summary data and conclusions are discussed in detail herein. Similarly, this review article includes a summary of an unpublished statistical investigation into the response of winter wheat varieties to time of sowing, based on data generated from variety trials carried out by the Scottish Agricultural Colleges.

Winter barley

A number of workers have investigated the effect of sowing date on winter barley. Green et al. (1985) compared successive sowings of Igri between early September and mid-November, and concluded that yield of grain declined as drilling was delayed; losses were related to a decrease in fertile tiller and grain number per unit area. Other experiments, however, have demonstrated little difference in yields between mid-September and mid-October drillings of Igri (Anon, 1985c). ADAS experiments carried out since 1979 were reviewed by Martindale (1984) who concluded that the response of winter barley to early drilling was influenced by soil type, geographical location and seasonal weather conditions. Provided these factors were taken into account, advisory guidelines could be given on the optimum date of sowing under any given conditions - although the possible need for extra agrochemical inputs on early-drilled crops had to be carefully considered.

Preliminary investigations of interactions between variety and sowing date in winter barley reported by Selman (1980) and Kirby (1980), showed that varieties exhibiting a rapid rate of primordium development suffered considerable winter damage when sown early. A coordinated trial series was initiated by ADAS and the NIAB to test new and established varieties for variety and sowing date interactions. The unpublished data collected is summarised and reviewed here in detail.

ADAS/NIAB - WINTER WHEAT VARIETY AND TIME OF SOWING EXPERIMENTS (1982-87)

Introduction

The primary objective of this experiment was to investigate the effect of early drilling on new varieties. This work was necessary because many commercial crops were sown earlier than most official trials, and data were required to determine whether or not varietal yield potential changed under such circumstances.

A total of 52 site/years of experimental data was collected between 1982 and 1987 and is reviewed here; work continues during 1988.

Materials and methods

A total of 32 varieties was tested over six years (Table 1). Avalon and Longbow were included for the duration of the experiment as control varieties, but most of the others were retained for three consecutive years. Guardian, Boxer, Renard, Ambassador, Corinthian, Maris Huntsman and Minaret were tested for one year only and Dauntless, Hornet and Parade were introduced in 1987. The seed of all varieties was treated with single-purpose organo-mercury dressing.

The target drilling dates were approximately 7-23 September (early), 24 September-10 October (normal) and 11-20 October (late) but the extent to which these were achieved varied considerably. In the early years of the experiment the majority of centres had two sowing date treatments, early and late, but by 1985 most were achieving three. Weeds, pests and diseases were controlled to ensure that the early drillings were not affected unduly, for example, by the use of overall insecticide application to control Barley Yellow Dwarf Virus (BYDV). Fertiliser was applied at the optimum level for each site. Plant and fertile tiller numbers were recorded, together with lodging indices and disease assessments as appropriate. Grain yields were measured and moisture content, specific weight and thousand grain weight were recorded, together with Hagberg Falling Number at certain sites.

Table 1. Summary of varieties tested, during the ADAS/NIAB winter wheat variety and time of sowing experiment, 1982-87 (√, tested; -, untested).

Variety	Year 1982	1983	1984	1985	1986	1987
Ambassador	-	-	-	-	√	-
Aquila	√	√	√	-	-	-
Armada	√	√	√	-	-	-
Avalon	√	√	√	√	√	√
Bounty	√	√	-	-	-	-
Boxer	-	-	-	√	-	-
Brigand	√	√	√	-	-	-
Brimstone	-	-	-	√	√	√
Brock	-	-	-	√	√	√
Corinthian	-	-	-	-	√	-
Dauntless	-	-	-	-	-	√
Fenman	√	√	√	-	-	-
Galahad	-	-	√	√	√	-
Gawain	-	-	-	√	√	-
Guardian	√	-	-	-	-	-
Hornet	-	-	-	-	-	√
Hustler	√	√	-	-	-	-
Longbow	√	√	√	√	√	√
Maris Huntsman	-	-	√	-	-	-
Mercia	-	-	-	-	√	√
Minaret	-	-	√	-	-	-
Mission	-	√	√	√	-	-
Moulin	-	-	√	-	√	√
Norman	√	√	√	-	-	-
Parade	-	-	-	-	-	√
Rapier	√	√	√	-	-	-
Renard	-	-	-	√	-	-
Rendezvous	-	-	-	-	√	√
Slejpner	-	-	-	-	√	√
Stetson	-	√	√	-	-	-
Virtue	√	√	√	-	-	-
Vuka	√	√	√	-	-	-

Treatments were replicated three times and arranged in a split-plot design with sowing dates constituting the main plots, and varieties the sub-plots. Data from individual sites were aggregated and treatment means were subjected to an analysis of variance.

Results

Harvest year 1982: Six sites (Northumberland, Essex, Boxworth EHF, Norfolk, Gloucestershire and Devon) were included in the over-site analysis. Drilling dates ranged from 8-23 September (early) to 13 October-5 November (late).

The mean yield of the controls was 8.02 t/ha with an average yield advantage of 4% in favour of early sowing (Fig. 1a). Brigand, Hustler, Norman, Rapier and Vuka tended to give the greatest response, and Armada, Avalon, Bounty and Guardian the least, but differences were relatively small. The performance of these varieties was consistent at three out of the six individual centres, but not at Norfolk, Gloucester and Devon.

At Boxworth EHF early, medium and late-drilling treatments were established. Hustler and Norman gave a yield penalty from late drilling together with Armada and Longbow. Armada was not adversely affected by late sowing in other trials, and the reasons for this result were unclear. Fenman and Vuka yielded more at the medium than either early or late sowing dates. Green leaf area assessments carried out on 14 July revealed a decline with progressively earlier sowing for all varieties.

Harvest year 1983: Trials were carried out at a total of eight sites (Cumbria, Essex, Boxworth EHF, Norfolk, Bedfordshire, Suffolk, Wiltshire and Devon). The sowing dates achieved were 1-23 September (early) and 11-31 October (late).

Over-site analysis revealed a mean benefit of 4% to early sowing for the control varieties (Fig. 1b). This agreed with 1982 results. Vuka, Brigand and Norman were the most responsive to early sowing;

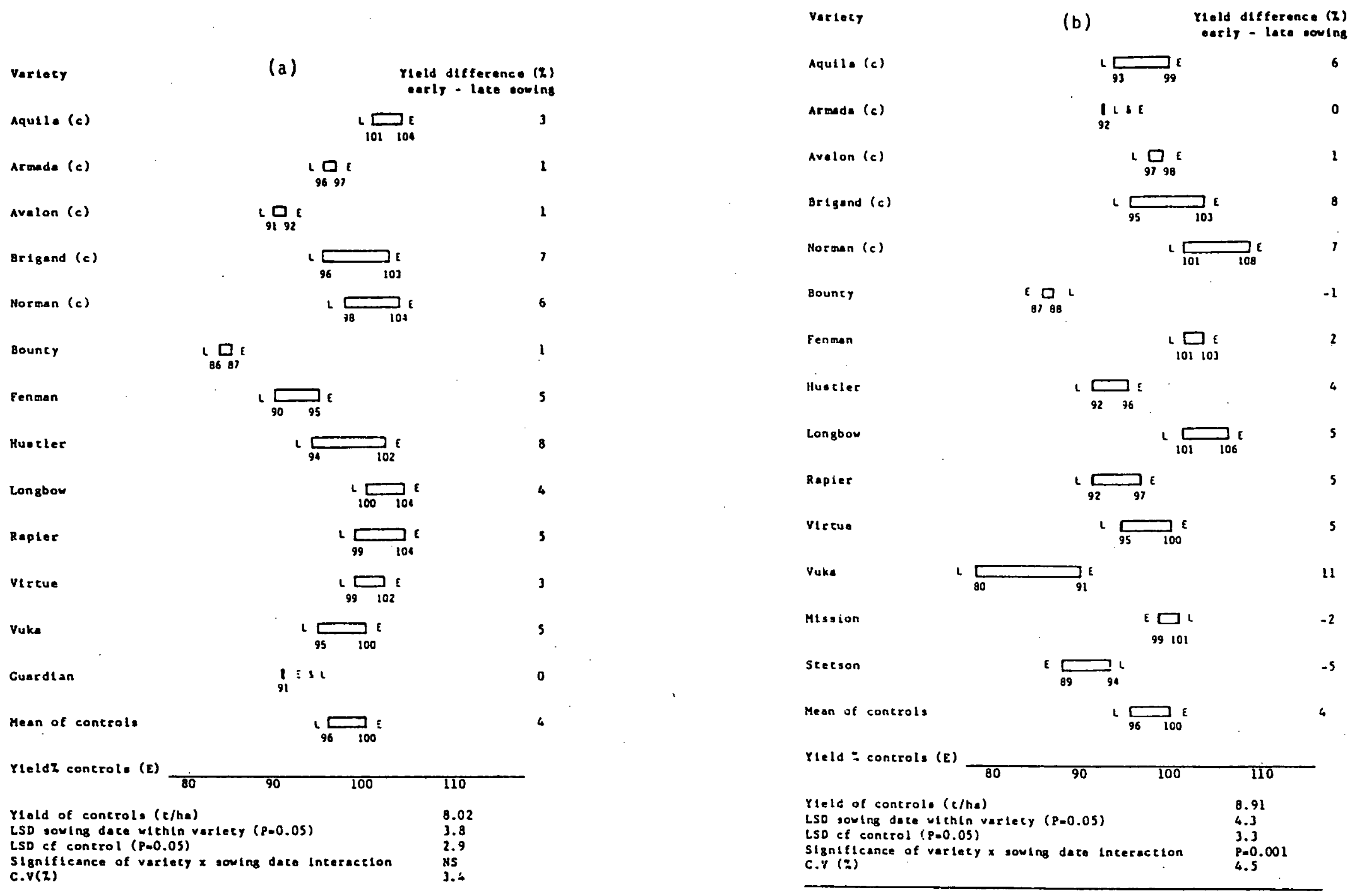

Fig. 1. Effect of early and late sowing date on grain yield of winter wheat. (a) 1982; (b) 1983. Yields expressed as a percentage of Aquila, Armada, Avalon, Brigand and Norman at the early date of sowing E, Early Sowing; L, Late Sowing

Vuka was more responsive than in 1982 but had low absolute yields. Aquila, Longbow, Rapier and Virtue also gave higher yields when sown early. Avalon, Armada, Bounty and Mission were insensitive to drilling date, repeating a trend apparent in the previous year and Stetson suffered a yield penalty of 5% from early sowing. In Cumbria, there was a tendency for higher levels of take-all from early sowing. Norman and Armada were affected most and Fenman, Longbow and Rapier least, although this was not related to grain yield on which eyespot and lodging exerted a greater influence.

Early, medium and late treatments were included at Boxworth EHF and Bedfordshire. The first sowing date achieved at Bedfordshire was 1 September and tended to give a slight yield reduction compared with 22 September, with the possible exception of Norman and Longbow. An increase in fertile tiller numbers was noted as sowing was progressively delayed at this centre, except for Armada and Mission which also gave higher yields when sown later.

Harvest year 1984: Yield data from nine sites (Gleadthorpe EHF, Boxworth EHF, Bridgets EHF, Lincs, Durham (2), Suffolk, Wiltshire and Devon) were subjected to over-site analysis (Fig. 2a).

There was an apparent benefit of 6% to early sowing for the control varieties, as in previous years, but this was not statistically significant. Yields of Brigand and Vuka were increased most by early sowing, as in 1983, and again Longbow and Virtue were responsive. The remaining varieties were relatively insensitive to sowing date, with Armada, Stetson, Fenman, Mission and Avalon tending to be affected least.

Three dates of sowing were included at Gleadthorpe EHF, Boxworth EHF, Bridgets EHF and Suffolk. At these sites, late-September drilling tended to give higher yields than later, or to a lesser extent earlier sowing. The sensitivity of varieties to date of sowing at these centres was similar to that elsewhere. Mean drilling dates were slightly earlier in 1984 than in previous years.

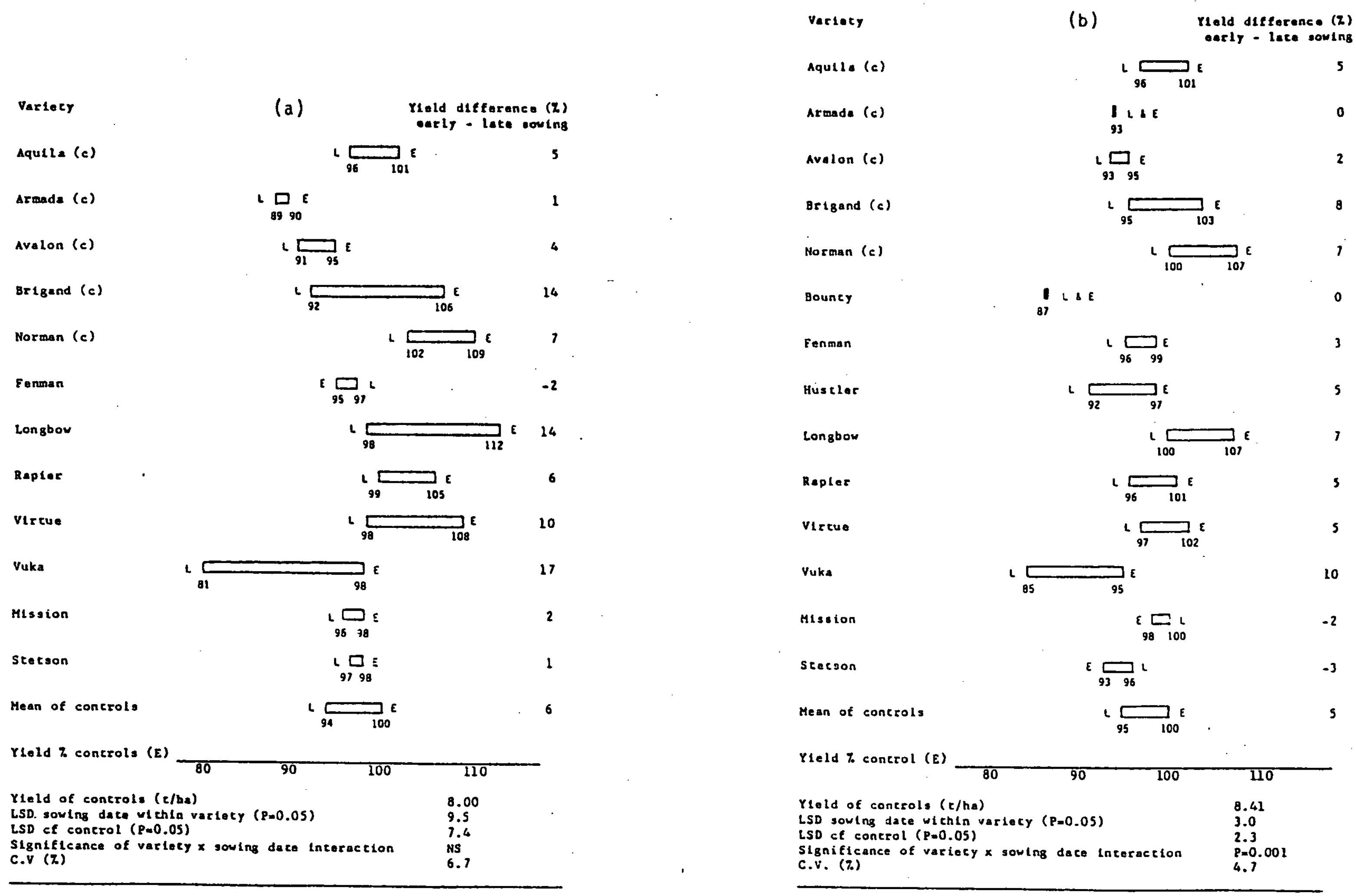

Fig. 2. Effect of early and late sowing date on grain yield of winter wheat. (a) 1984; (b) 1982-84. Yields expressed as a percentage of Aquila, Armada, Avalon, Brigand and Norman at the early date of sowing E, Early Sowing; L, Late Sowing

Harvest years 1982-84: An over-years analysis was carried out combining data from each season between 1982 and 1984, and varieties tested for two or more years during this period. The resulting data matrix included 14 varieties and 18 site/years of experimentation combinations (Fig. 2b).

The majority of varieties gave higher yields when sown in mid-, to late September compared with October. The mean increase for the control varieties was 5%, but Vuka, Brigand, Norman and Longbow were most responsive. All of these were tested for a full three years and consitently gave above average yields compared with other varieties when sown early.

Some varieties were relatively insensitive to variations in sowing date between mid-, to late-September and October including Armada, Bounty, Avalon and Mission. These results were consistent between sites and seasons, although Bounty and Mission were tested for two years only. Fenman also tended to be less responsive to early sowing than the majority of other varieties, but did give a yield increase in 1982. Stetson was unaffected by sowing date in 1983, but in 1984 yield tended to decline as a consequence of September sowing.

Harvest year 1985: From 1985 onwards the experimental design was modified to include three dates of sowing at the majority of sites. The targets were 7-23 September (early), 24 September-10 October (normal), and 11-20 October (late). Sites failing to achieve these dates were omitted from annual and over-years summaries.

Ten trials were carried out in 1985 located at Gleadthorpe EHF, Bedfordshire, Essex, Lincolnshire, Boxworth EHF, Terrington EHF, Bridgets EHF, High Mowthorpe EHF, Rosemaund EHF and Wiltshire. The latter three centres included only two drilling dates and were not, therefore, included in the over-site analysis.

Early sowing reduced the control yield by 4% compared with normal, which in turn tended to give a small advantage (3%) over late sowing (Fig. 3a). The yields of most varieties tended to decline with early sowing, especially those of Brimstone, Galahad and Brock. Longbow and

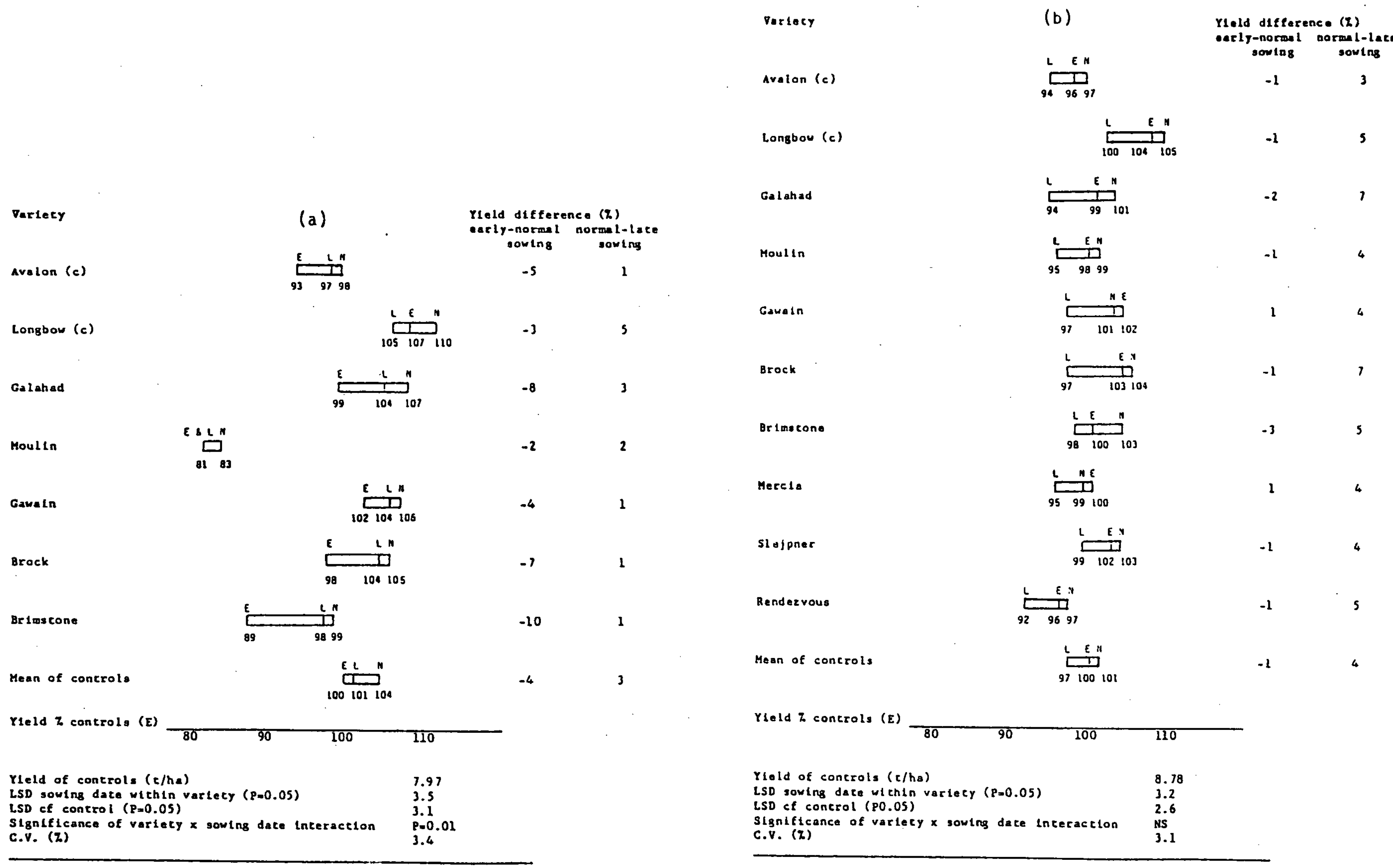

Fig. 3. Effect of early, normal and late sowing date on grain yield of winter wheat. (a) 1985; (b) 1986. Yields expressed as a percentage of Avalon and Longbow at the early date of sowing
E, Early Sowing; N, Normal Sowing; L, Late Sowing

Moulin were least affected by early drilling with the former following the pattern established in previous years. Yields of Moulin were generally severely reduced in 1985 by poor grain set and its performance could not, therefore, be directly compared with the other varieties. Late sowing tended to reduce yields slightly for all varieties, with Longbow affected most and showing a 5% yield penalty.

Most sites were affected by lodging due to adverse weather, and this was generally most severe on the early-sown treatments, possibly causing the poor yields recorded nationally. Similarly, the small yield difference between the normal and late sowings measured overall was evident at most trial sites.

The three sites with only two dates of drilling behaved similarly to the main series, with higher yields from later sowing; again, probably due to differential levels of lodging.

Renard was tested in 1985 only and was not, therefore, included in summary data but generally gave a large yield penalty from early sowing similar to that of Brock, a closely related variety. At the Bedfordshire site this was associated with higher levels of take-all compared with Longbow, whereas at Boxworth EHF, greater BYDV infection was noted in comparison with other varieties when drilled on 10 September. Conversely Boxer, another variety tested in 1985 only, gave relatively high yields when drilled early because of its very good standing power.

<u>Harvest year 1986:</u> Eight trials were carried out (Gleadthorpe EHF, Bedfordshire, Lincolnshire, Essex, Boxworth EHF, Terrington EHF, Bridgets EHF and High Mowthorpe EHF) and were included in the over-site summary. There were three other sites with two dates of sowing, located at Rosemaund EHF, Dorset and Devon. Early sowing did not affect the yield of the control, in contrast to the previous year when a reduction was measured (Fig. 3b). Furthermore, late sowing resulted in a reduction of 4% compared with normal, whereas in 1985 this effect was less marked (3%).

The performance of most varieties was similar to that of the control, none giving a significant yield difference between early and normal sowing but most tended to give slightly lower yields when drilled early, especially Brimstone. Avalon tended to give the least yield reduction from late sowing, whereas Brock was most severely affected with a 7% penalty.

Trials were less affected by lodging than in 1985, but the tendency for early sowings to be more severely penalised remained; for example at Gleadthorpe EHF. The early drillings were also frequently affected by slow emergence due to dry seed beds. Overall, responses to drilling date were consistent at most sites and correlated well with the national mean. At High Mowthorpe EHF, yield reductions from late sowing were associated with lower fertile tiller numbers, whilst at Rosemaund EHF grain specific weight declined as sowing was delayed.

Three sites with only early and late sowing treatments behaved similarly to the main series, with a general yield increase from early sowing, but relatively small and inconsistent indications of possible interactions between variety and drilling date.

Harvest year 1987: Trials were carried out at High Mowthorpe EHF, Nottinghamshire, Rosemaund EHF, Essex, Boxworth EHF, Terrington EHF and Bridgets EHF providing data suitable for over-site aggregation (Fig. 4a). At Drayton EHF, the early sowing was severely damaged by pest attack and the Devon and Oxford sites achieved only two dates of sowing.

There was no difference between the control yields for early and normal drilling, correlating well with the data obtained in the previous year. Again, however, late sowing gave a yield penalty of 4% but this failed to reach significance (P=0.05).

Moulin gave an apparent response of 6% to early drilling but suffered from poor grain set, as in 1985, negating the value of this result. Most other varieties showed no difference between early and normal drilling apart from Brimstone where a 9% penalty occurred from early sowing. This variety also suffered a 5% yield reduction from late

(a)

Variety	Sowing order (low → high)	Yield % controls (E)	Yield difference (%) early-normal sowing	Yield difference (%) normal-late sowing
Avalon (c)	L E N	93 95 96	-1	3
Longbow (c)	L N E	99 102 105	3	3
Moulin	L N E	71 74 80	6	3
Brock	L E N	97 99 101	-2	4
Brimstone	E L N	90 94 99	-9	5
Mercia	E & L N	98 100	-2	2
Slejpner	L E & N	102 105	0	2
Rendezvous	L E N	98 102 103	-1	5
Mean of controls	L E N	97 100 101	-1	4

Yield % controls (E): 80 90 100 110

Yield of controls (t/ha)	7.94
LSD sowing date within variety (P=0.05)	4.4
LSD cf control (P0.05)	3.6
Significance of variety x sowing date interaction	P=0.001
C.V. (%)	4.3

(b)

Variety	Sowing order (low → high)	Yield % controls (E)	Yield difference (%) early-normal sowing	Yield difference (%) normal-late sowing
Avalon (c)	L E N	94 95 97	-2	3
Longbow (c)	L E & N	102 105	0	3
Galahad	L E N	98 99 103	-4	5
Moulin	L N E	83 86 88	2	3
Gawain	L E N	100 102 103	-1	3
Brock	L E N	99 100 103	-3	4
Brimstone	E L N	93 97 100	-7	3
Mercia	E & L N	98 100	-2	2
Slejpner	L E N	102 103 104	-1	2
Rendezvous	L E N	96 98 100	-2	4
Mean of controls	L E N	98 100 101	-1	3

Yield % controls (E): 80 90 100 110

Yield of controls (t/ha)	8.24
LSD sowing date within variety (P=0.05)	2.1
LSD cf control (P0.05)	1.8
Significance of variety x sowing date interaction	P=0.001
C.V. (%)	3.6

Fig. 4. Effect of early, normal and late sowing date on grain yield of winter wheat. (a) 1987; (b) 1985-87. Yields expressed as a percentage of Avalon and Longbow at the early date of sowing E, Early Sowing; N, Normal Sowing; L, Late Sowing

sowing, together with Rendezvous. The remainder were less sensitive, and relatively unaffected by variations in drilling date.

As in the previous year, differences were recorded between sites in the relative performance of varieties at different sowing dates. In some cases these effects could be explained by poor crop establishment at certain sowing dates, or increased lodging when varieties with low standing power were sown early. In others, however, crop development records did not provide an adequate explanation of yield differences. The sites with two dates of drilling gave variable results with a yield increase from early sowing in Wiltshire, and a decrease in Oxfordshire. The supporting data did not explain these trends.

Harvest years 1985-87: An over-years analysis was carried out combining yield data collected between 1985 and 1987, with all varieties tested for two or more years during this period included. In total, 20 site/years of data were aggregated for 10 varieties.

Seasonal effects were considerable over the three-year period with a trend for negative responses to early sowing and no difference between normal and late during 1985. Conversely, late sowing generally reduced yield in 1986, with little difference between early and normal. In 1987, differences between sowing dates tended to be smaller overall, but the effect of sowing date on certain varieties was greater than usual. Consequently, the aggregation of data from three years with distinct seasonal trends was of limited value (Fig. 4b).

In general, most varieties tended to give maximum yield at the normal (late September) sowing date, with the exception of Longbow which performed equally well when drilled early. Yield depressions from early, compared with normal sowing, tended to be very small, but were greatest with Brimstone, Galahad and Brock. This effect may have been related to lodging in the case of Brimstone and Galahad, and suscepti-biity to take-all in the case of Brock, but direct evidence was lacking. The majority of varieties tested tended to give a small yield reduction from late (mid-October) versus normal sowing; particularly Galahad (5%). Those least affected were Mercia and Slejpner which also tended to be least sensitive overall, to date of drilling.

PLANT BREEDING INSTITUTE - WINTER WHEAT VARIETY AND TIME OF SOWING EXPERIMENTS (1981-86)

A series of experiments was carried out at the Plant Breeding Institute, Cambridge (Bingham et al., 1984) using methodology similar to that of the ADAS/NIAB series. A number of sowing dates was compared ranging from 3 September to early March.

The first two years of trials showed differences in varietal response to September and October drilling (Table 2).

Table 2. Plant Breeding Institute winter wheat variety and sowing date trials 1981-82. Grain yield expressed as a percentage of the mean of all varieties at the first sowing date (9.1 t/ha).

Variety	Sowing date					
	9 Sept.	30 Sept.	21 Oct.	4 Dec.	26 Jan.	early March
Wembley	91	102	102	83	75	79
Aquila	107	105	101	91	84	61
Avalon	92	104	103	84	68	64
Fenman	99	104	104	86	67	75
Maris Huntsman	87	100	99	80	73	63
Norman	109	118	110	85	76	68
Moulin	106	106	105	94	79	80
Gawain	109	112	106	95	86	72

Aquila, Moulin and Gawain performed equally well when sown in either early or late September, indicating suitability for early drilling. Conversely Avalon, Fenman and Maris Huntsman gave higher yields when sowing was delayed until late September, and no yield penalty occurred from mid-October drilling. The performance of all winter varieties declined considerably when drilled from early December onwards. Wembley spring wheat gave its best performance when sown in late September or mid-October and its performance declined with traditional spring drilling, but not to the same extent as the true winter types.

A similar experiment was repeated during 1983 (Table 3). These data did not reveal large varietal interactions for September and October drillings, underlining the seasonal variability encountered in ADAS/NIAB trials, and only Avalon and Wembley tended to give a yield reduction from drilling on 3 September compared with 11 October. As in previous seasons, yield declined rapidly with all varieties when sown from 30 October onwards.

Table 3. Plant Breeding Institute winter wheat variety and sowing date trials 1983. Grain yield expressed as a percentage of the mean of all varieties at the first sowing (10.1 t/ha).

Variety	Sowing date					
	3 Sept.	20 Sept.	11 Oct.	30 Oct.	3 Dec.	10 Jan.
Wembley	85	93	98	85	76	59
Aquila	100	99	92	80	72	40
Avalon	89	95	102	91	81	61
Brigand	102	105	101	89	88	58
Galahad	106	101	99	86	73	61
Longbow	108	108	107	88	78	63
Norman	108	105	103	90	81	57
Moulin	100	105	105	90	80	69
Gawain	104	108	102	91	81	62
Brock	99	107	100	92	80	70
Brimstone	98	103	101	93	79	60

Trials continued in subsequent years, concentrating on just three dates of sowing to screen new varieties and advanced breeders' lines (Bingham et al., 1987). Yield data for 1986 showed relatively few differences between 18 September and 9 October drillings although Longbow, Norman, Brimstone and Rendezvous were most responsive to earlier drilling. Avalon, Brock, Hornet and Mercia tended to be least affected. Most of the varieties tested gave a yield penalty when drilled on 1 November, but Avalon, Brimstone and Rendezvous were least reduced.

SCOTTISH AGRICULTURAL COLLEGES - WINTER WHEAT VARIETY AND TIME OF SOWING INVESTIGATION (1978-84)

Data from the Scottish Colleges' wheat variety trials were examined for variety and sowing date interactions. A total of 72 experiments was carried out between 1978 and 1984, testing 21 varieties. Each variety was not included in every trial, and soil type, rotational position and previous cropping varied. Drilling dates for these trials ranged from mid-September to late November, but most were sown during October.

Yield response to a range of sowing dates was examined by regression analysis. This technique estimated the extent to which a variety's yield performance increased or decreased relative to other varieties, the later that trials were sown. Table 4 gives the average yield response of varieties to time of sowing. A positive figure indicates that a variety performed better than average from later sowing; a negative figure suggests a variety performed less well than average. For example, the yield of Maris Huntsman tended to decrease relative to other varieties by 27 kg/ha, on average, for every day that sowing was delayed. At the other extreme, Renard was affected least by delayed sowing and yield tended to increase relative to other varieties by 54 kg/ha on average for every day sowing was delayed.

The importance attributed to the regression coefficient depends, however, on the precision of the experiment. Maris Huntsman and Renard gave clear responses to drilling date, but the remaining varieties gave regression coefficients similar to, or smaller than, the standard error (Table 4). Maris Huntsman suffered a yield penalty from later sowing, but four of the six other varieties exhibiting this trend (Longbow, Norman, Galahad and Fenman) shared a common parent, Hobbit. It was also noted that five of these six varieties had above average susceptibility to *Septoria tritici*. Renard gave higher yields when sowing was delayed, with a number of other varieties showing a similar trend. Trials where a full fungicide programme was applied to prevent disease were analysed separately, but did not suggest any relationship between variety, time of sowing and fungicide usage.

Table 4. Average response of winter wheat varieties to sowing date in S.A.C. trials 1978-84.

	No fungicide			Fungicide treated		
	Regression coeff (t/ha)	SE	No. of trials	Regression coeff (t/ha)	SE	No. of trials
Maris Huntsman	-.027	.008	36			
Fenman	-.011	.009	32	-.007	.020	11
Longbow	-.010	.009	35	.015	.015	13
Avalon	-.007	.005	54	-.007	.014	11
Galahad	-.006	.006	42	-.002	.012	13
Mardler	-.002	.008	47	-.008	.014	13
Stetson	-.001	.010	30	-.012	.015	11
Mission	.001	.013	19	-.019	.016	9
Armada	.002	.005	64	.024	.020	11
Stuart	.003	.006	46			
Flanders	.003	.005	59			
Rapier	.003	.008	20			
Boxer	.003	.012	13			
Aquila	.004	.004	67	.006	.014	13
Bounty	.007	.011	25			
Brimstone	.008	.016	13			
Hustler	.008	.007	39			
Brock	.009	.015	13			
Sentry	.013	.007	39			
Renard	.054	.018	13			

WINTER WHEAT - DISCUSSION AND CONCLUSIONS

The relative popularity and Recommended List status of winter wheat varieties has changed considerably during recent years. The majority were tested for three years in ADAS/NIAB trials, and in view of strong seasonal effects this often proved to be inadequate. Furthermore, certain varieties, e.g. Renard and Boxer were tested for one year only, and, therefore, provided data of limited value.

A number of trials were abandoned; frequently because of severe pest damage, or dry seedbeds adversely affecting the establishment of the first drilling. This was a greater problem in the earlier trials and more recently has been largely prevented by careful site management. Achieving the target sowing dates to ensure comparability between sites also proved difficult. Inevitably, drilling was delayed on some occasions by adverse weather, and this led to a significant number of trials being omitted from annual and over-years summaries.

The different sowing date treatments were harvested on a common date, despite observed differences in time of ear emergence and flag leaf senescence as the crops ripened, for example at Boxworth EHF in 1982 and High Mowthorpe EHF in 1986. In general, however, harvesting was delayed until the latest sowing was fully ripe, and there was no evidence that the accuracy of yield measurements was affected by this technique. It was likely, however, that grain quality was influenced, particularly Hagberg Falling Number, where the relationship between variety and sowing date varied greatly according to season.

Variety and sowing date interactions were frequently small compared with the effects of site and season, particularly when data from different sites and years were aggregated. This was inevitable, but more consistent, and intensive monitoring of crop development at individual sites may have provided a deeper understanding of the data.

The Plant Breeding Institute, and later ADAS/NIAB experiments generally included three dates of sowing, permitting optimum dates of drilling to be established more clearly than with only two dates, both for single varieties, and overall.

Grain Yield: The effect of sowing date on yields varied between sites and season. In 1985, for example, the ADAS/NIAB tended to give slightly lower yields from mid-September than late September sowing, but no difference between late September and mid-October sowings. Conversely, mid-October drilling generally reduced yield in 1986, with no difference apparent between mid- and late September. Lodging was very severe in 1985 due to adverse pre-harvest weather, and at most sites the early sowings lodged first, and more extensively with consequently greater yield reductions.

Between 1982 and 1984, ADAS/NIAB trials (mostly with two dates of sowing) gave a mean yield advantage of 5% to mid-, to late-September drilling, compared with mid-October and this trend was consistent. Experiments from 1985-87 incorporating three sowing-date treatments also revealed a tendency for the optimum sowing date to be late September in the majority of situations. Any yield depression from sowing in mid-September generally tended to be very small, but the effect of delaying until mid-October tended to be greater, at 3%.

Experiments carried out by the Plant Breeding Institute generally confirmed that late September was the optimum sowing date for winter wheat, and that small deviations from this had little effect on yield. Furthermore, these trials demonstrated that penalties were frequently severe when sowing was delayed until November or December, confirming conclusions drawn by McClean (1981) from earlier trials. A recent series of ADAS experiments indicated that where sowing was delayed until November or December there was frequently a yield increase, and rarely a penalty, to sowing spring wheat varieties instead of winter varieties (McDonald, 1986). Work has continued to determine the best spring wheat varieties for sowing under these circumstances, and appropriate levels of husbandry.

Variations between sites and seasons tended to obscure varietal interactions with sowing date, but clear trends were apparent, both for the ADAS/NIAB and Plant Breeding Institute trial series (Table 5). In terms of yield, Longbow, Norman, Brigand and Vuka were most suitable for mid-September drilling, although Vuka generally gave disappointing yields overall. These varieties tended to give, at best, slightly higher yields when sown in mid-September compared with late September or October, and at worst gave no yield reduction from early sowing. Virtue, Rapier, Aquila and Hustler also proved to be suitable for early drilling, giving significant yield increases in most cases from September sowing, but not as great as those obtained by the first group. Similarly, these varieties withstood early sowing well in situations where this practice was rendered difficult by adverse growing conditions.

Table 5. The relative suitability of winter wheat varieties for early-, or late-autumn sowing. Summary of all reviewed data.

Variety	Suitability for early-, or late-autumn sowing
Longbow, Norman, Brigand, Vuka, Virtue, Rapier, Aquila and Hustler.	Best sown from mid-September to early October. Less suitable for mid-October (or later) sowing than other varieties.
Brimstone, Renard, Stetson, Galahad, Brock, Avalon and Fenman.	Best sown in late September or early October. Earlier or later sowing may lead to yield loss in some years.
Slejpner, Mercia, Armada, Bounty and Mission.	Relatively insensitive to sowing date, giving similar yields over a range of dates between mid-September and mid-October.

Conversely, another group of varieties was detected where yield was generally reduced by mid-September sowing, including Brimstone, Renard, Stetson, Galahad and Brock. The first three performed consistently, but Galahad and Brock showed considerable differences between sites and years. The optimum drilling date for this group was generally late September, with small yield depressions tending to occur when sowing was delayed until mid-October. The penalties from late sowing were frequently greater than those from mid-September, suggesting that these varieties should be drilled as closely as possible to the optimum sowing date. Where this was not possible slightly early sowing was preferable.

Certain varieties tended to be relatively unaffected by variations in sowing date between mid-September and mid-October, including Slejpner and Mercia. From 1985 to 1987, these gave a mean difference between sowing dates of only 2% in the ADAS/NIAB trials. Between 1982 and 1984, only two drilling dates were included in this series. Consequently, the identification of insensitive varieties was more difficult, but Armada, Bounty and Mission tended to fall into this group and gave differences of 2% or less between mid-, or late-September and mid-October sowing.

Plant Breeding Institute trials demonstrated that the optimum sowing date for Avalon was generally late September, and this was confirmed by the ADAS/NIAB series. In most situations, this variety exhibited an intermediate level of sensitivity to earlier or delayed sowing, with a trend for small yield reductions, but these were not as great as those of Galahad. Fenman also tended to give the highest yield when drilled in late September, but reacted variably to earlier or later sowing.

Varietal characteristics/sowing date: These experiments have demonstrated clear trends for varieties to yield differently according to sowing date, but the reasons for these effects were frequently difficult to identify. This was sometimes due to a lack of supporting data recording crop growth and development.

Lodging was frequently an important factor; straw length (visual observations only) and severity of lodging generally increased with earlier sowing. This trend was particularly marked in 1985, when severe summer weather adversely affected early drillings at most ADAS/NIAB sites. There was evidence of a relationship between the inherent standing power of varieties and their ability to yield well when sown early. Brimstone, for example, had poor standing power, and yields were reduced when this variety was sown in mid-September, particularly during 1985. There were also indications that the yields of Galahad, Longbow and Fenman (with moderate standing power) were occasionally reduced when sown early.

Conversely, Brigand, Virtue and Norman with strong straw were amongst the most suitable varieties for early sowing; they lodged later and less severely than most others, and gave relatively high yields. There were some indications that the yield of weak-strawed varieties sown in mid-September could be improved by the use of growth regulators. In 1987, for example, the performance of Brimstone was improved by sequential application of chlormequat (Cycocel) and mepiquat chloride + 2 chloroethyl phosphonic acid (Terpal) in ADAS/NIAB trials.

Apical development was monitored at certain sites, and varieties exhibiting a relatively slow rate of development generally proved responsive to early drilling. Conversely, rapidly developing varieties tended to give their optimum yield when sowing was delayed until late September.

Common eyespot was not recorded in all trials, but limited data indicated that levels tended to be higher with early sowing. This may have led to yield reductions when susceptible varieties, such as Armada, were drilled in mid-September. These observations were confirmed by surveys of commercial crops carried out between 1980 and 1987 (Thomas, 1987) which also showed an increase in sharp eyespot levels from early drilling.

Take-all tended to increase with early sowing. There was some evidence of varietal effects, and at one site in 1985 Longbow was less affected by take-all than Renard, and the former gave higher yields when sown in mid-September. In 1983, there were indications that Norman and Armada were more severely affected by take-all than Longbow, Fenman or Rapier, although in this case there was no correlation with yield.

Occasionally, the autumn levels of other foliar diseases were increased by early sowing, but there was no evidence that these effects persisted until spring, or that consistent differences existed between varieties. Similarly, although early drillings suffered earlier leaf senescence from mid-July onwards, there was no indication that disease was a causal factor. Survey data (Thomas, 1987) demonstrated that early sowing gave a lasting increase in levels of *Septoria tritici*.

At Boxworth EHF, Renard tended to suffer a higher level of BYDV infection than other varieties when sown in mid-September, and gave progressively higher yields with later drilling. This effect has not been observed at other sites, or with other varieties.

The effects of early sowing on grain quality were inconsistent, but there was a tendency for specific weight and thousand grain weight to be reduced. These trends were frequently associated with higher fertile tiller numbers, and earlier, or more severe lodging. Interactions between sowing date and variety were detectable, and at Boxworth EHF in 1983 mid-September drilling reduced the specific weight of Aquila, Armada, Bounty and Mission, but increased that of Virtue. There was also a tendency for high yield and specific weight to be correlated. Hagberg Falling Number varied according to both variety and sowing date, but this effect was obscured by differences between seasons and sites. Virtually all trials were harvested on a single date, usually when the last drilling was fully ripe. Earlier sowings may, therefore, have been unduly affected by experimental technique.

Winter proudness and susceptibility to frost kill were varietal characteristics suggested as detrimental to successful early sowing (Bingham *et al*., 1986). This was partially confirmed by a number of ADAS/NIAB trials, including Gleadthorpe EHF in 1985, where all varieties tested proved to be more winter hardy when sowing was delayed until mid-October.

General conclusions: The data collected from variety by date of sowing trials has proved useful to farmers, and advisers, by confirming the conclusions drawn from earlier experiments on the optimum sowing date for winter wheat. In most cases, the highest yields tended to be achieved by late-September sowing, but earlier drilling in mid-September generally gave little or no yield penalty.

A fairly wide sowing window was identified between mid-September and mid-October permitting intensive cereal growers to begin work early to ensure that the operation was not completed too late, in November.

The ADAS/NIAB trial series achieved limited success in identifying varieties most suitable for early or later sowing within the mid-September to mid-October period, as did those carried out by the Plant Breeding Institute. Whilst certain varieties gave optimum yield when sown in mid-, to late September, others were better drilled from late September to mid-October. Furthermore, several varieties proved relatively insensitive to sowing date and, therefore, demonstrated a useful degree of flexibility in this respect. Such information has allowed farmers with a large area, and several varieties of winter wheat, to schedule each variety according to its suitability for early or later drilling.

Variety by sowing date trials have given some clues as to why varieties react differently to date of drilling, but yield differences were often difficult to explain. Important factors include standing power and disease resistance - particularly to eyespot and take-all infection. Most trials included a comprehensive crop protection regime, and were not designed to explore the effect of drilling date on agrochemical input levels, but there were indications that appropriate management techniques could be used to extend the optimum sowing period for a given variety. This would tend to increase the flexibility of certain varieties under commercial conditions, allowing their use in a wider range of situations than would otherwise be the case.

<u>Economic implications</u>: Varietal interactions with sowing date have been shown to have significant effects on crop yield, but these were relatively small compared with those of site and season (Table 6).

Yield variation between trial sites during the 1985-87 period ranged from 2.0 to 3.0 t/ha for most varieties, and between seasons was typically 1.0 t/ha. In contrast, the mean difference between mid-, and late-September sowing was only 0.16 t/ha, whilst that between late September and mid-October was 0.26 t/ha.

Table 6. The relative effect on grain yield of site, season and variety/sowing date interaction. ADAS/NIAB winter wheat variety and time of sowing experiment (1985-87).

Variety	Yield range due to site and season at the early sowing date (t/ha)		Yield at early, normal and late sowing dates (t/ha)		
	Site	Season	Early	Normal	Late
Avalon	6.77-8.77	7.53-8.40	7.83	7.99	7.74
Longbow	6.74-9.52	8.08-9.05	8.65	8.65	8.40
Galahad	6.52-9.15	7.92-8.59	8.16	8.49	8.07
Moulin	4.69-8.44	6.07-8.54	7.41	7.24	6.84
Gawain	6.73-9.41	7.95-8.79	8.40	8.49	8.24
Brock	6.96-9.37	7.86-8.89	8.24	8.49	8.16
Brimstone	6.88-9.23	7.49-8.83	7.66	8.24	7.99
Mercia	7.04-9.25	7.84-8.59	8.07	8.24	8.07
Slejpner	6.67-9.46	8.27-8.89	8.49	8.57	8.40
Rendezvous	6.54-9.19	7.90-8.33	8.07	8.24	7.91
Mean	6.55-9.18	7.69-8.69	8.10	8.26	7.98

It is also probable that varietal characteristics, such as standing power and disease resistance, generally have a greater effect on yield than sensitivity to sowing date. Despite this, however, it has been demonstrated that certain varieties suffer economically signifcant yield losses when sown too late, or too early. Similarly, some other varieties have been shown to yield consistently over a range of sowing dates. Farmers may, therefore, schedule the drilling of varieties according to their relative suitability for early or late sowing. Alternatively, an insensitive variety can be selected for situations where the crop sowing date is uncertain, for example, where winter wheat follows cash roots. An understanding of interactions between varieties and sowing date will, therefore, provide a small, but economically worthwhile, increase in yield where certain sensitive varieites are grown, and permit the most appropriate variety to be chosen where sowing date is uncertain.

ADAS/NIAB - WINTER BARLEY VARIETY AND TIME OF SOWING EXPERIMENTS (1984-87)

Introduction

In view of trends towards earlier sowing of winter barley, and the introduction of new varieties, an experimental series was initiated in autumn 1983. The aim was to determine the effect of early sowing on different winter barley varieties, and to validate NIAB Recommended List trials. A total of 21 site-years of experimental data was collected between 1984 and 1987; work continues during 1988.

Materials and methods

A total of 26 varieties was tested over four years between 1984 and 1987 (Table 7).

Table 7. Summary of varieties tested during the ADAS/NIAB winter barley variety and time of sowing experiment 1984-87 (√, tested; -, untested).

Variety	Year				Variety	Year			
	1984	1985	1986	1987		1984	1985	1986	1987
Concert	-	-	√	√	Maris Otter	√	√	√	-
Fallon	-	-	-	√	Metro	√	√	-	-
Flamenco	-	-	√	-	Monix	√	√	-	-
Gerbel	√	-	-	-	Natalie	-	√	-	-
Halcyon (c)	√	√	√	√	Nevada	-	√	√	-
Igri (c)	√	√	√	√	Opera	-	√	√	-
Impact	√	√	-	-	Panda (c)	√	√	√	√
Jennifer	-	-	-	√	Pipkin	-	√	√	√
Kaskade	-	√	√	√	Pirate	√	-	-	-
Libra	-	√	-	-	Sonate	-	-	√	-
Magie	-	-	√	√	Tipper	√	√	-	-
Mallard	-	-	-	√	Torrent	-	-	-	√
Marinka	-	-	√	√	Vixen	-	-	-	√

(c) Control varieties 1984-87

Control varieties (Igri, Panda and Halcyon) were retained for the duration of the experiment; most of the other varieties were included for two or three seasons. Gerbel, Pirate, Libra, Natalie, Flamenco and Sonate were tested for one year only, whilst Fallon, Jennifer, Mallard, Torrent and Vixen were introduced for the first time in 1987.

The target drilling dates were mid-September, and mid-October, with an interval of at least 15 days. Weed, pest and disease control was carried out at a level to ensure that the early drilling was not unduly affected by agronomic problems. For example, herbicides were generally applied in the autumn, to prevent competition from early germinating grass and broad-leaved weeds on the first sowing. Seedbed cultivations were carried out separately for each drilling, where necessary. Fertiliser was applied at the optimum level for each site. Plant and fertile tiller numbers were recorded, together with lodging indices and foliar and stem-base disease assessments, as appropriate. Grain yields were measured, and moisture content and specific weight were recorded.

Treatments were replicated three times and arranged in a split-plot design with sowing dates constituting the main plots and varieties the sub-plots. Data from individual sites were aggregated, and treatment means were subjected to an analysis of variance.

Results

Yield data for each season were examined separately and expressed as a percentage of the mean yield of the controls (Igri, Panda and Halcyon) at the early date of sowing.

Harvest year 1984: Yield data from Gleadthorpe EHF, Bedford, Norfolk, Suffolk and Dorset were aggregated for over-site analysis (Fig. 5a). At remaining centres, drilling dates achieved ranged within the period 19-29 September (early) and 14-24 October (late).

The mean yield of the controls was 7.69 t/ha, with the highest values from the 6-row varieties Gerbel and Pirate; Maris Otter and Monix had the lowest yields. All varieties gave a yield increase when drilled early, with an average yield advantage of 9% over the controls. Over-

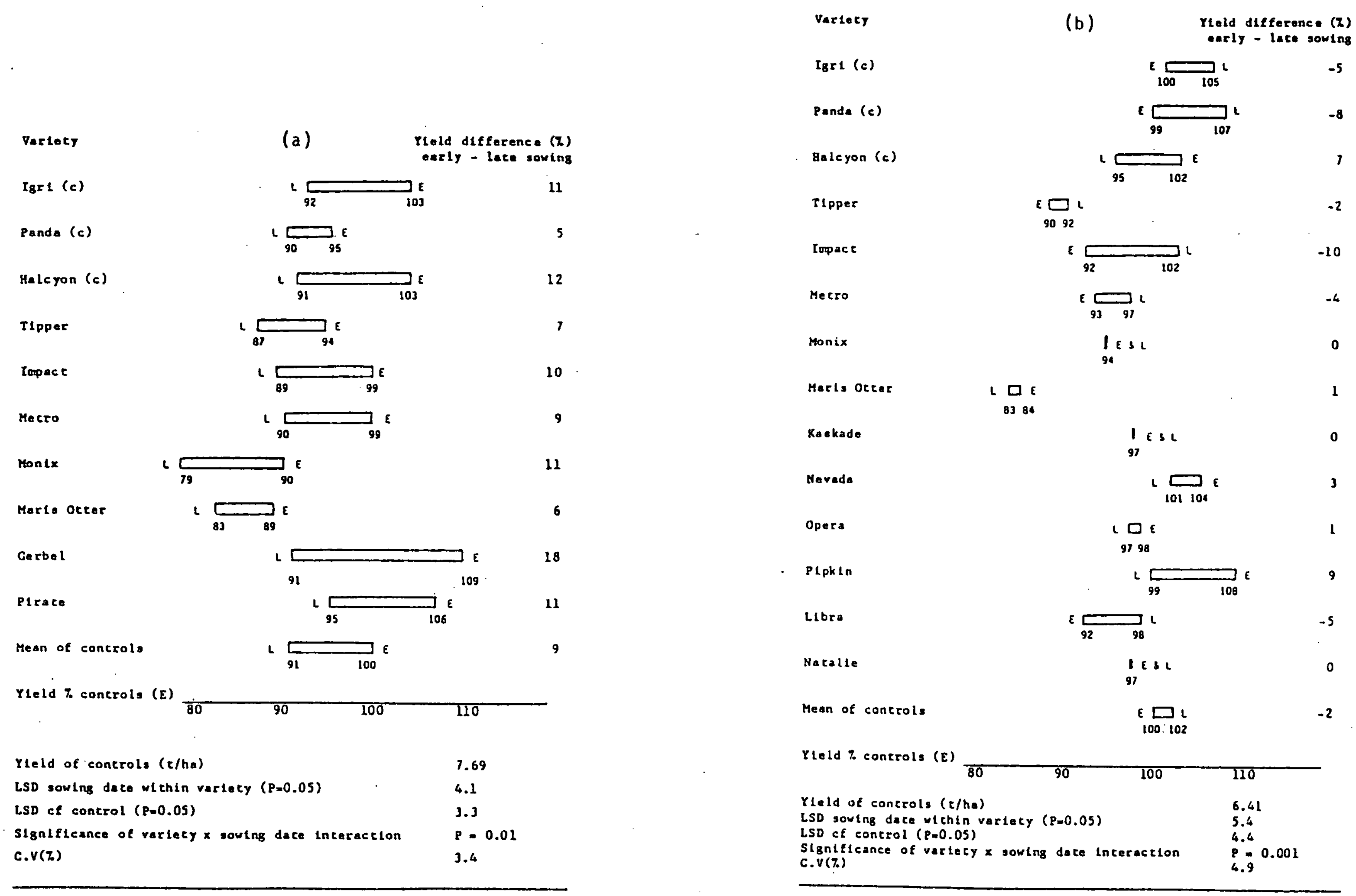

Fig. 5. Effect of early and late sowing date on grain yield of winter barley. (a) 1984; (b) 1985. Yields expressed as a percentage of Igri, Panda and Halcyon at the early date of sowing E, Early Sowing; L, Late Sowing

site analysis indicated that Gerbel, and to a lesser extent Halcyon, were most responsive to early sowing, and Panda, Maris Otter and Tipper the least responsive. Similar trends were apparent within most experimental sites.

At Gleadthorpe EHF, Bedford and Norfolk a third, very early, date of drilling treatment was included with sowings on 1, 5 and 9 September respectively. Yields were reduced by 3% on average from early September sowing, compared with late September. There was no indication of differences in varietal response, other than at Gleadthorpe EHF where Halcyon and Tipper suffered from severe lodging when sown on 5 September.

Harvest year 1985: Yield data suitable for over-site analysis (Fig. 5b) were collected from six centres located at Gleadthorpe EHF, Bedford, Norfolk, Wiltshire, Devon and Suffolk. Drilling dates ranged from 13 September to 1 October (early) and 8 October to 1 November (late).

The mean yield of the controls was lower than in 1984 (6.41 t/ha) reflecting national trends (Anon, 1985b). The highest yields were obtained from Pipkin and Panda, with Maris Otter and Tipper again the lowest. Few varieties responded to early drilling in 1985, but over-site analysis revealed that Halcyon and Pipkin responded positively to early sowing, whilst yields of Impact and Panda tended to decline. Other varieties were insensitive to sowing date. The relative performance of Halcyon, Pipkin, Impact and Panda was fairly consistent within experimental sites, but adverse weather in the summer of 1985 tended to result in early and severe lodging, which was frequently an overriding factor. An early-September drilling was again included at Gleadthorpe EHF, and gave an overall yield increase of 9% compared with late September. Gleadthorpe EHF was generally more responsive than other sites, with a 13% benefit in favour of late-September sowing against October. This site was not, however, adversely affected by lodging, or delayed harvesting.

Harvest year 1986: The four trials included in the over-site analysis were located at Gleadthorpe EHF, Norfolk, Suffolk and Wiltshire. Sowing dates were similar to those of previous seasons.

Grain yields were generally higher than in 1985, with Marinka and Concert giving the best performance at the early drilling date (Fig. 6a). The control varieties gave a yield response of 14% to early sowing which was higher than in the previous two years. Examined separately, all of the varieties under test gave higher yields when sown early. There was not, however, a tendency for Panda to give a small response as observed in previous seasons, and Halcyon and Pipkin were no more responsive than other varieties. There were significant yield increases from early sowing, at each experimental site, and at Gleadthorpe EHF where three dates of drilling were included, there was an additional response of 6% to the earliest treatment.

Harvest year 1987: Date were aggregated from sites in Nottinghamshire, Norfolk and Gloucestershire (Fig. 6b). Sowing dates varied from 16-23 September (early) and 15-24 October (late).

The mean yield of the control varieties was 6.91 t/ha with Torrent, Magie and Marinka tending to give the highest yields at the early date of sowing, and Mallard the lowest. Early drilling gave a mean yield increase of 5% for the control varieties, which was less than in 1986. Most varieties tended to give yield responses, with Torrent, Vixen and Magie giving the largest responses. Panda and Mallard, however, were relatively insensitive to sowing date, exhibiting only small yield increases from early drilling. At individual sites, the overall effects of sowing date were consistent with the national mean, but there was considerable variation in the performance of varieties, other than Torrent, which responded well to early drilling at all sites.

Harvest year 1984-85: An over-years analysis was carried out combining two annual summaries, and varieties tested in both 1984 and 1985. The resulting data matrix was based on 11 site/years of experimentation (Fig. 7a). The aggregation of data from 1984 (large yield responses to early sowing) and 1985 (with small yield responses) proved to be of limited value in view of the seasonal contrast.

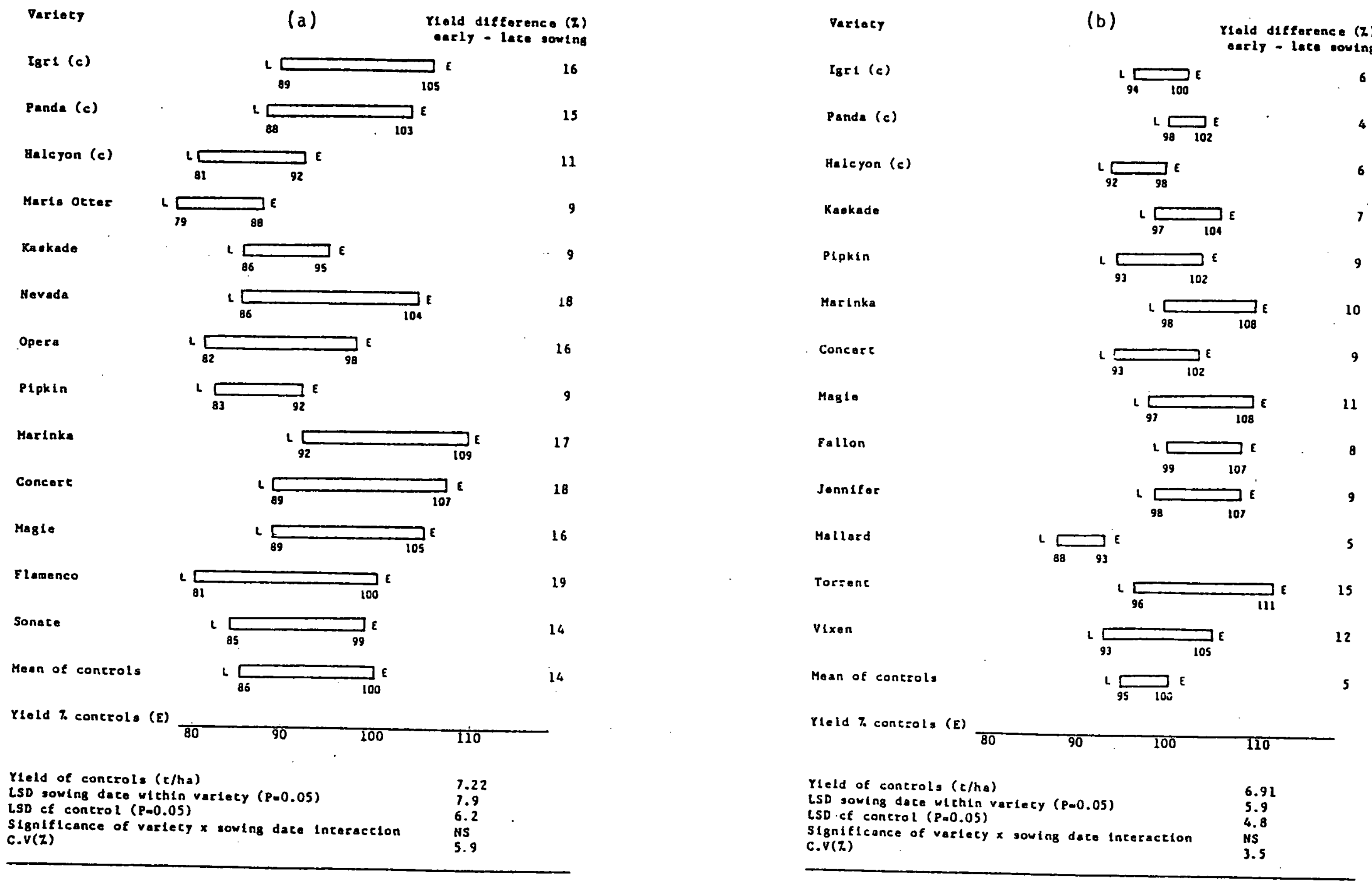

Fig. 6. Effect of early and late sowing date on grain yield of winter barley. (a) 1986; (b) 1987. Yields expressed as a percentage of Igri, Panda and Halcyon at the early date of sowing E, Early Sowing; L, Late Sowing

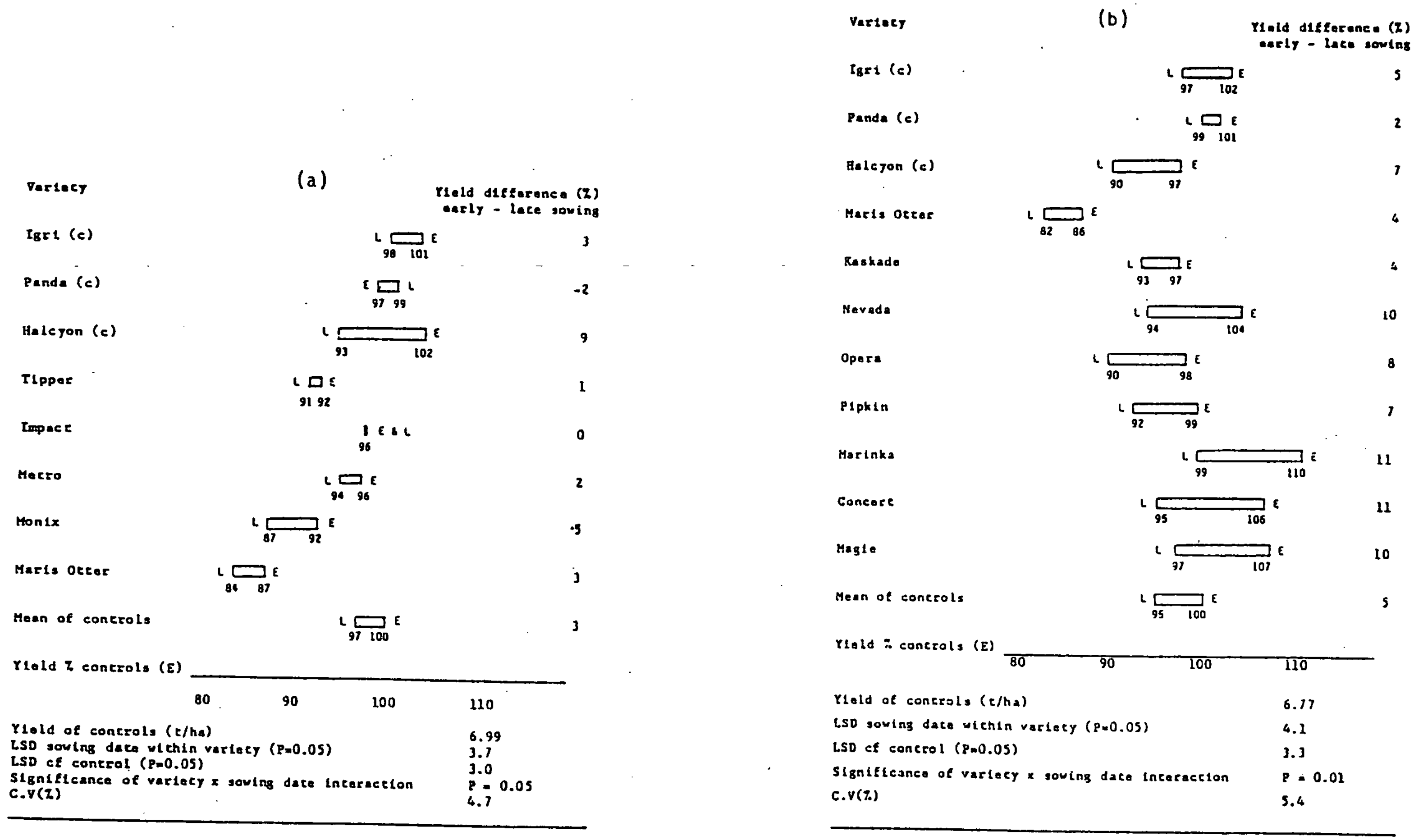

Fig. 7. Effect of early and late sowing date on grain yield of winter barley. (a) 1984-85; (b) 1985-87. Yields expressed as a percentage of Igri, Panda and Halcyon at the early date of sowing E, Early Sowing; L, Late Sowing

The control varieties gave a yield increase of 3% from early sowing when averaged over both seasons. Halcyon and Monix responded well over both seasons, with 9 and 5% yield increases respectively. Gerbel and Pirate, which were very sensitive to drilling date in 1984, were not tested in 1985 and are, therefore, excluded from the over-years analysis. Panda was the least responsive variety to early drilling tested in 1984-85, tending to exhibit this characteristic in both years.

Harvest years 1985-87: An over-years analysis for 1985-87 included yield data from a total of 13 site/years. Eleven varieties were included which were tested in at least two of the three seasons (Fig. 7b).

The control varieties gave a 5% mean yield increase from early sowing, similar to 1984-85. Marinka and Concert were most responsive, and Halcyon which performed well in 1984-85, continued to give a yield increase from early sowing in 1985-87. Panda, Maris Otter and Kaskade did not respond to early drilling, with Panda again proving to be the least sensitive variety, perpetuating the trend established in 1984-85. Maris Otter also did not respond to early sowing during both periods.

WINTER BARLEY - DISCUSSION AND CONCLUSIONS

Although the popularity and Recommended List status of winter barley varieties has changed since experiments began in 1984, the process has been slower than with winter wheat. In view of this, it was possible to retain common control varieties between 1984 and 1987, and to test 15 varieties for periods of two or three consecutive years. In both 1986 and 1987, however, a number of new varieties were tested for the first time, and in the case of those introduced in 1987, the single year of trial data available had to be treated with caution.

As with the ADAS/NIAB winter wheat variety and time of sowing experiments, certain trial sites were abandoned, because of poor seedbeds or pest attack, reducing the quantity of data available for analysis. Again, however, this tendency has been reduced in recent years by appropriate site management. The majority of sites included two sowing-date treatments only, reducing the success of this series in determining the optimum sowing date for the different varieties. Practical difficulties were encountered frequently in achieving the target sowing dates (mid-September and mid-October), due to wet weather. Data from sites where drilling was delayed was of some value, but not directly comparable with that from the remainder, and could not, therefore, be aggregated and subjected to over-site, or over-years analysis.

The effects of site and season tended to obscure possible variety and sowing date interactions. Such difficulties were to some extent unavoidable, but monitoring of crop growth and development was insufficiently intensive, preventing full interpretation of data from individual centres.

The effect of sowing date on the yield of the control varieties varied from season to season, with mid-September sowing giving yield increases of 9% and 14% in 1984 and 1986 respectively. In 1987, however, the increase was much smaller, and in 1985 there was a tendency for yields to be slightly reduced by early sowing. There were considerable between-site differences in 1985, with a tendency for sites in the South West of England to give yield reductions from early sowing, whereas those in the Eastern Counties gave small increases. The South-Western sites were severely affected by adverse weather, and the remaining data for 1985, and for other years, suggested a fairly consistent overall benefit from mid-September drilling compared with mid-October.

Despite differences between seasons and sites, trends could be identified suggesting that certain varieties responded characteristically and fairly consistently to sowing date (Table 8).

Table 8. The relative suitability of winter barley varieties for early-, or late-autumn sowing. Summary of all reviewed data.

Variety	Suitabilty for early-, or late-autumn sowing
Halcyon, Pirate, and Gerbel.	Best sown in mid-, to late September. October sowing may lead to yield penalties.
Monix, Pipkin, Nevada, Marinka, Concert and Magie.	Best sown in mid-, to late September but yield penalties unlikely when sown in early October.
Panda, Maris Otter, and Kaskade.	Less suited to early sowing than other varieties. Sowing should usually be carried out in late September or early October.

In terms of grain yield, Halcyon proved to be the most suitable variety for early sowing, giving yield increases from mid-September drilling during each year of experimentation, even in 1985. At centres with three sowing-date treatments, this trend frequently continued up to the first drilling in early September, but did not do so consistently.

In 1984, the 6-rowed varieties Pirate and Gerbel also gave a response to early drilling, but with only a single year of data, these varieties were not fully tested.

The majority of other tested varieties also tended to be more suited to mid-September than mid-October drilling, but were subject to greater seasonal and inter-site variation than Halcyon. Those exhibiting the greatest response to early sowing were Monix, Pipkin and Nevada (three years of testing); Marinka, Concert and Magie (two years); and Torrent and Vixen (one year of testing).

Panda did not generally respond to mid-September sowing to the same extent as other varieties but a small yield increase was detectable in 1984, and a larger one in 1986. A yield reduction of 8% was recorded during 1985, however, and although the response of this variety varied from year to year it consistently gave smaller yield benefits to early sowing than others. Maris Otter was tested between 1984 and 1986 and tended to show a similar, but less distinct trend, as did Kaskade.

The remaining varieties in the ADAS/NIAB experimental series, either gave very small yield differences, inconsistent results due to site and seasonal factors, or were included in trials for an insufficient period for even tentative conclusions to be drawn. This group included Igri, which tended to give small yield increases from early sowing, but did not do so consistently.

Although the ADAS/NIAB experiments revealed trends for some varieties to react differently to drilling date, the reasons for these effects were generally difficult to determine, which was frequently due to insufficient records of crop development.

Sowing in mid-September generally increased fertile tiller numbers compared with mid-October, but any varietal difference observed was not correlated with yield. Crop length was reduced by mid-September drilling and consequently less brackling and lodging were observed. At a few sites, however, the opposite occurred occasionally, with early sowing increasing straw height and lodging. The reason for this was unclear, but may have been due to the earlier application of plant growth regulators to the crop drilled early, often in poorer growing conditions, when such products may have been less effective. There was some evidence of a relationship between varietal standing power and ability to yield well when sown late, under greater lodging pressure. At certain sites, for example, Halcyon, and Pipkin lodged more severely when sown in October and consequently gave lower yields. Furthermore, when these varieties failed to respond to early drilling, this effect was frequently associated with high overall lodging levels, including the early-sown treatment.

The effects of drilling date on grain quality were inconsistent, but there was a tendency for early sowing to slightly reduce specific weight, which was possibly related to increased fertile tiller numbers. No consistent interactions between sowing date and variety were detectable. Similarly, no firm conclusions could be drawn from assessments of foliar and stem-base diseases. There was a tendency, however, for crops from mid-September drillings to experience higher levels of foliar disease in the autumn, but this effect did not persist following overall fungicide application. Surveys of commercial crops showed that levels of eyespot, sharp eyespot and net blotch were increased by early sowing (Polley, 1987).

Trials were assessed for winter hardiness, but differences between sowing dates were rarely recorded, and no varietal differences were noted.

The ADAS/NIAB trial series confirmed earlier results indicating that winter barley generally gave higher yields when sown in mid-, or late-September rather than mid-October. Interactions between variety and sowing date were minor, with Halcyon tending to show the clearest response to early drilling and the majority of other varieties exhibiting similar but less consistent trends. More interestingly Panda, and to a lesser extent Kaskade and Maris Otter tended not to give yield increases when sown in mid-September. In the case of Panda and Maris Otter, this effect may have been caused by winter proudness, and poor frost hardiness from early sowings. With Kaskade and Maris Otter high disease levels may have contributed to poor performance from early drilling. Unfortunately, there was insufficient evidence to support these hypotheses, and the experimental technique used was only capable of detecting comparatively large treatment effects.

Economic implications: Interactions between variety and sowing date have had significant affects on the yield of winter barley. These were small compared with the effects of site, but comparable with those of season (Table 9).

Table 9. The relative effect on grain yield of site, season and variety/sowing date interaction. ADAS/NIAB winter barley variety and time of sowing experiment (1985-87).

Variety	Yield range due to site and season at the early sowing date (t/ha)		Yield at early and late sowing dates (t/ha)	
	Site	Season	Early	Late
Igri	5.59-7.69	6.54-7.01	6.90	6.57
Maris Otter	4.55-6.66	5.43-6.02	5.82	5.55
Panda	5.72-7.79	6.59-6.91	6.84	6.70
Halcyon	5.52-7.00	6.26-6.51	6.57	6.09
Kaskade	5.36-7.45	6.21-6.77	6.57	6.30
Nevada	5.70-7.55	6.56-6.86	7.04	6.36
Opera	5.37-7.26	6.24-6.52	6.63	6.09
Pipkin	5.86-7.09	6.30-6.65	6.70	6.23
Marinka	5.94-8.04	6.92-7.27	7.45	6.70
Concert	5.77-7.84	6.66-7.07	7.18	6.43
Magie	5.81-7.87	6.75-7.09	7.24	6.57
Mean	5.56-7.48	6.40-6.79	6.81	6.33

Yield variation between sites averaged approximately 2.0 t/ha for most varieties, but the effects of season did not generally exceed 0.4 t/ha. The mean difference between mid-September and mid-October sowing was 0.48 t/ha. Yield differences due to sowing date were, therefore, greater with winter barley than winter wheat, both in absolute terms, and relative to the influence of site and season.

As with winter wheat, however, an understanding of varietal interaction with sowing date is necessary because although the majority of winter barley varieties give higher yields when sown in mid-September, certain commercially important varieties have shown a clear tendancy to give higher yields, under some circumstances, when sown slightly later.

RECOMMENDATIONS FOR FURTHER STUDY

Winter wheat

The value of experiments to determine interaction effects on yield between winter wheat varieties and date of sowing has been reduced by a number of factors. Site and season effects have frequently obscured those of treatment, and although these are unpredictable, more intensive monitoring may permit a more adequate interpretation of the data. To minimise site effects the previous tendency for certain trial centres to be relocated at intervals should be avoided. Similarly, top priority must be given to ensure that, as far as possible, target drilling dates are achieved at all sites. Clearly this is not possible on all occasions, but delays to one or more sowing-date treatments have tended to reduce the usefulness of data from the affected centres by preventing direct comparison with others.

For previous experiments, most clues to the existence of interactions between sowing date and variety have taken the form of trends which failed to reach statistically significant levels; trials conducted by the Plant Breeding Institute in 1981 and 1982 were, however, an exception. Nevertheless, such indications are valuable in assessing the suitability of new varieties for relatively early or late drilling. Varietal sensitivity to sowing date cannot be determined solely on the basis of characteristics such as standing power, and disease resistance observed in other trials; it is, therefore, essential that the separate screening of new varieties continues in the form of variety/sowing date experiments.

In order to optimise use of resources, and to detect smaller treatment effects fewer, but more detailed experiments, should be undertaken and a number of adjustments should be made to experimental technique.

i. Three dates of drilling should be included at all sites, and top priority given to carrying out treatments within the target periods.

ii. The management problems associated with these trials would be eased by locating all sites on ADAS Experimental Husbandry Farms, or other Institutes offering similar facilities.

iii. Trials at one site should not be relocated onto different soil types once established, and consideration should be given to maintaining a similar position in the crop rotation from year to year.

iv. The split-plot experimental design adopted for ADAS/NIAB trials has limited the extent to which statistical methods can be used to test for interactions between varieties and sowing dates. Consideration should be given to full randomisation of sowing date treatments, although this is only feasible on easily worked and lighter soils. Where soil conditions are more difficult the use of a split-plot design should continue.

v. Considerable difficulty has been encountered in extrapolating results of experiments from year to year or site to site. In future, a better understanding of treatment effects could be obtained if the effects of factors such as soil moisture availability, the timing of inputs and the incidence of disease and lodging could be better quantified.

A model of the growth and production cycle of winter wheat has been developed by the AFRC Letcombe Laboratory,* Long Ashton Research Station, the Plant Breeding Institute and Rothamstead Experimental Station (Porter et al., 1981). The aim of this model was to provide a research tool for investigating the causes of variation in winter wheat yields in the United Kingdom. At one stage ADAS EHFs contributed to the validation of the model by recording the growth of wheat crops (Weir et al., 1984). At Rosemaund EHF, this detailed monitoring proved useful in explaining treatment effects in experiments previously assessed by traditional techniques. This approach was used in 1987 to monitor the growth and development of two varieties with contrasting development rates sown on different dates, and provided useful data for the interpretation of a

* no longer operating

winter wheat variety and sowing date trial (Clare _et al_., 1986). Such techniques should be incorporated into existing winter wheat variety by time of sowing trials and regular assessments carried out at all sites of:-

a. Plants per m^2
b. Tillers per m^2
c. Ears per m^2 (GS 65 - pre-harvest)
d. Total above-ground dry weight (g/m^2)
e. Dry weight of ears (GS 65- pre-harvest)
f. Dry weight of straw (GS 65 - pre-harvest)
g. Nitrogen % (partitioned between ears and straw where appropriate).

Target sampling dates should be:-

a. At emergence of late sowing
b. December
c. Early March
d. GS 31
e. GS 39
f. GS 65
g. Leaf area index = 0. (Determined by accumulated temperature above 9^oC, sampling when 280 day degrees has been reached after GS 61)
h. Pre-harvest.

Recording of winter hardiness, lodging and disease should be carried out, as previously, but greater uniformity of assessment techniques and timing should be maintained. Meteorological records would be necessary to supplement crop growth data.

Improved monitoring of individual experiments will permit better comparison of data between sites and seasons, and allow a more detailed interpretation of the annual results from each site.

The technique described above is necessary for a full understanding ofthe data, but the cost of such work is high, particularly when compared with the relatively small interactions between variety and sowing date detected to-date. In view of this, alternative techniques for obtaining the minimum necessary data should be investigated.

Newly available winter wheat varieties could be subjected to simple screening trials to detect any interaction between variety and sowing date. Unreplicated small plots of each variety under test could be sown at 7-10 day intervals, over a 70-day period between 7 September and 15 November. The availability of between 7 and 10 sowing-date treatments would permit yield data to be interpreted by regression analysis rather than analysis of variance. This technique has a number of advantages, for example, missing values could be derived by interpolation, or for extremely early or late sowing dates, by extrapolation using data from equivalent sowings at other sites. Similarly, yields from different sites and seasons would be more readily comparable, and it may be possible to explain certain site and season effects. This experimental technique may also have potential for examining other factors which interact with sowing date, such as sharp eyespot infection.

The monitoring of plots should be minimal, with assesments of lodging, disease and measurement of apical development rate. The wide range of sowing dates would render plant and tiller counts of limited value, and no longer cost effective. Where possible, plots should be managed uniformly across the range of sowing dates, but for certain pesticide applications, trials would be sub-divided into two or three sowing date groups.

This experiment would be of limited duration, with the objective of establishing a relationship between apical development rate and variety/sowing date interaction. Subsequently, newly available varieties could be screened merely by measuring their rate of apical development.

Winter barley

The ADAS/NIAB trial series was affected by considerable differences between sites and seasons, tending to obscure interactions between variety and sowing date, but a deeper understanding of treatment effects was prevented by insufficiently uniform and detailed assessments of crop growth.

For the majority of varieties tested, the results of ADAS/NIAB experiments have failed to reveal consistent responses to sowing date. It is unclear whether such effects existed for these varieties, or if their magnitude was too small to permit detection by the methods adopted. A few varieties, however, tended to give higher than normal yield increases from mid-September drilling, whilst others performed relatively well when sown late. No statistical significance could be attached to these observations, but some trends were sufficiently consistent for tentative conclusions to be drawn. In most instances, however, the response of varieties could be explained by differences in standing power, winter hardiness, or susceptibility to disease observed in other experiments.

Winter barley variety by sowing date experiments have been of limited value, and their continuation should be given a lower priority than that of winter wheat. As with winter wheat, however, these trials would provide better data if monitoring techniques were standardised. Three sowing date treatments should be adopted, and the following assessments undertaken:-

a. Plants per m^2 (December and March)
b. Tillers per m^2 (December and March)
c. Ears per m^2 (GS 65)
d. Disease assessments (November, GS 31 and GS 59)
e. Lodging index (GS 59 and pre-harvest).

Unfortunately, no computer-based model yet exists to aid the investigation of yield variation for winter barley. The alternative experimental technique described for winter wheat trials utilising sequentially sown unreplicated plots would be equally applicable, and cost-effective, for detecting interactions between variety and sowing date in winter barley.

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