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PRELIMINARY ASSESSMENT OF THE POTENTIAL FOR VARIETY TYPING IN WINTER BARLEY : STEM WATER SOLUBLE CARBOHYDRATE MEASUREMENTS

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PRELIMINARY ASSESSMENT OF THE POTENTIAL FOR VARIETY TYPING IN WINTER BARLEY : STEM WATER SOLUBLE CARBOHYDRATE MEASUREMENTS

by

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CONTENTS

SUMMARY

Levels of water soluble carbohydrates in stems of 13 winter barley varieties were measured on crops grown at Rosemaund, near Hereford and High Mowthorpe, near York. By making appropriate ancillary measurements the results were expressed as tonnes of water soluble carbohydrate (WSC) per hectare. There was a range of over one tonne/ha between mean levels of water soluble carbohydrates, with the highest levels being found in Halcyon (2.33 t/ha) and the lowest levels being found in Rifle (1.30 t/ha) at both sites. There was a significant correlation ($r=0.758$, $p < 0.01$) between mean levels of water soluble carbohydrates measured at the two sites, suggesting a worthwhile degree of varietal determination. This varietal determination of WSC was seen against a background of greater total and stem dry matter produced at High Mowthorpe. In comparison with amounts of stem WSC for winter wheat varieties in Recommended List trials in recent seasons, the winter barley varieties tested had lower amounts of stem WSC but the range of values was broadly similar. Therefore currently grown barley varieties by analogy to winter wheat differ meaningfully in potential tolerance of late-season stress. The provision of information on varietal charateristics in the recommended list information would therefore aid the choice of variety for, for example, droughty or high take-all risk sites and the likely response of a variety to late season pest or disease control. These improvements are shown to potentially worth £30/ha on droughty or high take-all risk sites, and savings of £15/ha in fungicide inputs.

Based on these limited data on stem water soluble carbohydrate, the outlook for transferring the technology of typing trials from wheat to barley looks encouraging. It will require collection of appropriate data in a number of sites and seasons and appropriate candidate traits are discussed.

INTRODUCTION

The potential contribution of physiology in understanding how to improve yields and economic performance of cereal crops was identified in HGCA research review no 18. (Sylvester-Bradley *et al.*, 1990). The review identified important physiological characteristics, and subsequently there has been much valuable work which in winter wheat has both improved our understanding of the role of these characters in affecting varietal suitabilities to specific environments and quantified the varietal ranges for the most important indicative traits in an HGCA-funded project "The exploitation of varieties for UK Cereal Production" (Scott *et al.* 1998). The value of using just two appropriate varietal traits to the wheat industry has been estimated as £45 million (Foulkes *et al* 1998). This varietal information on physiological characteristics of wheat is now widely available to the industry in the Cereal Varieties Handbook (NIAB, 1998), the "Wheat Growth Guide" (HGCA, 1997) and Scott *et al.* (1998). However, in spite of its high potential value in barley there has been little progress in measuring the range of physiological attributes of modern varieties, a situation which was commented on by the farming community at the launch of the Wheat Growth Guide. The higher initial priority given to wheat reflects the greater area of wheat grown in the U.K. and its greater value as a crop, but in view of the high potential benefit of this information to barley producers it is time to start redressing the balance. This process has been started with this initial assessment of the value of variety typing trials for physiological characteristics in winter barley using amount of water soluble carbohydrates in stems as the test character.

Water soluble carbohydrate (WSC) amount in stems was chosen as the initial character to study because of its important contribution to grain filling, particularly in the later phases as the photosynthetic green area of the plant senesces (Schnyder, 1993). If senescence of photosynthetic organs is accelerated by drought during grain filling then the importance of this contribution to total yield is increased significantly (Foulkes *et al.*, 1998). Also there is evidence that WSC is a much more important component of grain yield in diseased barley grown in New Zealand (Wright and Gaunt, 1992). Recognition of its value to growers has been shown by its inclusion in recommended list information for winter wheat. In barley most of the widely available data on WSC is on outdated varieties (Austin *et al.*, 1980, Bidinger *et al.*, 1977, Bonnett and Incoll, 1992, 1993, Ellen, 1993). Furthermore this information was not collected in trials grown to a standard protocol and therefore it is not possible to cross-reference standard varieties and make comparisons across data sets. The aim of this initial experiment is to quantify WSC amounts in stems of a number of current barley varieties to see if there are significant differences in amounts between varieties, and if the differences between varieties are consistent across sites. If there are significant differences between varieties the next step will be to see whether the differences are large enough to affect the performance of the varieties in circumstances where WSC is important, such as the stresses caused by late season drought and disease

OBJECTIVE

To establish the range of values of amounts of water soluble carbohydrate in stems of winter barley varieties and to determine if the relative level for a variety within the range is consistent across sites in a single season.

MATERIALS AND METHODS

The data were collected on winter barley variety trials at ADAS Rosemaund, Preston Wynne, Hereford and at ADAS High Mowthorpe, Duggelby, Malton, North Yorkshire. The trials were sown on 22nd and 21st September 1997 respectively as three replications of randomised blocks in both fungicide-treated and untreated areas. The crops were grown and managed in the standard manner used for NIAB trials. The measurements of WSC were made on the 13 varieties grown on both sites on the fungicide-treated areas to avoid possible variation in WSC caused by differing disease levels at the two sites. The stem WSC measurements were made on the day after 80 degree-days from anthesis, as this is near to the time of maximum stem WSC in barley (Austin, *et al* 1980). Progress of development towards flowering was recorded every two or three days so that so that date of anthesis could be accurately determined, and then thermal time was calculated daily to determine the appropriate measurement date for each variety at each site. The samples for stem WSC were taken between 10 am and 1 pm, to minimise fluctuations due to time of day, by collecting 8 flowering stems, cut off at ground level, from separate plants then immediately wrapping them in a polythene bag and placing them in a prechilled cool box. On return to the lab the fresh weight of the shoots was recorded. Then the leaves to the ligule, and the ears from the collar were removed and the fresh weight of the remaining stems was recorded. The stems were then flash dried, without cutting at 102 °C for 2h in gauze trays in a preheated forced draught oven. The dried samples were then reweighed and sealed in polythene bags before transfer to the ADAS Wolverhampton Laboratory for determination of % WSC. On the same day as the WSC sample was taken, stem and total biomass per unit area were also determined as follows: an area of the plot of 6 rows by 1.0 m was cut at ground level and sealed in polythene bags and the inter-row distance was recorded. On return to the laboratory the fresh weight of the whole sample was recorded, and a 10% by fresh weight sub-sample taken. The sub-sample was divided into stem, leaf and ear fractions and after recording the number of stems the dry weights of the fractions were recorded after drying at 80 °C for 16 h. Amounts of water soluble carbohydrate per unit area were calculated by multiplying stem weight per unit area by the proportion of WSC in the stem.

RESULTS

Here the results will be considered first in terms of the component directly found to be most useful in wheat, namely, the amount of WSC in the stems. Then the main factors likely to influence amounts of WSC namely: total dry weight, stem dry weight, percentage of WSC in the stem and leaf dry weight will be compared between varieties and sites.

Water soluble carbohydrates

There was a considerable varietal range in WSC at each site with a range of 1.19 tonnes/hectare at Rosemaund and 0.88 tonnes/hectare at High Mowthorpe (Table 1). It was also noted that the varieties with the lowest (Rifle) and highest (Halcyon) WSC levels were the same at each site. Overall analysis of variance showed significant differences between varieties but the WSC amounts between sites were not

Table 1 Stem water soluble carbohydrate (t/ha) of barley varieties at Rosemaund and High Mowthorpe

Variety	Water Soluble Carbohydrate in stems t/ha		
	Rosemaund	High Mowthorpe	Mean
Angora	1.78	1.95	1.87
Baton	1.40	1.71	1.55
Fanfare	1.80	2.07	1.93
Gleam	1.28	1.69	1.49
Halcyon	2.34	2.33	2.33
Hanna	1.84	2.00	1.92
Intro	2.17	1.89	2.03
Muscat	1.82	1.99	1.91
Peridot	1.48	1.60	1.54
Regina	1.57	1.45	1.51
Rifle	1.15	1.45	1.30
Spirit	1.75	1.52	1.63
Vertige	1.61	1.61	1.61
MEAN	1.69	1.79	1.74
SED Varieties	0.196	$p < 0.001$	
SED Sites	0.077	$p = 0.21$	
SED Varieties x Sites	0.277	$p < 0.84$	

significantly different and the interaction of sites and varieties was not significant. The mean varietal values of WSC were also highly correlated between sites (Fig. 1) suggesting a useful degree of varietal determination. It is also a preliminary indicator that WSC may be a heritable character but in view of the many possible influences on WSC, direct confirmation of the degree of heritability available to the breeder will require appropriate crossing programmes and measurement of realised heritability. When examined separately at the sites the varietal differences in WSC at Rosemaund were significant (p = 0.008), but they were not significant at High Mowthorpe. This suggests that some replication across sites will be essential in reliably detecting significant differences between varieties.

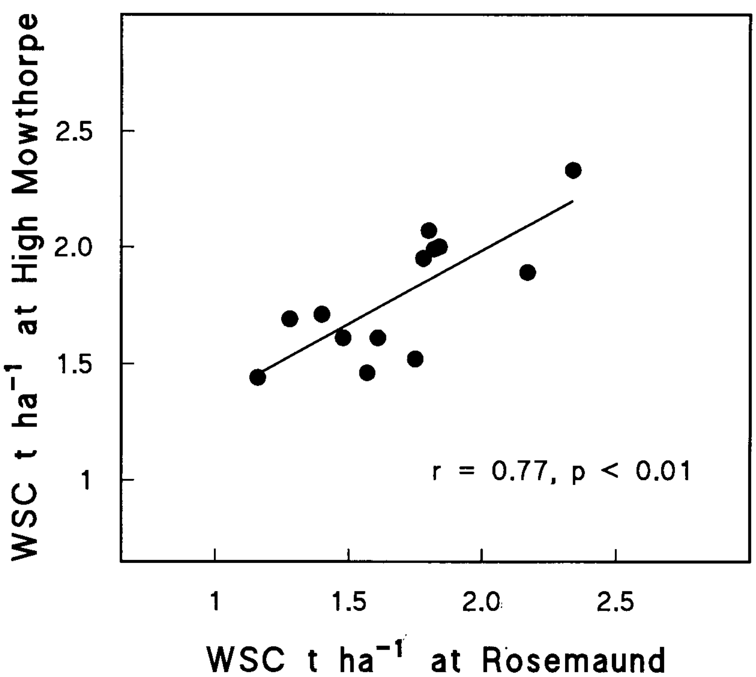

Figure 1 Relation between WSC levels in barley varieties grown at two sites

Components of dry matter at time of WSC sample

The data collected here also allows the varietal components of i) total, ii) stem (plus attached leaf sheath) and iii) leaf (i.e. leaf lamina) dry matter to be studied at the time of WSC sampling. Total dry matter (Table 2) was significantly greater at High Mowthorpe than at Rosemaund but varietal differences were not significant. The higher values were related to the greater time from sowing to sampling at the same stage of development (80 degree-days after anthesis) at the more northerly site with the correspondingly greater incident solar radiation (20% greater at High Mowthorpe from 1st January to sampling than at Rosemaund).

Stem dry matter (Table 3) followed a similar pattern to total dry matter with significant differences between sites, and as for total dry weights, stem dry weights were much higher at High Mowthorpe than Rosemaund. There were no significant differences amongst varieties. This result is important because it demonstrates the significant varietal effect on stem WSC amount was determined more by differences in partitioning between soluble (non-structural) and non-soluble (structural) dry matter in stems than the total amount of stem dry matter accumulated. The percentage

WSC in stems (Table 4) provides a direct estimate of the proportion of non-structural dry matter.

Table 2 Total dry matter of barley varieties at Rosemaund and High Mowthorpe at time of WSC sample

Variety	Total dry matter tonnes/ha		
	Rosemaund	High Mowthorpe	Mean
Angora	9.0	12.9	11.0
Baton	8.7	11.4	10.0
Fanfare	10.2	12.7	11.5
Gleam	9.2	11.4	10.3
Halcyon	11.5	14.0	12.8
Hanna	9.4	11.7	10.6
Intro	10.7	10.7	10.7
Muscat	11.6	13.0	12.3
Peridot	10.4	10.7	10.6
Regina	9.5	12.9	11.2
Rifle	6.9	11.5	9.2
Spirit	9.3	10.4	9.8
Vertige	8.7	12.8	10.7
MEAN	9.6	12.1	10.8
SED Varieties	1.07	$p = 0.11$	
SED Sites	0.42	$p < 0.001$	
SED Varieties x Sites	1.51	$p = 0.58$	

Table 3 Stem (plus attached leaf sheath) dry matter of barley varieties at Rosemaund and High Mowthorpe at time of WSC sample

Variety	Stem (plus attached leaf sheath) dry matter tonnes/ha		
	Rosemaund	High Mowthorpe	Mean
Angora	6.2	9.0	7.6
Baton	6.1	7.6	6.9
Fanfare	6.9	8.9	7.9
Gleam	6.1	7.4	6.7
Halcyon	7.8	9.7	8.8
Hanna	6.7	8.3	7.5
Intro	7.1	6.9	7.0
Muscat	7.6	9.2	8.4
Peridot	6.8	7.2	7.0
Regina	6.0	8.8	7.4
Rifle	4.9	7.8	6.3
Spirit	6.3	6.9	6.6
Vertige	6.2	8.8	7.5
MEAN	6.5	8.2	7.3

SED Varieties	0.81	$p = 0.15$
SED Sites	0.32	$p < 0.001$
SED Varieties x Sites	1.15	$p = 0.74$

Table 4 Percentage of water soluble carbohydrate in stems of barley varieties at Rosemaund and High Mowthorpe.

Variety	Percentage of WSC in stems (including attached leaf sheaths)		
	Rosemaund	High Mowthorpe	Mean
Angora	28.7	21.4	25.1
Baton	22.9	22.4	22.7
Fanfare	26.1	23.5	24.8
Gleam	21.1	23.0	22.1
Halcyon	29.9	24.0	27.0
Hanna	27.8	24.3	26.1
Intro	31.4	27.1	29.3
Muscat	24.1	21.9	23.0
Peridot	21.9	23.1	22.5
Regina	26.6	16.6	21.6
Rifle	24.5	18.5	21.5
Spirit	27.9	22.0	24.9
Vertige	26.3	18.5	22.4
MEAN	26.1	22.0	24.1
SED Varieties	1.60	$p < 0.001$	
SED Sites	0.63	$p < 0.001$	
SED Varieties x Sites	2.26	$p = 0.011$	

Table 5 Leaf lamina dry matter of barley varieties at Rosemaund and High Mowthorpe at time of WSC sample

Variety	Leaf lamina dry matter tonnes/ha		
	Rosemaund	High Mowthorpe	Mean
Angora	0.52	1.50	1.01
Baton	1.12	2.23	1.68
Fanfare	1.26	2.07	1.67
Gleam	0.70	1.82	1.26
Halcyon	1.20	2.49	1.85
Hanna	1.14	1.87	1.51
Intro	1.29	2.11	1.71
Muscat	1.14	1.90	1.52
Peridot	0.66	1.71	1.19
Regina	1.06	1.77	1.42
Rifle	0.44	1.68	1.06
Spirit	0.60	1.38	0.99
Vertige	0.67	1.86	1.27

MEAN	0.91	1.87	1.39
SED Varieties	0.144	$p < 0.001$	
SED Sites	0.056	$p < 0.001$	
SED Varieties x Sites	0.203	$p = 0.41$	

There were significant differences between sites with higher percentage WSC at Rosemaund, and among varieties. There was also a significant interaction between variety and site. In varieties where the difference between the two sites was significant (i.e. Angora, Halcyon, Regina, Rifle, Spirit and Vertige if a LSD test is used) the higher percentage WSC was always found at Rosemaund, the site with the lowest total and stem dry weights. This is consistent with the view that the larger plants at High Mowthorpe had a higher proportion of structural material. In the longer term it may be important to look for varieties where there is better maintenance of the proportion of non structural material at higher stem and total weights to increase the amount of reserves available to contribute to grain filling. However, other features that determine the total amount of reserves per unit area of crop will also need to be taken into account and these factors are outside the scope of this experiment.

Average leaf lamina dry matter was also significantly lower at Rosemaund than High Mowthorpe (Table 5). However, in contrast with the other dry weights there were significant differences between varieties and a significant correlation between sites. This was also demonstrated by the consistent ranking of varieties across sites with three of the top four ranking varieties at High Mowthorpe also appearing in the top four at Rosemaund. At the lower end of the varietal ranking table there was a common pool of four varieties across the two sites.

Yield

Overall, yield was significantly higher at High Mowthorpe than at Rosemaund, and

Table 6 Combine harvested yield of barley varieties at Rosemaund and High Mowthorpe at 15% moisture content.

Variety	Combine harvested yield tonnes/ha		
	Rosemaund	High Mowthorpe	Mean
Angora	4.1	5.9	5.0
Baton	6.1	5.4	5.7
Fanfare	4.4	5.4	4.9
Gleam	4.2	5.6	4.9
Halcyon	4.3	5.1	4.7
Hanna	5.4	5.7	5.5
Intro	4.4	5.8	5.1
Muscat	5.3	5.6	5.4
Peridot	4.9	6.4	5.7
Regina	5.5	7.0	6.2
Rifle	4.0	5.5	4.8
Spirit	4.9	6.9	5.9

Vertige	4.9	6.7	5.8
MEAN	4.8	5.9	5.4
SED Varieties	0.439	$p = 0.013$	
SED Sites	0.172	$p < 0.001$	
SED Varieties x Sites	0.620	$p = 0.175$	

most varieties followed this trend apart from Baton, but as the interaction was not significant this result will need to be confirmed. The greater yields at High Mowthorpe reflect the higher total dry matter at sampling (Table 2) and may also relate to the 8% higher solar radiation integral from sampling to harvest (a period slightly longer than but including grain filling). There was some late lodging at both sites, probably too late to significantly reduce yield and giving rise to only minimal combine losses.

DISCUSSION

The aim of this initial trial is to quantify WSC amounts in stems of a number of current winter barley varieties to see if there are significant differences amongst varieties, and to see if the differences are consistent between sites. This initial objective has been successfully met, and a significant varietal range in WSC has been demonstrated, and it has been shown to have a significant varietal component across two sites. Further work to demonstrate that these conclusions will apply when the data are extended to more than one season will be important. It was noted that the range encountered in WSC in barley was less than in wheat, this could just be the range in the single season studied here, or the limited range of variation in the relatively small pool of varieties studied. Alternatively, lower levels of mobile reserves could be an inherent characteristic of all barley varieties and this would indicate that production of varieties with higher WSC would be a worthwhile longer term aim in breeding programmes. In the current data no significant linear relationship with yield was seen, a contrast with the situation reported in typing trials for winter wheat (Scott *et al.* 1998). However, in the wheat data there were a number of important differences. Firstly, varieties with a greater range of date of introduction were used and this approach may be necessary to provide sufficient variation in yield to detect an overall yield response to WSC. Secondly, in the wheat data both yield and WSC amounts were averaged over three site-seasons, and this degree of replication may be needed to detect significant effects in barley. Thirdly, in winter barley harvest is earlier than in winter wheat, and thus grain filling is less subject to water stress in barley. It is at higher water stress that the contribution of high WSC levels would be expected to be particularly important. This mechanism may particularly have been masked in this data collected in the relatively wet summer of 1998. This contrasted with the dry summers of 1994 and 1995 when wheat typing trials were carried out. It should also be noted that spring barley is usually grown on lighter land when grown for malting and is usually harvested later than winter barley for feed or malting crops and thus is more likely to be water stressed during grain filling. Thus, determination of WSC levels in spring barley should provide useful insights in this area, and will be particularly valuable in view of the approximately equal importance of the spring and winter barley crops. Further understanding of the role of WSC in relation to yield will also be helped by studies on the amount of WSC used in grain filling. The interpretation of the role of WSC in barley will be assisted by further work defining the time course of accumulation of WSC since rapid changes in WSC after anthesis have been demonstrated in barley (Austin *et al*, 1980), and the timing of samples used here was fixed by analogy with wheat.

A secondary aim of this project was to examine the background information on physiological characters other than stem WSC to develop a list of candidate physiological characteristics for use in any future typing trials. The developments discussed here have drawn extensively on the analyses of characteristics in wheat in the Final Project Report on the project "Exploitation of varieties for UK cereal production" (Scott *et al.* 1998). In general terms the most useful physiological characteristics, apart from water soluble carbohydrate which is discussed above, are: developmental parameters, tillering characteristics, nitrogen use characteristics, components of lodging risk, extinction coefficients and yield-forming processes. These will each be considered below:

Developmental parameters

An overriding factor in determining suitability of a particular variety for a given sowing date is the mechanisms governing initiation of floral primordia. In winter crops these mechanisms are responsible for the avoidance of excessive frost damage to the young reproductive apex by delaying the onset of stem extension until the risk of frost is low. In spring crops the developmental control of flowering must allow the initiation of floral apices with a minimal vernalisation requirement. In both winter and spring crops they are responsible for ensuring an appropriate timing of flowering. The magnitude of these developmental responses are related to the varietal parameters which determine the plant's response to climatic variables such as the accumulation of thermal time, daylength and satisfaction of vernalisation requirements. There are known varietal differences in these responses in barley (Kirby *et al.,* 1985). Thus in future typing trials it will be important to quantify appropriate developmental parameters such as phyllochron (the thermal time interval between successive leaves, which acts as the basic developmental unit of time) and the dates of the most important developmental stages i.e. 31 (indicative of the time of maximum frost risk), 39 and 61.

Tillering characteristics

Tillering characteristics are an important varietal trait for consideration in typing trials for three principal reasons: Firstly if a variety has high tillering potential, then there may be the potential for seed to be sown less densely and vice versa. Secondly, if tillering of a variety is excessive then there is the greater potential for losses of yield due to the dry matter lost in aborted shoots. Thirdly in profusely tillered crops there is increased risk of yield loss due to water stress caused by excessive early-season water uptake followed by late-season drought or take-all. Thus in typing trials it will be important to characterize maximum shoot number which is attained at about the double ridge stage of apical development (Hay & Kirby, 1991) and final shoot number which is usually constant after flowering. The potential value of these data can be seen from HGCA project 0037/1/91 on wheat which showed varietal variation in shoot number at GS31 in the range 850 - 1,300 per m^2 which would equate to a potential saving of one third in seed costs over the varietal range. The same project quantified the varietal range in aborted shoots as 400 - 800 per m^2, which corresponded to a range of dry matter lost in shoots destined-to-die of 1.5 - 2.5 t/ha. It also demonstrated that varieties with low dry matter lost in aborted shoots, such as Lynx, perform relatively better in second wheat environments with high risk of take-all.

Tillering in winter barley is similar to that for winter wheat, with greater maxima of around 1,500 per m^2, declining to around 600 - 800 per m^2 at harvest (Gallagher *et al.*, 1975). Similar conclusions to those for wheat have been reached for winter barley on the relationship between dry matter lost in aborted tillers and suitability to particular growing conditions. Jones & Kirby (1977) predicted that genotypes which produced few large tillers having a high rate of survival should be able to achieve relatively high yields in drought conditions without sacrificing yield potential under optimal conditions. Ellen (1993a) has reported, for a range of winter barley and winter wheat varieties, the average decrease in number of shoots during shoot/ear development was 67% in barley compared with 51% in wheat. Thus, appropriate varietal choice in barley could have a greater effect on suitability to particular conditions such as drought than in wheat. With regard to tillering patterns and optimal seed rate, Kirby (1969) found the potential for significant reductions in seed rate for profusely tillering barley genotypes, as has been observed for wheat by Darwinkel (1978).

Nitrogen Economy

Since nitrogen fertiliser timing and amounts are important management decisions in all arable crops an important component of variety typing trials is assessment of the specific nitrogen requirements of individual varieties. One of the most useful management parameters is canopy nitrogen requirement (CNR), the ratio of N taken up in the above-ground leaves and stems (g/m^2) to green surface area (m^2 per m^2 ground area) which is usually constant for a given variety , site and season from GS31 onwards. Together with spring soil N analysis, CNR can be used to accurately determine the amount of fertiliser N required to produce a given canopy size. This information could be extremely useful in specifying optimum N applications to malting barley and thus avoiding excessive grain nitrogen. It could also be applied in breeding of malting varieties to since it is important in these crops to maximise area whilst minimising N uptake, i.e. producing canopies with a low CNR. For wheat, CNR has been found to vary significantly amongst varieties in the range 2.3 – 3.6 g/m^2 (Scott *et al*, 1998) implying that the amount of N required to generate optimal canopy size differs amongst modern genotypes. It would be expected that similar differences would occur amongst barley varieties. In addition to indicating requirement for fertiliser N, CNR may point to susceptibility to foliar pathogens, and a greater need for precise fungicide use with varieties of high CNR. Since knowledge of CNR allows greater precision in estimation of fertiliser requirements it can be used to minimise lodging risk, and in sites with inherently high fertility it can be used to indicate those varieties less likely to produce excessively large canopies.

Basic components of lodging risk

In choice of a variety for a given situation on a farm assessment of lodging risk of the site is important. Because of the serious reduction in yield where lodging occurs the presence of a high lodging risk on a site should be accompanied by the use of a variety with high lodging resistance. Because of the difficulty in assessing lodging potential in traditional variety trials where the occurrence of lodging conditions may vary between years an alternative approach which allows assessment of the underlying lodging potential of a variety is more appropriate to typing trials. A previous HGCA project (Research to understand, predict and control factors affecting lodging in wheat, Research Report 169) has identified basic factors relating to, lodging risk, and of these spread of root plate, height of centre of gravity, and stem diameter are the simplest to measure in typing trials so should receive the highest priority. Shoot number, an important component of lodging risk is covered under previous headings.

Extinction Coefficient

The extinction coefficient and the associated light transmission characteristics are useful basic parameters for calculation of minimum canopy sizes that will intercept sufficient light to maximize growth potential of a variety. This, together with the canopy nitrogen requirement and knowledge of the soil nitrogen status, can then be used to calculate appropriate fertiliser requirements in an analogous way to 'canopy management' as developed for wheat (Sylvester -Bradley *et al.*, 1998), so that overlarge canopies are not produced. This is particularly important in the context of minimizing nitrogen uptake by those crops intended for malting.

A second area in which knowledge of light transmission characteristics has been demonstrated to be useful in American barley varieties is in their differing ability to suppress wild oat infestations (Lanning *et al.*, 1997). Thus information on appropriate light transmission characteristics will be directly relevant to variety choice in those situations where competition from wild oats is a problem.

Yield forming processes

In considering utilisation of varieties an important consideration is the degree of flexibility in the yield forming processes that is able to compensate for differences in environmental conditions in successive seasons that will contribute to stability of yield. In particular the varietal range for harvest index and yield components is greater in barley than wheat. Harvest index together with combine grain yield will be used to calculate the total crop dry biomass at harvest. This is particularly useful since total biomass has been shown to be strongly associated with yield in barley (Naylor *et al.*, 1998); and for winter barley significant varietal differences in total harvest biomass in the range 11.8 – 13.4 t/ha have been reported by Ellen (1993a). Scott *et al.* (1998) reported the range for harvest crop biomass amongst modern wheat varieties examined was 14.0 – 15.5 t/ha. In irrigation experiments examining varietal responses to drought in the same project, larger biomass was associated with greater capacity for water and nutrient uptake in some varieties. Thus characterization of differences in total biomass production in barley varieties should highlight those better adapted to perform well on drought-prone soil types, particularly useful in the more drought-prone spring barley crop.

Another important aid to understanding how yield is determined is the relation between gain size, grain number per ear and the number of fertile shoots. In winter wheat, each spikelet produces about 2 - 3 fertile florets; whereas in barley, each spikelet produces only one fertile floret. To compensate for this, winter barley produces more spikelets per ear about 50 (of which about 40% may die) compared to about 20 spikelets per ear in wheat (of which few die). In Scott *et al.* (1998), the number of grains per ear was shown to differ significantly for current wheat varieties with values in the range 35 – 45 in typing trials. It seems reasonable to assume that differences in grains/ear also exist for modern UK barley genotypes. When attempting to reduce seed rates to the economic optimum, information on grain number per ear will assist growers to identify those varieties with potentially lower optimal seed rates than the norm.

Conclusion: Value of typing barley varieties to growers :

If further barley typing trials are conducted on the basis of this report considerable advances in the provision of information allowing selection of the most appropriate variety for a given site will occur. At present due to the scarcity of information it is difficult to estimate accurately the likely benefits to the industry, but some initial attempts are made below using economic data from Nix (1998) for typing characteristics that will allow account to be taken of specific site and seasonal requirements in variety selection.

- Ability to maintain yield in drought-prone soils. The range of WSC was found to be over 1 tonne/hectare in these data, and for the reasons mentioned above this may be a minimum estimate. The value of this in years when late drought affects barley can be assessed by analogy with wheat. An increase in WSC of 1 tonne/hectare could lead to a yield advantage of 0.4 tonnes/hectare, resulting in a benefit of £30 per hectare at an average grain price of £75 per tonne.
- Ability to maintain yield in crops where take-all is likely to be a problem. Since the effects of take all on the plant are similar to those of drought, a similar minimum benefit of £ 30 per hectare is likely to result.
- Need for control of late season disease. Since the cost of controlling late season disease is likely to be at least £15/hectare, this could be saved in varieties where this is shown to be less important due to high levels of reserves.
- The likelihood of lodging at a particular site. If varieties with high inherent resistance to lodging are identified the possible savings of growth regulators costing £15/hectare and the potentially much higher losses caused by severe lodging of say 2.5 tonnes/hectare of £187 per hectare can be identified.
- The weediness of the site. Identification of varieties that are better able to suppress weeds is likely to save half of the cost of herbicides resulting in a saving of £17/hectare.
- Choice of an appropriate seed rate for the sowing date. Understanding the tillering characteristics of barley where there is apparently greater loss of tillers than in wheat, and therefore being able to relate seed rate more precisely to sowing date will result in a potential saving of perhaps one third of current seed costs, a saving of about

£17/hectare.

- Optimising nitrogen management. Understanding optimum nitrogen levels and canopy nitrogen requirements should reduce the likelihood of malting barley being produced with too high grain nitrogen content, with the resulting lost premium costing at least £10/tonne.

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