PROJECT REPORT No. 320

BARLEY QUALITY AND GRAIN SIZE HOMOGENEITY FOR MALTING:

VOLUME I: AGRONOMIC EFFECTS ON VARIETIES

VOLUME II: ASSESSMENT AND CONTROL

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BARLEY QUALITY AND GRAIN SIZE HOMOGENEITY FOR MALTING:

VOLUME I: AGRONOMIC EFFECTS ON VARIETIES

By

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Volume I is the final report of a 34-month project that started in July 2001. The research was funded by a grant of £149,345 from HGCA (project no. 2306).

VOLUME II: ASSESSMENT AND CONTROL

By

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Volume II is the final report of a 36-month project that started in July 2001. The research was funded by a grant of £128,000 from HGCA (project no. 2294).

Joint abstract covering Project Report No. 120, Volumes I and II

Homogeneity, a measure of grain uniformity, is important for malting and brewing performance and is of increasing interest to maltsters who have to produce a homogeneous malt. The aim of this project was to investigate how barley and malt homogeneity are affected and could be improved by, agronomic management and malting process.

The work was conducted at two sites over three years.

Field trials (Volume I of Project Report No. 120)

The influences of barley variety, nitrogen application, seed rate, fungicide treatment and sowing date on barley properties were examined by ADAS.

Malting trials (Volume II of Project Report No. 120)

The grain produced in the field trials was passed to Brewing Research International for malting. The influence of the malting process (both commercial and laboratory) on malt homogeneity was then examined.

Reducing plant density significantly increased grain size and, possibly, grain size distribution. Grain size has a large influence on the homogeneity of a sample of barley. Seed rate may therefore be a practical way of agronomically influencing homogeneity. Grain nitrogen also increased at reduced plant densities. This effect was greater than that of variety and should be taken into consideration to achieve malting specification.

Fertiliser nitrogen rate and fungicide programme affected grain size by altering crop canopy size and duration and also influenced homogeneity. Nitrogen rate effects on grain nitrogen and thus endosperm structure are a major influence on homogeneity. There is a need to balance use of these agronomic treatments for homogeneity whilst aiming to optimise yield.

The main factors influencing the homogeneity of the malt were damage to grain, endosperm structure of the grain and the corn size distribution. Commercial malting plants did not have a major effect of malt homogeneity.

The main factor influencing the homogeneity of malt was the quality of the barley and the way it was treated in the field. The three key results found when malting grain obtained from the field trials were:

- a significant influence of the seed rate on the corn size distribution (mentioned above),
- a significant influence of nitrogen application on the endosperm structure of the grain (by LTm),
- a significant influence of variety on endosperm structure, corn size distribution and on homogeneity.

Treatments in the commercial malting plant had much less influence than did agronomic factors. This suggests that there are opportunities to grow malting barley under agronomic management to increase homogeneity. However, as such management regimes may not necessarily optimise output for the grower, premiums would have to be set to encourage their adoption.

Contents

Abstract

The aim of this project was to provide maltsters with a better understanding of the factors that influence the homogeneity of modification of malt. Thus for the purposes of this project homogeneity was defined as the grain-to-grain variation of modification. The standard (reference) method used to determine this parameter was the Carlsberg Calcofluor method for homogeneity.

The project was divided into three parts:
1. Laboratory experiments to determine the relative importance of factors influencing malt homogeneity.
2. Experiments in commercial malting plant to compare the influence that these have on the resulting homogeneity.
3. Field trials to determine the influence of various agronomic effects.

The principal conclusions of the project were:
A. The main factors influencing homogeneity of malt were damage to grain, endosperm structure of the grain and the corn size distribution. Surprisingly the influences of germination characteristics and of commercial malting practice were much smaller than the former. Thus a combination of endosperm structure (by LTm) and corn size distribution could be used to predict the (Calcofluor) homogeneity of the final malt (F.pr. <0.001, $r= 0.83$).
B. Commercial malting plants did not have a major effect of malt homogeneity. Contrary to the impression given by the literature, we found that neither steeping nor kilning had a large influence on the final product quality. This statement should be taken in the context of maltsters being aware of the potential influences of these steps and having taken action to prevent problems. One factor that did have an observable effect in these trials was the positioning of the air inlet on kilns. Lower friabilities were observed in grain obtained nearer to the air inlet.
C. The field trials demonstrated the influence of nitrogen application, seed rate, fungicide use, variety and harvest date on barley and malt properties related to issues of grain homogeneity.

Taking note of the comments on predicting homogeneity above three key results were obtained:
i) The significant influence of nitrogen application on the endosperm structure of the grain (by LTm).
ii) The significant influence of the seed rate on the corn size distribution.
iii) The significant influence of variety on endosperm structure, corn size distribution and on homogeneity.

The overall implication was that the main factor influencing the homogeneity of malt was the quality of the barley and the way it was treated in the field. Treatments in commercial malting plant have much less influence than do the agronomic factors.

Summary

Aims

The aim of this project was to provide maltsters with a better understanding of the factors that influence the homogeneity of malt. Although the importance of malt homogeneity has be discussed by other authors several aspects remain unknown:

1. What is the relative importance of agronomic factors, barley quality factors, and malting factors for the final homogeneity of the malt?
2. Which are the key aspects that influence homogeneity within these factors
3. Can the homogeneity of malt be predicted from barley parameters?
4. Do different commercial systems promote or ameliorate homogeneity issues? It is widely reported that steeping and kilning influence homogeneity but are some commercial plant more or less sensitive to this issue?
5. Can anything be done to control homogeneity? Is it possible to improve the homogeneity of malt made from heterogeneous barley?

The project was divided into three parts:
1. Laboratory experiments to determine the relative importance of factors influencing malt homogeneity.
2. Experiments in commercial malting plant to compare the influence that these have on the resulting homogeneity.
3. Field trials to determine the influence of various agronomic effects.

Methods

Barley and malt analysis:
The standard analyses for barley and malt presented here were performed according to the Recommended Methods of the Institute of Brewing. The homogeneity of malt was measured using the Calcofluor sanded block system.

Other analyses:
The analysis of endosperm structure used the BRi Rapid LTm as described by Chandra et al. (2001 J. Inst. Brew. **107**, 39-47). The LTm provided two values associated with endosperm structure:
a) The LTm value was a measure of the average light transmittance value for the sample. This value was sensitive to the particular structure of the endosperm of the grain.
b) The H80 value measured the slope of the line obtained when 80% of grains measured were on an individual basis and plotted in increasing order.
If the LTm value is analogous to the modification score of the Calcofluor test then the H80 value may be considered to be analogous to the homogeneity score of the same.

Statistical analysis:
Statistical analysis used Genstat for Windows 3.2.

Key results and conclusions:
1). Laboratory work. The main factors influencing homogeneity of malt were assessed in two sets of experiments. These were direct laboratory experiments and by correlation between large sample sets.

Laboratory experiments were used to investigate the main factors that could influence malt homogeneity. Optic and Fanfare barleys were treated so as to obtain various levels of heterogeneity. The grain was steeped using a two-steep schedule and then germinated for only two days to maximise any problems with homogeneity. Homogeneity was assessed using the Carlsberg Calcofluor procedure.
The factors that influenced homogeneity fell into three groups:

Group A: Grain damage and the different corn sizes had a very large influence on the modification of the fractions examined and hence on the homogeneity of the bulk sample.
Group B. Hydrostatic pressure and kilning had a moderate influence on the modification of the fractions.
Group C. Surface effects and gibberellic acid had a very small effect. Although the effect of gibberellic acid was consistent it was surprisingly small compared to the influence of some of the other factors. It has been suggested that the germination period (2 days) was too short to manifest large differences due to GA especially in a grain variety that modifies fairly quickly.

In searching for correlation between sample analyses in large sets the most important factors influencing homogeneity were grain size and endosperm structure (by LTM). Surprisingly germination characteristics had no discernable influence on homogeneity of the final malt (Please note: that is not to say that germination did not influence modification, these parameters did not correlate with homogeneity of germination as measured by the methods used here).

A combination of endosperm structure and corn size distribution could be used to predict the (Calcofluor) homogeneity of the final malt. Thus for example using Optic barley:

Calcofluor homogeneity = (0.185 x LTm) + (0.297 x % 2.5-2.8mm fraction) + 62.3
(F.pr. <0.001, r= 0.83)

It should be noted that the regression was related to the variety used.

Novel methods to control and improve homogeneity
An attempt was made to control the level of homogeneity during the malting process. The procedure was designed to provide a growth shock to grains that were germinating quickly but to which non-germinated grains would be immune. The aim was to hold back the germinating grains so allowing those that had not yet germinated to catch up. The concept was similar to the process of using a prolonged final steep.

Although there was some evidence that shocking malt could improve homogeneity the results were not sufficiently consistent, nor large, to warrant further investigation.

2). Work in commercial maltings. Commercial malting plants did not have a major effect on malt homogeneity. Neither steeping nor kilning showed a large influence on the final product quality. This statement should be taken in the context of maltsters being aware of the potential influences of these steps and taking action to prevent problems.
Steeping.
There was some evidence that grain from the surface of the steep vessel modified differently (more quickly) than grain at depth. Although this could be associated with hydrostatic pressure it was noted that there was no change of effect with depth. It is possible then that the effect was associated with access to oxygen rather than depth *per se*. The clearest example of this was the non-aerated, deep flat vessel. The differences in friability between the surface and lower layers were large.
Kilning.
Kilning has been described in the literature as having a major influence on malt homogeneity. In the commercial systems that we examined the effects were not large. One factor that did have an observable effect in these trials was the positioning of the air inlet on kilns. Lower friabilities were observed in grain obtained near the air inlet.

3). The field trials demonstrated the influence of nitrogen application, seed rate, fungicide use, variety and harvest date on barley and malt properties related to issues of homogeneity. Three particularly interesting results were obtained:

i). The significant influence of nitrogen on the endosperm structure of the grain (as measured by LTm).
ii). The significant influence of the seed rate on the corn size distribution.

Both of these parameters were shown to be important for homogeneity in malting experiments.

In addition:
iii) The significant influence of variety on endosperm structure, corn size distribution and on homogeneity. Variety also had a significant effect on homogeneity directly.

Implications

One of the main aims of this work was to compare various aspects of the malting process to determine the relative importance of different factors in regard to achieving homogeneous malt. The two main groups of factor examined were:
i). the influence of growing conditions and the properties of the barley and
ii). the subsequent effects of the malting process on the homogeneity of the final malt.

The clear conclusion of this project was that the properties of the barley have a much greater effect on malt homogeneity than do the effects of malting. Indeed in the commercial situation the maltings generally introduced very little heterogeneity. The key factors influencing the homogeneity of the grain are highlighted in this report.

Technical details

Introduction

It has been observed that the increase in problems attributed to poor homogeneity may be associated with faster malting times and higher steep temperatures with shorter, more frequent, steep times (Freeman and Rehmanji, 1992; Palmer, 1994). So it may be that a reduction in malting times highlights the natural propensity of barley grain to vary in germination time and speed since longer germination periods will allow slower, less vigorous grain to 'catch up'. Griggs (1996) has shown that grain homogeneity becomes mores variable during the middle stages of malting but becomes more uniform by the later stages.

Why is homogeneity important?

Although a malt may have an average specification that is exactly as required, the bulk of grain may contain material that does not meet that specification. A small proportion will have a lower or a higher value than the average. Under many circumstances there will be a normal distribution of values around the mean. In other cases, especially for percentage values, the distribution is not likely to be normal. In the case where malts have been blended the distribution may be bimodal.

There are several reasons why the "non-average" grain may be important. In some cases it is not the average but the worst case that has maximum influence on the process. For example during the milling process an under-modified grain will give a different particle size distribution and hence grist, than a well- or an over-modified grain. For example during mashing, a small proportion of poorly modified grain (with a high level of beta-glucan) may have a disproportionate influence on run-off even though the average value is good (Palmer 2000).

It is generally considered that homogeneous grain is best. In fact this may not always be the case. Homogeneous grain may consistently lack a particular nutrient. A more heterogeneous sample is less likely to show this effect. Limited heterogeneity is probably ideal.

Methods to examine barley homogeneity

A lack of such uniformity can be difficulty to identify. Normal analytical procedures begin with the grinding of malt to form a flour and so any lack of uniformity is immediately lost. In this way cell wall material is broken up, and grains that are low in enzyme activity are mixed with those containing high activity. The same cell wall material could give rise to mashing problems whilst low enzyme malt may perform poorly in high adjunct mashes. Normal malt analyses do not distinguish between samples that are, on average, of high quality with little variation and those that are on average of high quality but with a large spread.

According to the literature the most commonly used method to determine the homogeneity of malt relies on an examination of the non-friable fraction obtained during friability measurement, the so-called Baxter Index (Baxter and O'Farrel, 1983; Burbidge, 1994; Martin et al. 1986 and others). A sample of malt is ground in a friabilimeter and the friability determined in the usual way. The material that was not broken up by this procedure is then passed through a 2.2 mm sieve. The material that does pass through the sieve (x2) expressed as a percentage is considered to be the homogeneity index.

Another popular method of examining homogeneity is the use of dye staining of sectioned grains. Two dyes have been used methylene blue (Drost et al., 1980; Greif, 1980) and Calcofluor (Gibbons, 1980; Aastrup et al. 1981).
The former relies on a non-specific penetration of modified endosperm by the blue dye. Grains are embedded into a resin matrix and are sectioned by sanding. They are then stained and dried and sanded once again. The dye is able to penetrate regions of modified endosperm but unmodified areas appear white.

The Calcofluor method uses a similar procedure but, because the dye is specific for cell wall material, a second sanding is not required. The specific nature of the staining results in this procedure being more sensitive than the former.
The methylene blue method is not quantitative although semi-quantitative assessments can be obtained by experienced users. The Calcofluor method can be used in a quantitative manner, with the appropriate equipment, but is most frequently conducted in the semi-quantitative manner of the methylene blue test. Both of these tests are labour intensive and somewhat subjective, furthermore they are unable to discriminate between well-modified malts.

Several other methods of assessing homogeneity have been proposed including immunochemistry (for alpha amylase - Daussant, 1980), image analysis (Tepral Patent; Reinikainen et al., 1993 &1996; Griggs, 1996); germination profile (Riis and Bang-Olsen, 1991) and NIR (Sinnaeve et al., 1994). Both IOB and Congress type mashes have been modified to reflect differences in malt modification but because the malt is milled these give very little information about homogeneity. Various other mashing tests have also been proposed (for example see Bourne and Wheeler, 1982; Lintzenburger, 1997) as well as a procedure for mashing in individual grains (Palmer, 1975).

Some authors emphasise that because the barley itself is so important for subsequent malt quality, that barley uniformity should be examined by electrophoresis (Schildbach, 1980; Schildbach and Burbidge, 1985).

Where does heterogeneity come from?
The influences on barley and malt homogeneity are many and varied. Figures 1 and 2 list many possible sources of heterogeneity both as a result of treatment in the field and in the maltings respectively. The influence of agronomic conditions is very important in this regard and has not been ignored in the project.

Factors affecting the homogeneity of malt
Poor homogeneity arises from a multitude of factors, but these may be divided into two main groups (figure 1):

In the Field. Factors such as growing site, agricultural inputs, climate and local weather all influence homogeneity of the barley grain. Plant associated factors such as variety, plant, tiller and even within ear variation have a similar effect.

Agronomic factors that may influence homogeneity are site, seed rate, agrochemical, variety and harvest date. Malting factors include steeping, germination and kilning. Between the field and the maltings (at least conceptually) lie the actual properties of the grain. Key parameters in this regard are uniformity of germination, endosperm structure and grain size distribution. All of these factors have been investigated during this project.

In the Maltings. The conditions to which the barleys are subjected to in the maltings are equally important in determining malt homogeneity (figure 2.). These include steeping germination and kilning stages.

One source of heterogeneity is the blending of malts. This is not due to some property of the grain or of the process but is a consequence of the management of production. So, when two malts are blended, the new value of a parameter is the average of the two component averages, however the new variability is the sum of the component variation (See figure 3). Standard methods of optimisation for this process are available but these are not the subjects of the present research. For this reason they have not been dealt with here.

Reasons for poor homogeneity

1. The Barley

Home et al. (1997) have identified several features of the barley itself which may lead to non-homogeneous malt modification. These included:

1. Uneven start of germination due to embryo differences (GE, GC etc).
2. Different protein levels in the grains.
3. Kernel size and shape may influence both water uptake and distribution.
4. Enzyme level and distribution.
5. Endosperm structure and cell wall thickness.

All of these may result from the different growing conditions experienced before harvest. Variations in temperature, moisture, light intensity and nutrient levels will influence grain condition even within a single field. These may in part be reflected in grain size and smaller grains are routinely separated from the bulk. Grain will also vary on an individual ear, sometimes by more then between plants (Fischbeck, 1971) and between tillers (Cocherane, 1994).

Brennan et al. (1996) have considered the influence of grain structure and suggest that differences in modification may be attributed to variations in the patterns of protein accumulation. This detailed structural feature of the grain is not usually examined although the traditional use of the farinator may reflect the importance of this parameter. The ability of barley grains to take up water and, more significantly, to re-distribute that water throughout the endosperm, is crucial in obtaining a uniform distribution of enzymes and hence uniform endosperm modification. (Davies, 1992; Chandra et al., 1998). Rath (1996) has emphasised the role of the endosperm structure in the uniform distribution of water throughout the grain. He has shown that different barleys (of feed and malting grades) take up water at different rates. At least some of these differences can be accounted for by the condition of the embryo, but the endosperm structure also plays a significant role.

2. The Process

Freeman and Rehmanji (1992) have examined the homogeneity of commercial malts in relation to processing conditions. They found that grain which had been steeped three times modified more rapidly then grain steeped only twice but latter generated more homogeneous malt. Higher out of steep moistures also improved uniformity. Their conclusion was that different steeping regimes may arrive at the same level of modification but by different ‘ routes’. These may not give the same homogeneity.

Work at BRI

Several projects at BRI have been concerned with the relationship between barley characteristics and malt homogeneity.

Our project on endosperm structure (HGCA Project Report No. 141) has highlighted the role of beta-glucan and protein in limiting the distribution of water within the endosperm. Since this is clearly important for subsequent malting a transflectance meter has been developed at BRI as part of a project partially funded by the HGCA (Project Report No. 248) This meter can be used to detect quality differences in endosperm structure between individual barley and malt grains. It is anticipated that the meter will play a key role in assessing homogeneity in this proposed project.

Some important questions that remain unanswered include:

Which factors influence malt homogeneity and how important are these relative to each other?

What properties of the grain influence uniform germination? Does grain possess a mechanism that ensures a range of germination times?
Does germinating grain produce inhibitors that hold back other grains?
Can barley germination be entrained, as is the case for other seeds?

Which types of malting plant/process give the most homogeneous malt?

Can the malting process improve homogeneity or merely compound problems with the barley. That is does analytical homogeneity deteriorate during malting or do any of the processes involved improve or ameliorate variability.

Conclusion
It seems clear that recent concerns over the homogeneity of malt have coincided with the move towards shorter faster malting regimes. Previously it seems that a leisurely approach to malting permitted grains of different character to modify to the same extent if at different rates. Now that it is necessary to malt in shorter times the process has become very sensitive to small differences in grain quality. BRI is addressing the issues of endosperm structure but must also deal with the embryo condition.

Materials and Methods

Barley and Malt analysis:

The standard analyses for barley and malt presented here were performed according to the Recommended Methods of the Institute of Brewing.

Measurement of homogeneity:

Different authors consider the homogeneity of malt to mean different things. For the purposes of this report homogeneity considers the uniformity of analyses between different grains. The basis for the measurement of malt homogeneity is the Calcofluor plate system.

Other analyses:

The analysis of endosperm structure used the BRi Rapid LTm as described by Chandra et al. (2001). The LTm measurement is the average LTm value obtained using this machine to analyse 97 grains. The H80 value is the reciprocal of the gradient of the first 80 grains and therefore provides some indication of the homogeneity of the value. The LTm value and the H80 may be taken as analogous to the modification and homogeneity values for friability or for Calcofluor.

Statistical analysis.

Statistical analysis used Genstat for Windows 3.2. Please note that x is used as the multiplier in equations.

A note on homogeneity v modification of fraction

The homogeneity of modification of a bulk is determined by the individual measurements of sub-samples from that bulk. This may lead to some confusion regarding the measurement of homogeneity when considering these sub-samples. Hence at several points in this project the homogeneity of the bulk is determined by the measurement of modification of the samples.

Aim of the project.

The aim of this project is to provide practical tools for the maltster to measure, limit and control homogeneity of the final malt product.

Plan of the Report

Rather than organize the work by year, the project has been organized on a functional basis: Thus the bulk of this report is organized in the following manner:

1. Laboratory work

2. Work in commercial maltings

3. Field work

Anova

- a Year 1
- b Year 2
- c Year 3

Correlation Analysis

Raw Data

Laboratory work

A. Protocols to assess homogeneity

It has been assumed throughout this project that three aspects of barley quality will influence the homogeneity of the malt. These are

1. the sizes of the grain in the bulk
2. the germinative capability of the embryo and
3. the structure of the endosperm.

These parameters were examined further to obtain a predictive measurement of homogeneity, either of the barley or the malt.

1. Size fractions

The size fractions of the grain are easily measured by sieve analysis and it was not considered necessary to develop any improvement of this method of analysis. However it was discovered that there was a good correlation between the size properties of the barley sample and subsequent malt properties.

Details are compared with modification Table 1

Table 1. Correlation between barley grain size and malt modification analysis

	Explanatory	Response	F.pr.	r^2
1	Percent greater than 2.8 mm	Malt Calcofluor Modification	<.001	.18
2	Percent greater than 2.8 mm	Malt Calcofluor Homogeneity	<.001	.23
3	Percent 2.2 to 2.5 mm	Malt Calcofluor Modification	<.001	.12
4	Percent 2.2 to 2.5 mm	Malt Calcofluor Homogeneity	<.001	.17
5	Percent 2.5 to 2.8 mm	Malt Calcofluor Modification	<.001	.20
6	Percent 2.5 to 2.8 mm	Malt Calcofluor Homogeneity	<.001	.25
7	1 and 3	Malt Calcofluor Modification	<.001	.19
8	1 and 3	Malt Calcofluor Homogeneity	<.001	.24
9	1,3 and 5	Malt Calcofluor Modification	<.001	.17
10	1,3 and 5	Malt Calcofluor Homogeneity	<.001	.27

Since these regressions appeared to be highly significant (if the correlation a bit low) it was decided to use this as the basis for a prediction (see later section).

2. Germination

The germinative capability of the grain may influence homogeneity because grains that germinate late are likely to modify later than grains that germinate early. In addition grains that germinate late may also modify more slowly. For these reasons the standard germinative tests were modified to provide more information about the germination characteristics of the grain.

Throughout this project the standard 4ml (germinative energy), 8ml (water sensitivity) and peroxide tests (germinative capacity) tests were used. In addition a new test was developed to examine the variation in germination of a sample. A sample of 100 grains was germinated according to the protocol for the germinative energy test. As the grains chitted the number was recorded and they were removed from the test. The profile of chitting verses time could be plotted as a graph (see figure 4.) and was fitted to a Gompertz curve. Two values could be obtained from this fit. Gompertz m is a measure of the delay before any grains chit (called here germinative delay), Gompertz b is a measure of the uniformity of chitting (called here germinative rate).

Using the protocol described in the methods section the germination profile was fitted to a Gompertz curve. This provides two parameters, a germination delay (that is the time before

any germination begins) and a germination rate (that is the time over which all of the grains germinate). Figure 5 shows two samples of grain, one showing a small Gompertz b (fast germination rate), the other showing a large Gompertz b (slow grermination rate).

The value of these parameters was assessed during the course of this project.

Table 2. Correlation between barley germination properties and malt modification analysis

Explanatory	Response	F.pr.	Maximum Value	Minimum Value
4ml Germinative Energy	Malt Calcofluor Modification	.368	100	96
4ml	Malt Calcofluor Homogeneity	.414		
8ml Water Sensitivity	Malt Calcofluor Modification	.160	98	66
8ml	Malt Calcofluor Homogeneity	.131		
Peroxide Viability	Malt Calcofluor Modification	.497	100	92
Peroxide	Malt Calcofluor Homogeneity	.446		
Germination delay	Malt Calcofluor Modification	.216	29.6	22.8
Germination delay	Malt Calcofluor Homogeneity	.489		
Germination rate	Malt Calcofluor Modification	.714	2.036	.11
Germination rate	Malt Calcofluor Homogeneity	.767		

There was no compelling evidence that the germination parameters correlated with any indication of malt homogeneity. The variation in the values for germinative energy and viability was very small (although realistic for malting samples) and it is possible that this prevented the generation of a significant result. This is not likely to be the case with the other analysis, which show good variation.

3. The structure of the endosperm

It is generally agreed that the structure of the barley endosperm might influence malt modification. To examine this BRi has developed a device known as the LTm to examine barley and malt endosperm structure (See figure 6). During this project the use of the LTm was extended to assess the homogeneity of the barley and malt endosperm. Correlations were sought between parameters measured by the LTm and barley and malt parameters.

Table 3 Correlation between barley endosperm structure (by LTm) and malt modification analysis

Explanatory	Response	F.pr.	r^2
Barley LTm	Malt Calcofluor Modification	<.001	.55
Barley LTm	Malt Calcofluor Homogeneity	<.001	.58
Barley H80	Malt Calcofluor Modification	<.001	.40
Barley H80	Malt Calcofluor Homogeneity	<.001	.47
Malt LTm	Malt Calcofluor Modification	-	-
Malt LTm	Malt Calcofluor Homogeneity	-	-
Malt H80	Malt Calcofluor Modification	.38	-
Malt H80	Malt Calcofluor Homogeneity	.982	-

Although the aim of this experiment was to determine a relationship between the H80 values and the homogeneity of the final malt, there was clearly a relationship between this endosperm parameter as measured by LTm and the homogeneity of the final malt as well. This will be explored in more detail in the section on prediction of homogeneity.

B. Laboratory scale trials to examine influences on homogeneity

Index of this section:

1. Introduction

This section details laboratory work conducted to examine the influence of different malting factors on the homogeneity of final malt. It is widely recognised that there are three important factors influencing the homogeneity of malt. These are:

1. Barley properties (Reference Home)
2. Steeping systems
3. Kilning procedure

Laboratory scale trials were conducted to confirm these, to examine other potential influences on homogeneity, and to compare the significance of these. The goal of his stage of the work was to determine where the major influences were and to seek potential methods of influencing and improving homogeneity.

In each case the grain was germinated for two days in order to maximise heterogeneity, malting for longer periods resulted in less observable heterogeneity, until about day six when there very little heterogeneity observed by Calcofluor. It remains possible however that the grain would still be heterogeneous at this later time even though it could not be observed by Calcofluor. One batch of Optic barley was used throughout these experiments.

As was mentioned in the overall introduction, the reader should consider the relevance of modification and homogeneity measurements of samples in relation to homogeneity of the whole. That is a difference in modification between fractions is manifest as heterogeneity of the bulk. The homogeneity values presented are of the samples analysed, they do not refer to the bulk.

To aid reading this section with out having to refer to other parts of the document each part of the work considers a different factor and is divided into a background, experimental, results and conclusion section.

2. Effects of hydrostatic pressure on homogeneity

Back ground

The influence of hydrostatic pressure on homogeneity has been reported before (Freeman and Rehmanji 1992).

Experimental

Tall tubes were used to steep grain at different depths of water. Optic barley (350g) was placed in a tall tube in a 12^0 room and subjected to a 7, 17, 7, 17, 1 steeping regime with different levels of de-ionised water. A full tube contained 150 cm of water. Therefore a ½ filled tube contained 75 cm. Minimum steeping contained water up to the level of the grain. The grain was then transferred to a sweet jar at 16^0C and germinated for 2 days. The grain was kilned in a fan oven (45^0C 7 hrs, 65^0C 17 hrs). Day 2 dried samples were analysed by Calcofluor staining. A, B and C are replicates.

Results

Table 4 Influence of hydrostatic pressure on malt modification by Calcofluor staining

	Full tube		Half full tube		Minimum water in tube	
	Modification	Homogeneity	Modification	Homogeneity	Modification	Homogeneity
A	48	57	51	48	59	51
B	46	53	50	43	56	49
C	47	59	47	50	55	47
Average	47	56	49	47	57	49

Table 5 Summary of results of table 4

	Modification	Homogeneity
Full tube	47	56
Half full tube	49	47
Minimal water in tube	57	49

This data is presented as figure 7.

Calcofluor staining showed that at greater depth a lower modification was seen. Considering the caveat (discussed at the beginning of this section) heterogeneity will be introduced into the grain by only 150 cm of water. This may be due to an increase in hydrostatic pressure or it may be due to the grain at the surface having better access to oxygen. This result was also observed in commercial systems as well.

Conclusion

With all replicates as with the pilot experiment greater level of water equated to a lower level of modification. The greatest modification was observed in the grain closest to the surface. It is not clear whether the difference between ½ full and full was significant. The result was consistent but not large in the replicated experiment.

Possible reasons for the difference in modification:

1. Hydrostatic pressure influenced grain germination
2. Grain at the surface had better exchange of gases (more oxygen/less carbon dioxide).

Additional Note: These results can be compared to a similar set of trials on a commercial scale. The results of the commercial trials (p41) suggested that depth was less of an issue than access to oxygen. The top layers modified more effectively than other layers.

3. Surface effects on homogeneity

Back ground

It was observed that there was more root growth of grains at the sides/base of a sweet jar than in the middle. This might be associated with greater modification. There are a number of possible reasons for this:

- That the roots can not go straight down causes them to mat together giving the appearance of being further advanced, in fact there is no difference.
- At the base of the jar there is more available water due to gravity, causing greater modification
- A surface effect of the glass is either facilitating the uptake of water on reacting with some unknown germination inhibitor
- The grains near the sides may get some light if the cupboard is not completely dark.

Experimental

Optic barley (350g) was subjected to a 7, 17, 7, 17, 1 steeping regime and then germinated for 2 days without shaking. The jars were kept in a dark cupboard in black bin liners to remove the possible effects of light. The malt was kilned in a fan over (45^0C 7 hrs, 65^0C 17 hrs). The modification and homogeneity were then assessed using Calcofluor staining.

Results

Table 6 Influence of surface position on malt modification by Calcofluor staining

Position	Modification	Homogeneity
Top	69	66
Middle	69	67
Bottom	72	65

Averages of 4 samples

Modification was only very slightly affected by position of the grain in the sweet jar during germination. Visual inspection of the jars showed that the grains at the bottom and sides, next to the glass had matted together. This had the effect of making the roots appear longer. It is likely that there was no effect on modification

Conclusion

Homogeneity of the samples was largely unaffected by position in the jar.

4. Effects of different coloured lights on homogeneity

Background

Roth-Bejerano et al. And Casal et al. have investigated the effects of light on barley germination. They have found that prolonged exposure to light caused a reduction in germination particularly when performed under water stressed conditions. They suggest that the inhibition may be caused by an accumulation of Ca^{2+}. This was backed up by the fact that lanthanum, a Ca channel blocker, overcame the inhibitory effects of light. Rapid germination may reduce cytosolic Ca^{2+} accumulation whereas slow germination promotes Ca^{2+} accumulation from endogenous sources. In continual darkness cytosolic Ca^{2+} may be chelated, a process which could be inhibited by light.

Germination under different coloured filters

Experimental

Initial experiment: 6 ml H_20 was added to a 90 mm petri dish containing a single Whatmans No1 filter paper and 100 grains of Optic barley. The petri dishes were placed in a dark cupboard at 16^0C and the number of grains germinated monitored. They were illuminated with a single fluorescent tube held at 50 cm when required.

Results

When grains were steeped with excess water, the rate of germination did not differ greatly for different lights under these conditions. Initially the sample in the dark germinated faster. However after 40 hours this was overtaken and by 113 hours the final count, the sample germinated in the dark trial had the most non germinating grains (See figure 8.) . Differences between light and dark germinated grain were, however, small.

As noted the experiment above was conducted with excess water. This was not a realistic situation as the availability of water during steeping is usually limiting and the final moisture of the grain is approximately 45%. For this reason the experiment was repeated in limited water. In order to limit the water availability two approaches were used. Grains were steeped in sorbitol solutions and with reduced volumes of liquid. Sorbitol is not metabolised either by the barley embryo or by the microorganisms found on malt. It nevertheless has an influence on the osmotic pressure.

Effect on white light on germination and homogeneity under conditions of limiting moisture.

Experimental

To establish the effects of short periods of light on germination samples of 100 grains with 3ml or 5ml sorbitol (0-1M), were maintained in the dark or exposed to fluorescent light. Grains were examined for germination at 36 hrs and the actual moisture levels of the grains were determined. The results achieved are summarised below.

Results

Grain that was given ready access to water achieved a moisture content of some 45%, grains that had some water limitation achieved 42.5% moisture. Neither of these experiments showed any influence by light on germination. However grain that was steeped in higher concentrations of sorbitol achieved only 40% moisture content. In this case there was some evidence that light inhibited germination (see figure 9.). Specifically grain that was steeped in 3ml of 0.3M sorbitol germinated more slowly in the light than in the dark.

Conclusion

The academic literature suggests that light may inhibit germination and under certain conditions of moisture we have been able to demonstrate this. The experimental circumstances needed for light to influence germination, however, were not those used during commercial malting. Therefore this parameter may not be relevant to homogeneity in commercial situations.

5. Effects of kilning on homogeneity

Background

It is widely recognized that kilning can have a profound influence on the homogeneity of malt. (Freeman and Rehmanji 1992).

Drying is initially greatest at the bottom of the kiln, reducing enzyme activity and hence slowing modification at the base first and moving progressively upwards. Modification can continue during kilning provided the malt is not dry. The elevated temperatures higher in the kiln may even assist modification whilst the grain at the bottom of the kiln is dried quickly and modification stops.

Experimental

A pilot scale malting (50 kg) was carried out, germinated to 2 days and the sample was then kilned in the BRi Pilot kiln. The kilning was carried out in 12 temperature stages over 30 hours. The break point was at 18 hours after which time 90% recirculation of air was used. Samples were taken of green malt, half way through kilning and at the end of kilning. All samples were then dried at 50 ^{0}C for 24 hours using a high air-flow oven. Samples (2) were taken from the top, middle and bottom of the kiln. The samples taken within each level were mixed and analysed by Calcofluor staining, and friability.

Results

Calcofluor staining analysis

The samples were also analysed by Calcofluor staining. Here the predicted trend was seen. (Shown in Figure 10). Modification (and Homogeneity not shown) were lowest at the base of the kiln and progressively more homogeneous higher in the kiln.

Friability

No difference in modification was seen (results not shown). This is in contrast to other reported results (Freeman and Rehmanji 1992). Other results may have referred to commercial kilns. Different regimes may have been used, allowing the top to continue germinating for longer.

Conclusion

Kilning clearly did have a major influence on modification and homogeneity of the final malt. Please see the final section of this part of the report for a comparative assessment of this.

6. Effects of grain size on homogeneity of malting

Background

Experimental
Optic barley was separated into fractions of <2.2 mm, 2.2-2.5 mm, 2.5-2.8 mm and >2.8 mm. 100 grains and 4 ml of water were added to a petri dish and incubated at 16^0C for four days. At 2 days they were assessed for germination rates, dried (45^0C 7 hrs, 65^0C 17 hrs) and analysed by Calcofluor staining.

Results
The results are shown in Figure 11. The Calcofluor analysis showed grains <2.2 mm had low modification. Grains of this size are almost all removed before malting. Of the grains remaining greatest modification was seen for grains 2.5-2.8 mm. Modification of the grains in the size fraction 2.8-3.5 mm was slightly reduced compared to the previous fraction.

Conclusions
It is well known that grain size influences moisture uptake into grain (see for example figure 12). The largest grains show slower water up take. Hence it is considered that the size profile will have an important influence on the final modification of the malt

7. Effect of damage and GA on homogeneity

Background

The pericarp of barley is impermeable to aqueous solutions. Artificial damage of the grain may increase water uptake and also uptake of exogenous gibberellic acid. How this will influence homogeneity is unclear but since the damage is likely to be very different between grains the potential to influence homogeneity is clear.

Gibberellic acid is a naturally occurring plant growth hormone. It shortens malting time by increasing the production of hydrolytic enzymes.

Experimental

Grains were damaged artificially using a rotating wire brush machine. This treatment resulted in tiny scarifications being made through the pericarp-testa mainly at the distal end. Exogenous gibberellic acid (0.2 ppm) was applied as described below.

Assessment of damage to grains

In order to differentiate between damage to the pericarp and the testa of the grain, the damage was assessed by the charring test (lighter damage to pericarp only) and by the iodine test (more server damage to both).

Table 7 Typical results for the charring test.

Grain	Non-abraded	Abraded
Number Distal charring	2	147
Total number of grains	184	173
% with distal pericarp damage	1	85.0

Table 8 Typical results for the iodine test.

Grain	Non-abraded	Abraded
Number Distal stained	2	89
Total number stained	3	112
Total number grains	173	170
% with distal testa lesions	1.16	52.35
% with testa lesions	1.73	65.88

Experimental

Barley (Optic 350g) was placed in a sweet jar and subjected to a 7,17, 7, 17, 1 steeping/air rest program at 16^0C. At cast samples were sprayed with gibberellic acid as shown below. Batches were germinated for 5 days with daily shaking, and analysed after 2 days by Calcofluor analysis and after 5 days by friability.

Table 9 Influence of damage and GA on malt modification by Calcofluor staining

	Replicates	Abraded	Gibberellic acid
1	2	Yes	0.2ppm
2	2	No	0.2ppm
3	2	Yes	None
4	2	No	None

Results

Calcofluor analysis

Calcofuor analysis was performed on samples taken at 2 days of germination, the results are shown in Figure 13.

By day two the abraded grains were almost completely modified. At this stage they were also highly homogenous. The non-abraded grains were less modified as expected, they also had a lower homogeneity.

Friability analysis

Friability analysis was performed on 5 day sample.

Table 10 Influence of hydrostatic pressure on malt modification by friability

Sample	Modification	Homogeneity
Damaged 0 ppm GA	88.98	98.32
Damaged 0 ppm GA	88.12	98.88
Damaged 0.2 ppm GA	92.32	99.68
Damaged 0.2 ppm GA	95.32	99.64
Undamaged 0 ppm GA	94.18	98.86
Undamaged 0 ppm GA	95.96	99.12
Undamaged 0.2 ppm GA	95.68	99.68
Undamaged 0.2 ppm GA	96.06	99.80

By day 5 the grains were all very well modified. The results appear to show slightly lower modification for damaged grains with and without GA, the homogeneity for damaged without GA also appeared to be lower. These results, however, are not sufficiently different to draw any real conclusions. It seems likely that the barley used combined with the relatively long malting conditions have resulted in full modification of all the samples and so it is not possible to draw conclusions from the friability work,

Conclusion

Experiments with shorter germination periods show that damage to grain can have a large influence on modification and homogeneity.

8. Final Conclusion: Comparison of effects:

The aim of these experiments was to compare the importance of the different effects.

Table 11 Summary and comparison of laboratory experiments

Condition	Max Value	Min Value	Difference	Condition Max
Hydrostatic pressure	57	47	10	Low pressure
Surface effects	72	69	3	-
Kilning	77	71	6	Top of kiln
Size fractions	92	71	21	2.5-2.8 mm
Damage	85	61	24	Abraded
Gibberellic acid	64	61	3	GA

The column <Condition Max> indicates the experimental condition that gave maximum homogeneity.

The factors that influenced homogeneity fell into three groups:

Group A: Grain damage and the different sizes had a very large influence on the modification of the fractions examined and hence on the homogeneity of the bulk sample.

Group B. Hydrostatic pressure and kilning had a moderate influence on the modification of the fractions.

Group C. Surface effects and gibberellic acid had a very small effect. Although the effect of gibberellic acid was consistent but it was surprisingly small compared to the influence of some of the other factors. It has been suggested that the germination period (2 days) was too short to manifest large differences due to GA especially in a grain variety that modifies fairly quickly. Alternatively the GA effects may have been small because the variety used tends to modify quickly naturally. Larger effects may be observed in other varieties.

C. Control of homogeneity in the Maltings

This section is divided into two parts:

- Predicting homogeneity
- Novel methods to control and improve homogeneity in the maltings.

A. Predicting homogeneity

Part of this project examined novel ways of controlling and possibly improving the homogeneity of malt in the maltings (see next section). However before a maltster would take steps to control homogeneity they would require an indication that homogeneity is going to be a problem. For this reason a simple prediction of homogeneity from barley properties was sought.

Three parameters were examined:

1. Germination

Figure 14 shows the modification of a malt against the time of chit. Several of these experiments were conducted although only a single figure is presented. This figure illustrates especially clearly that grain with the same rate of chitting could produce different malts whereas grains with different chitting properties could produce malts with the same level of modification. This suggests that, taken in isolation, the germination properties of the grain were not a good predictor of malt properties. Furthermore they did not enhance other predictions as part of a multiple regression.

There is a second disadvantage in using germination properties to predict malt parameters and that is the time required obtaining the germination characteristics. Germination measurements are generally slow. For these reasons germination properties were not pursued as a predictive test.

2 Grain size

Earlier indications suggested that grain size fraction might be a useful indicator of malt homogeneity (see Protocols to assess homogeneity: size fractions). The use of adventitious samples indicated that there was a highly significant relation ship between certain size fractions of barley and malt homogeneity (See Figure 15, tables 12 and 30). However the samples for the previous investigation were selected from available batches rather than from a designed experiment and hence the correlations were not very good. For this reason experiments were designed using ANOVA protocols in order to improve these correlations.

Table 12 Correlation between barley grain size and malt modification by Calcofluour staining (unstructured experiment)

	Explanatory	Response	F.pr.	r^2
1	2.2 to 2.5	Malt Calcofluor Modification	.84	
2	2.2 to 2.5	Malt Calcofluor Homogeneity	.73	
3	2.5 to 2.8	Malt Calcofluor Modification	.040	.17
4	2.5 to 2.8	Malt Calcofluor Homogeneity	.113	
5	2.8 to 3.0	Malt Calcofluor Modification	.238	
6	2.8 to 3.0	Malt Calcofluor Homogeneity	.399	
7	1 and 3	Malt Calcofluor Modification	.125	
8	1 and 3	Malt Calcofluor Homogeneity	.222	
9	3 and 5	Malt Calcofluor Modification	.002	.47
10	3 and 5	Malt Calcofluor Homogeneity	.043	.22
11	1, 3 and 5	Malt Calcofluor Modification	.005	.46
12	1, 3 and 5	Malt Calcofluor Homogeneity	.061	

3. Endosperm properties

When the project began it was not known that LTm H80 (for an explanation of H80 see Methods section) might be a useful predictor of malt homogeneity. Variation in endosperm structure influences modification and hence uniformity of the final malt. A major influence on the LTm measurement is the structure of the endosperm, thus LTm may be a useful predictor of malt homogeneity. Figure 16 shows the relationship between endosperm structure as measured by the LTm and final malt homogeneity as measured by Calcofluor staining for Optic barley. The correlation between LTm measurement of the barley and malt homogeneity was very good and may provide a useful prediction.

Can barley grain size be used as a predictor of malt homogeneity?

Background

The purpose of this part of the project was to examine the effect of barley grain size distribution on homogeneity of the malted grain and to determine whether the distribution can be used to predict malt homogeneity. In order to investigate the effect of grain size distribution on homogeneity, two batches of barley (Optic and Fanfare) were separated into grain size fractions by sieving and defined mixtures were prepared (as detailed in table 14). Samples were made up with a controlled composition of a specific range of grain sizes, and then malted using a precise malting schedule. A short germination time was chosen to maintain any discrete features of each sample.

The grain sizes used to make up the samples were as follows.

2.2 – 2.5 mm
2.5 – 2.8 mm
2.8 – 3.0 mm
3.0 – 3.25 mm
>3.25 mm

Barley was supplied in 25 kg sacks. Two types of barley were investigated – Optic 99/16 and Fanfare 99/15. In order to prepare defined size ranges a sack of each barley variety was sieved using the pilot scale cleaning and screening machine.

The following quantities of each barley were obtained from the large scale sieving.

Table 13 Yields of different size fractions for two barleys

	FANFARE	OPTIC
Sieve size (mm)	Weight (g)	Weight (g)
2.25-2.50	644	298
2.50-2.80	5658	2423
2.80-3.00	21400	11622
3.00-3.25	3289	17252
>3.25	16	271

It was found that the distribution of the five grain sizes was not balanced across the range, with most of the grains in the mid-range for both samples and very few grains at each extreme

of size. A precise set of fractions was determined and 350g sweet jars were prepared according to the required specifications – see following table for required distribution.

Table 14 Structured experiment to determine effect of grain size on malt modification properties (target recombination of fractions)

Optic	Fanfare	2.2-2.5	2.5-2.8	2.8-3.0	3.0-3.25	GT3.25
1	0	0	0	0	100	0
1	0	0	0	100	0	0
1	0	0	100	0	0	0
1	0	0	50	25	25	0
1	0	0	25	50	25	0
1	0	0	25	25	50	0
1	0	0	10	35	55	0
1	0	5	10	32	53	0
1	0	0	10	32	53	5
1	0	5	10	30	50	5
Optic	Fanfare	2.2-2.5	2.5-2.8	2.8-3.0	3.0-3.25	GT3.25
0	1	0	0	0	100	0
0	1	0	0	100	0	0
0	1	0	100	0	0	0
0	1	0	50	25	25	0
0	1	0	25	50	25	0
0	1	0	25	25	50	0
0	1	0	20	70	10	0
0	1	5	20	65	10	0
0	1	0	20	65	10	5
0	1	5	20	60	10	5

All figures are percentages.

Having sieved the barley on the cleaning and screening machine to obtain approximate fractions, more precise sieving was then needed. Each fraction that had been obtained by "rough" sieving was now run over the small-scale sieves until enough of each size was obtained to make up the sweet jars. The actual weight required of each grain size is shown in the following tables. The percentages of each grain size were weighed out to make up each jar, and then the contents of each jar were sieved again on the small sieves to obtain precise weights (and thus precise percentages) of each grain size. The actual weights and actual percentages are also shown in the tables. Note: all work was carried out in duplicate (this was necessary for the statistical analysis that was to be applied to the results).

Table 15 Experiment to determine the effect of grain size on homogeneity
Fanfare (Set A)

350g sweet jars containing Fanfare 99/15 barley to be made up in the following ratios (set A)

sample	2.2-2.5	reqd wt	act wt	act per	2.5-2.8	reqd wt	act wt	act per	2.8-3.0	reqd wt	act wt	act per
	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)
1	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
2	0	0	0.0	0	0	0	0.0	0	100	350	350.0	100
3	0	0	0.0	0	100	350	350.0	100	0	0	0.0	0
4	0	0	0.0	0	50	175	167.0	48	25	87.5	101.4	29
5	0	0	0.0	0	25	87.5	89.9	26	50	175	168.7	48
6	0	0	0.0	0	25	87.5	85.4	24	25	87.5	93.8	27
7	0	0	0.0	0	20	70	75.1	22	70	245	229.7	66
8	5	17.5	17.2	5	20	70	76.9	22	65	227.5	212.1	61
9	0	0	0.0	0	20	70	75.3	22	65	227.5	214.4	61
10	5	17.5	17.3	5	20	70	73.9	21	60	210	201.1	57

sample	3.0-3.25	reqd wt	act wt	act per	>3.25	reqd wt	act wt	act per	total wt
	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)	(g)
1	100	350	350.0	100	0	0	0.0	0	350.0
2	0	0	0.0	0	0	0	0.0	0	350.0
3	0	0	0.0	0	0	0	0.0	0	350.0
4	25	87.5	79.2	23	0	0	0.0	0	347.6
5	25	87.5	89.3	26	0	0	0.0	0	347.9
6	50	175	169.7	49	0	0	0.0	0	348.9
7	10	35	43.6	13	0	0	0.0	0	348.4
8	10	35	43.5	12	0	0	0.0	0	349.7
9	10	35	44.0	13	5	17.5	15.2	4	348.9
10	10	35	42.8	12	5	17.5	14.7	4	349.8

Table 15 Experiment to determine the effect of grain size on homogeneity
Fanfare (Set B)

350g sweet jars containing Fanfare 99/15 barley to be made up in the following ratios (set B)

sample	2.2-2.5	reqd wt	act wt	act per	2.5-2.8	reqd wt	act wt	act per	2.8-3.0	reqd wt	act wt	act per
	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)
1	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0.00
2	0	0	0.0	0	0	0	0.0	0	100	350	350.0	100.00
3	0	0	0.0	0	100	350	350.0	100	0	0	0.0	0.00
4	0	0	0.0	0	50	175	165.8	48	25	87.5	97.9	28.16
5	0	0	0.0	0	25	87.5	90.1	26	50	175	168.2	48.26
6	0	0	0.0	0	25	87.5	84.6	24	25	87.5	98.5	28.23
7	0	0	0.0	0	20	70	76.3	22	70	245	228.7	65.59
8	5	17.5	17.2	5	20	70	76.0	22	65	227.5	215.9	61.74
9	0	0	0.0	0	20	70	72.2	21	65	227.5	217.2	62.34
10	5	17.5	17.0	5	20	70	74.9	21	60	210	200.2	57.28

sample	3.0-3.25	reqd wt	act wt	act per	>3.25	reqd wt	act wt	act per	total wt
	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)	(g)
1	100	350	350.0	100.0	0	0	0.0	0.0	350.0
2	0	0	0.0	0.0	0	0	0.0	0.0	350.0
3	0	0	0.0	0.0	0	0	0.0	0.0	350.0
4	25	87.5	83.9	24.1	0	0	0.0	0.0	347.6
5	25	87.5	90.2	25.9	0	0	0.0	0.0	348.5
6	50	175	165.8	47.5	0	0	0.0	0.0	348.9
7	10	35	43.7	12.5	0	0	0.0	0.0	348.7
8	10	35	40.6	11.6	0	0	0.0	0.0	349.7
9	10	35	44.2	12.7	5	17.5	14.8	4.2	348.4
10	10	35	41.4	11.8	5	17.5	16.0	4.6	349.5

Table 16 Experiment to determine the effect of grain size on homogeneity
Optic (Set A)

350g sweet jars containing Optic 99/16 barley to be made up in the following ratios (set A)

sample	2.2-2.5	reqd wt	act wt	act per	2.5-2.8	reqd wt	act wt	act per	2.8-3.0	reqd wt	act wt	act per
	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)
1	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
2	0	0	0.0	0	0	0	0.0	0	100	350	350.0	100
3	0	0	0.0	0	100	350	350.0	100	0	0	0.0	0
4	0	0	0.0	0	50	175	161.9	47	25	87.5	99.4	29
5	0	0	0.0	0	25	87.5	90.8	26	50	175	168.3	48
6	0	0	0.0	0	25	87.5	87.7	25	25	87.5	98.0	28
7	0	0	0.0	0	10	35	40.0	11	35	122.5	130.1	37
8	5	17.5	16.4	5	10	35	39.7	11	32	112	124.7	36
9	0	0	0.0	0	10	35	41.3	12	32	112	122.5	35
10	5	17.5	15.4	4	10	35	42.0	12	30	105	115.9	33

sample	3.0-3.25	reqd wt	act wt	act per	>3.25	reqd wt	act wt	act per	total wt
	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)	(g)
1	100	350	350.0	100	0	0	0.0	0	350.0
2	0	0	0.0	0	0	0	0.0	0	350.0
3	0	0	0.0	0	0	0	0.0	0	350.0
4	25	87.5	86.3	25	0	0	0.0	0	347.5
5	25	87.5	89.2	26	0	0	0.0	0	348.2
6	50	175	162.6	47	0	0	0.0	0	348.3
7	55	192.5	179.2	51	0	0	0.0	0	349.4
8	53	185.5	168.8	48	0	0	0.0	0	349.6
9	53	185.5	170.3	49	5	17.5	14.5	4	348.6
10	50	175	161.8	46	5	17.5	14.6	4	349.8

Table 17 Experiment to determine the effect of grain size on homogeneity
Optic (Set B)

350g sweet jars containing Optic 99/16 barley to be made up in the following ratios (set B)

sample	2.2-2.5	reqd wt	act wt	act per	2.5-2.8	reqd wt	act wt	act per	2.8-3.0	reqd wt	act wt	act per
	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)
1	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
2	0	0	0.0	0	0	0	0.0	0	100	350	350.0	100
3	0	0	0.0	0	100	350	350.0	100	0	0	0.0	0
4	0	0	0.0	0	50	175	167.0	48	25	87.5	96.7	28
5	0	0	0.0	0	25	87.5	94.6	27	50	175	165.1	48
6	0	0	0.0	0	25	87.5	85.9	25	25	87.5	98.0	28
7	0	0	0.0	0	10	35	41.1	12	35	122.5	131.1	38
8	5	17.5	15.8	5	10	35	41.4	12	32	112	118.2	34
9	0	0	0.0	0	10	35	39.4	11	32	112	122.8	35
10	5	17.5	15.5	4	10	35	40.1	11	30	105	113.1	32

sample	3.0-3.25	reqd wt	act wt	act per	>3.25	reqd wt	act wt	act per	total wt
	(%)	(g)	(g)	(%)	(%)	(g)	(g)	(%)	(g)
1	100	350	350.0	100	0	0	0.0	0	350.0
2	0	0	0.0	0	0	0	0.0	0	350.0
3	0	0	0.0	0	0	0	0.0	0	350.0
4	25	87.5	82.0	24	0	0	0.0	0	345.8
5	25	87.5	87.7	25	0	0	0.0	0	347.4
6	50	175	163.0	47	0	0	0.0	0	346.9
7	55	192.5	177.0	51	0	0	0.0	0	349.2
8	53	185.5	174.4	50	0	0	0.0	0	349.8
9	53	185.5	171.8	49	5	17.5	15.4	4	349.4
10	50	175	167.1	48	5	17.5	14.0	4	349.8

The malt was produced in sweet jars using the following schedule.

STEEP:	8hrs wet / 16hrs air-rest / 24hrs wet
GERMINATION:	3 days at 16 degrees C
DRYING:	8hrs at 45 degrees C / 16hrs at 65 degrees C

The resulting malts were analysed using the following methods.

CALCOFLUOR:	giving a result for the MODIFICATION of the malt and the CALCOFLUOR HOMOGENEITY of the malt
FRIABILITY:	giving a result for the FRIABILITY of the malt and the FRIABILITY HOMOGENEITY of the malt

The results of the analysis are given in the following tables, the labeling referees to the previous tables (15-17)

Results

Experiment to determine the effect of grain size on homogeneity

350g sweet jars (containing FANFARE 99/15 in precise grain size ratios) were malted.

The malting schedule was:

Steep	8hrs wet/16hrs air-rest/24hrs wet
Germination	3 days at 16 degrees C
Drying	8hrs at 45 degrees C/16hrs at 65 degrees C

All work was carried out in duplicate. Thus the sample names were 1A,1B, 2A, 2B etc.

For each malt sample, the following analysis was carried out:

Friabilty and Homogeneity
Calcofluor Modification and Homogeneity

Table 18 Results Fanfare

Sample	Friability (%)	Fr.Homogeneity (%)	Calcofluor Modification (%)	Ca.Homogeneity (%)
1A	38.7	56.3	42	62
1B	38.8	54.8	53	58
2A	57.9	73.0	55	60
2B	50.8	68.6	54	60
3A	61.2	74.6	62	60
3B	64.7	79.0	76	55
4A	49.2	66.4	66	54
4B	51.1	65.5	62	54
5A	56.0	71.6	57	53
5B	48.9	66.9	60	58
6A	46.3	62.2	68	59
6B	49.4	66.8	66	58
7A	49.5	67.6	63	57
7B	50.7	65.4	60	63

8A	52.5	68.1	65	57
8B	42.8	59.7	54	62
9A	49.6	65.9	56	58
9B	54.1	70.0	56	64
10A	47.6	65.7	61	66
10B	48.1	65.3	50	67

Experiment to determine the effect of grain size on homogeneity

350g sweet jars (containing OPTIC 99/16 in precise grain size ratios) were malted.

The malting schedule was:

Steep	8hrs wet/16hrs air-rest/24hrs wet
Germination	3 days at 16 degrees C
Drying	8hrs at 45 degrees C/16hrs at 65 degrees C

All work was carried out in duplicate. Thus the sample names were 1A,1B, 2A, 2B etc.

For each malt sample, the following analysis was carried out:

Friabilty and Homogeneity
Calcofluor Modification and Homogeneity

Results:

Table 19 Results Optic

Sample	Friability (%)	Fr.Homogeneity (%)	Calcofluor Modification (%)	Ca.Homogeneity (%)
1A	82.7	95.6	83	56
1B	84.5	96.5	86	63
2A	80.7	92.3	91	67
2B	84.2	95.5	94	72
3A	78.3	90.0	93	71
3B	82.1	92.1	93	70
4A	82.6	94.3	92	70
4B	79.7	91.5	93	71
5A	78.8	90.4	91	65
5B	83.3	94.7	93	74
6A	81.8	93.9	89	65
6B	81.0	92.5	95	77
7A	79.1	91.3	85	61
7B	82.4	94.8	86	61
8A	81.0	92.4	90	68
8B	84.3	96.3	88	66
9A	80.8	92.9	92	71
9B	84.2	95.7	88	62
10A	82.1	94.3	90	68
10B	83.7	95.6	92	72

Analysis of Results 1. Optic

This is an analysis of results in table 19.

Table 20 Statistical analysis of results for Optic

Response	Regression parameters	F.Pr	% var
Calc Mod.	All	0.018	44.4
	Best size fractions 2.5-2.8;2.8-3.0	0.002	46.8
Calc Homog.	All	0.173	17.8
	Best size fractions 2.5-2.8;2.8-3.0	0.43	22.7
Friability Mod.	All	0.374	4.2
	Best constant only	-	-
Friability Homog.	All	0.069	30.4
	Best 3.0-3.25	0.019	23

Statistical analysis suggested that the best regression to use for prediction of Calcofluor parameters came from the 2.5-2.8 and 2.8-3.0 size fractions. The table below shows the predicted and true-predicted difference for Calcofluor results using this regression:
Calcofluor homogeneity = (0.104 x %2.5-2.8 fraction) + (0.0902 x % 2.8-3.0 fraction) + 61.86

Calcofluor modification = (0.0851 x %2.5-2.8 fraction) + (0.0766 x %2.8-3.0 fraction) + 85.48

Table 21 A comparison between true and predicted results: Optic

Ca.Homogeneity (%)	Ca.Homogeneity (%)	Calcofluor Modification (%)	Calcofluor Modification (%)
Prediction	True-Predicted value	Prediction	True-Predicted value
62	-6	85	-2
62	1	85	1
71	-4	93	-2
71	1	93	1
72	-1	94	-1
72	-2	94	-1
69	1	92	0
69	2	92	1
69	-4	91	0
69	5	91	2
67	-2	90	-1
67	10	90	5
66	-5	89	-4
67	-6	89	-3
66	2	89	1
66	0	89	-1
66	5	89	3
66	-4	89	-1
66	2	89	1
66	6	89	3
s.d.	4.29		2.27

Due to the poor correlations the friability data was not examined further.

2. Fanfare

This is an analysis of results in table 18

Table 22 Statistical analysis of results for Fanfare

Response	Regression parameters	F.Pr	% var
Calc Mod.	All	0.031	35.2
	Best size fractions: 2.5-2.8;2.8-3.0	0.007	38.0
Calc Homog.	All	0.031	35.2
	Best size fractions: 2.5-2.8;2.8-3.0;3.0-3.25	0.014	37.5
Friability Mod.	All	<0.001	72.6
	Best 2.2-2.5;2.5-2.8;2.8-3.0;3.0-3.25	<0.001	72.6
Friability Homog	All	<0.001	71.7
	Best 2.2-2.5;2.5-2.8;2.8-3.0;3.0-3.25	<0.001	71.7

Calcofluor homogeneity = (-0.8x%2.5-2.8) + (-0.77x%2.8-3.0) + (-0.766x%3.0-3.25) + 135.6
Calcofluor modification = (0.1983x%2.5-2.8) + (0.0452x%2.8-3.0) + 51.63

Friability homogeneity = (-0.846x%2.2-2.5) + (0.056x%2.5-2.8) + (-0.007x%2.8-3.0) + (-0.145x%3.0-3.25) + 69.8
Friability modification = (-0.872x%2.2-2.5) + (0.167x%2.5-2.8) + (0.078x%2.8-3.0) + (-0.064x%3.0-3.25) + 44.6

Table 23 A comparison between true and predicted results: Fanfare

Ca.Homogeneity (%)	Ca.Homogeneity (%)	Calcofluor Modification (%)	Calcofluor Modification (%)
Prediction	True-Predicted value	Prediction	True-Predicted value
59.00	3.0	51.63	-9.6
59.00	-1.0	51.63	1.4
58.60	1.4	56.15	-1.2
58.60	1.4	56.15	-2.2
55.60	4.4	71.46	-9.5
55.60	-0.6	71.46	4.5
57.25	-3.2	62.48	3.5
57.27	-3.3	62.36	-0.4
57.93	-4.9	58.95	-1.9
57.93	0.1	58.94	1.1
58.06	0.9	57.70	10.3
58.06	-0.1	57.71	8.3
58.00	-1.0	58.88	4.1
57.99	5.0	58.93	1.1
61.78	-4.8	58.73	6.3
61.78	0.2	58.73	-4.7
61.36	-3.4	58.69	-2.7
61.30	2.7	58.56	-2.6
65.06	0.9	58.42	2.6
65.27	1.7	58.47	-8.5
s.d.	2.8		5.5

Friability Homogeneity (%)	Friability Homogeneity (%)	Friability Modification (%)	Friability Modification (%)
Prediction	Tru-Pred	Prediction	Tru-Pred
55.30	1.0	38.20	0.5
55.30	-0.5	38.20	0.6
69.10	3.9	52.40	5.5
69.10	-0.5	52.40	-1.6
75.40	-0.8	61.30	-0.1
75.40	3.6	61.30	3.4
68.98	-2.6	53.44	-4.2
68.77	-3.3	53.22	-2.1
67.19	4.4	51.05	4.9
67.16	-0.3	51.03	-2.1
63.93	-1.7	47.67	-1.4
64.07	2.7	47.81	1.6
68.73	-1.1	52.54	-3.0
68.75	-3.3	52.57	-1.9
64.64	3.5	47.92	4.6
64.74	-5.0	48.01	-5.2
68.75	-2.8	52.19	-2.6
68.68	1.3	52.11	2.0
64.62	1.1	47.52	0.1
64.77	0.5	47.65	0.5
sd	2.7		3.0

Table 24

Conclusions

The predictions for homogeneity for Fanfare were good (S.D. = 2.7) but the predictions for Optic were less so (S.D. = 4.9). The predictions are however based on a specific treatment (malting schedule) and it may be possible to produce a better prediction with a different schedule. In a commercial situation different grain will respond to the same malting conditions in different ways. Hence different grain will normally be treated (malted) in different ways to achieve the same endpoint of good modification.

The problem with predicting the over all modification of a grain is that the result will depend the on the particular variety and on the how the grain was malted. So that even though these experiments produced some predictions of very good accuracy these results may not be useful because they do not take into account changes in the malting process to accommodate variety. Assuming that the malting process is uniform, however, the variability of the malt will depend on the properties of the grain. For this reason we can hope to predict variability without knowing the malting process. Therefore even though the predictions for homogeneity were (in many cases) not as good as those for modification, they are likely to be more useful.

Control of homogeneity in the Maltings – Shock experiments

B. Novel methods to control and improve homogeneity in the maltings.

Experiment to determine effect of shocking grain during malting on homogeneity of the final malt as assessed by Calcofluor.

The purpose of this part of the project was to investigate whether applying a shock to the grain during malting has an effect on the homogeneity of the malt.

The idea behind these experiments was based upon the fact that in medical applications, certain types of shock can restrict actively growing cells but does not influence quiescent cells. For example heat shock can kill actively growing cancer cells but does not damage non-metastatic cells. It was hoped that shocking the grain would hold back the growth of germinated grains, and so enable those that had not yet germinated to catch up. This concept is similar to the empirical use of a long (24hr) second steep traditionally used to hold back grain which germinated quickly allowing slow grains to catch up.

A series of experiments were carried out using Optic 99/16 barley. Earlier work had shown that malting just 100 grains (in 30ml of water) gave a close approximation to a full size sweet jar in terms of Calcofluor analysis. Initial tests were carried out on just 100 grains, and were called “mini sweet jar maltings”.

The malting cycle was chosen to be as follows.

Steep	7hr wet / 17hr air rest / 7hr wet / 17hr air rest / 1hr wet
Germination	3 days at 16°C
Drying	8hr at 45°C / 16hr at 65°C

The shocks were applied at three distinct stages. The stages were (1) barley, (2) end of first air rest, (3) end of second air rest. If the shock was to be applied to the grain in liquid (e.g. electric shock, sonic shock), the shock was applied (1) start of first steep, (2) start of second steep, (3) start of final steep. For each type of shock, a control was set up that was malted without receiving any shock at any stage. The short germination period was chosen to maintain any discrete features of each sample.

The effectiveness of the procedure was assessed in two different ways:
1. In order to screen in a rapid manner as many shock types as possible the LTm H80 was used. The H80 value assesses the slope of the line linking the individual LTm values for each grain. The greater the slope the more heterogeneous the sample and hence the reciprocal of the slope is used to assess homogeneity. Thus the H80 provides some measure of the homogeneity of the LTm value. In this particular set of experiments we were looking for a situation where the homogeneity of the malt was high but the homogeneity of the barley was low. Thus the value Malt H80-BarleyH80 was used. The larger this difference was, the more the homogeneity had improved during the experiment.
2. After the screening experiments, the Calcofluor homogeneity test was used.

Eight different shocks were applied to the grain during malting. These were as follows:
1) Heat shock at 30°C
2) Heat shock at 35°C
3) Light shock
4) Sonic shock
5) Electric shock

6) Short Drying Period shock
7) Acid pH shock
8) Alkaline pH shock

Prior to any malting, all the samples were analysed using the LTm. This method was used again after malting to determine whether the shocks had affected the Homogeneity. If any shock appeared to have been effective, the experiments were to be repeated on full size sweet jars (350g of grain in 700ml water), and a more comprehensive program of analysis applied.

Experiment One – Heat Shock at 30°C
This set of samples were called HSA(C), HSA(1), HSA(2) and HSA(3) which denoted Heat Shock A – Control, Heat Shock A – stage one, Heat Shock A – stage two, etc.
To apply the shock, the relevant sample was spread out on a tray, with a plastic covering to minimise moisture loss, and placed in an oven at 30°C. The heat shock was applied for one hour at each stage.

Experiment Two – Heat Shock at 35°C
This set of samples were called HSB(C), HSB(1) etc. as before. The heat shock was applied at each stage as in experiment one, but at a higher temperature.

Experiment Three – Light Shock
This set of samples were called LS(C), LS(1), etc. The shock was applied by spreading the relevant sample on a tray, which was covered in plastic to minimise moisture loss. The light shock was 18w of fluorescent light that was applied for one hour. During the malting process, all samples that were not receiving shock were kept in the dark as much as possible. The samples did receive some very brief daylight when, for example, the steep water was being added or drained.

Experiment Four – Sonic Shock
This set of samples were called S(C),S(1), etc. To apply this shock, 100 grains and 30 ml of water were put in a plastic tube, which was placed in an ultrasonic bath and subjected to a 10 second burst of ultrasound.

Experiment Five – Electric Shock
This set of samples were called ES(C), ES(1), etc. At each stage, the relevant sample was submerged in a bath containing 0.1% salt solution (100 ml solution in 400 ml beaker). A voltage of 9V was then passed through the electrolyte. The voltage of the battery was checked before and after each shock to ensure no significant voltage drop had occurred. The shock was applied to each sample for one hour. The salt solution was rinsed off with water once the shock was completed.

Experiment Six – Short Drying Period Shock
This set of samples were called SDP(C), SDP(1), etc. At each stage, the relevant sample was placed in an oven that had room temperature (RT) air blowing through it. It was important to record the room temperature on each day that the shock was applied in order to allow for any appreciable variations. Stage 1 RT = 23.0°C, stage 2 RT = 22.0°C and stage 3 RT = 20.5°C. The shock was applied for one hour at each stage.

Experiment Seven – pH2 Shock
This set of samples were called pH2(C), pH2(1), etc. At each stage, the relevant sample was submerged (30ml liquid in a 100ml beaker) in acid buffer at pH 2.8 for one hour. The grains were then rinsed

thoroughly with de-ionised water to remove any external acid, and then transferred to another beaker containing neutral buffer (pH7.6) for a further one hour.

Experiment Eight – pH9 Shock

This set of samples were called pH9(C), pH9(1), etc. At each stage, the relevant sample was subjected to a shock of pH 8.5, using the same method as in experiment seven, but with an alkaline buffer.

Note: for the shocks that were carried out in liquid, the time in liquid was included as part of the steep schedule e.g. for pH2 shock the grains were one hour in acid buffer, one hour in neutral buffer and then five hours in steep water, making a total of seven hours wet, as called for by the schedule.

For all samples, the H80 value was calculated for both barley and malt.

Table 25 Trail shocks to germinating grain. See method for abbreviations

Sample	Barley % Mealy	Malt % Mealy	Barley H80	Malt H80	Malt H80 - Barley H80
HSA(C)	70	89	30	73	43
HSA(1)	73	90	33	68	35
HSA(2)	80	91	43	94	51
HSA(3)	69	84	31	55	24

Sample	Barley % Mealy	Malt % Mealy	Barley H80	Malt H80	Malt H80 - Barley H80
HSB(C)	74	94	36	73	37
HSB(1)	81	89	46	86	40
HSB(2)	75	86	38	63	25
HSB(3)	67	85	29	68	39

Sample	Barley % Mealy	Malt % Mealy	Barley H80	Malt H80	Malt H80 - Barley H80
LS(C)	79	92	43	77	34
LS(1)	74	90	35	70	35
LS(2)	69	94	29	79	50
LS(3)	77	92	41	79	38

Sample	Barley % Mealy	Malt % Mealy	Barley H80	Malt H80	Malt H80 - Barley H80
SDP(C)	75	93	41	83	42
SDP(1)	79	87	45	80	35
SDP(2)	75	85	38	63	25
SDP(3)	77	91	35	68	33

Sample	Barley % Mealy	Malt % Mealy	Barley H80	Malt H80	Malt H80 - Barley H80
ES(C)	76	85	37	59	22
ES(1)	73	87	34	76	42
ES(2)	82	93	47	108	61
ES(3)	83	92	44	93	49

Sample	Barley % Mealy	Malt % Mealy	Barley H80	Malt H80	Malt H80 - Barley H80
S(C)	81	91	44	82	38
S(1)	73	93	33	80	47
S(2)	75	91	38	91	53
S(3)	75	93	39	80	41

Sample	Barley % Mealy	Malt % Mealy	Barley H80	Malt H80	Malt H80 - Barley H80
pH2(C)	77	89	42	76	34
pH2(1)	79	85	45	61	16
pH2(2)	78	84	37	62	25
pH2(3)	79	91	45	92	47

Sample	Barley % Mealy	Malt % Mealy	Barley H80	Malt H80	Malt H80 - Barley H80
pH9(C)	74	95	35	103	68
pH9(1)	82	90	49	70	21
pH9(2)	74	92	37	75	38
pH9(3)	72	82	34	50	16

At this point during the project there appeared to be some effect from shocking at stage two i.e. after the first air rest. It was decided to repeat some of the shocks (using full-size (350g) sweet jars). The shocks to be repeated were:

Heat Shock at 30°C
Light Shock
Electric Shock
Sonication

Two new shocks were to be investigated using full-size jars – these were:
Saline Shock
Sterilant Shock

The saline shock was 0.1% solution applied for one hour; the sterilant shock was a solution of 50% NaOCl and 50% de-ionised water, and this was applied for one minute.
Four full size sweet jars were set up for each shock – these were a control, shock at barley, shock at end of first air-rest, shock at end of second air rest. The same malting schedule was used as for the mini sweet jars. H80 was again calculated for the barley and for the malt. Calcofluor modification and homogeneity were calculated for each sample. Friability and friability homogeneity were also calculated for each sample. The results are given in the following tables:

Summary of abbreviations:

Table 26 Shocks used in second trail
HS = Heat Shock - 30 degrees C for one hour
LS = Light Shock - 18W fluorescent light for one hour
S = Sonication - ultrasound shock for ten seconds
ES = Electric Shock - 9V applied for one hour
SA = Saline Shock - steeped in 0.1% salt solution for one hour
ST = Sterilant Shock - steeped in 50% solution of Sodium Hypochlorite for one minute

Table 27 Results of second shock trial. See method for abbreviations

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
HS(C)	28	92	64
HS(1)	35	99	64
HS(2)	31	116	85
HS(3)	34	103	69

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
LS(C)	33	100	67
LS(1)	31	88	57
LS(2)	34	104	70
LS(3)	35	105	70

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
S(C)	38	80	42
S(1)	36	98	62
S(2)	35	71	36
S(3)	45	89	44

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
ES(C)	33	92	59
ES(1)	37	86	49
ES(2)	45	82	37
ES(3)	45	88	43

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
SA(C)	46	98	52
SA(1)	40	92	52
SA(2)	47	86	39
SA(3)	42	107	65

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
ST(C)	47	82	35
ST(1)	42	85	43
ST(2)	32	92	60
ST(3)	42	95	53

Calcofluor results. See method for abbreviations

Sample	Friability (%)	F.Homogeneity (%)	Calcofluor mod (%)	C Homogeneity (%)
HS(C)	84.5	96.5	90	71
HS(1)	85.4	96.5	93	74
HS(2)	87.9	97.8	96	77
HS(3)	84.9	96.4	97	81
LS(C)	86.0	96.6	92	66
LS(1)	86.8	97.0	93	72
LS(2)	86.9	97.2	94	74
LS(3)	85.5	97.1	97	84
S(C)	81.1	93.2	91	85
S(1)	85.1	96.3	95	78
S(2)	83.3	95.3	95	74

S(3)	82.7	95.3	95	75

ES(C)	83.8	95.8	96	81
ES(1)	86.6	96.8	94	75
ES(2)	82.1	93.7	97	82
ES(3)	84.0	95.7	95	79

SA(C)	84.7	96.0	92	73
SA(1)	86.1	96.5	94	73
SA(2)	83.7	95.7	96	83
SA(3)	84.6	96.2	96	77

ST(C)	83.0	94.4	98	87
ST(1)	82.0	94.2	96	80
ST(2)	83.1	95.4	92	71
ST(3)	75.1	89.5	90	64

From the results of the LTm analysis in particular there appeared to be some effect on the homogeneity of the samples that received sterilant shock and heat shock. It was decided to repeat the sterilant shock and also the heat shock. The heat shock would be evaluated at 25 degrees C, 30 degrees C and 35 degrees C. The samples underwent the same malting schedule as before. The results are given in the following tables:

Summary of abbreviations:

Table 29 Repeat of selected shock trails
HS25 = Heat Shock at 25 degrees C for one hour
HS30 = Heat Shock at 30 degrees C for one hour
HS35 = Heat Shock at 35 degrees for one hour
STE = Sterilant Shock of 50/50 solution of sodium hypochlorite for one minute

C = control - no shock received at any stage
1 = shock applied to barley i.e. at beginning of steep schedule
2 = shock applied at end of first air rest
3 = shock applied at end of second air rest

Table 30 results. See method for abbreviations

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
HS25(C)	42	78	36
HS25(1)	42	91	49
HS25(2)	38	87	49
HS25(3)	39	89	50

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
HS30(C)	53	67	14
HS30(1)	38	78	40

HS30(2)	39	95	56
HS30(3)	35	88	53

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
HS35(C)	45	68	23
HS35(1)	45	92	47
HS35(2)	40	95	55
HS35(3)	54	104	50

Sample	Barley H80	Malt H80	Malt H80 - Barley H80
STE(C)	36	94	58
STE(1)	43	112	69
STE(2)	53	59	6
STE(3)	45	53	8

Table 31 Calcofluor results. See method for abbreviations

Sample	Friability (%)	F.Homogeneity (%)	Calcofluor mod (%)	C Homogeneity (%)
HS25(C)	74.0	88.5	92	68
HS25(1)	78.0	91.8	86	61
HS25(2)	77.3	91.2	84	55
HS25(3)	78.9	92.3	88	68
HS30(C)	74.2	88.1	70	52
HS30(1)	80.1	93.4	85	45
HS30(2)	75.8	88.5	83	56
HS30(3)	78.5	92.3	83	53
HS35(C)	67.8	83.5	74	50
HS35(1)	72.0	87.5	77	53
HS35(2)	68.7	83.0	80	55
HS35(3)	68.4	83.3	78	55
STE(C)	73.6	87.4	80	61
STE(1)	78.2	91.7	87	79
STE(2)	72.2	86.1	77	64
STE(3)	64.2	82.7	72	60

Again, from the LTm analysis in particular, a heat shock applied at the end of the first air rest appeared to improve the homogeneity of the finished malt. The sterilant shock appeared to be detrimental to the homogeneity of the finished malt.

Conclusion

Although there is some evidence that shocking malt can improve homogeneity the results were not sufficiently consistent to warrant further investigation.

Trials at commercial sites

Introduction

Purpose of the investigation:
It has been widely reported that aspects of the malting process can influence the homogeneity of the final malt. The two major influences are steeping (especially related to the hydrostatic pressure encountered) and kilning (especially related to the depth of bed in the kiln) (Piglas et al. 1988, Freeman and Rehmanji1992).
The purpose of this investigation was to determine if different malting plant had different effects and whether the heterogeneity induced by some types of plant was greater or less than others. Investigations were carried out at three commercial malting sites in the UK.

Note: All samples were analysed under the same conditions of moisture. This was achieved by drying at low temperatures in a high airflow oven.

Methods

Steeping investigation

The principal method used in this investigation was to sample the process at different points in the commercial maltings, and then continue the malting process under the same conditions at BRi.

- Sample from bottom/middle/top of vessel.
- From a conveyor at vessel cast unless indicated otherwise or with a sampling spear during air rest.
- Germinate samples at BRi
- Standard BRi micro-malting procedure
- Same number of germination days as was employed in the commercial maltings.
- Standard BRi oven drying cycle of 45 ºC for 8 hours followed by 65 ºC for 16 hours.
- Evaluate extent of modification after kilning by routine analysis
- Follow time course during germination using LTm

Kilning investigation

- Sample from bottom/middle/top of vessel with sampling spear on the kiln.
- Drying samples at BRi 55 ºC for 16 hours in a (high air flow) drying oven.
- Evaluate extent of modification after kilning by routine analysis

See the end of this section for a discussion and summary of conclusions.

Results
Steeping investigations

Site 1 Vessel 19

Table 32: Non-aerated, deep flat vessel, sampled at first air rest (bottom inaccessible):

VESSEL	"V19". Fanfare barley.		
DETAILS	2.5 m water depth. Not aerated.		
TIME OF SAMPLE	Late in first air rest.		
DETAIL	Cycle 8/14/12. 11 degC water.		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	no result	5.0	4.8
HWE (0.2mm)	no result	302	309
HWE (0.7mm)	no result	294	307
F/C difference	no result	**8**	**2**
Colour	no result	1.9	2.0
TSN	no result	0.53	0.65
TN	no result	1.67	1.59
SNR	no result	**32**	**41**
FAN	no result	0.10	0.12
pH	no result	5.93	5.97
Fermentability	no result	no result	79
Viscosity	no result	**1.67**	**1.55**
Friability	no result	**54.5**	**86.0**
Homogeneity	no result	68.3	96.2

Largest differences seen in F/C difference, SNR and friability with some influence on viscosity of different fractions.

Table 33: Same vessel (Vessel 19) sampled at cast:

VESSEL	"V19". Fanfare barley.		
DETAILS	2.5 m water depth. Not aerated.		
TIME OF SAMPLE	Cast.		
DETAIL	8/14/12 11 degC water. cycle.		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	5.5	5.0	5.1
HWE (0.2mm)	309	308	310
HWE (0.7mm)	304	303	307
F/C difference	**5**	**5**	**3**
Colour	1.9	1.9	1.8
TSN	0.53	0.54	0.61
TN	1.65	1.59	1.65
SNR	**32**	**34**	**37**
FAN	0.09	0.09	0.10
pH	6.09	6.10	6.07
Fermentability	76	76	77
Viscosity	**1.72**	**1.64**	**1.60**
Friability	**68.8**	**67.6**	**79.8**
Homogeneity	85	84.9	93.5

Although the different levels have to some extent ‘caught up’ there are still small differences in SNR, F/C, viscosity and friability. A noticeable feature of the differences is that the surface layer has modified more extensively than both of the deeper layers.

Site 1 Vessel 58

Table 34: Aerated shallow flat vessel, sampled at cast:

VESSEL	"V 58" Optic.		
DETAILS	1.5 m water depth		
TIME OF SAMPLE	Cast.		
DETAIL	Air on 2m off 10 cycle 6/18/10		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	4.8	4.6	4.6
HWE (0.2mm)	315	315	314
HWE (0.7mm)	312	313	312
F/C difference	**3**	**2**	**2**
Colour	2.4	2.1	2.6
TSN	0.63	0.61	0.62
TN	1.63	1.64	1.61
SNR	**39**	**37**	**39**
FAN	0.11	0.11	0.11
pH	6.00	6.02	6.00
Fermentability	78	77	78
Viscosity	**1.46**	**1.45**	**1.44**
Friability	**93.0**	**92.7**	**93.4**
Homogeneity	99.3	99.6	99.2

There is very little difference between the key parameters of this malt.

Site 1 Vessel 117

Table 35: Aerated, deep flat vessel, sampled at cast:

VESSEL	"V 117". Optic barley.		
DETAILS	2.5 m water depth		
TIME OF SAMPLE	Cast.		
DETAIL	Air on 5m off 10m in steep 6/16/10 cycle.15degC		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	5.2	5.1	4.8
HWE (0.2mm)	314	315	314
HWE (0.7mm)	313	313	312
F/C difference	**1**	**2**	**2**
Colour	2.0	2.1	1.9
TSN	0.57	0.57	0.61
TN	1.66	1.63	1.59
SNR	**34**	**35**	**38**
FAN	0.10	0.10	0.11
pH	6.02	6.03	5.96
Fermentability	78	78	79
Viscosity	**1.48**	**1.47**	**1.46**
Friability	**89.2**	**89.6**	**90.8**
Homogeneity	98.6	98.5	99.0

In this case there is very little evidence for a difference in modification between the different levels. There is an indication that the top was better modified than the bottom layer (SNR, Viscosity, Friability) but the differences are small and may not be significant.

Site 1 Vessel 118

Table 36: Aerated deep flat bottom sampled at cast:

VESSEL	"V 118". Maris Otter barley.		
DETAILS	2.5 m water depth		
TIME OF SAMPLE	Near end air rest		
DETAIL	Air on 5m off 10m in steep 15degC 6/16/10 cycle.		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	no result	4.4	4.3
HWE (0.2mm)	no result	309	309
HWE (0.7mm)	no result	304	303
F/C difference	no result	**5**	**6**
Colour	no result	2.0	1.9
TSN	no result	0.5	0.47
TN	no result	1.49	1.41
SNR	no result	**34**	**33**
FAN	no result	0.10	0.09
pH	no result	6.01	6.03
Fermentability	no result	76	76
Viscosity	no result	**1.77**	**1.65**
Friability	no result	**80.5**	**80.2**
Homogeneity	no result	94.6	96.6

In this case there is no indication of greater modification at the top of the vessel.

Site 1 Vessel 59

Table 37: Flat aerated, deep but lower level not accessible:

VESSEL DETAILS	"QH59". Optic barley. Aerated.		
TIME OF SAMPLE	Late in air rest		
DETAIL	Air on 15m off 5m during wet 6/18/10 cycle.		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	no result	4.2	4.6
HWE (0.2mm)	no result	314	315
HWE (0.7mm)	no result	312	313
F/C difference	no result	**2**	**2**
Colour	no result	2.5	2.4
TSN	no result	0.64	0.65
TN	no result	1.67	1.61
SNR	no result	**38**	**40**
FAN	no result	0.12	0.12
pH	no result	5.90	5.99
Fermentability	no result	77	78
Viscosity	no result	**1.52**	**1.47**
Friability	no result	**88.2**	**89.6**
Homogeneity	no result	98.1	97.9

Again there is no indication of greater modification at the top of the vessel.

Site 2 Vessel C2

Table 38: Conical aerated 3.6m deep sampled at cast:

VESSEL	Vessel C2.		
DETAILS	7.5 tonne of barley.		
	Rectangular vessel and hopper		
	X-section 3.02 x 2.65 m		
	1.8 m top to top of cone,		
	but barley fill 30 cm from top.		
	2.10 m high rectangular cone.		
	Aeration 5 mins in 30.		
	No CO2 extraction		
TIME OF SAMPLE	Cast.		
DETAIL	Regina. 1.8% N.		
	Steep cycle 8/12/15, temp 16.5C		
	SAME AS VESSEL D2		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	5.6	5.9	5.5
HWE (0.2mm)	304	302	301
HWE (0.7mm)	298	296	297
F/C difference	**6**	**6**	**4**
Colour	2.0	2.0	2.0
TSN	0.54	0.57	0.59
TN	1.76	1.82	1.82
SNR	**31**	**31**	**32**
FAN	0.13	0.14	0.15
pH	5.96	5.88	5.85
Fermentability	75	75	76
Viscosity	**1.68**	**1.69**	**1.68**
Friability	**54.1**	**56.1**	**60.1**
Homogeneity	74.3	75.2	79.4

There was some indication differential modification in vessel C2 as shown by the friability. It should be noted however that the friabilities were low, this is not a reflection on the malting procedure at the commercial site because the grain was malted at BRi. Nevertheless this process gave much lower friabilities than other plant.

Site 2 Vessel D2

Table 39: Details the same as Vessel C2:

VESSEL	Vessel D2		
DETAILS	7.5 tonne of barley.		
	Rectangular vessel and hopper		
	X-section 3.02 x 2.65 m		
	1.8 m top to top of cone,		
	but barley fill 30 cm from top.		
	2.10 m high rectangular cone.		
	Aeration 5 mins in 30.		
	No CO2 extraction		
TIME OF SAMPLE	Cast.		
DETAIL	Regina. 1.8% N.		
	Steep cycle 8/12/15, temp 16.5C		
	SAME AS VESSEL C2		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	5.7	6.1	6.2
HWE (0.2mm)	301	301	300
HWE (0.7mm)	290	289	288
F/C difference	**11**	**12**	**12**
Colour	2.0	2.0	2.0
TSN	0.54	0.53	0.52
TN	1.81	1.8	1.81
SNR	**30**	**29**	**29**
FAN	0.13	0.13	0.13
pH	5.88	5.86	5.82
Fermentability	74	75	nr
Viscosity	**1.77**	**1.76**	**1.78**
Friability	**39.5**	**42.0**	**43.9**
Homogeneity	54.7	57.9	59.8

This vessel was essentially identical to the proceeding vessel and once again the primary indication of heterogeneity was the friability. Again this was low but the levels were different.

Site 2 Vessel E5
Table 40: Cylindro-conical 4.2 m deep:

VESSEL	Vessel E5.		
DETAILS	22.5 tonne of barley.		
	Cylindroconical, 4.9 m diameter.		
	Grain appr. 1.5m below vessel top.		
	Grain top to cone top 1.9m.		
	Cone height 2.25m.		
	Aeration 3 mins on 15 off		
	CO2 extraction 15 on 30 off		
TIME OF SAMPLE	Cast.		
DETAIL	Optic. 1.7-1.9% N.		
	Steep cycle 7/14/7, temp 16.5C.		
	At cast grain temp was 22.4C.		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	6.0	5.8	6.0
HWE (0.2mm)	306	307	307
HWE (0.7mm)	303	303	302
F/C difference	**3**	**4**	**5**
Colour	2.0	2.0	2.0
TSN	0.56	0.57	0.49
TN	1.84	1.87	1.89
SNR	**30**	**30**	**26**
FAN	0.12	0.13	0.10
pH	5.84	5.84	5.95
Fermentability	74	75	74
Viscosity	**1.50**	**1.52**	**1.52**
Friability	**63.5**	**70.2**	**60.7**
Homogeneity	82.5	86.7	79.6

In this case there was no clear trend in the data.

Site 2
Table 41 Vessel SGV

VESSEL	SGV.		
DETAILS	180 tonne of barley.		
	Fed from 6x30 tonne steep vessels.		
	Diameter 11.5m, vessel height 4.5m.		
	Grain depth approx. 2.80m		
	Aeration 3 mins on 15 off		
	CO2 extraction 15 on 30 off		
TIME OF SAMPLE	Cast.		
DETAIL	Robust (6 row barley).		
	1.5 h final steep in previous SV.		
	Then 2 hours transfer.		
	Finally 1.5 hours steep then drain.		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	5.6	5.6	5.5
HWE (0.2mm)	295	296	296
HWE (0.7mm)	292	293	294
F/C difference	**3**	**3**	**2**
Colour	2.1	2.1	2.0
TSN	0.71	0.77	0.71
TN	2.09	2.09	2.05
SNR	**34**	**37**	**35**
FAN	0.15	0.17	0.15
pH	5.81	5.87	5.92
Fermentability	76	77	77
Viscosity	**1.53**	**1.51**	**1.50**
Friability	**59.2**	**62.4**	**65.5**
Homogeneity	90.6	93.7	93.0

Friability indicated that there was a small difference between the top and the other levels again the effect was small.

Site 3

Table 42 end of kiln, center position:

VESSEL	Redler		
DETAILS	Pearl 2002, lager		
	90 cm bed depth		
	26 m diameter single deck		
	indirectly heated		
	12h, 60C/4h, 62,5C/5h, 62,5/1h, 0C		
TIME OF SAMPLE	after kiln, before stripping		
DETAIL	near center column		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	6.5	6.1	6.5
HWE (0.2mm)	310	311	311
HWE (0.7mm)	308	308	307
F/C difference	**2**	**3**	**4**
Colour	2.2	2.2	2.4
TSN	0.66	0.66	0.66
TN	1.65	1.67	1.68
SNR	**40**	**40**	**39**
FAN	0.18	0.19	0.20
pH	5.97	5.96	5.97
Fermentability	75	76	76
Viscosity	**1.57**	**1.56**	**1.54**
Friability	**82.0**	**84.0**	**86.0**
Homogeneity	97.0	96.9	97.0
LTM		90	92
TBZ	5.6	5.44	5

Although there is very little difference between these parameters there is a slightly higher friability at top than at the bottom. Again although the difference is small it observed in some other systems.

Site 3

Table 43: Same as previous but at edge end of kiln:

VESSEL	Redler		
DETAILS	Pearl 2002, lager		
	90 cm bed depth		
	26 m diameter single deck		
	indirectly heated		
	12h, 60C/4h, 62,5C/5h, 62,5/1h, 0C		
TIME OF SAMPLE	after kiln, before stripping		
DETAIL	near edge		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	5.4	5.8	6.5
HWE (0.2mm)	311	311	310
HWE (0.7mm)	308	308	308
F/C difference	**3**	**3**	**2**
Colour	2.1	2.1	2.1
TSN	0.66	0.65	0.71
TN	1.68	1.66	1.68
SNR	**40**	**39**	**42**
FAN	0.18	0.19	0.18
pH	6.01	6.01	6.00
Fermentability	75	76	75
Viscosity	**1.58**	**1.56**	**1.57**
Friability	**83.0**	**84.0**	**84.0**
Homogeneity	96.4	96.7	96.7
LTM	90	94	98
TBZ	5	4.68	4.28

This sample was from the same kiln as the previous but from the edge rather than the center, it is more homogeneous.

Site 3

Table 44: Break point hence high moisture but dried before friability measurement, center position:

VESSEL	Buhler Tower		
DETAILS	200 t Regina 2002, lager		
	90 cm bed depth		
	24 m diameter single deck		
	directly heated (50 kg S added)		
	12h, 60C/6h, 64C/1h, 0C		
TIME OF SAMPLE	after break point		
DETAIL	near center column		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	15.5	31.6	41.9
HWE (0.2mm)	308	309	308
HWE (0.7mm)	304	304	304
F/C difference	**4**	**5**	**4**
Colour	1.9	2.1	2.1
TSN	0.6	0.61	0.61
TN	1.65	1.63	1.7
SNR	**36**	**37**	**36**
FAN	0.15	0.11	0.12
pH	5.96	6.01	6.02
Fermentability	74	74	75
Viscosity	**1.59**	**1.58**	**1.56**
Friability	**73.0**	**75.0**	**77.0**
Homogeneity	90.1	92.9	93.4
LTM	88	92	91
TBZ	2	2.08	2.2

Sampled from the center position this trial again shows slightly higher friability at top.

Site 3
Table 45 Break point edge**:**

VESSEL	Buhler Tower		
DETAILS	200 t Regina 2002, lager		
	90 cm bed depth		
	24 m diameter single deck		
	directly heated (50 kg S added)		
	12h, 60C/6h, 64C/1h, 0C		
TIME OF SAMPLE	after break point		
DETAIL	near edge		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	15.6	40.0	43.4
HWE (0.2mm)	309	309	309
HWE (0.7mm)	305	306	305
F/C difference	**4**	**3**	**4**
Colour	1.9	2.1	2.1
TSN	0.6	0.6	0.6
TN	1.64	1.66	1.63
SNR	**37**	**36**	**37**
FAN	0.11	0.12	0.12
pH	6.04	6.04	6.04
Fermentability	74	75	75
Viscosity	**1.57**	**1.57**	**1.59**
Friability	**76.0**	**74.0**	**77.0**
Homogeneity	92.8	91.5	93.8
LTM	84	90	94
TBZ	2.4	2.96	2.16

As shown in the previous tables samples from the edge were more homogeneous.

Site 4
Table 46: various places break point

VESSEL	Redler/QuarterHall as "double deck kiln"		
DETAILS	180 t Fanfare, Lager		
	1,2 m bed depth		
	20 m diameter "single deck"		
	indirectly heated		
	5h, 55C/5h 62C/18h, 65C/6h 70C/6h 75C		
TIME OF SAMPLE	at break point (24h after firing up)		
DETAIL	from various places in kiln		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	4.5	6.7	25.6
HWE (0.2mm)	313	312	312
HWE (0.7mm)	310	311	311
F/C difference	**3**	**1**	**1**
Colour	2.4	2.4	2.4
TSN	0.61	0.6	0.61
TN	1.72	1.72	1.69
SNR	**35**	**35**	**36**
FAN	0.11	0.11	0.11
pH	6.12	6.11	6.12
Fermentability	75	75	75
Viscosity	**1.51**	**1.52**	**1.54**
Friability	**86.0**	**87.0**	**84.0**
Homogeneity	98.2	98.5	97.8
TBZ	5.64	4.88	2.88

There is no clearly systematic change in the friability in this case, and although the TBZ values decrease with position they are generally low any way.

Site 4
Table 47: center of kiln**:**

VESSEL	Redler/QuarterHall as "double deck kiln"		
DETAILS	180 t Fanfare, Lager		
	1,1 m bed depth		
	20 m diameter "single deck"		
	indirectly heated		
	5h, 55C/5h 62C/18h, 65C/6h 70C/6h 75C		
TIME OF SAMPLE	after kiln, just before stripping		
DETAIL	near center column		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	4.4	4.0	3.9
HWE (0.2mm)	312	311	311
HWE (0.7mm)	310	310	310
F/C difference	**2**	**1**	**1**
Colour	2.9	3.7	3.5
TSN	0.65	0.65	0.63
TN	1.82	1.85	1.83
SNR	**36**	**35**	**34**
FAN	0.10	0.10	0.10
pH	6.13	6.07	6.03
Fermentability	74	73	73
Viscosity	**1.47**	**1.47**	**1.48**
Friability	**84.0**	**81.0**	**85.0**
Homogeneity	97.4	95.8	98.0
TBZ	14.68	18.36	19.36

Unlike the previous kiln there is no evidence of homogeneous issues near the center of the kiln.

Site 4
Table 48 sampled at edge:

VESSEL	Redler/QuarterHall as "double deck kiln"		
DETAILS	180 t Fanfare, Lager		
	1,1 m bed depth		
	20 m diameter "single deck"		
	indirectly heated		
	5h, 55C/5h 62C/18h, 65C/6h 70C/6h 75C		
TIME OF SAMPLE	after kiln, just before stripping		
DETAIL	edge		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	3.4	3.9	4.3
HWE (0.2mm)	312	310	311
HWE (0.7mm)	309	310	309
F/C difference	**3**	**0**	**2**
Colour	3.2	3.5	3.4
TSN	0.58	0.63	0.65
TN	1.81	1.84	1.82
SNR	**32**	**34**	**36**
FAN	0.10	0.10	0.10
pH	6.08	6.06	6.07
Fermentability	73	74	74
Viscosity	**1.48**	**1.47**	**1.48**
Friability	**75.0**	**84.0**	**83.0**
Homogeneity	91.8	97.5	91.8
TBZ	16.48	18.68	16.36

Lower friabilities were observed at the edge in this case.

Site 4
Table 49 Various places mixed:

VESSEL	Seeger (Saladin Boxes)		
DETAILS	85 t Fanfare, Ale malt		
	95 cm bed depth		
	16 m diameter single deck		
	indirectly heated		
	2h, 55C/ 7h, 65C/3h, 70C/5h 70-95C/4h 95C		
TIME OF SAMPLE	before break point (eight hours after firing)		
DETAIL	various places from kiln		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	8.2	34.4	39.4
HWE (0.2mm)	316	318	318
HWE (0.7mm)	315	315	315
F/C difference	**1**	**3**	**3**
Colour	2.1	2.1	2.1
TSN	0.68	0.69	0.68
TN	1.56	1.56	1.49
SNR	**44**	**44**	**46**
FAN	0.13	0.13	0.13
pH	6.06	6.06	6.04
Fermentability	77	78	78
Viscosity	**1.54**	**1.54**	**1.54**
Friability	**93.0**	**91.0**	**93.0**
Homogeneity	99.6	99.3	99.8
TBZ	4.24	3.56	3.68

There is no evidence of heterogeneity in this case.

Site 4
Table 50 Center:

VESSEL	Seeger (Saladin Boxes)		
DETAILS	85 t Fanfare, Ale malt		
	95 cm bed depth		
	16 m diameter single deck		
	indirectly heated		
	2h, 55C/ 7h, 65C/3h, 70C/5h 70-95C/4h 95C		
TIME OF SAMPLE	after kiln, before stripping		
DETAIL	near center column		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	3.0	3.3	3.3
HWE (0.2mm)	317	317	316
HWE (0.7mm)	314	314	314
F/C difference	**3**	**3**	**2**
Colour	5.1	4.6	4.6
TSN		0.68	0.68
TN	1.52	1.54	1.54
SNR		**44**	**44**
FAN	0.12	0.13	0.12
pH	5.95	5.94	5.96
Fermentability	72	71	72
Viscosity	**1.55**	**1.55**	**1.54**
Friability	**96.0**	**97.0**	**94.0**
Homogeneity	99.6	99.6	99.7
TBZ	38.4	36.16	33.2

There is no evidence of heterogeneity in this case

Site 4
Table 51 sampled at edge:

VESSEL	Seeger (Saladin Boxes)		
DETAILS	85 t Fanfare, Ale malt		
	95 cm bed depth		
	16 m diameter single deck		
	indirectly heated		
	2h, 55C/ 7h, 65C/3h, 70C/5h 70-95C/4h 95C		
TIME OF SAMPLE	after kiln, before stripping		
DETAIL	near edge		
	"BOTTOM"	**"MIDDLE"**	**"TOP"**
Moisture	2.7	3.4	3.5
HWE (0.2mm)	317	317	317
HWE (0.7mm)	315	315	315
F/C difference	**2**	**2**	**2**
Colour	4.6	4.6	4.6
TSN	0.68	0.68	0.67
TN	1.52	1.52	1.53
SNR	**45**	**45**	**44**
FAN	0.12	0.12	0.12
pH	5.97	5.95	5.97
Fermentability	72	72	72
Viscosity	**1.51**	**1.49**	**1.55**
Friability	**94.0**	**95.0**	**94.0**
Homogeneity	99.8	99.6	99.8
TBZ	32.24	33.28	32.56

There is no evidence of heterogeneity in this case

Discussion

Steeping

In most cases heterogeneity manifests itself as the upper layers of grain being more modified than the lower or middle. This was even the case in quite deep (3.6 metres) vessels. This would mean that there is no disadvantage from the homogeneity point of view of cylindro-conical vessels (as long as they are aerated see below). There was no significant lagging behind in modification in even deeper (4.1 metres) vessels where there was more aeration and also CO_2 extraction. However, there was a need for three days of germination before convergence in this case.

One site had a large SGV which was employed as a "buffer" to increase the maltings throughput. The difference in the top/middle/bottom samples would then have arisen from only a 1.5 hour steep. This did give differences in the viscosity and friability values. It may have been that aeration was inefficient in a wide, flat-bottomed vessel. The LTm values showed no difference in the three samples.

At another site there was a flat-bottomed steep that ws not aerated. There were big differences in samples from the middle and top of the bed towards the end of the air rest (Figure 1). Vessels S118 and QH59 were also sampled at end of air rest, and there were only slight differences, presumably because these vessels were aerated. After cast and then germination at BRi the top/middle/bottom samples from the non-aerated steep were all very different, especially the top sample. The differences are very significant but not as dramatic as at the end of air rest; convergence has started in the second steep.

Vessel R58 is a shallow (1.5 meters) vessel that is well-aerated. There were no clear analytical differences between the top, middle and bottom samples. The LTm results demonstrate that the samples converged by Day 3 of germination.

Similarly vessel S117 shows only small analytical differences with the top sample again moving ahead in terms of modification. The LTm data indicates convergence after 2 days of germination. Convergence was rapid presumably because of the high aeration rate (5 minutes on 10 minutes off), since the water level was quite deep at 2.5 meters.

Kilning

No major differences between the different layers at the end of kilning were observed.
In some cases, slight differences between the layers could be recognised at the beginning and during kiln (at breaking point). In these cases, the higher temperature of the bottom layer shows it's effect as higher colour development and higher TBA. Whereas the colour increase mainly happened towards the end of kilning, the increase in the TBA seems to be continuos. Effects on other malt analysis parameters were inconclusive.

In most cases the standard malt analysis is similar for the three different layers at the same sample point, independent of the time of sampling {as examples}. (Looking at this set of samples taken at different locations in the kiln, the samples taken near the center column are slightly inhomogeneous in terms of colour and TBA compared to the ones taken at the edge of the kiln.) Drying related changes during kilning such as decrease in moisture and increase in TBA could be seen.

The state of the art technology produces malt that is homogenous throughout the different layers in the kiln at the end of the process.
Whether this is because the green malt prior to kilning is itself homogeneous or that the kiln has an equalizing effect, could be the subject of further research work.

Conclusions

1. Steeping

- There is a need for aeration to maximise homogeneity, a deep non-aerated vessel led to heterogeneous malt.
- There is no disadvantage of the extra depth of cylindro-conical steep vessels, at least up to four metres deep, as long as aeration is employed. Indeed the lower surface area of a cylindro-conical steep suggests that there is actually an advantage.
- There is evidence that the rate of aeration affects the homogeneity of the resultant malt
- Absence of carbon dioxide extraction does not appear to have a major effect, at least in medium-sized vessels

2. Kilning

- No significant differences between the single layers in the kiln could be identified at the end of kilning
- The different stages of drying through the layers, starting at the bottom, could be monitored as well as the increasing effect of the heat treatment
- Differences, if they occur, manifest themselves as the “bottom” layer being slightly darker and less modified
- The positioning of air inlet could influence malt homogeneity

Protocols to control the homogeneity of barley: Field Work

Background

It is clear from the laboratory work that the influence of barley quality on the homogeneity of the final malt is even more important that initially suspected. The size fractions of the grain and the quality of the endosperm are key indicators, the germination tests did not appear to be so useful, given adequate viability and lack of dormancy.

For this reason it is extremely important to understand the influence of growing conditions on the grain to be used for malting. Thus different varieties of barley for malting were grown under different conditions of nitrogen, fungicide and seed rate. In the final year grain from a normal and late harvest were also examined.

The grain was examined for features of size fraction, germination and endosperm structure. Grain from years 1 and 3 were malted. Full analyses of all of the samples are presented as appendices.

BRi is grateful to ADAS for growing and supplying these barley samples.

Index of this section:

Although this section contains a great many results a summary of the key points can be found in the conclusion at the end.

Note on how to read these results:

The experiments were designed for ANOVA analysis. Thus the result is a value of the F probability (F.pr.) for the null hypothesis (H0 = there was no influence by the field condition on the barley/malt property).

A high value of F.pr. (0.1-1) indicates that the field condition (explanatory) likely had no influence on the outcome, (that is that there was a high probability of the null hypothesis). A low F.pr. (<0.05) indicates that it is likely that the field condition had an influence on the outcome. In such a case a table describing the influence is provided with a standard error. The value s.e. is the standard error of the grand mean.

A correlation analysis between the responses has also been provided.

Protocols

The following abbreviations have been used throughout this report:
Site: BG Bridgets
Experiment: FN Fungicide Nitrogen, SR Seed rate, AU Amistar, Unix, OC Opus Corbel.
AUA indicates Amistar, Unix and then Amistar again.
The following experimental conditions were used:
Year 1. 2000
Table 52 Experiment FN

Seedrate

1 100 seed/m^2
2 400 seed/m^2

Nitrogen

1 50 kg N/ha
2 100 kg N/ha
3 150 kg N/ha

Fungicide

1 Amistar Pro 2l/ha plus
Unix 0.67 kg/ha GS 30-31
2 Opus 1.0l/ha plus
Corbel 0.5l/ha GS 30-31
3 Amistar Pro 2l/ha plus
Unix 0.67 kg/ha GS 30-31 +
Amistar Pro 2l/ha GS 45-59

Table 53 Experiment SR

Variety

1= Optic
2= Chariot
3= Cellar
4= Tavern

Seedrate/m^2

1= 50
2= 100
3= 200
4= 400
5= 800

Year 1
Barley parameters
ANOVA analysis of ADAS samples Year 1 – Variety Optic only.
BG2000FN
Factors (levels): Batch (germination analysis group, 5), Block, (3), Fungicide (amistar/unix; opus/corbel; amistarx2/unix3), Nitrogen (3), Plot (54), Seed rate (2).

Variables: Germinative Energy (4ml), Water sensitivity (8ml), Germinative capacity (H2O2), LTm, Germination delay (Gompertz M), Germination rate (Gompertz B). Seed size GT2.8, LT2.2.

Table 54 ANOVA for barley analysis year 1 (2000) FN
One way analysis variance (no blocking) – GT2.8

Factor	F.pr.
Batch	.900
Block	.711
Fungicide	.004
Nitrogen *1	.087
Seedrate	.001

*1 F.pr. decrease with separation of factors

Factor	Grand Mean	AUA	AU	OC	S.E.
Fungicide	64.0	70.3	66.0	55.9	4.25

Factor	Grand Mean	100	400	S.E.
Seedrate	64	74.3	53.8	2.55

One way analysis variance (no blocking) – LT2.2

Factor	F.pr.
Batch	0.894
Block	0.754
Fungicide	.025
Nitrogen *1	.123
Seedrate	.001

*1 F.pr. decrease with separation of factors

Factor	Grand Mean	OC	AU	AUA	S.E.
Fungicide	.677	.873	.67	.488	.1367

Factor	Grand Mean	100	400	S.E.
Seedrate	.677	.490	.864	.1069

One way analysis variance (no blocking) - LTm

Factor	F.pr.
Batch	.346
Block	.703

Fungicide	.856
Nitrogen	.001
Seedrate	.916

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	52.5	87.4	51.4	18.7	3.96

One way analysis variance (no blocking) – 4ml plates

Factor	F.pr.
Batch	.100
Block	.045
Fungicide	.115
Nitrogen	.920
Seedrate	.076

One way analysis variance (no blocking) – 8ml plates

Factor	F.pr.
Batch	.379
Block	.519
Fungicide	.658
Nitrogen	.253
Seedrate	.03

Factor	Grand Mean	100	400	S.E.
Seedrate	90.37	89.15	91.63	1.11

One way analysis variance (no blocking) - Peroxide

Factor	F.pr.
Batch	.610
Block	.253
Fungicide	.513
Nitrogen	.318
Seedrate	.633

One way analysis variance (no blocking) – Germinative delay

Factor	F.pr.
Batch	.001
Block	.028
Fungicide	.292
Nitrogen	.706
Seedrate	.565

One way analysis variance (no blocking) – Germination Rate

Factor	F.pr.
Batch	.024
Block	.567
Fungicide	.040

Nitrogen	.485
Seedrate	.099

Factor	Grand Mean	AU	AUA	OC	S.E.
Fungicide	.1535	.1611	.1552	.1442	.00654

Two way analysis of variation interaction only – GT2.8

Factor	F.pr.
Fungicide nitrogen	.989
Nitrogen seedrate	.191
Seedrate fungicide	.108

Two way analysis of variation interaction only – LT2.2

Factor	F.pr.
Fungicide nitrogen	.055
Nitrogen seedrate	.461
Seedrate fungicide	.365

Two way analysis of variation interaction only – LTm

Factor	F.pr.
Fungicide nitrogen	.773
Nitrogen seedrate	.526
Seedrate fungicide	.842

Two way analysis of variation interaction only – 4ml

Factor	F.pr.
Fungicide nitrogen	.417
Nitrogen seedrate	.043
Seedrate fungicide	.380

Two way analysis of variation interaction only – 8ml

Factor	F.pr.
Fungicide nitrogen	.111
Nitrogen seedrate	.062
Seedrate fungicide	.050

Two way analysis of variation interaction only – Peroxide

Factor	F.pr.
Fungicide nitrogen	.094
Nitrogen seedrate	.965
Seedrate fungicide	.991

Two way analysis of variation interaction only – Germinative delay

Factor	F.pr.
Fungicide nitrogen	.130
Nitrogen seedrate	.310
Seedrate fungicide	.517

Two way analysis of variation interaction only – Germinative rate

Factor	F.pr.
Fungicide nitrogen	.438
Nitrogen seedrate	.416
Seedrate fungicide	.224

ANOVA analysis of ADAS samples. Year 1 – Multiple Varieties.
BG2000SR
Varieties: Cellar Chariot optic Tavern.
Factors (levels): Block, (3), Plot (60), Variety (4), Seedrate (5).

Variables: Germinative Energy (4ml), Water sensitivity (8ml), Germinative capacity (H2O2), LTm, Germination delay (Gompertz M), Germination rate (Gompertz B). Seed size GT2.8, LT2.2.

Table 55 ANOVA for barley analysis year 1 (2000) SR
One way analysis variance (no blocking) – GT28

Factor	F.pr.
Variety	.82
Seedrate	<.001
Block	.536
Batch	.878

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	77	84	83	77	71	67	2.77

One way analysis variance (no blocking) – Between 2.5-2.8

Factor	F.pr.
Variety	.113
Seedrate	<.001
Block	.529
Batch	.863

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	18.9	11.3	13.3	17.2	23.9	27.0	1.9

One way analysis variance (no blocking) – Between 2.2-2.5

Factor	F.pr.
Variety	.019
Seedrate	<.001
Block	.551
Batch	.904

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	3.5	2.3	2.7	3.3	4.1	5.3	.43

Factor	Grand Mean	Cellar	Chariot	Optic	Tavern	S.E.
Variety	3.5	3.10	4.12	4.12	2.80	.51

One way analysis variance (no blocking) – LT2.2

Factor	F.pr.
Variety	.004
Seedrate	.002
Block	.883
Batch	.865

Factor	Grand Mean	Cellar	Chariot	Optic	Tavern	S.E.
Variety	.362	.256	.516	.343	.326	.070

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	.362	.302	.35383	.323	.277	.577	.077

One way analysis variance (no blocking) - LTm

Factor	F.pr.
Variety	.001
Seedrate	.149
Block	.084
Batch	<.001

Factor	Grand Mean	Cellar	Chariot	Optic	Tavern	S.E.
Variety	75	87	70	72	73	4.1

One way analysis variance (no blocking) – 4ml plates

Factor	F.pr.
Variety	.848
Seedrate	.008
Block	.128
Batch	.057

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	99.00	98.00	99.42	98.83	99.33	98.55	.459

One way analysis variance (no blocking) – 8ml plates

Factor	F.pr.
Variety	.163
Seedrate	<.001
Block	.172
Batch	.446

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	86.07	79.38	83.08	89.33	88.92	90.55	2.48

One way analysis variance (no blocking) - Peroxide

Factor	F.pr.
Variety	.095
Seedrate	.001
Block	.283
Batch	.281

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	97.95	97.00	97.42	99.33	98.42	97.64	.587

One way analysis variance (no blocking) – Germinative delay

Factor	F.pr.
Variety	.306
Seedrate	.702
Block	.006
Batch	<.001

One way analysis variance (no blocking) – Germination Rate

Factor	F.pr.
Variety	.013
Seedrate	.323
Block	.231
Batch	.034

Factor	Grand Mean	Cellar	Chariot	Optic	Tavern	S.E.
Variety	.1525	.1518	.1506	.1430	.1639	.0063

Table 56
Linear correlation between variates
Only values ≤0.05 provided

Response	Explanatory	t.pr.	% variation
Germ Delay	8ml	.05	4.8
H2O2	LTm	<.001	16.1
H2O2	8ml	.015	8.3
LTm	8ml	.01	9.3
GT2.8	Lt2.2	<.001	18.7
GT2.8	8ml	.002	14
4ml	8ml	.012	8.9

Malt parameters

Year 1

ANOVA analysis of ADAS Malts
BG2000FN– Variety Optic only.

Factors (levels): Batch (analysis group, 5), Block, (3), Fungicide (amistar/unix; opus/corbel; amistarx2/unix3), Nitrogen (3), Plot (54), Seedrate (2).

Variables: Extract (Course), Extract (Fine), Fine Course Difference, Folates, Friability, Fermentability, Barley H80, Malt H80, Calcofluor modification, Calcofluor homogeneity.

Table 57 ANOVA for malt analysis year 1 (2000) FN
One way analysis variance (no blocking) – Course Extract

Factor	F.pr.
Batch	.185
Block	.349
Fungicide	0.915
Nitrogen *1	<.001
Seedrate	.980

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	83.8	84.7	84.0	82.6	0.200

Factor	Grand Mean	AUA	AU	OC	S.E.
Fungicide					

Factor	Grand Mean	100	400	S.E.
Seedrate				

One way analysis variance (no blocking) – Fine Extract

Factor	F.pr.
Batch	.192
Block	.348
Fungicide	.245
Nitrogen *1	<.001
Seedrate	.739

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	84.6	85.4	84.8	83.8	.145

One way analysis variance (no blocking) - Fermentability

Factor	F.pr.
Batch	.046
Block	.014
Fungicide	.399
Nitrogen	<.001

Seedrate	.647

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	74.2	75.4	74.1	73.1	.501

One way analysis variance (no blocking) – Fine Course Difference

Factor	F.pr.
Batch	.218
Block	.468
Fungicide	.097
Nitrogen	<.001
Seedrate	.509

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	.85	.583	.783	1.183	.118

One way analysis variance (no blocking) – Folates

Factor	F.pr.
Batch	.835
Block	.418
Fungicide	.836
Nitrogen	.108
Seedrate	.776

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	3.06	2.99	2.91	3.27	.176

One way analysis variance (no blocking) - Friability

Factor	F.pr.
Batch	.712
Block	.286
Fungicide	.164
Nitrogen	.001
Seedrate	.213

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	83.9	92.2	85.6	73.8	2.28

One way analysis variance (no blocking) – Barley H80

Factor	F.pr.
Batch	.708
Block	.837
Fungicide	.753
Nitrogen	<.001
Seedrate	.839

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	41.8	69.2	33.8	22.4	2.88

One way analysis variance (no blocking) – Malt H80

Factor	F.pr.
Batch	.026
Block	.104
Fungicide	.011
Nitrogen	.032
Seedrate	.027

Factor	Grand Mean	AUA	AU	OC	S.E.
Fungicide	123.1	126.3	132.5	110.4	7.24

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	123.1	123.1	133.1	113.1	7.40

Factor	Grand Mean	100	400	S.E.
Seedrate	123.1	130	116	6.10

One way analysis variance (no blocking) – Calcofluor Modification

Factor	F.pr.
Batch	.999
Block	.913
Fungicide	.015
Nitrogen	<.001
Seedrate	0.97

Factor	Grand Mean	AUA	AU	OC	S.E.
Fungicide	94.9	92.6	95.2	96.9	1.44

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	94.9	98.5	95.0	91.2	1.18

One way analysis variance (no blocking) – Calcofluor Homogeneity

Factor	F.pr.
Batch	.705
Block	.952
Fungicide	.021
Nitrogen	<.001
Seedrate	.167

Factor	Grand Mean	AUA	AU	OC	S.E.
Fungicide	80.5	77.1	79.8	84.6	2.65

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	80.5	87.4	80.4	73.6	2.11

Two way analysis of variation interaction only –Extract (Course)

Factor	F.pr.
Fungicide nitrogen	.674
Nitrogen seedrate	.858
Seedrate fungicide	.844

Two way analysis of variation interaction only – Extract (Fine)

Factor	F.pr.
Fungicide nitrogen	.452
Nitrogen seedrate	.665
Seedrate fungicide	.739

Two way analysis of variation interaction only – Fermentability

Factor	F.pr.
Fungicide nitrogen	.799
Nitrogen seedrate	.639
Seedrate fungicide	.888

Two way analysis of variation interaction only – Fine Course Difference

Factor	F.pr.
Fungicide nitrogen	.433
Nitrogen seedrate	.934
Seedrate fungicide	.979

Two way analysis of variation interaction only – Friability

Factor	F.pr.
Fungicide nitrogen	.287
Nitrogen seedrate	.902
Seedrate fungicide	.770

Two way analysis of variation interaction only – Folates

Factor	F.pr.
Fungicide nitrogen	.967
Nitrogen seedrate	.279
Seedrate fungicide	.826

Two way analysis of variation interaction only – Barley H80

Factor	F.pr.
Fungicide nitrogen	.179
Nitrogen seedrate	.795
Seedrate fungicide	.995

Two way analysis of variation interaction only – Malt H80

Factor	F.pr.
Fungicide nitrogen	.895
Nitrogen seedrate	.547
Seedrate fungicide	.602

Two way analysis of variation interaction only – Calcofluor modification

Factor	F.pr.
Fungicide nitrogen	.010
Nitrogen seedrate	.891
Seedrate fungicide	.846

Fungicide	Nitrogen	50	100	150
AU		98.7	94.0	93.0
AUA		98.0	93.5	86.2
OC		98.3	97.5	94.3

Two way analysis of variation interaction only – Calcofluor homogeneity

Factor	F.pr.
Fungicide nitrogen	.235
Nitrogen seedrate	.597
Seedrate fungicide	.644

Year 2

Barley Parameters

ANOVA analysis of ADAS samples. Year 2 – Multiple Varieties.

Varieties: Cellar, Chariot, Optic, Tavern.
Factors (levels): Block, (3), Plot (60), Variety (4), Seed rate (5).

Variables: Germinative Energy (4ml), Water sensitivity (8ml), Germinative capacity (H2O2), LTm, Germination delay (Gompertz M), Germination rate (Gompertz B). Seed size GT2.8, between 2.8 and 2.5, between 2.5 and 2.2, LT2.2.

Total number of samples = 60

BG2000SR

Table 58 ANOVA for barley analysis year 2 (2001) SR

One way analysis variance (no blocking) – GT28

Factor	F.pr.
Variety	.019
Seedrate	<.001
Block	.879

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	90.45	90.4	92.23	93.18	90.06	86.35	1.34

One way analysis variance (no blocking) – LT2.2

Factor	F.pr.
Variety	<.001
Seedrate	.583
Block	.557

Factor	Grand Mean	Cellar	Chariot	Optic	Tavern	S.E.
Variety	.317	.420	.433	.210	.173	.058

One way analysis variance (no blocking) - LTm

Factor	F.pr.
Variety	.058
Seedrate	<.001
Block	.779

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	73.2	48.6	57.8	74.9	91.2	93.5	4.48

One way analysis variance (no blocking) – 4ml plates

Factor	F.pr.
Variety	.17
Seedrate	<.001

Block	.944

Factor	Grand Mean	50	100	200	400	800	S.E.
Seedrate	93.9	91.8	93.1	94	95.1	95.4	.851

One way analysis variance (no blocking) – 8ml plates

Factor	F.pr.
Variety	.596
Seedrate	.232
Block	.071

One way analysis variance (no blocking) - Peroxide

Factor	F.pr.
Variety	.016
Seedrate	.460
Block	.003

Factor	Grand Mean	Cellar	Chariot	Optic	Tavern	S.E.
Variety	97.85	97.2	98.7	97.5	98	.495

Factor	Grand Mean	Block 1	Block 2	Block 3	S.E.
Block	97.85	97.05	97.95	98.55	.421

One way analysis variance (no blocking) – Germinative delay

Factor	F.pr.
Variety	.731
Seedrate	.055
Block	.015

Factor	Grand Mean	Block 1	Block 2	Block 3	S.E.
Block	18	9.5	23.2	22.6	5.17

One way analysis variance (no blocking) – Germination Rate

Factor	F.pr.
Variety	.211
Seedrate	.215
Block	.560

Two way analysis of variation with blocks. Interaction between seed rate and variety only.

Factor	F.pr. of interaction
GT2.8	<.001
LT2.2	.007
LTm	.011
Pl4ml	.769

Pl8ml	.748
Peroxide	.895
Germination delay	.604
Germination rate	.161

Linear correlation between variates
Only values ≤0.05 provided

Response	Explanatory	t.pr.	% variation
Germination delay	Peroxide	.013	9
Germination delay	H80	.001	16
Germination delay	LTm	.014	9
H80	LTm	<.001	60
H80	2.5 to 2.8	<.001	39
H80	Greater 2.8	<.001	24
LTm	2.2 to 2.5	.003	12
LTm	2.5 to 2.8	.004	12

ANOVA analysis of ADAS samples Year 2 - Variety Optic only.
Factors (levels): Batch (germination analysis group, 5), Block, (3), Fungicide (amistar/unix; opus/corbel; amistarx2/unix3), Nitrogen (3), Plot (54), Seedrate (2). No Blocking (blocking has very little effect).

Variables: Germinative Energy (4ml), Water sensitivity (8ml), Germinative capacity (H2O2), LTm, Germination delay (Gompertz M), Germination rate (Gompertz B). Seed size GT2.8, between 2.8 and 2.5, between 2.5 and 2.2, LT2.2.

Table 59 ANOVA for barley analysis year 2 (2001) FN
One way analysis variance (no blocking) – GT2.8

Factor	F.pr.
Batch	.767
Block	.841
Fungicide	.469
Nitrogen *1	<.001
Seedrate	<.001

Factor	Grand Mean	1	1	3	S.E.
Nitrogen	89.29	86.97	90.40	90.51	1.01

Factor	Grand Mean	100	400	S.E.
Seedrate	89.29	91.04	87.55	.802

One way analysis variance (no blocking) – LT2.2

Factor	F.pr.
Batch	.283
Block	.441
Fungicide	.215
Nitrogen *1	.441
Seedrate	.949

One way analysis variance (no blocking) - LTm

Factor	F.pr.
Batch	.542
Block	.940
Fungicide	.311
Nitrogen	<.001
Seedrate	<.001

Factor	Grand Mean	50	100	150	S.E.
Nitrogen	60.1	73.8	60.2	46.4	5.84

Factor	Grand Mean	100	400	S.E.
Seed rate	60.1	45.3	75	3.86

One way analysis variance (no blocking) – 4ml plates

Factor	F.pr.
Batch	.261
Block	.449
Fungicide	.058
Nitrogen	.045
Seedrate	.001

Factor	Grand Mean	100	400	S.E.
Seed rate	97	95.8	98.2	.70

One way analysis variance (no blocking) – 8ml plates

Factor	F.pr.
Batch	.286
Block	.471
Fungicide	.500
Nitrogen	.281
Seedrate	.159

One way analysis variance (no blocking) - Peroxide

Factor	F.pr.
Batch	.285
Block	.127
Fungicide	.658
Nitrogen	.807
Seedrate	.159

One way analysis variance (no blocking) – Germinative delay

Factor	F.pr.
Batch	.373
Block	.579
Fungicide	.597
Nitrogen	.205
Seedrate	<.001

Factor	Grand Mean	100	400	S.E.
Seed rate	18.3	23.0	13.5	2.67

One way analysis variance (no blocking) – Germination Rate

Factor	F.pr.
Batch	.001
Block	.056
Fungicide	.420
Nitrogen	.015
Seedrate	.102

Factor	Grand Mean	AU	AUA	OC	S.E.
Fungicide	.1173	.1270	.1220	.1028	.008

Two way analysis of variation interaction only – GT2.8

Factor	F.pr.
Fungicide nitrogen	.878
Nitrogen seedrate	.215
Seedrate fungicide	.380

Two way analysis of variation interaction only – LT2.2

Factor	F.pr.
Fungicide nitrogen	.321
Nitrogen seedrate	.038
Seedrate fungicide	.736

Two way analysis of variation interaction only – LTm

Factor	F.pr.
Fungicide nitrogen	.879
Nitrogen seedrate	.058
Seedrate fungicide	.770

Two way analysis of variation interaction only – 4ml

Factor	F.pr.
Fungicide nitrogen	.054
Nitrogen seedrate	.879
Seedrate fungicide	.962

Two way analysis of variation interaction only – 8ml

Factor	F.pr.
Fungicide nitrogen	.855
Nitrogen seedrate	.575
Seedrate fungicide	.198

Two way analysis of variation interaction only – Peroxide

Factor	F.pr.
Fungicide nitrogen	.830
Nitrogen seedrate	.619
Seedrate fungicide	.887

Two way analysis of variation interaction only – Germinative delay

Factor	F.pr.
Fungicide nitrogen	.921
Nitrogen seedrate	.025
Seedrate fungicide	.517

Two way analysis of variation interaction only – Germinative rate

Factor	F.pr.
Fungicide nitrogen	.997
Nitrogen seedrate	.215
Seedrate fungicide	.313

Comparison between years one and two

Table 60 Comparison between barley properties for years 1 and 2 (2000/1) N=108

One way analysis of variation – Year only

Response	F.pr.
Greater than 2.8 mm	<0.001
Between 2.8 and 2.5	<0.001
4ml Germinative energy	<0.001
8 ml Water sensitivity	<0.001
Peroxide germinative capacity	0.004
Germinative delay	<0.001
Germination rate	<0.001
LTm	0.180
H80	<0.001

Two way analysis of variation interaction only – Factor with year

Response	Other factor	F.pr.
Greater than 2.8 mm	Fungicide	0.007
Between 2.8 and 2.5	Fungicide	0.026
All germination tests	Fungicide	>0.1
All LTm tests	Fungicide	>0.1
All size fractions	Nitrogen	>0.1
4ml germinative energy	Nitrogen	0.053
Germination rate	Nitrogen	0.008
LTm	Nitrogen	<0.001
H80	Nitrogen	<0.001
Greater than 2.8 mm	Seed rate	<0.001
Between 2.8 and 2.5	Seed rate	<0.001
4ml germinative energy	Seed rate	<0.001
8 ml Water sensitivity	Seed rate	<0.001
LTm	Seed rate	.0192
H80	Seed rate	<0.001

Year 3

Barley parameters

ANOVA analysis of ADAS samples. Year 3 – Early v Late Harvest. Multiple Varieties.

Varieties:

cellar	optic	tavern	chariot	static	county	chalice
pewter	colston	cocktail	vortex	novello	sebastien	

Factors (levels): Block, (3), Plot (60), Variety (13), Harvest date (2).

Variables: Germinative Energy (4ml), Water sensitivity (8ml), Germinative capacity (H2O2), LTm, H80, Seed size GT2.8, between 2.8 and 2.5, between 2.5 and 2.2, LT2.2.

Total number of samples = 78

Table 61 ANOVA for barley analysis year 3 (2002) Harvest date

One way analysis variance (no blocking) – % Greater than 2.8 mm

Factor	F.pr.
Variety	<0.001
Harvest Date	0.367

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	66.7	81.61	91.5	2.2
	Optic		Novello	

One way analysis variance (no blocking) – % between 2.5 and 2.8

Factor	F.pr.
Variety	<0.001
Harvest Date	0.159

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	6.4	13.85	25.6	1.61
	Novello		Optic	

One way analysis variance (no blocking) – % between 2.2 and 2.5

Factor	F.pr.
Variety	<0.001
Harvest Date	0.52

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	1.6	3.67	6.43	.58
	Novello		Optic	

One way analysis variance (no blocking) – 4ml Germinative energy

Factor	F.pr.
Variety	0.129
Harvest Date	0.011

Factor	Grand Mean	Normal	Late	S.E.
Harvest	96.4	95.8	96.9	.426

One way analysis variance (no blocking) – 8ml Water sensitivity

Factor	F.pr.
Variety	<0.001
Harvest Date	0.172

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	42.3	54.5	72.3	4.63
	Vortex		Cocktail	

One way analysis variance (no blocking) – Peroxide test

Factor	F.pr.
Variety	0.059
Harvest Date	0.006

Factor	Grand Mean	Normal	Late	S.E.
Harvest	96.8	97.4	96.1	.428

One way analysis variance (no blocking) – LTm value

Factor	F.pr.
Variety	0.08
Harvest Date	<0.001

Factor	Grand Mean	Normal	Late	S.E.
Harvest	37.8	20.6	55.0	2.83

One way analysis variance (no blocking) – H80

Factor	F.pr.
Variety	0.014
Harvest Date	<0.001

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	19.1	24.4	34.3	3.75
	Optic		Cellar	

Factor	Grand Mean	Normal	Late	S.E.
Harvest	24.4	19.2	29.6	1.09

Table 62 ANOVA for barley analysis year 3 (2002) Harvest date interactions

Two-way analysis of variation interaction only – Variety and harvest date

Response	F.pr.
Greater than 2.8	0.944
Between 2.8 and 2.5	0.927
Between 2.5 and 2.2	0.926
4 ml germinative energy	0.831
8 ml water sensitivity	0.596
Peroxide germinative capacity	0.357
LTm	0.072
H80	<0.001

Malt parameters

Year 3

Varieties:

cellar	optic	tavern	chariot	static	county	chalice
pewter	colston	cocktail	vortex	novello	sebastien	

Factors (levels): Block, (3), Plot (60), Variety (13), Harvest date (2).

Variables: Calcofluor modification, Calcofluor homogeneity, Extract – Coarse, Extract – Fine, F/C difference, Fermentability, Friability, Friability homogeneity, Malt LTm, Malt H80.

Total number of samples = 78

Table 63 ANOVA of malt analysis for year 3 (2001) Harvest Date
One way analysis variance (no blocking) – Calcofluor modification

Factor	F.pr.
Variety	<0.001
Harvest Date	0.004

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	70.17	87.65	93.33	2.42
	County		Chariot	

Factor	Grand Mean	Normal	Late	S.E.
Harvest	87.65	85.41	89.90	1.51

One way analysis variance (no blocking) – Calcofluor homogeneity

Factor	F.pr.
Variety	0.006
Harvest Date	0.311

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	64.83	70.99	77.67	3.04
	County		Chariot	

One way analysis variance (no blocking) – Extract - Coarse.

Factor	F.pr.
Variety	<0.001
Harvest Date	0.949

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	79.58	80.89	82.01	0.43
	Static		Cocktail	

One way analysis variance (no blocking) – Extract - Fine.

Factor	F.pr.
Variety	<0.001
Harvest Date	0.10

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	81.01	82.25	83.13	0.38
	Static		Cocktail	

One way analysis variance (no blocking) – F/C difference

Factor	F.pr.
Variety	<0.001
Harvest Date	<0.001

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	0.967	1.37	2.22	0.19
	Chariot		County	

Factor	Grand Mean	Normal	Late	S.E.
Harvest	1.371	1.546	1.195	0.099

One way analysis variance (no blocking) – Fermentability

Factor	F.pr.
Variety	0.003
Harvest Date	<0.001

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	71.00	72.73	73.67	0.628
	County		Pewter	

Factor	Grand Mean	Normal	Late	S.E.
Harvest	72.73	72.26	73.21	0.26

One way analysis variance (no blocking) – Friability

Factor	F.pr.
Variety	<0.001
Harvest Date	0.200

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	64.5	71.4	82.0	3.69
	County		Cocktail	

One way analysis variance (no blocking) – Friability homogeneity

Factor	F.pr.
Variety	<0.001
Harvest Date	0.23

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	78.42	89.58	95.63	2.53
	Static		Pewter	

One way analysis variance (no blocking) – Malt LTm

Factor	F.pr.
Variety	<0.001
Harvest Date	0.310

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	91.67	95.96	98.76	1.45
	Colsten		Cellar	

One way analysis variance (no blocking) – Malt H80

Factor	F.pr.
Variety	<0.001
Harvest Date	0.67

Factor	Minimum	Grand Mean	Maximum	S.E.
Variety	80.8	132	192	16.8
	Colsten		Cellar	

Conclusion to field work:
The following experiments were conducted:
Year 1: The influence of nitrogen, seed rate, fungicide and variety on barley and malt parameters.

Year 2: The influence of nitrogen, seed rate, fungicide and variety on barley parameters.

Year 2: A comparison between years 1 and 2 barley analyses.

Year 3 The influence of variety and harvest date on barley and malt parameters

Summary of results
Laboratory work has demonstrated that key factors influencing malt homogeneity are grain size distribution and endosperm quality (by LTm). These, with certain aspects of germination were examined with respect to the growing condition in the field. The following figures show the smallest F. probabilities obtained in each experiment. These figures are summaries of the most interesting and relevant points from the tables above (the tables above contain far more detail).

Figures 17 shows that the data for a single variety (Optic) in year 1 (barley) demonstrated that fungicide and seed rate had an influence on grain size and that nitrogen levels influenced endosperm structure. There were some effects on germination characteristics but these were not as significant. Similar results were obtained with multiple varieties (Figure 18).

Figure 19 shows the summarised results for the malt homogeneity analyses. Nitrogen clearly had an effect. The influence of seed rate was smaller than expected.

In the second year nitrogen and seed rate had a clear influence on grain size, again nitrogen had an influence on endosperm structure. Seed rate influenced several germination characteristics. In the set of four varieties both seed rate and variety influenced size and endosperm structure (LTm). Figures 20 (Optic) and 21 (Four varieties).

The barley parameters for the first and second years were compared for variety Optic only. Almost all of the parameters were significantly different. A major surprise, however, was that the LTm values were not significantly different by year, it is not clear why this should be. Figure 22 compares a range of parameters by year only, Figure 23 examines whether the year altered the effect of one of the other factors.

In year 3 a different set of experiments were conducted using thirteen different varieties and 2 different harvest dates. Variety had a clear influence on size and endosperm structure, harvest date also had several effects but not (significantly for homogeneity) on grain size (shown in figure 24). When the grain was malted there was a clear effect by variety on homogeneity (using Calcofluor) but, as the grain size work would predict, harvest date did not influence this response. The effects on the malt are shown in figure 25.

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Appendices

There are three appendices:

1. The first is a list of all of the barley and malt analyses for the three years of the project.
2. The second consists of three correlation matrices, one for each of the years data.
3. The figures referred to in the text.

All barley data year 1

BRiID	Variety	Seedrate	Nitrogen	Fungicide	BarleyH80	BarleyLtm	Genergy	Watersens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2	GrowthDelay	GrowthRate
00/116	Optic	400	100	OC	29	27	100	91	95	56.79	33.53	8.89	0.79	24.02	0.1641
00/117	Optic	100	100	AUA	24	26	97	92	95	81.76	14.62	3.37	0.25	25.80	0.1856
00/118	Optic	400	150	OC	24	15	97	95	100	41.33	42.16	14.71	1.80	24.33	0.1571
00/119	Optic	400	150	AUA	21	9	96	91	97	65.93	27.08	6.41	0.58	27.34	0.1496
00/120	Optic	400	50	AUA	43	73	100	84	99	65.43	29.46	4.47	0.64	24.72	0.1761
00/121	Optic	400	50	AU	66	92	100	91	98	59.81	32.03	7.38	0.78	25.35	0.1880
00/122	Optic	400	100	AUA	39	55	98	94	99	67.74	27.51	4.47	0.28	26.05	0.1873
00/123	Optic	100	150	AUA	22	7	99	93	97	76.92	18.40	4.30	0.38	27.00	0.1388
00/124	Optic	100	150	AU	22	9	100	86	99	72.67	21.65	5.03	0.65	25.71	0.1445
00/125	Optic	400	150	AU	23	8	99	82	100	57.19	33.17	8.62	1.02	25.00	0.1825
00/126	Optic	400	50	OC	77	89	100	92	99	36.71	47.76	14.48	1.05	27.11	0.1540
00/127	Optic	100	150	OC	22	18	100	93	98	68.43	24.60	6.32	0.65	28.09	0.1238
00/128	Optic	100	50	OC	58	84	97	91	98	69.73	24.88	4.95	0.44	28.27	0.1445
00/129	Optic	100	100	AU	33	51	96	80	100	75.75	19.63	4.08	0.54	26.73	0.1759
00/130	Optic	400	100	AU	47	74	100	93	98	61.63	31.35	6.38	0.64	28.39	0.1430
00/131	Optic	100	50	AUA	62	86	98	92	98	76.79	19.38	3.62	0.21	26.84	0.1390
00/132	Optic	100	50	AU	66	93	97	91	96	72.67	22.00	4.97	0.36	27.00	0.1626
00/133	Optic	100	100	OC	30	54	99	88	97	72.32	22.26	5.00	0.42	23.53	0.1238
00/134	Optic	400	100	AUA	43	71	100	92	94	64.96	27.65	6.42	0.97	27.13	0.1571
00/135	Optic	100	100	AU	32	50	98	85	97	81.29	15.16	3.23	0.32	26.44	0.14782
00/136	Optic	400	150	AU	22	19	100	89	99	61.11	32.31	5.95	0.63	26.2	0.188
00/137	Optic	400	50	OC	70	88	99	98	96	39.06	44.48	15.53	0.93	25.01	0.1611
00/138	Optic	400	150	AUA	26	21	100	84	97	61.71	30.42	7.54	0.33	26.78	0.1728
00/139	Optic	100	150	OC	22	23	100	84	96	71.07	22.33	5.98	0.62	25.74	0.1212
00/140	Optic	100	150	AU	32	59	99	94	98	75.36	20.68	3.73	0.23	25.02	0.2036
00/141	Optic	100	100	OC	44	78	98	78	98	61.23	31.13	7.06	0.58	27.01	0.1606
00/142	Optic	400	100	AU	26	18	100	93	99	75.81	19.23	4.40	0.56	26.7	0.156
00/143	Optic	400	150	OC	24	23	100	91	97	44.53	40.66	13.44	1.37	25.71	0.1582
00/144	Optic	100	150	AUA	24	24	97	89	98	80.01	16.11	3.24	0.68	26.83	0.1473
00/145	Optic	400	100	OC	40	70	100	89	98	54.72	35.65	8.93	0.70	26.25	0.1338
00/146	Optic	400	50	AUA	69	89	99	89	99	52.40	38.11	8.83	0.66	26.75	0.1555
00/147	Optic	100	100	AUA	33	49	100	91	96	80.89	15.58	3.07	0.46	26.03	0.1507

BRiID	Variety	Seedrate	Nitrogen	Fungicide	BarleyH80	BarleyLtm	Genergy	Watersens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2	GrowthDelay	GrowthRate
00/148	Optic	100	50	OC	60	82	100	88	99	71.16	23.28	5.07	0.49	25.9	0.1135
00/149	Optic	100	50	AU	76	93	100	97	100	71.16	23.72	4.53	0.59	24.5	0.14557
00/150	Optic	100	50	AUA	54	83	97	92	97	75.94	17.72	4.22	0.12	25.7	0.1231
00/151	Optic	400	50	AU	67	91	100	95	97	43.44	43.45	12.18	0.93	25.9	0.1337
00/152	Optic	100	150	OC	17	20	100	92	98	62.86	27.35	8.55	1.24	25.7	0.1274
00/153	Optic	400	100	AUA	30	47	100	94	99	66.49	26.79	6.13	0.59	26.9	0.1574
00/154	Optic	100	100	AU	32	46	98	87	98	77.89	17.97	4.01	0.13	25.08	0.15778
00/155	Optic	400	150	AU	21	16	100	92	99	61.05	31.08	6.89	0.98	24.4	0.1506
00/156	Optic	400	50	AU	99	91	100	89	97	42.38	45.03	12.01	0.58	26.06	0.1467
00/157	Optic	400	100	AU	35	64	99	91	98	57.16	34.08	7.78	0.98	24.9	0.1547
00/158	Optic	400	100	OC	28	55	100	96	99	43.30	42.69	12.72	1.29	25.5	0.15898
00/159	Optic	100	50	OC	87	97	100	92	98	66.33	26.63	6.45	0.59	24.62	0.1098
00/160	Optic	100	100	OC	30	61	100	85	97	77.52	17.94	4.28	0.26	24.53	0.1804
00/161	Optic	100	50	AUA	65	87	99	89	100	77.37	18.89	3.41	0.33	25.1	0.1846
00/162	Optic	400	50	AUA	75	92	99	94	100	42.65	44.54	11.93	0.88	24.02	0.1403
00/163	Optic	400	50	OC	65	89	100	97	99	29.58	49.35	20.92	0.15	24.96	0.1377
00/164	Optic	400	150	AUA	16	18	97	91	96	60.47	31.75	6.91	0.87	25.26	0.1392
00/165	Optic	100	50	AU	87	98	100	90	97	66.93	25.40	6.04	1.63	24.36	0.1675
00/166	Optic	100	150	AU	19	22	99	89	98	74.95	17.43	5.11	0.51	25.83	0.1519
00/167	Optic	400	150	OC	20	16	100	97	98	38.64	42.14	16.87	2.35	24.9	0.1663
00/168	Optic	100	150	AUA	26	16	100	87	100	81.68	14.28	3.77	0.27	26.43	0.1533
00/169	Optic	100	100	AUA	33	41	99	92	98	85.95	11.72	2.04	0.29	26.65	0.1365
00/170	Cellar	800	100	AU		76	97	94	96	70.77	23.65	5.16	0.42	25.30	0.1773
00/171	Chariot	400	100	AU		73	99	92	100	66.48	27.77	5.29	0.46	28.63	0.1576
00/172	Tavern	50	100	AU		79	98	86	97	88.33	9.87	1.51	0.29	27.10	0.1794
00/173	Optic	400	100	AU		82	97	92	99	69.36	25.57	4.59	0.48	26.30	0.1764
00/174	Chariot	200	100	AU		75	97	91	99	67.59	27.32	4.68	0.41	28.40	0.1761
00/175	Optic	100	100	AU		77	98	74	97	83.47	13.42	2.88	0.23	28.00	0.1452
00/176	Tavern	200	100	AU		84	97	80	98	82.99	14.81	2.06	0.14	27.30	0.1747
00/177	Chariot	100	100	AU		82	100	86	99	78.30	17.99	3.15	0.56	26.90	0.1539
00/178	Optic	800	100	AU		82	100	88	98	58.67	33.98	6.87	0.48	27.60	0.1361
00/179	Cellar	50	100	AU		92	97	88	98	85.71	11.92	2.31	0.06	22.80	0.1143
00/180	Tavern	800	100	AU		79	100	88	97	66.85	27.35	5.32	0.48	28.85	0.1654

BRiID	Variety	Seedrate	Nitrogen	Fungicide	BarleyH80	BarleyLtm	Genergy	Watersens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2	GrowthDelay	GrowthRate
00/181	Chariot	50	100	AU		69	98	66	98	80.01	15.09	4.11	0.79	29.10	0.1421
00/182	Cellar	100	100	AU		92	100	88	97	88.07	9.62	2.03	0.28	28.80	0.1685
00/183	Tavern	100	100	AU		76	100	88	97	89.48	8.93	1.53	0.06	27.93	0.1444
00/184	Optic	200	100	AU		82	99	88	99	76.26	19.17	4.08	0.49	25.90	0.1420
00/185	Cellar	400	100	AU		95	100	94	99	71.19	24.82	3.68	0.31	26.87	0.1907
00/186	Cellar	200	100	AU		92	97	93	100	69.60	25.13	4.83	0.44	29.00	0.1197
00/187	Optic	50	100	AU		62	99	71	96	86.00	11.43	2.45	0.12	28.30	0.1308
00/188	Tavern	400	100	AU		86	100	98	99	75.87	20.42	3.43	0.28	27.00	0.1562
00/189	Chariot	800	100	AU		76	99	89	98	64.55	29.83	4.85	0.77	26.90	0.1827
00/190	Optic	800	100	AU		89	99	93	98	54.93	37.24	7.22	0.61	27.00	0.1355
00/191	Tavern	200	100	AU		90	100	88	100	79.53	17.78	2.63	0.06	26.17	0.1701
00/192	Chariot	50	100	AU		73	98	81	99	79.30	16.73	3.47	0.50	28.00	0.1186
00/193	Cellar	50	100	AU		87	99	79	100	91.35	7.33	1.26	0.06	27.00	0.1464
00/194	Optic	100	100	AU		79	100	84	99	83.00	13.63	3.09	0.28	25.50	0.1286
00/195	Optic	200	100	AU		77	100	93	98	79.18	17.23	3.29	0.30	26.10	0.1399
00/196	Optic	400	100	AU		84	100	89	98	50.25	42.16	7.36	0.23	25.50	0.1451
00/197	Cellar	800	100	AU		88	100	96	97	72.72	22.17	4.62	0.49	26.20	0.1400
00/198	Cellar	100	100	AU		95	100	89	97	84.34	13.49	2.12	0.05	26.50	0.1239
00/199	Chariot	400	100	AU		72	100	81	97	76.85	19.74	3.00	0.41	26.60	0.1142
00/200	Tavern	400	100	AU		62	100	88	98	73.45	22.71	3.76	0.08	25.50	0.1658
00/201	Chariot	200	100	AU		68	100	91	100	74.60	21.02	4.23	0.39	26.70	0.1540
00/202	Chariot	100	100	AU		66	100	82	99	78.29	17.40	3.85	0.46	26.30	0.1601
00/203	Tavern	100	100	AU		62	97	78	96	74.54	20.63	3.89	0.94	24.70	0.1650
00/204	Chariot	800	100	AU		46	100	92	99	70.46	23.88	5.07	0.59	24.70	0.1638
00/205	Cellar	200	100	AU		79	100	93	100	83.17	14.34	2.14	0.35	26.80	0.1509
00/206	Tavern	50	100	AU		62	97	82	99	91.54	7.24	1.04	0.18	25.50	0.1620
00/207	Tavern	800	100	AU		54	100	98	98	74.81	20.83	3.94	0.42	24.30	0.1445
00/208	Optic	50	100	AU		54	98	88	95	83.62	13.69	2.42	0.27	25.20	0.1478
00/209	Cellar	400	100	AU		82	100	92	99	73.86	21.95	3.98	0.21	25.30	0.1622
00/210	Optic	200	100	AU		60	100	87	99	74.94	21.74	3.08	0.24	26.00	0.1365
00/211	Cellar	100	100	AU		77	100	87	99	84.98	11.86	2.87	0.29	26.40	0.1318
00/212	Chariot	100	100	AU		66	98	83	97	83.35	13.14	2.90	0.61	26.40	0.1318
00/213	Tavern	100	100	AU		57	100	68	98	88.56	9.38	1.87	0.19	26.10	0.1604

BRiID	Variety	Seedrate	Nitrogen	Fungicide	BarleyH80	BarleyLtm	Genergy	Watersens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2	GrowthDelay	GrowthRate
00/214	Cellar	400	100	AU		93	100	91	100	81.86	15.18	2.76	0.20	27.20	0.1594
00/215	Optic	800	100	AU		63	100	86	97	63.19	30.15	5.94	0.72	24.40	0.1561
00/216	Optic	400	100	AU		93	98	83	99	67.74	27.13	4.96	0.17	26.40	0.1315
00/217	Cellar	200	100	AU		93	99	96	100	81.80	15.87	2.04	0.29	24.70	0.1578
00/218	Tavern	50	100	AU		82	100	84	96	90.24	8.32	1.20	0.24	27.20	0.1761
00/219	Chariot	400	100	AU		81	98	89	97	71.90	23.30	4.45	0.35	27.10	0.1461
00/220	Tavern	800	100	AU		74	100	90	97	69.26	25.33	4.93	0.48	29.64	0.1625
00/221	Cellar	50	100	AU		73	98	75	95	83.76	13.35	2.75	0.14	25.65	0.1826
00/222	Chariot	50	100	AU		63	96	69	98	85.71	10.65	3.10	0.54	29.20	0.1409
00/223	Cellar	800	100	AU		76	100	89	99	74.54	20.63	3.89	0.94	25.39	0.1826
00/224	Tavern	200	100	AU		86	98	90	99	81.69	15.52	2.49	0.30	28.53	0.1517
00/225	Optic	50	100	AU		58	96	75	92	88.35	9.65	1.75	0.25	28.41	0.1318
00/226	Chariot	200	100	AU		78	99	82	100	75.21	20.57	3.75	0.47	27.83	0.1545
00/227	Chariot	800	100	AU		69	100	81	98	63.99	29.75	5.83	0.43	25.89	0.1630
00/228	Tavern	400	100	AU		68	100	78	96	81.26	16.13	2.47	0.14	27.10	0.1615
00/229	Optic	100	100	AU		41	100	90	94	88.45	9.46	1.81	0.28	26.65	0.1611

All malt data year 1

Malt H80	Calc mod	Calc homog	Folates	Friability	Fermentability	PG	Fextract	CExtract	Fcdifference
112	97	85	2.2	80	73	37.08	84.0	83.0	1.0
145	93	79	3.1	74	73	37.08	84.3	83.5	0.8
121	97	85	3.7	82	73	36.70	82.8	81.9	0.9
116	88	69	2.8	63	73	36.83	83.5	82.4	1.1
141	97	84	2.75	89	74	37.70	85.2	84.0	1.2
129	99	91	3	95	75	37.92	85.5	84.7	0.8
154	93	75	3	81	71	37.53	85.3	84.9	0.4
101	78	63	2.7	52	70	36.96	83.6	81.4	2.2
129	89	69	3.2	63	70	36.33	83.6	82.0	1.6
99	93	74	3.2	71	71	36.70	83.6	82.6	1.0
95	100	97	2.9	95	73	37.76	85.2	85.0	0.2
123	96	83	3	75	71	36.44	83.5	82.5	1.0
134	99	91	3.3	90	75	37.83	84.8	84.1	0.7
155	93	76	2.9	84	75	37.49	84.6	83.6	1.0
177	98	83	3.1	93	75	37.79	85.3	84.6	0.7
143	97	81	2.9	89	75	37.92	85.4	84.7	0.7
166	99	85	3.1	91	76	38.14	85.3	84.7	0.6
128	96	80	2	87	75	38.28	84.6	83.6	1.0
139	97	83	2.7	91	74	37.79	85.2	84.4	0.8
119	95	79	2.5	86	74	37.41	84.7	84.2	0.5
110	93	74	2.6	74	73	36.90	83.7	82.3	1.4
113	99	89	1.8	95	75	37.88	84.9	84.0	0.9
123	90	72	3	76	72	37.36	84.3	82.8	1.5
95	91	72	3.1	74	72	36.95	83.5	82.6	0.9
136	99	88	3	92	76	37.48	85.0	84.4	0.6
117	99	94	3.6	92	76	37.89	85.4	84.7	0.7
107	88	67	2.6	68	73	36.98	83.7	82.2	1.5
109	94	78	3.3	83	75	37.20	83.8	83.0	0.8
128	91	73	4.4	70	74	37.24	84.0	83.2	0.8
110	99	92	3.3	92	75	37.44	84.8	84.6	0.2
127	99	90	3.3	94	76	38.13	85.5	84.9	0.6

148	88	70	3.4	79	74	37.52	84.6	83.4	1.2
Malt H80	Calc mod	Calc homog	Folates	Friability	Fermentability	PG	Fextract	CExtract	Fcdifference
146	97	78	3.2	92	77	37.84	85.5	84.9	0.6
140	99	91	3.8	92	78	38.01	85.5	84.8	0.7
126	98	84	2.7	87	75	37.78	85.5	85.4	0.1
113	98	82	2.7	96	77	37.77	85.5	85.6	-0.1
86	91	71	3.3	77	75	36.91	83.6	82.7	0.9
102	95	81	2.8	89	73	37.64	85.2	84.2	1.0
120	92	75	3.7	83	72	37.22	84.6	83.8	0.8
133	93	76	4.4	82	73	36.92	84.1	83.0	1.1
125	100	92	1.9	95	74	37.79	85.3	84.7	0.6
166	98	82	3.2	93	76	37.57	85.4	84.8	0.6
86	98	89	3.2	94	75	37.48	84.6	84.1	0.5
114	98	86	3.2	92	75	37.59	85.3	85.0	0.3
147	96	81	3	86	74	37.48	84.6	84.1	0.5
123	98	85	3.3	89	74	37.74	85.6	84.7	0.9
85	99	89	2.8	95	76	37.88	85.6	85.2	0.4
76	100	97	4.2	93	76	38.14	85.2	84.7	0.5
92	85	65	3.7	72	74	37.45	84.3	82.8	1.5
119	97	81	2.9	91	76	37.83	85.5	84.7	0.8
142	91	71	3	75	75	37.34	84.5	83.1	1.4
75	97	75	3.8	81	75	36.68	83.4	82.6	0.8
117	85	67	2.7	67	73	36.94	84.1	82.3	1.8
164	95	77	2.1	89	76	37.75	85.6	84.7	0.9

All barley data
year 2

BRiID	Variety	Seedrate	Nitrogen	Fungicide	Barley H80	BarleyLTm	Genergy	WaterSens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2	GrowthDelay	GrowthRate
01/16	Optic	100	50	AU	15	69	100	83	100	91.0	7.2	1.2	0.6	20.689	0.12527
01/17	Optic	200	200	AUA	51	89	97	84	100	88.3	9.5	1.7	0.5	12.74	0.07176
01/18	Optic	200	150	AU	9	54	98	79	100	91.9	6.3	0.4	0.4	7.30	0.07440
01/19	Optic	100	150	AUA	7	31	94	87	98	91.1	6.1	2.4	0.4	20.96	0.06890
01/20	Optic	200	150	AUA	7	51	94	72	96	89.8	7.6	1.9	0.7	-9.70	0.05310
01/21	Optic	200	150	OC	20	77	99	88	99	89.7	8.3	1.4	0.6	2.20	0.08721
01/22	Optic	100	50	AUA	9	56	96	79	99	90.2	7.7	1.6	0.5	23.47	0.12430
01/23	Optic	200	200	AU	19	75	100	84	99	88.4	9.4	1.8	0.4	22.61	0.11717
01/24	Optic	100	200	OC	11	67	97	92	100	91.4	6.3	1.8	0.5	19.88	0.08830
01/25	Optic	100	50	OC	9	56	99	88	99	90.7	6.9	41.8	0.6	23.01	0.10215
01/26	Optic	200	50	OC	71	86	100	79	99	78.7	17.7	2.8	0.8	20.59	0.13870
01/27	Optic	200	50	AUA	30	79	98	80	99	81.9	15.7	1.8	0.6	20.70	0.14398
01/28	Optic	100	150	OC	7	31	97	79	98	91.2	5.9	2.3	0.6	21.60	0.11536
01/29	Optic	100	200	AUA	7	31	98	76	99	90.3	7.3	2.0	0.4	22.02	0.15427
01/30	Optic	100	200	AU	7	34	97	83	98	93.2	4.9	1.5	0.4	26.42	0.11783
01/31	Optic	100	150	AU	6	35	97	77	99	91.5	6.1	1.9	0.5	26.82	0.13152
01/32	Optic	200	50	AU	32	85	98	81	100	88.5	9.5	1.5	0.5	18.43	0.15270
01/33	Optic	200	200	OC	35	86	99	86	100	88.9	9.0	1.6	0.5	24.39	0.13430
01/34	Optic	200	50	OC	61	88	99	85	99	80.4	16.5	2.4	0.7	18.37	0.13984
01/35	Optic	200	150	OC	16	72	99	84	98	87.8	9.7	1.8	0.7	19.62	0.12380
01/36	Optic	200	150	AU	16	68	100	85	100	89.4	8.1	2.0	0.5	-29.47	0.08318
01/37	Optic	100	50	AUA	10	62	99	83	98	90.0	7.6	1.9	0.5	18.6	0.09192
01/38	Optic	100	200	OC	10	54	97	77	99	90.8	6.8	1.8	0.6	23.35	0.12130
01/39	Optic	200	200	OC	52	86	100	84	98	90.3	8.1	1.4	0.2	19.624	0.16510
01/40	Optic	200	200	AUA	15	68	99	86	98	90.1	8.0	1.5	0.7	21.11	0.12990
01/41	Optic	100	200	AU	7	38	93	79	100	92.4	5.6	1.6	0.4	27.29	0.10658
01/42	Optic	100	150	OC	8	33	99	77	99	92.1	5.8	1.9	0.2	25.16	0.08780
01/43	Optic	200	50	AUA	49	87	98	71	100	86.5	11.4	1.6	0.5	14.94	0.10400
01/44	Optic	200	200	AU	16	75	99	81	99	91.6	6.6	1.5	0.3	19.12	0.11920
01/45	Optic	100	50	AU	9	65	97	77	96	92.2	6.3	1.1	0.4	12.7	0.08530

BRiID	Variety	Seedrate	Nitrogen	Fungicide	Barley H80	BarleyLTm	Genergy	WaterSens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2	GrowthDelay	GrowthRate
01/46	Optic	200	150	AUA	10	48	94	77	99	91.0	7.3	1.3	0.4	-15	0.10370
01/47	Optic	100	150	AU	8	34	95	74	98	92.0	6.1	1.3	0.6	25.719	0.11065
01/48	Optic	100	150	AUA	8	27	91	77	99	91.1	5.9	2.0	1.0	25.049	0.10599
01/49	Optic	100	200	AUA	8	44	91	85	97	90.1	7.4	2.1	0.4	29.62	0.09659
01/50	Optic	100	50	OC	12	62	96	79	99	92.3	5.8	1.6	0.3	24.506	0.10761
01/51	Optic	200	50	AU	43	87	97	82	100	83.6	13.5	2.3	0.6	16.806	0.11397
01/52	Optic	200	150	AU	12	57	97	71	98	90.1	8.1	1.3	0.5	22.82	0.10578
01/53	Optic	100	150	OC	7	44	95	78	98	90.6	7.0	2.0	0.4	21.29	0.09530
01/54	Optic	200	200	OC	26	82	100	84	99	89.8	8.1	1.5	0.6	20.127	0.14080
01/55	Optic	100	50	AU	17	69	91	76	98	92.2	6.4	1.1	0.3	20.05	0.11180
01/56	Optic	100	50	OC	9	62	94	76	97	92.3	6.0	1.3	0.4	23.094	0.14586
01/57	Optic	200	50	OC	75	95	99	81	100	79.3	18.2	1.9	0.6	6.6	0.14910
01/58	Optic	100	50	AUA	12	62	99	86	98	89.7	8.3	1.5	0.5	15.57	0.11930
01/59	Optic	200	200	AUA	22	76	98	77	99	90.5	7.5	1.5	0.5	0.8	0.10600
01/60	Optic	100	200	AU	9	44	99	79	99	92.8	5.8	1.2	0.2	21.654	0.13576
01/61	Optic	100	150	AUA	6	24	86	77	97	89.2	7.3	2.4	1.1	28.26	0.08706
01/62	Optic	100	150	AU	8	20	95	82	98	88.8	7.2	3.0	1.0	24.61	0.10480
01/63	Optic	100	200	OC	8	38	98	78	98	89.1	6.9	3.0	1.0	25.306	0.12109
01/64	Optic	200	50	AUA	36	82	99	83	98	83.6	13.3	2.3	0.8	18.115	0.14308
01/65	Optic	200	200	AU	12	66	98	92	97	89.5	8.5	1.6	0.4	20.993	0.12823
01/66	Optic	100	200	AUA	6	30	97	87	99	89.7	6.5	2.8	1.0	24.711	0.14136
01/67	Optic	200	50	AU	18	76	100	85	95	82.4	14.3	2.4	0.9	21.974	0.18770
01/68	Optic	200	150	AUA	10	60	96	93	100	90.4	7.5	1.5	0.6	24.715	0.15751
01/69	Optic	200	150	OC	13	70	96	91	100	91.5	6.7	1.4	0.4	24.785	0.15460
01/70	Tavern	50	100	AU	21	38	90	85	97	94.1	4.6	1.2	0.1	27.11	0.1086
01/71	Cellar	400	100	AU	179	95	93	51	96	93.4	5.6	0.8	0.2	24.54	0.1170
01/72	Cellar	200	100	AU	126	93	95	71	97	95.1	4.3	0.4	0.2	25.73	0.1465
01/73	Optic	200	100	AU	23	64	92	88	96	91.7	6.5	1.6	0.2	23.74	0.1547
01/74	Optic	400	100	AU	64	83	96	85	97	89.0	8.8	1.9	0.3	-48.30	0.0988
01/75	Chariot	200	100	AU	44	77	94	80	99	92.6	5.8	1.4	0.2	24.49	0.1101
01/76	Optic	800	100	AU	65	88	94	67	97	87.4	10.2	2.1	0.3	19.31	0.1632
01/77	Cellar	100	100	AU	34	73	96	73	98	94.2	4.8	0.8	0.2	20.66	0.1030

BRiID	Variety	Seedrate	Nitrogen	Fungicide	Barley H80	BarleyLTm	Genergy	WaterSens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2	GrowthDelay	GrowthRate
01/78	Tavern	800	100	AU	111	93	94	76	98	86.5	11.8	1.6	0.1	11.78	0.1382
01/79	Optic	50	100	AU	24	31	92	81	96	88.2	8.4	2.9	0.5	23.87	0.1282
01/80	Chariot	800	100	AU	155	96	97	80	100	84.5	13.2	1.8	0.5	23.65	0.1149
01/81	Cellar	50	100	AU	33	66	94	74	95	90.7	7.7	1.3	0.3	23.38	0.1512
01/82	Chariot	50	100	AU	30	59	93	69	97	86.4	9.9	3.0	0.7	15.99	0.0808
01/83	Chariot	100	100	AU	36	73	95	72	100	90.4	7.1	2.0	0.5	20.17	0.1168
01/84	Tavern	400	100	AU	134	98	95	82	96	91.8	6.9	1.0	0.3	-52.20	0.1056
01/85	Optic	100	100	AU	21	44	92	77	97	91.6	6.3	1.7	0.4	28.48	0.1514
01/86	Chariot	400	100	AU	179	96	97	75	99	89.7	8.9	1.0	0.4	5.80	0.0950
01/87	Tavern	200	100	AU	48	82	93	83	96	95.1	3.9	0.7	0.3	7.80	0.0904
01/88	Cellar	800	100	AU	269	96	95	78	94	81.6	16.5	1.6	0.3	-59.06	0.0981
01/89	Tavern	100	100	AU	19	51	93	80	96	95.9	3.4	0.7	0.0	22.39	0.1136
01/90	Tavern	400	100	AU	38	78	95	89	100	92.3	6.7	0.9	0.1	13.61	0.1058
01/91	Chariot	100	100	AU	25	60	94	80	98	90.0	8.0	1.8	0.2	27.78	0.1335
01/92	Cellar	400	100	AU	182	95	97	87	98	89.7	8.9	1.1	0.3	21.37	0.1623
01/93	Chariot	50	100	AU	23	49	95	76	98	87.1	9.4	2.6	0.9	25.56	0.1150
01/94	Optic	200	100	AU	20	55	94	81	99	90.8	6.4	2.3	0.5	24.35	0.1435
01/95	Chariot	400	100	AU	104	87	95	84	98	92.0	6.7	1.1	0.2	24.21	0.1318
01/96	Tavern	200	100	AU	47	86	97	82	99	94.4	4.7	0.8	0.1	18.69	0.1496
01/97	Tavern	50	100	AU	23	53	83	80	98	95.4	3.6	0.8	0.2	29.53	0.1140
01/98	Cellar	200	100	AU	42	82	94	76	98	95.5	3.7	0.6	0.2	27.04	0.1421
01/99	Optic	50	100	AU	19	41	93	68	94	90.9	6.8	1.9	0.4	28.23	0.1180
01/100	Chariot	200	100	AU	39	74	93	86	98	91.8	6.4	1.3	0.5	26.01	0.1290
01/101	Tavern	800	100	AU	124	96	95	82	97	92.3	7.1	0.6	0.1	16.19	0.1285
01/102	Optic	400	100	AU	135	93	95	87	97	87.3	10.8	1.4	0.5	18.70	0.1283
01/103	Chariot	800	100	AU	156	95	95	80	99	86.9	11.1	1.8	0.2	22.83	0.1148
01/104	Optic	800	100	AU	134	95	97	87	99	82.4	15.2	2.0	0.4	16.87	0.1918
01/105	Cellar	100	100	AU	48	82	94	75	98	93.2	5.6	1.1	0.1	25.94	0.1272
01/106	Cellar	50	100	AU	25	61	94	85	98	93.1	5.8	0.9	0.2	26.47	0.1259
01/107	Cellar	800	100	AU	198	97	96	83	98	84.4	13.7	1.6	0.3	21.20	0.1075
01/108	Optic	100	100	AU	20	57	93	82	98	90.1	7.6	2.0	0.3	23.87	0.1164
01/109	Tavern	100	100	AU	22	51	86	70	97	95.2	3.8	0.8	0.2	26.24	0.0773
01/110	Tavern	200	100	AU	30	70	93	81	99	94.8	4.4	0.7	0.1	22.23	0.2231

BRiID	Variety	Seedrate	Nitrogen	Fungicide	Barley H80	BarleyLTm	Genergy	WaterSens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2	GrowthDelay	GrowthRate
01/111	Chariot	200	100	AU	45	81	95	83	98	90.9	6.8	1.7	0.6	26.03	0.0977
01/112	Tavern	400	100	AU	158	94	94	63	100	82.1	14.9	2.4	0.6	28.47	0.1086
01/113	Chariot	800	100	AU	45	84	95	86	100	94.6	4.7	0.5	0.2	19.89	0.1188
01/114	Cellar	50	100	AU	27	54	91	71	99	92.3	6.5	1.1	0.1	25.83	0.1257
01/115	Chariot	50	100	AU	24	46	91	66	99	82.8	12.4	4.0	0.8	26.10	0.1236
01/116	Tavern	100	100	AU	20	50	94	82	100	95.5	3.3	1.1	0.1	26.43	0.1138
01/117	Chariot	100	100	AU	25	62	95	73	100	89.5	7.5	2.7	0.3	26.17	0.0908
01/118	Chariot	400	100	AU	83	91	95	87	98	90.2	8.3	1.2	0.3	25.51	0.1179
01/119	Cellar	100	100	AU	30	66	93	88	96	93.1	5.2	1.3	0.4	27.72	0.1306
01/120	Optic	200	100	AU	17	46	92	84	98	90.4	7.2	2.0	0.4	22.83	0.1126
01/121	Cellar	400	100	AU	119	96	95	87	99	92.9	6.3	0.6	0.2	21.99	0.1204
01/122	Optic	800	100	AU	101	94	95	85	98	83.4	13.9	2.1	0.6	16.10	0.1325
01/123	Cellar	800	100	AU	187	98	95	84	99	81.0	16.7	1.9	0.4	16.75	0.1092
01/124	Tavern	50	100	AU	22	51	95	81	98	94.6	4.7	0.6	0.1	20.53	0.0920
01/125	Optic	400	100	AU	74	89	95	90	99	90.3	7.8	1.6	0.3	22.88	0.1283
01/126	Cellar	200	100	AU	90	89	96	85	99	95.1	4.1	0.6	0.2	19.78	0.0980
01/127	Optic	50	100	AU	18	34	91	75	97	89.2	8.1	2.2	0.5	17.20	0.1049
01/128	Optic	100	100	AU	18	25	92	80	96	88.1	8.2	3.0	0.7	22.73	0.1194
01/129	Tavern	400	100	AU	64	90	97	90	99	91.2	7.8	0.8	0.2	17.05	0.1792

All barley data year 3

BRi No	plot	blocks	varNum	Variety	Harvest	BarleyLTm	BarleyH80	GermE	WaterSens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2
02/155	1	1	6	County	N	17	15	96	65	99	75.65	19.18	4.53	0.64
02/156	2	1	5	Static	N	8	21	97	56	97	83.02	14.26	2.26	0.46
02/157	3	1	12	Novello	N	22	20	96	70	96	89.29	8.32	2.02	0.37
02/158	4	1	8	Pewter	N	28	19	96	62	94	86.03	11.36	2.28	0.33
02/159	5	1	7	Chalice	N	6	18	97	54	97	69.37	22.18	7.49	0.95
02/160	6	1	9	Colston	N	17	19	100	45	97	75.19	19.47	4.62	0.72
02/161	7	1	1	Cellar	N	57	24	98	74	98	84.03	12.24	3.13	0.6
02/162	8	1	13	Sebastien	N	26	17	96	61	100	82.77	12.73	3.83	0.68
02/163	9	1	4	Chariot	N	19	19	97	57	94	74.92	17.03	6.44	1.52
02/164	10	1	3	Tavern	N	14	20	98	72	94	87.04	10.14	2.22	0.6
02/165	11	1	11	Vortex	N	31	21	98	40	98	77.8	16.47	4.78	0.95
02/166	12	1	2	Optic	N	7	15	96	34	99	63.33	28.39	7.21	1.07
02/167	13	1	10	Cocktail	N	22	17	99	73	98	69.4	23.44	6.24	0.92
02/168	14	2	5	Static	N	11	24	99	43	96	77.8	17.19	4.6	0.41
02/169	15	3	10	Cocktail	N	28	18	100	85	97	66.11	25.24	7.45	1.2
02/170	16	3	3	Tavern	N	18	19	94	85	98	85.91	11.31	2.24	0.54
02/171	17	3	6	County	N	23	19	100	51	97	76.96	18.26	4.17	0.61
02/172	18	3	13	Sebastien	N	26	19	98	45	96	80.84	13.65	4.72	0.79
02/173	19	3	2	Optic	N	6	16	97	50	99	59.38	30.46	9.03	1.13
02/174	20	3	8	Pewter	N	26	20	98	59	96	81.97	14.32	2.98	0.73
02/175	21	2	3	Tavern	N	18	15	96	54	100	88.37	9.05	2.24	0.34
02/176	22	2	9	Colston	N	15	19	98	38	98	82.29	14.95	2.36	0.4
02/177	23	2	13	Sebastien	N	24	17	96	51	97	82.55	13.44	3.48	0.53
02/178	24	2	7	Chalice	N	17	17	96	47	98	81.09	14.22	4.17	0.52
02/179	25	2	4	Chariot	N	15	18	98	49	98	73.48	18.01	7.02	1.49
02/180	26	2	6	County	N	14	16	96	43	99	82.09	13.9	3.35	0.66
02/181	27	2	12	Novello	N	35	18	95	51	96	93.29	5.02	1.44	0.25
02/182	28	2	2	Optic	N	14	13	97	49	98	72.9	21.55	5.02	0.53
02/183	29	2	10	Cocktail	N	11	15	96	70	96	81.96	14.39	3.26	0.39
02/184	30	2	11	Vortex	N	20	21	97	45	96	88.34	9.29	2.03	0.34
02/185	31	2	8	Pewter	N	36	23	92	53	96	91.76	6.64	1.14	0.46

BRi No	plot	blocks	varNum	Variety	Harvest	BarleyLTm	BarleyH80	GermE	WaterSens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2
02/186	32	2	5	Static	N	6	23	98	59	98	87.56	10.12	2.02	0.3
02/187	33	2	1	Cellar	N	43	27	93	68	99	91.63	6.79	1.46	0.12
02/188	34	3	11	Vortex	N	18	25	95	47	97	87.98	9.65	2.15	0.22
02/189	35	3	9	Colston	N	15	19	98	49	99	81.54	15.48	2.66	0.32
02/190	36	3	1	Cellar	N	35	24	99	62	96	88.94	9.05	1.78	0.23
02/191	37	3	12	Novello	N	27	17	95	58	98	91.11	7.17	1.48	0.24
02/192	38	3	7	Chalice	N	11	18	98	67	98	82.92	13.35	3.32	0.41
02/193	39	3	4	Chariot	N	19	20	97	55	100	75.54	17.32	5.75	1.39
02/194	1	1	6	County	L	28	19	97	58	97	86.68	10.07	2.51	0.74
02/195	2	1	5	Static	L	48	28	96	41	98	85.78	10.98	2.46	0.78
02/196	3	1	12	Novello	L	53	30	95	46	95	92.26	6.00	1.27	0.47
02/197	4	1	8	Pewter	L	63	32	91	51	91	88.88	8.63	1.67	0.82
02/198	5	1	7	Chalice	L	59	29	96	60	98	81.10	14.10	3.96	0.84
02/199	6	1	9	Colston	L	57	31	95	57	97	84.10	12.56	2.73	0.61
02/200	7	1	1	Cellar	L	86	45	96	67	97	87.74	9.30	2.22	0.74
02/201	8	1	13	Sebastien	L	67	33	96	58	99	85.48	10.33	3.37	0.82
02/202	9	1	4	Chariot	L	45	24	97	48	95	78.00	14.61	5.34	2.05
02/203	10	1	3	Tavern	L	54	26	96	55	96	90.12	6.97	1.97	0.94
02/204	11	1	11	Vortex	L	73	38	92	40	97	87.20	8.86	3.03	0.91
02/205	12	1	2	Optic	L	48	25	95	33	97	68.62	24.80	5.01	1.57
02/206	13	1	10	Cocktail	L	64	31	96	71	94	75.33	18.42	5.00	1.25
02/207	14	2	5	Static	L	57	30	97	37	98	86.34	10.58	2.56	0.52
02/208	15	3	10	Cocktail	L	61	31	94	68	99	74.45	18.94	4.87	1.74
02/209	16	3	3	Tavern	L	42	27	96	57	96	88.91	8.83	1.88	0.38
02/210	17	3	6	County	L	38	25	96	55	97	83.70	12.24	3.09	0.97
02/211	18	3	13	Sebastien	L	74	39	92	38	96	84.06	12.08	2.98	0.88
02/212	19	3	2	Optic	L	33	20	99	56	92	63.14	27.83	7.19	1.84
02/213	20	3	8	Pewter	L	54	28	96	56	94	82.47	13.30	3.48	0.75
02/214	21	2	3	Tavern	L	44	28	98	60	93	89.62	7.49	2.14	0.75
02/215	22	2	9	Colston	L	54	28	96	52	99	81.52	13.82	3.94	0.72
02/216	23	2	13	Sebastien	L	67	34	99	53	96	82.08	12.7	4.3	0.92
02/217	24	2	7	Chalice	L	46	27	98	44	94	76.23	17.01	5.37	1.39
02/218	25	2	4	Chariot	L	47	25	97	46	97	75.03	16.07	5.95	2.95

BRi No	plot	blocks	varNum	Variety	Harvest	BarleyLTm	BarleyH80	GermE	WaterSens	Peroxide	Size>2.8	Size2.5-2.8	Size2.2-2.5	Size<2.2
02/219	26	2	6	County	L	35	23	97	49	94	85.08	11.63	2.53	0.76
02/220	27	2	12	Novello	L	67	34	91	50	91	91.64	5.94	1.77	0.65
02/221	28	2	2	Optic	L	54	26	97	47	96	73.12	20.75	5.13	1
02/222	29	2	10	Cocktail	L	37	21	98	67	97	71.73	20.24	5.98	2.05
02/223	30	2	11	Vortex	L	68	35	96	42	98	87.9	9.11	2.09	0.9
02/224	31	2	8	Pewter	L	66	33	96	42	95	85.88	11.16	2.18	0.78
02/225	32	2	5	Static	L	40	31	94	50	98	86.89	10.33	2.17	0.61
02/226	33	2	1	Cellar	L	82	42	98	64	100	87.27	9.36	2.55	0.82
02/227	34	3	11	Vortex	L	58	31	96	40	98	84.26	11.26	3.63	0.85
02/228	35	3	9	Colston	L	42	26	97	51	95	71.49	21.44	5.4	1.67
02/229	36	3	1	Cellar	L	83	44	97	75	99	88.02	8.75	2.53	0.7
02/230	37	3	12	Novello	L	54	28	93	69	95	91.63	6.04	1.7	0.63
02/231	38	3	7	Chalice	L	46	25	97	64	96	76.52	16.05	5.21	2.22
02/232	39	3	4	Chariot	L	52	24	94	41	96	72.97	16.43	6.82	3.78

All Malt data year 3

Friability	Frhomog	Fermentability	FCDifference	Cextract	Fextract	maltLTm	maltH80	CalcMod	CalcoHomog
64	82.8	71	2.2	80.2	82.4	88	79	72	67
58	77.0	72	1.9	79.6	81.5	97	149	86	75
77	94.0	72	1.4	81.4	82.8	95	96	91	73
81	97.2	73	1.4	81.3	82.7	100	146	91	74
79	93.2	73	1.2	81.8	83.0	95	119	91	73
73	91.9	72	1.6	81.4	83.0	89	73	82	63
81	96.4	73	1.2	83.3	84.5	99	214	89	75
80	93.9	74	1.1	82.9	84.0	99	170	91	74
77	95.2	73	1.2	81.6	82.8	99	144	92	75
75	94.1	72	1.4	80.9	82.3	98	134	90	74
81	95.5	73	1.1	82.6	83.7	99	148	88	72
74	89.6	72	2.1	81.2	83.3	96	105	86	67
81	95.7	73	1.3	82.2	83.5	98	122	84	64
67	84.2	73	1.3	80.4	81.7	92	96	85	72
86	97.1	75	1.3	82.8	84.1	98	152	91	75
78	94.0	74	1.5	81.5	83.0	99	153	84	68
67	83.7	71	2.4	80.3	82.7	92	95	67	67
81	95.0	74	0.9	83.1	84.0	98	159	91	75
69	85.8	72	2.0	81.0	83.0	96	81	82	67
80	95.8	74	1.2	81.4	82.6	99	135	89	65
67	88.5	71	1.3	80.2	81.5	96	114	89	75
56	78.5	70	1.9	80.2	82.1	89	65	85	75
65	85.4	71	1.9	80.3	82.2	95	111	91	74
72	91.3	72	1.6	80.3	81.9	98	115	88	71
71	93.2	72	0.9	80.0	80.9	93	82	87	68
55	74.8	70	2.6	78.8	81.4	91	63	65	66
64	88.9	71	1.4	79.8	81.2	91	91	84	65
54	72.7	70	2.2	79.5	81.7	91	64	70	64
73	90.1	73	1.3	80.8	82.1	94	108	88	66
73	91.4	72	1.4	81.7	83.1	98	176	88	74
75	93.2	73	1.6	79.6	81.2	97	164	88	71

Friability	Frhomog	Fermentability	FCDifference	Cextract	Fextract	maltLTm	maltH80	CalcMod	CalcoHomog
53	72.8	72	1.2	78.9	80.1	96	131	79	70
67	90.5	72	1.6	80.6	82.2	97	189	86	67
63	83.8	72	1.2	81.3	82.5	99	163	82	66
54	77.3	72	2.7	79.7	82.4	87	63	86	72
69	89.6	72	1.4	81.0	82.4	99	192	87	70
58	83.7	72	1.7	79.6	81.3	95	89	88	72
70	90.4	72	1.6	80.6	82.2	97	114	88	69
68	91.1	73	1.1	80.4	81.5	99	149	90	72
66	84.5	71	1.9	79.5	81.4	92	94	69	62
64	82.5	73	1.5	79.5	81.0	97	151	91	77
74	93.0	72	1.0	80.6	81.6	99	111	93	77
81	97.4	74	1.0	80.5	81.5	94	123	96	81
79	95.0	73	0.8	81.0	81.8	96	147	96	82
75	92.2	73	1.6	81.0	82.6	95	100	84	65
77	94.8	73	1.4	81.6	83.0	100	290	89	67
80	94.6	74	1.0	82.1	83.1	100	173	93	70
79	97.3	73	0.7	80.6	81.3	98	147	98	86
79	95.5	72	1.5	80.7	82.2	95	135	95	79
82	95.5	74	0.4	83.3	83.7	99	242	94	74
70	86.6	72	1.5	80.6	82.1	93	91	82	59
85	97.3	74	0.4	82.8	83.2	94	127	93	70
63	81.6	75	1.3	80.0	81.3	96	176	93	71
86	97.2	75	1.2	82.3	83.5	99	152	92	72
78	94.2	73	1.4	81.1	82.5	99	184	91	70
71	88.5	72	1.8	80.3	82.1	93	106	74	61
84	96.0	74	1.1	82.5	83.6	100	215	95	79
77	92.5	73	1.6	81.0	82.6	98	132	88	70
82	96.5	73	0.8	81.4	82.2	99	164	95	78
74	92.4	73	1.0	80.3	81.3	99	151	87	70
71	89.0	73	1.4	80.5	81.9	97	101	91	72
77	93.1	73	0.8	81.5	82.3	96	142	89	69
72	91.2	72	0.9	80.4	81.3	95	159	90	64
67	90.2	72	0.9	79.9	80.8	96	149	95	80

Friability	Frhomog	Fermentability	FCDifference	Cextract	Fextract	maltLTm	maltH80	CalcMod	CalcoHomog
64	82.7	71	2.4	78.6	81.0	97	110	74	66
65	89.6	72	1.2	80.2	81.4	97	135	89	70
60	80.1	72	1.9	79.6	81.5	89	79	87	69
81	95.6	72	1.2	81.2	82.4	98	134	94	75
68	85.5	72	1.3	81.5	82.8	95	127	82	58
76	93.7	75	0.5	81.0	81.5	97	144	92	79
50	72.4	74	1.4	79.1	80.5	90	91	84	59
69	90.8	75	1.2	81.6	82.8	98	129	87	62
60	80.1	74	1.3	81.4	82.7	99	189	85	65
69	89.3	74	1.6	80.8	82.4	93	83	95	81
71	91.0	74	1.1	81.9	83.0	99	139	95	73
67	88.6	75	0.4	81.0	81.4	93	128	94	72
71	88.8	74	1.2	80.9	82.1	99	122	97	76
69	91.2	75	1.0	81.0	82.0	94	115	98	85

Correlation analysis of all year 1 data

	BRiID	*Seedrate*	*Nitrogen*	*Barley H80*	*LTm*	*g4ml*	*g8ml*	*Peroxide*	*Size>2.8*	*Size2.5-2.8*	*Size2.2-2.5*	*Size2.2*
BRiID	1.00											
Seedrate	-0.10	1.00										
Nitrogen	-0.08	0.00	1.00									
Barley H80	0.16	0.03	-0.88	1.00								
LTm	0.17	-0.02	-0.92	0.90	1.00							
g4ml	0.28	0.24	-0.04	0.13	0.08	1.00						
g8ml	0.15	0.30	-0.17	0.20	0.15	0.15	1.00					
H2O2	0.16	0.07	-0.03	0.07	0.03	0.07	-0.05	1.00				
>28	-0.06	-0.74	0.16	-0.30	-0.21	-0.28	-0.37	-0.11	1.00			
2.5-2.8	0.03	0.78	-0.19	0.33	0.25	0.28	0.34	0.12	-0.99	1.00		
2.2-2.5	0.12	0.63	-0.10	0.22	0.13	0.26	0.41	0.08	-0.96	0.92	1.00	
<22	0.09	0.44	0.20	-0.06	-0.16	0.22	0.27	0.06	-0.60	0.57	0.59	1.00
GrowthDelay	-0.27	-0.08	0.08	-0.08	-0.06	-0.20	-0.11	-0.08	0.22	-0.20	-0.24	-0.27
GrowthRate	-0.24	0.23	0.10	-0.13	-0.08	-0.09	-0.14	0.09	0.02	0.01	-0.07	0.04
Malt H80	-0.21	-0.30	-0.18	0.08	0.21	-0.24	-0.18	-0.10	0.53	-0.49	-0.59	-0.40
Calc mod	0.06	0.18	-0.66	0.64	0.75	0.12	0.19	0.09	-0.44	0.46	0.37	0.14
Calc homog	-0.02	0.19	-0.67	0.68	0.77	0.11	0.21	0.11	-0.49	0.52	0.43	0.04
Folates	0.19	-0.04	0.22	-0.17	-0.13	-0.11	0.04	0.29	-0.08	0.06	0.12	0.20
Friab	0.24	0.17	-0.74	0.70	0.86	0.17	0.20	0.06	-0.39	0.42	0.31	0.07
Ferment	0.44	-0.06	-0.55	0.51	0.66	0.01	0.22	0.03	-0.18	0.18	0.17	0.10
PG	0.20	-0.02	-0.80	0.71	0.87	-0.03	0.10	-0.08	-0.10	0.13	0.03	-0.28
Fextract	0.28	-0.05	-0.82	0.75	0.89	0.06	0.08	0.03	0.00	0.05	-0.10	-0.33
CExtract	0.25	0.00	-0.82	0.76	0.91	0.03	0.14	0.02	-0.13	0.17	0.05	-0.21
Fcdiff	-0.13	-0.09	0.58	-0.55	-0.68	0.04	-0.21	0.01	0.34	-0.35	-0.30	-0.06

Correlation analysis of all year 1 data

	GrowthDelay	*GrowthRate*	*Malt H80*	*Calc mod*	*Calc homog*	*Folates*	*Friab*	*Ferment*	*PG*	*Fextract*	*CExtract*	*Fcdiff*
BRiID												
Seedrate												
Nitrogen												
Barley H80												
LTm												
g4ml												
g8ml												
H2O2												
>28												
2.5-2.8												
2.2-2.5												
<22												
GrowthDelay	1.00											
GrowthRate	-0.12	1.00										
Malt H80	0.23	0.16	1.00									
Calc mod	-0.17	0.05	0.12	1.00								
Calc homog	-0.10	0.04	0.00	0.91	1.00							
Folates	-0.07	-0.02	-0.12	-0.04	-0.01	1.00						
Friab	-0.17	-0.01	0.18	0.90	0.84	-0.08	1.00					
Ferment	-0.17	-0.16	0.17	0.60	0.51	0.06	0.72	1.00				
PG	-0.04	-0.07	0.28	0.58	0.61	-0.17	0.77	0.70	1.00			
Fextract	-0.01	-0.02	0.37	0.60	0.59	-0.17	0.78	0.62	0.88	1.00		
CExtract	-0.05	-0.06	0.29	0.75	0.70	-0.09	0.87	0.67	0.83	0.94	1.00	
Fcdiff	0.10	0.13	-0.05	-0.80	-0.70	-0.07	-0.77	-0.54	-0.50	-0.56	-0.80	1.00

Correlation analysis for all year 2 data

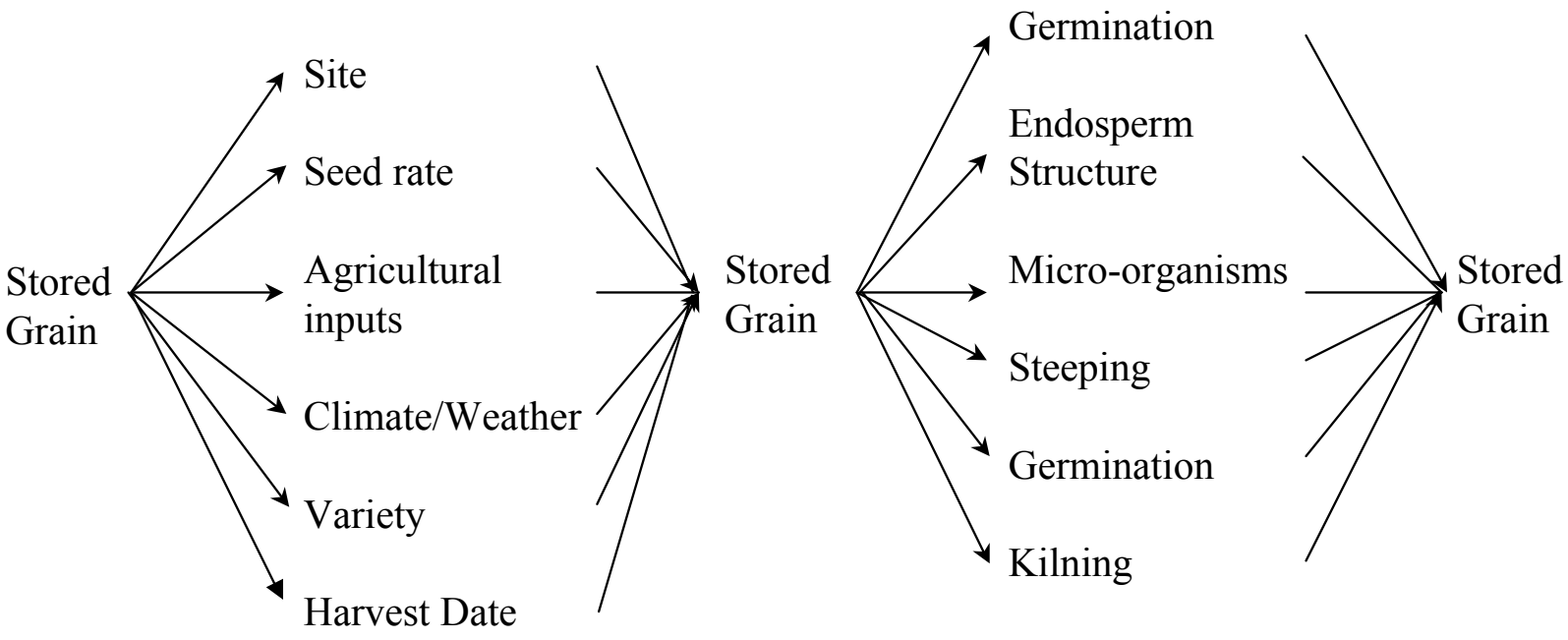
	BRlid	*Barley H80*	*BarleyLTm*	*Genergy*	*WaterSens*	*Peroxide*	*Size>2.8*	*Size2.5-2.8*	*Size2.2-2.5*	*Size<2.2*	*GrowthDelay*	*GrowthRate*
BRlid	1.00											
Barley H80	0.39	1.00										
BarleyLTm	0.22	0.72	1.00									
Genergy	-0.49	0.02	0.32	1.00								
WaterSens	-0.03	-0.09	0.12	0.29	1.00							
Peroxide	-0.20	-0.11	0.14	0.36	0.20	1.00						
Size>2.8	0.10	-0.36	-0.30	-0.32	0.01	-0.09	1.00					
Size2.5-2.8	-0.06	0.47	0.44	0.34	0.01	0.09	-0.98	1.00				
Size2.2-2.5	-0.16	-0.10	-0.11	0.12	0.09	0.05	-0.09	0.05	1.00			
Size<2.2	-0.36	-0.25	-0.30	0.19	0.00	0.06	-0.52	0.38	0.19	1.00		
GrowthDelay	0.11	-0.31	-0.28	-0.18	-0.06	0.18	0.18	-0.22	0.04	0.04	1.00	
GrowthRate	0.18	0.09	0.24	0.17	0.17	0.01	-0.14	0.18	-0.07	-0.08	0.25	1.00

Correlation analysis for all year 3 data

	BRlid	*varNum*	*LTm*	*H80*	*GermE*	*WaterSens*	*Peroxide*	*Size>2.8*	*Size2.5-2.8*	*Size2.2-2.5*	*Size<2.2*
BRlid	1.00										
varNum	-0.01	1.00									
LTm	0.71	0.07	1.00								
H80	0.67	0.02	0.91	1.00							
GermE	-0.26	-0.21	-0.37	-0.35	1.00						
WaterSens	-0.16	-0.10	-0.01	-0.05	0.12	1.00					
Peroxide	-0.22	-0.12	-0.18	-0.13	0.15	0.03	1.00				
Size>2.8	0.14	0.19	0.31	0.37	-0.42	0.09	-0.10	1.00			
Size2.5-2.8	-0.20	-0.20	-0.36	-0.41	0.44	-0.08	0.12	-0.99	1.00		
Size2.2-2.5	-0.10	-0.15	-0.25	-0.33	0.39	-0.08	0.10	-0.95	0.90	1.00	
Size<2.2	0.40	-0.15	0.20	0.07	0.05	-0.12	-0.14	-0.57	0.46	0.66	1.00
friability	-0.09	0.19	0.29	0.17	-0.03	0.33	-0.26	-0.16	0.11	0.23	0.23
Frhomo	-0.04	0.16	0.32	0.19	-0.08	0.34	-0.31	-0.04	-0.02	0.15	0.25
Fermentability	0.35	0.13	0.50	0.50	-0.19	0.22	-0.09	-0.01	-0.04	0.09	0.29
FCDiff	-0.32	-0.24	-0.49	-0.47	0.19	-0.11	0.28	-0.16	0.24	-0.01	-0.27
Cextract	-0.12	0.28	0.30	0.25	0.04	0.28	0.03	-0.16	0.13	0.23	0.12
Fextract	-0.31	0.21	0.09	0.04	0.14	0.27	0.17	-0.26	0.28	0.26	0.00
maltLTmmealy	0.07	0.03	0.28	0.30	-0.08	0.26	-0.10	0.16	-0.20	-0.05	0.07
maltLTmH80	0.12	-0.01	0.48	0.51	-0.20	0.16	-0.08	0.31	-0.35	-0.22	-0.02
CalcMod	0.28	0.17	0.42	0.36	-0.21	0.10	-0.25	0.05	-0.13	0.07	0.34
CalcoHomog	0.04	0.09	0.13	0.05	-0.12	-0.01	-0.25	0.01	-0.07	0.08	0.34

	friability	*Frhomo*	*Fermentability*	*FCDiff*	*Cextract*	*Fextract*	*maltLTmmealy*	*maltLTmH80*	*CalcMod*	*CalcoHomog*
BRlid										
varNum										
LTm										
H80										
GermE										
WaterSens										
Peroxide										
Size>2.8										
Size2.5-2.8										
Size2.2-2.5										
Size<2.2										
friability	1.00									
Frhomo	0.95	1.00								
Fermentability	0.48	0.46	1.00							
FCDiff	-0.54	-0.60	-0.63	1.00						
Cextract	0.77	0.70	0.55	-0.52	1.00					
Fextract	0.62	0.50	0.31	-0.08	0.89	1.00				
maltLTmmealy	0.57	0.57	0.43	-0.47	0.51	0.35	1.00			
maltLTmH80	0.47	0.46	0.44	-0.49	0.52	0.35	0.74	1.00		
CalcMod	0.52	0.61	0.61	-0.70	0.44	0.15	0.47	0.42	1.00	
CalcoHomog	0.32	0.37	0.28	-0.37	0.17	0.01	0.27	0.22	0.69	1.00

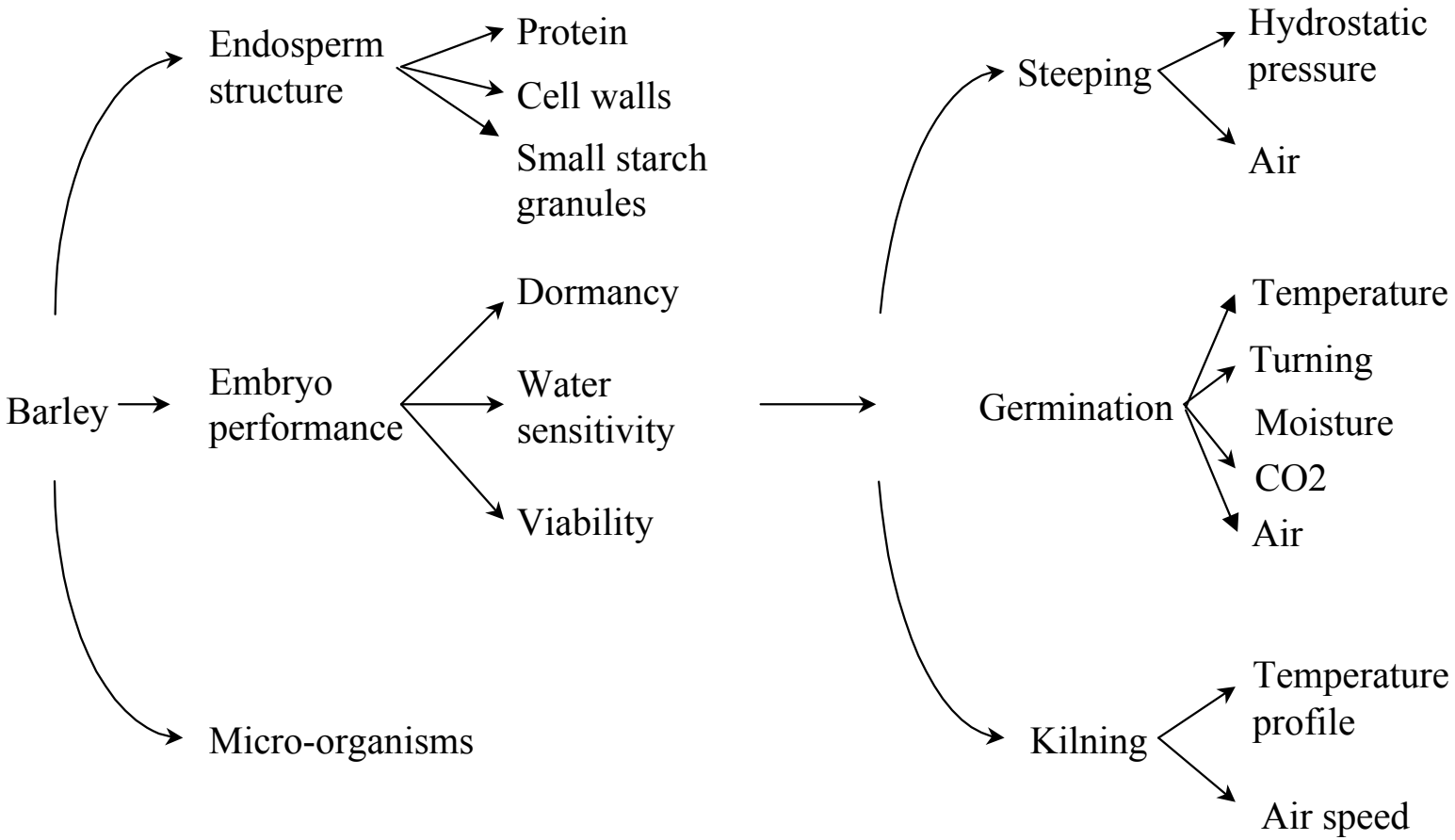
1. Potential Influences on Homogeneity I



In the Field

In the Maltings

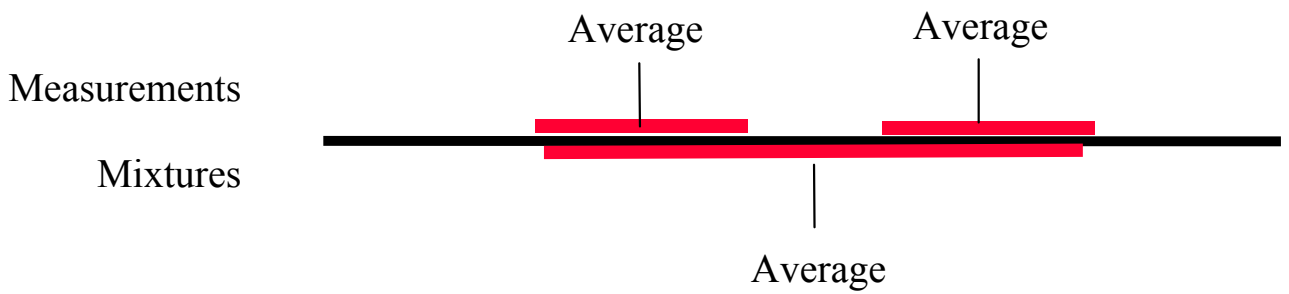
2. Potential Influences on Homogeneity II: Malting



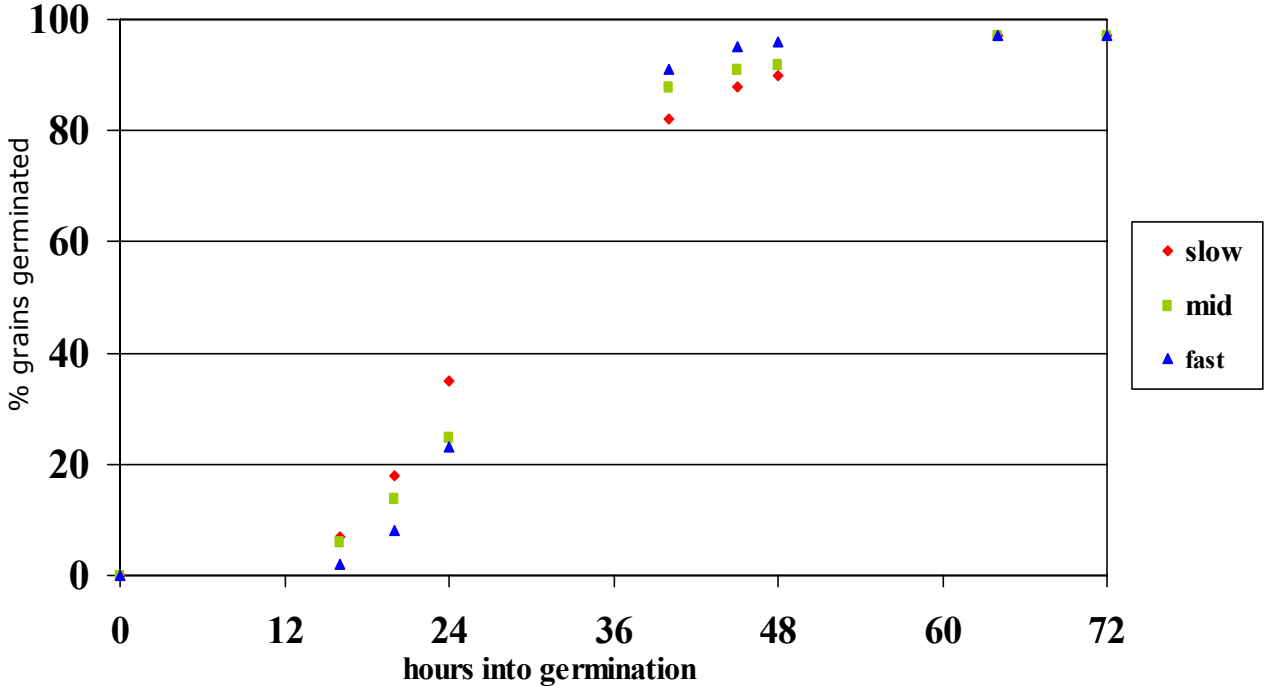
Grain Properties

Malting Procedure

3. Blending

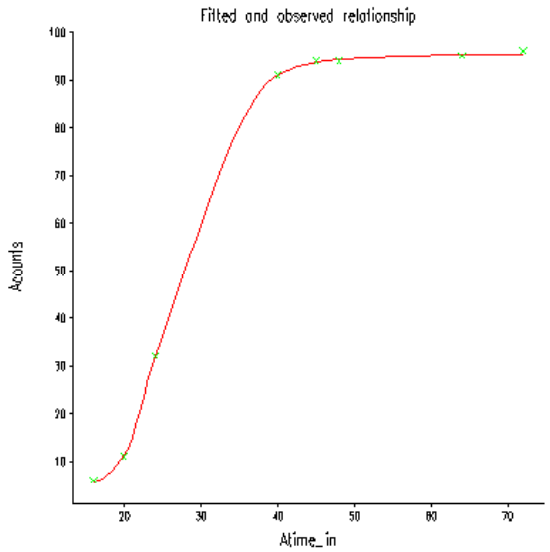


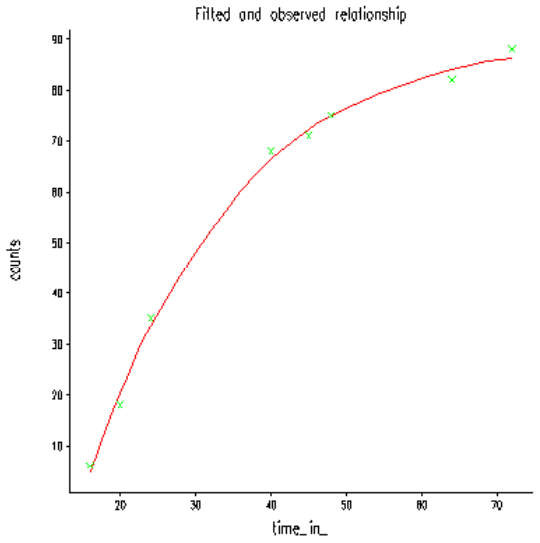
4. Measurement of germination rate



5. Germination rate

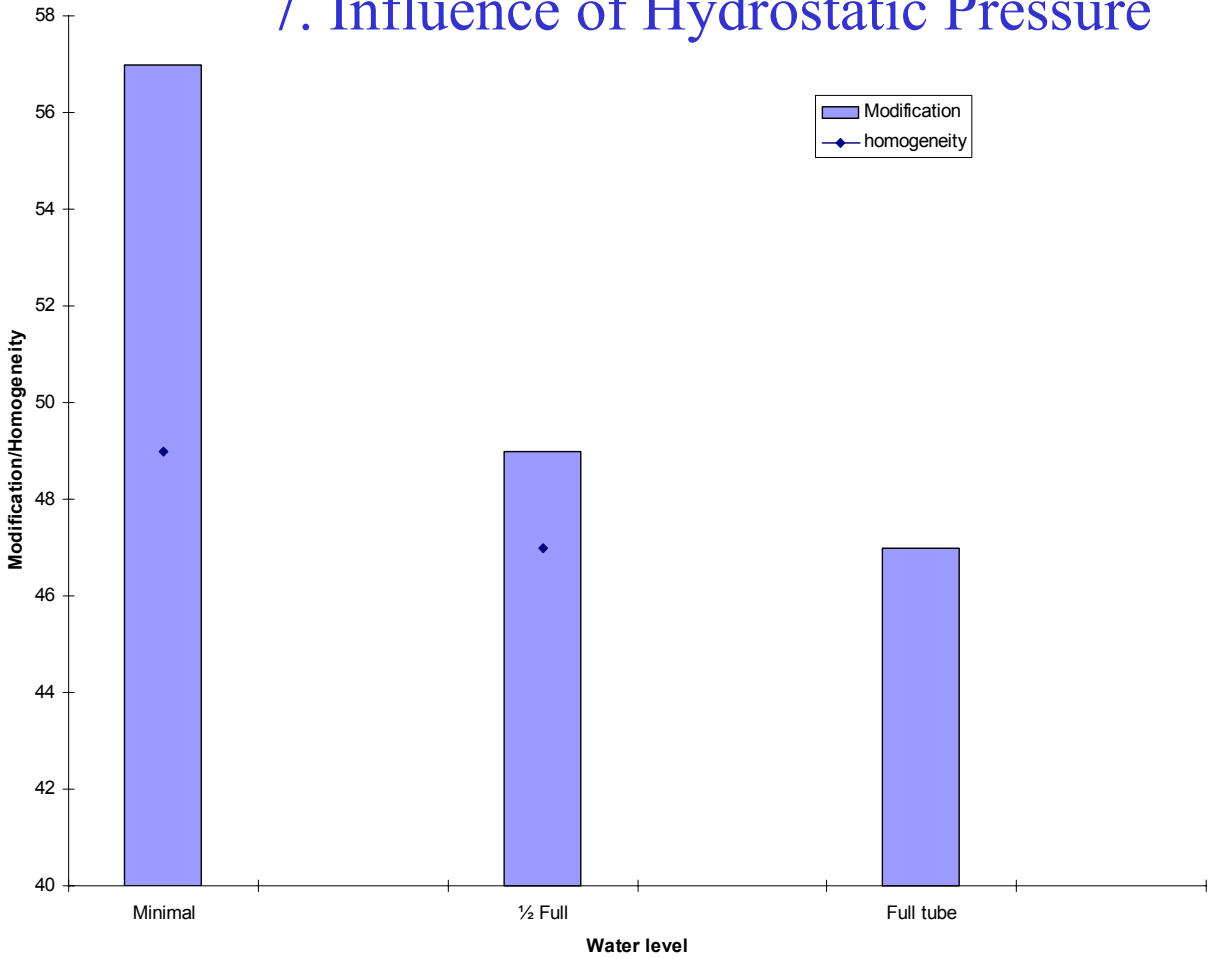
Examples of two grain samples showing different germination rates



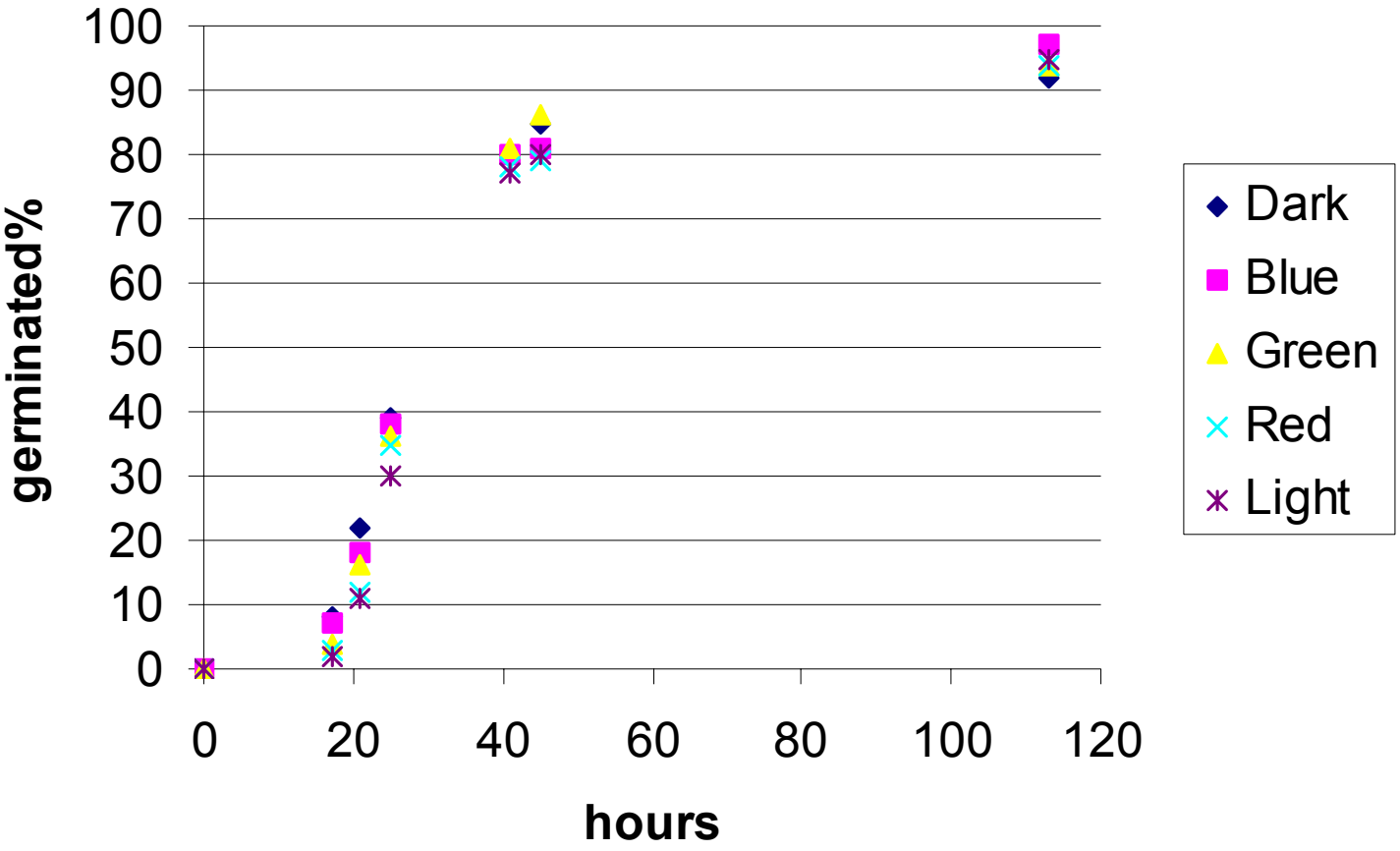


6. BRi Transflectance Meter (LTm)

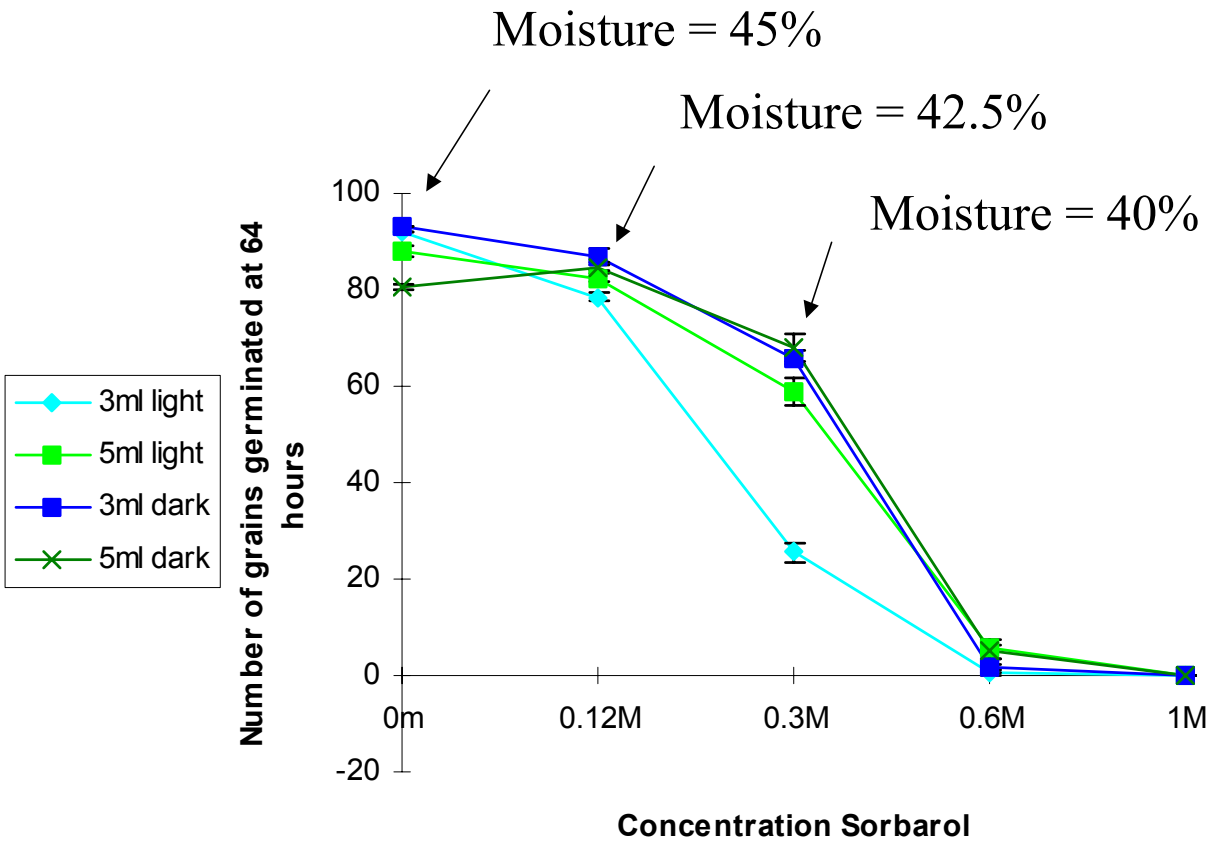
7. Influence of Hydrostatic Pressure



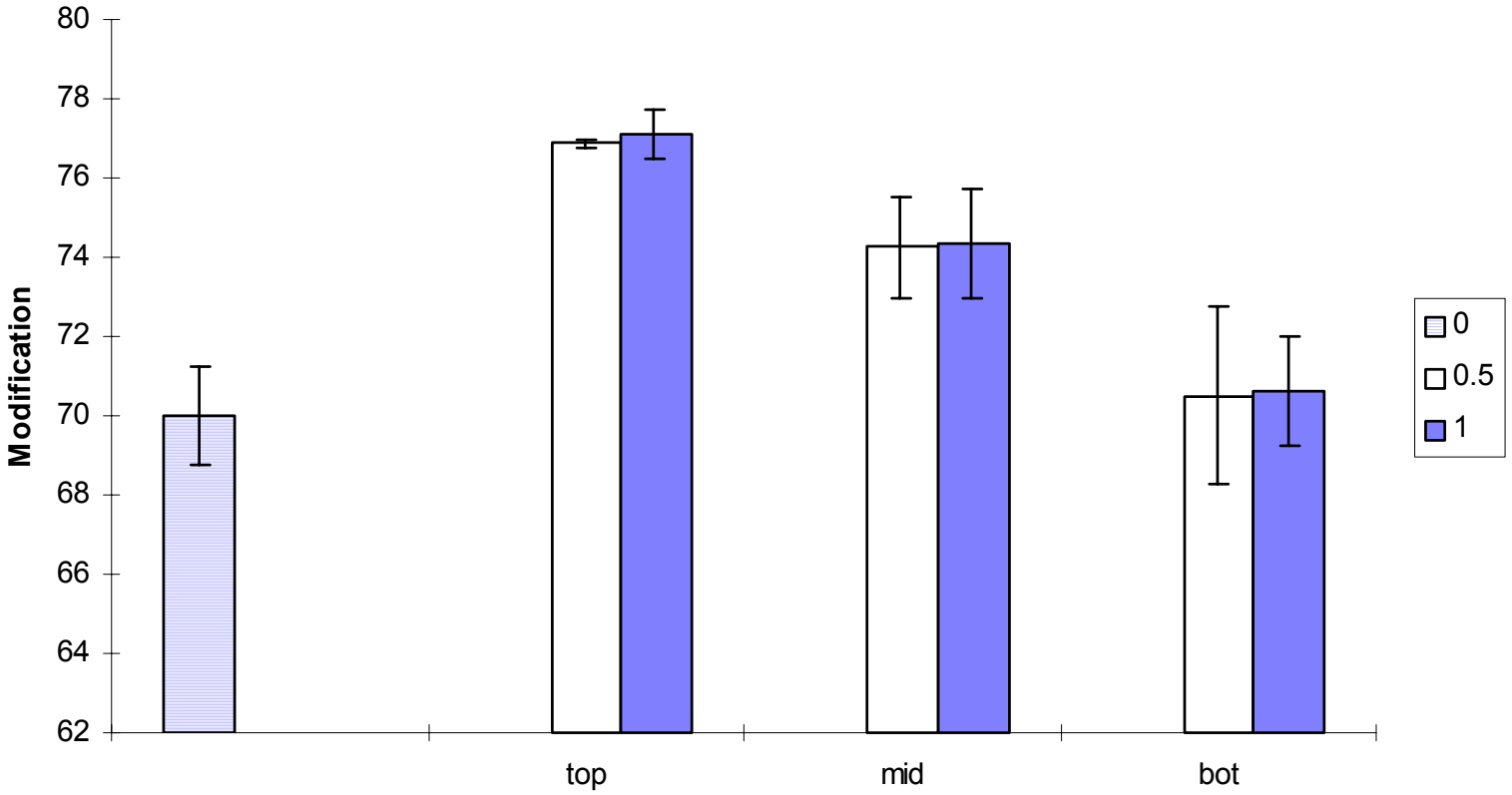
8. Effect of light on well steeped grain



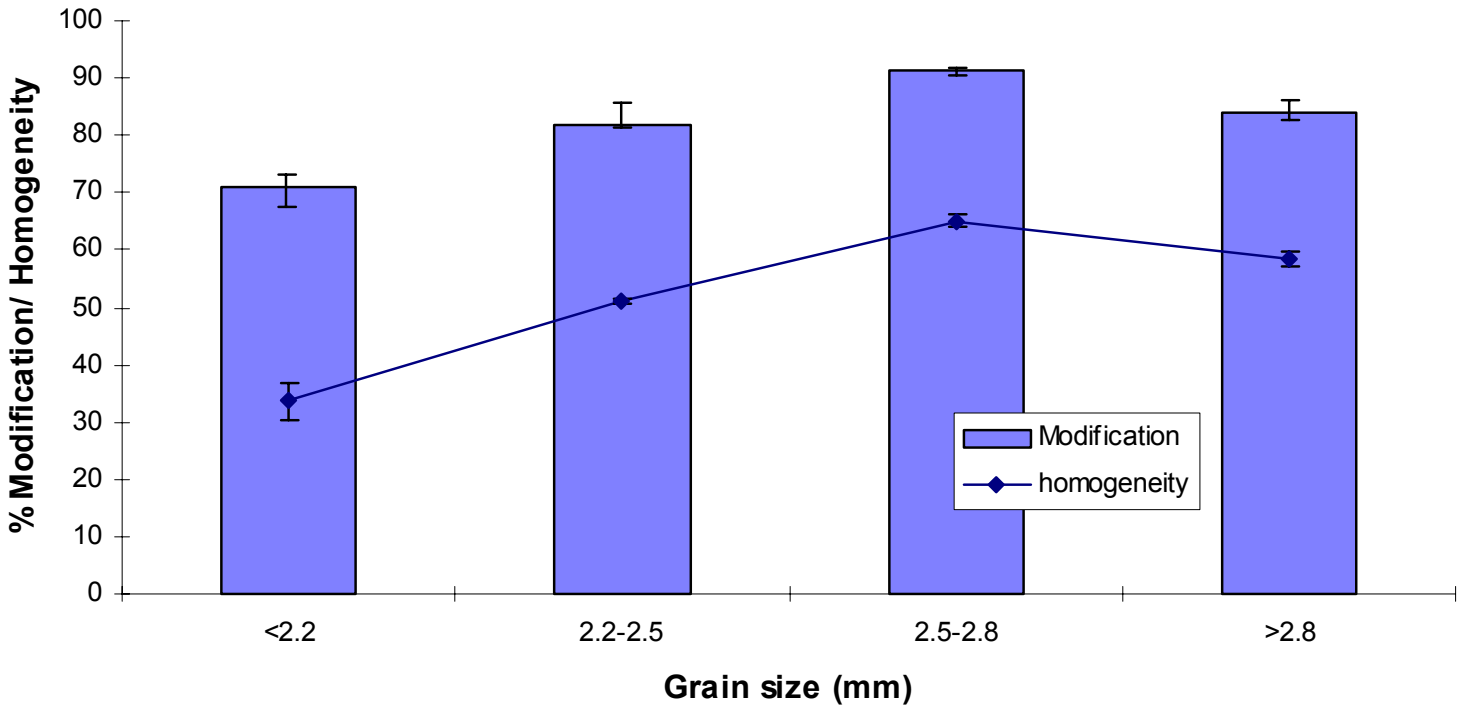
9. Influence of moisture on light effects



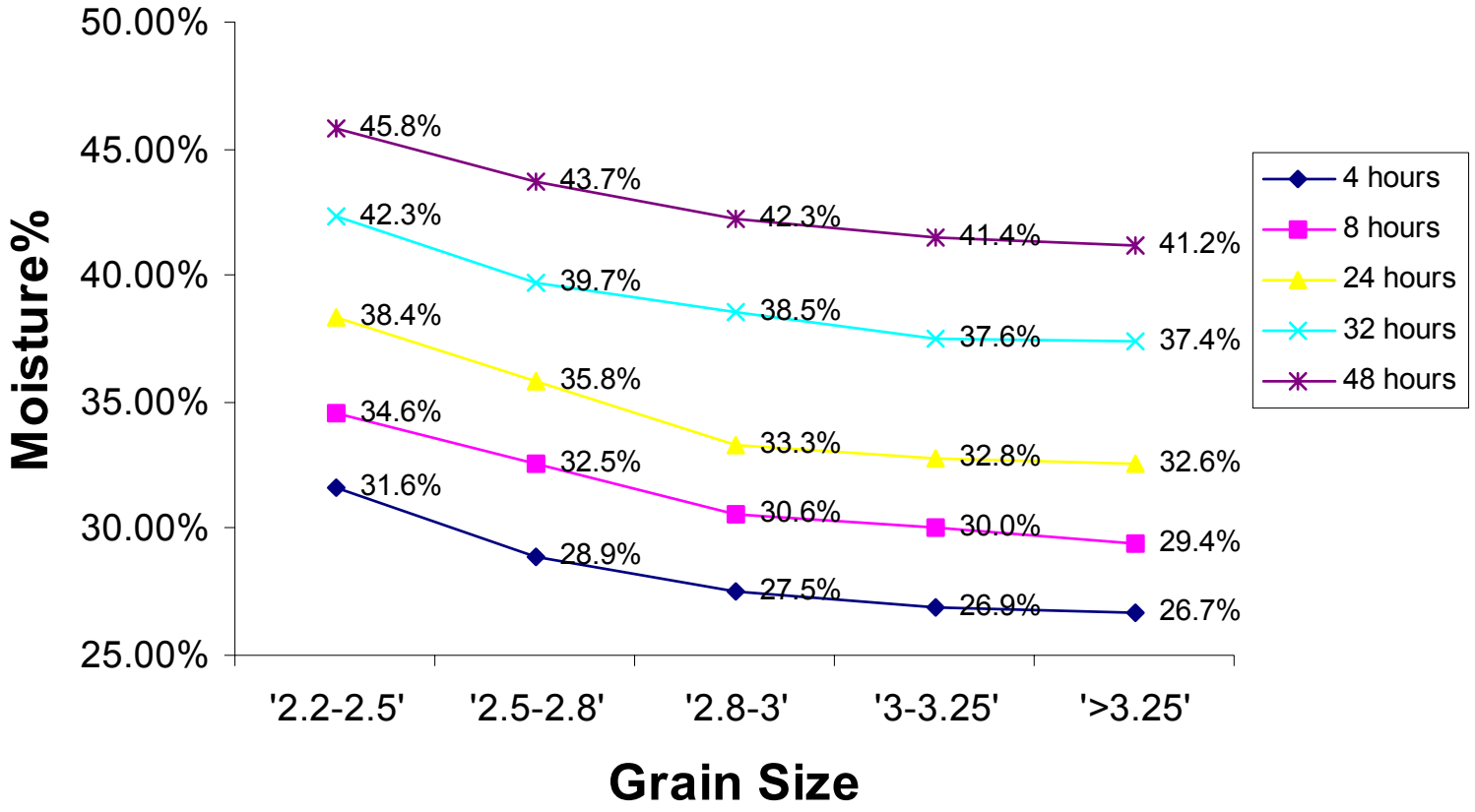
10. Influence of kilning



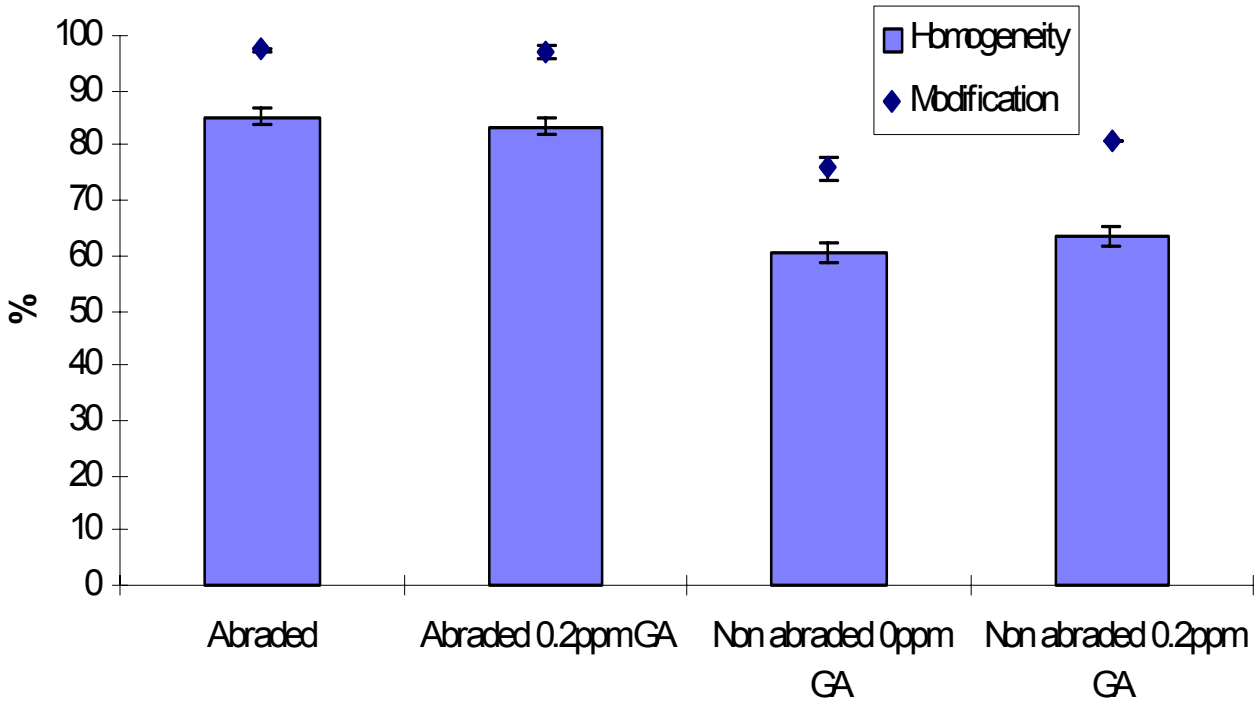
11. Grain size



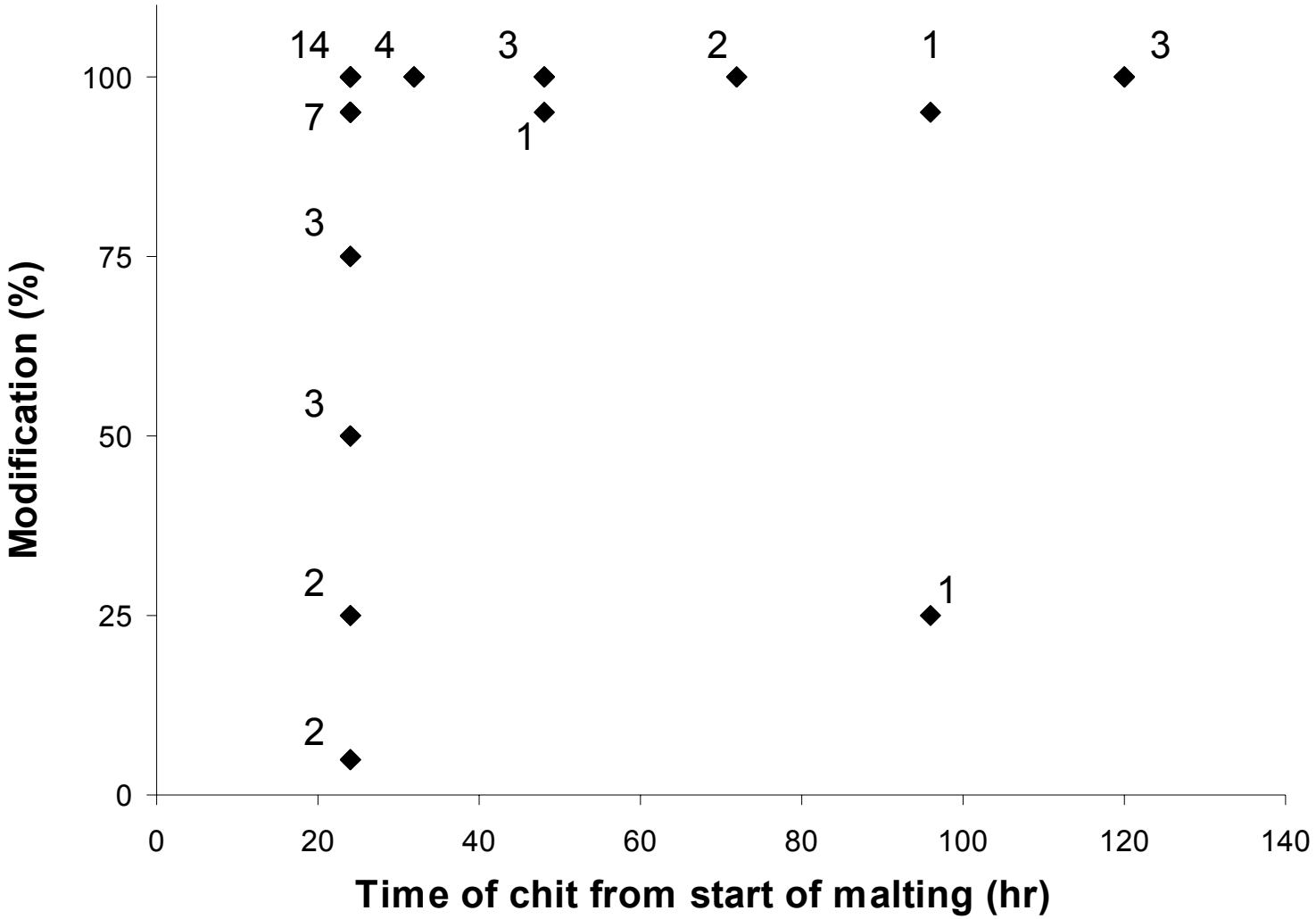
12. Moisture during steeping for different grain size



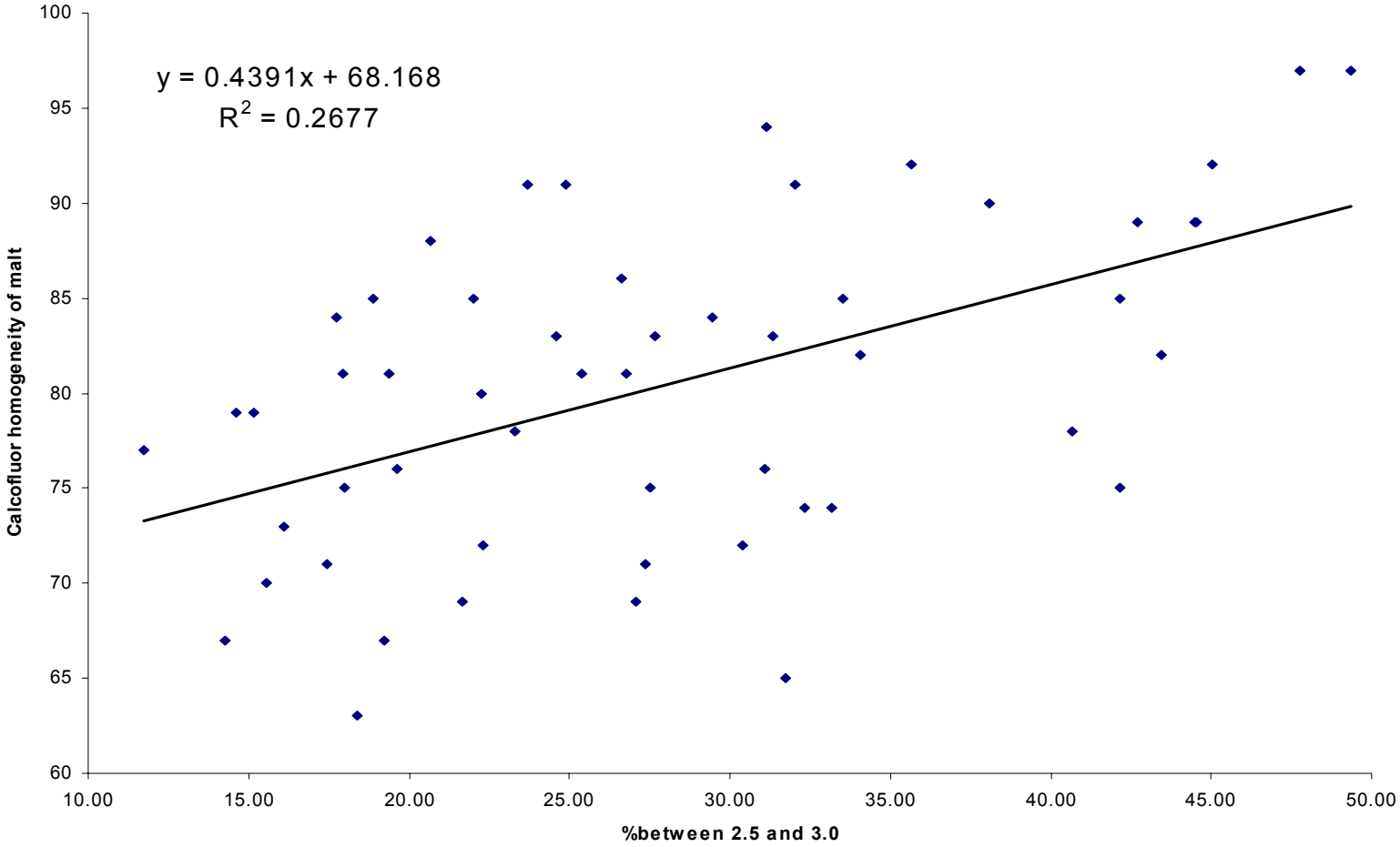
13. Grain damage and abrasion



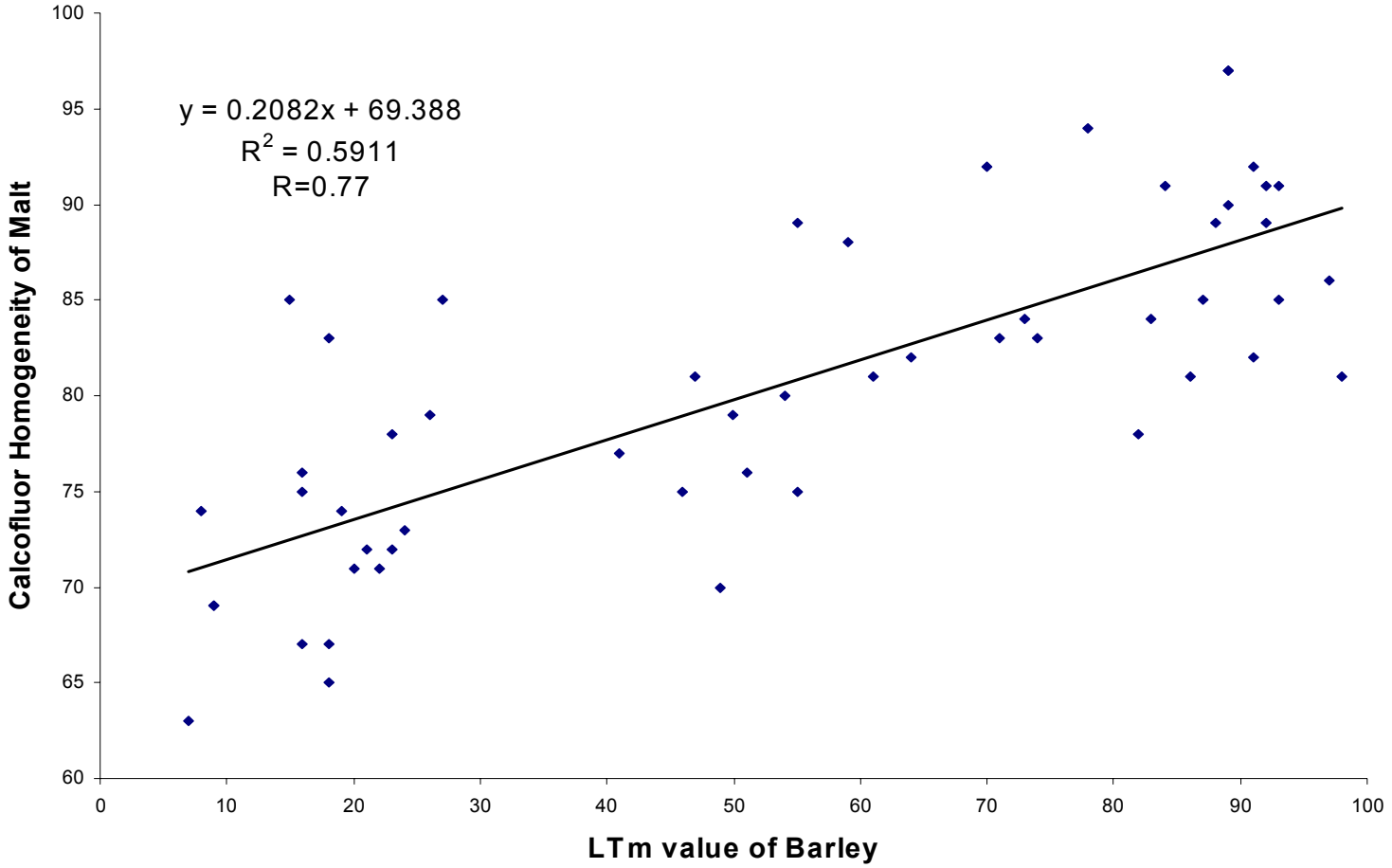
14. Malt Modification vs Time of Chit



15. Relationship between % 2.5 to 3.0 mm size fraction of Barley and Calcofluor homogeneity of Malt



16. Relationship between LTm of Barley and Calcofluour homogeneity of Malt



17. Factors influencing Barley Homogeneity: Single variety Year 1

Response	Explanatory	F.pr.
Grain size	Fungicide	.004
	Seed rate	.001
LTm	Nitrogen	.001
8 ml (ws)	Seed rate	.03
Germ' rate	Fungicide	.04

N=54

18. Factors influencing Barley Homogeneity: Four varieties Year 1.

Response	Explanatory	F.pr.
Size	Seed rate	.001
LTm	Variety	.001
4 ml (g.e.)	Seed rate	.002
8 ml (w.s.)	Seed rate	.001
Peroxide(g.c.)	Seed rate	.001
Germ' rate	Variety	.029

N=60

19. Factors influencing Malt Homogeneity by Calcofluor: Single variety Year 1

Explanatory	F.pr.
Fungicide	0.021
Seed rate	0.167
Nitrogen	<0.001

N=54

20. Factors influencing Barley Homogeneity: Single variety Year 2

Response	Explanatory	F.pr.
Grain size	Nitrogen	.001
	Seed rate	.001
LTm	Nitrogen	.001
4 ml (gc)	Seed rate	.001
Germ' Delay	Seed rate	.01

N=54

21. Factors influencing Barley Homogeneity: Four varieties Year 2.

Response	Explanatory	F.pr.
Size	Variety	.001
LTm	Variety	.064
4 ml (g.e.)	Seed rate	.001
LTm	Seed rate	.001
Peroxide(g.c.)	Seed rate	.001
Size	Seed rate	.001

N=60

22. Comparison between Years 1 and 2 Single Variety Optic

One way ANOVA only

Response	F.pr.
Greater than 2.8 mm	<0.001
Between 2.8 and 2.5	<0.001
4ml Germinative energy	<0.001
8 ml Water sensitivity	<0.001
Peroxide germinative capacity	0.004
Germinative delay	<0.001
Germination rate	<0.001
LTm	0.180
H80	<0.001

N=108

23. Comparison between Years 1 and 2 Single Variety Optic

Two way ANOVA

Response	Other factor factor	F.pr.
Greater than 2.8 mm	Fungicide	0.007
Between 2.8 and 2.5	Fungicide	0.026
All germination tests	Fungicide	>0.1
All LTm tests	Fungicide	>0.1
All size fractions	Nitrogen	>0.1
4ml germinative energy	Nitrogen	0.053
Germination rate	Nitrogen	0.008
LTm	Nitrogen	<0.001
H80	Nitrogen	<0.001
Greater than 2.8 mm	Seedrate	<0.001
Between 2.8 and 2.5	Seedrate	<0.001
4ml germinative energy	Seedrate	<0.001
8 ml Water sensitivity	Seedrate	<0.001
LTm	Seedrate	.0192
H80	Seedrate	<0.001

24. Factors influencing Barley Homogeneity: 13 varieties by harvest date Year 3.

Response	Explanatory	F.pr.
Size	Variety	.001
LTm	Variety	.008
8 ml (W.S.)	Harvest date	.001
Peroxide(g.c.)	Harvest date	.006
LTm	Harvest date	.001
H80	Harvest date	.001

N=78

25. Factors influencing Malt Homogeneity by Calcofluor: Multiple varieties Year 3

Explanatory	F.pr.
Variety	0.006