THE EFFECT OF VARIETY AND ENVIRONMENT ON THE MALTING QUALITY OF BARLEY

A Thesis

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by

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ABSTRACT

The purpose and operation of the malting laboratory, University of Manitoba, is described. A typical investigation is discussed in detail and it is shown that barley varieties differ markedly in malting quality. The environment under which the barley is grown also affects malting quality, and the varieties do not respond equally to changes in environment. The investigations that have been carried out in the last two years are summarized as comparisons of varieties with O.A.C.21 with respect to malting quality. Malting data for twenty varieties grown in Canada are presented and the varieties are divided into four groups -- six-rowed varieties admitted to malting grades; rough-awned, six-rowed varieties not admitted to malting grades; smooth-awned, six-rowed varieties; and two-rowed varieties.

Of the varieties admitted to the malting grades only two, Mensury and Mensury Ott.60, are considered equal to O.A.C.21 in malting quality. The other two varieties in this group, Gartons and Peatland, appear less suitable for malting than O.A.C.21 as they tend to produce higher nitrogen contents and lower extract yields than it.

The second group contains six varieties, Olli, Lapland, Brio, Pontiac, Bearer, and Trebi. Olli has some favourable qualities in that it produces higher extract yields and higher diastatic power than O.A.C.21, but some

of its characteristics are decidely different from those of O.A.C.21 and require elucidation. It is therefore classed only as a promising variety. Lapland was not studied extensively, but appears similar to Olli in quality and characteristics. Brio is also somewhat similar to Olli, though much lower than it in diastatic power. The data for Pontiac and Bearer are limited, but indicate that they cannot be considered equal to O.A.C.21 in malting quality as both varieties are lower in extract yield than it. Trebi appears definitely unsuitable for malting as it is extremely low in extract, diastatic power and proteolytic power.

Five smooth-awned varieties, Newal, Nobarb, Regal, Velvet and Wisconsin 38, were studied and none of them are considered equal to the standard in malting quality. However, these results are not taken as final evalcation of this class of barley. Regal and Wisconsin 38 are the two most commonly grown varieties of this class and appear deficient in malting quality, but Newal, Nobarb and Velvet, while not equal to O.A.C.21 in malting quality are considered to be improvements over Regal and Wisconsin 38, and it is suggested that it is not improbable that smooth-awned varieties that compare favourably with O.A.C.21 in malting quality may be developed.

It is pointed out that the malting test as at present constituted does not show two-rowed varieties to advantage, as they require a longer germination period than six-rowed varieties. As it is not advantageous to compare their performances with those for O.A.C.21, the data for the four two-rowed varieties studied are interpreted conservatively and the results are only of limited interest. Hannchen is taken as the standard of quality and as Charlottetown 80 and Victory both tended to be lower in the main malt qualities than Hannchen they are considered less suitable for malting than it. Rex, a smooth-awned variety, does not appear to possess the high extract yield characteristic of two-rowed varieties, but the investigation in which Rex was studied did not include Hannchen, so that proper evaluation of Rex was not possible.

The data for the effect of environment on the malting quality of barley are used to illustrate the relationships between nitrogen content and the main malt qualities. Extract yield is inversely related to nitrogen content while diastatic power and wort nitrogen content are directly related to nitrogen content. It is suggested that the further elucidation of these relationships might result in valuable contributions towards the solution of the problems which are met in defining the areas in Canada that are most suitable for the production of high quality malting barley.

The differential effects of environment on varietal malting qualities are demonstrated by histograms and it is shown that this differential effect is a limiting factor in the evaluation of varieties with respect to malting quality.

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INTRODUCTION

The Barley Situation in Canada

Barley is grown in Canada largely as a feed crop and in the Western provinces only about twenty percent of the crop finds its way into malt houses (3). As malting barley commands a premium on the market, attempts have been made to increase the proportion of malting barley grown in Canada, and thus bring larger remuneration to the farmer. Practically all the barley malted in Canada is home grown, so that any improvement in malting quality of Canadian barley would result in better quality malt and, though the internal market for barley would not be increased, an export trade might possibly be built up in Canadian barley for malting purposes.

Canadian barley is used, to a certain extent, in the British Isles for making diastatic malts used in the production of commercial grain alcohol, yeast, and the malt extracts used in the brewing, textile, laundry and baking industries. The competition in barley for these trades is very keen and the only way that Canada can hold this market is by producing a regular supply of high quality barley, which has been cleaned and dressed to the trade requirements.

The cleaning and handling of Canadian barley for export have received some attention (35) and are being further investigated. Improvements in these factors might assist the Canadian barley export trade materially but improvements in quality are also desired. The export market might possibly be enlarged by a more precise knowledge of the areas most suitable to the production of barley of the characteristics that are required for the various trades.

Great Britain annually imports large quantities of barley, for brewers' malt, from Australia and California which grow the Mediterranean class of barleys. This type of barley is six-rowed with large, long kernels and heavy, coarse hulls. This type of barley has been grown in Canada, but the only variety that has met with any widespread approval, and is still grown, is Trebi. This variety is not likely to find favour with maltsters as it germinates very unevenly and makes a very ragged malt with poor modification. It is therefore obvious that Canada cannot compete with these countries by attempting to grow the same type of barley that they do.

The type of barley that is most widely grown in Canada is the Manchurian class, which is six-rowed, and it seems probable that improvements in the quality of this type might provide Canada with a chance to compete in the open market for British trade, although these barleys have not been widely used in Great Britain. Their kernels are much smaller than those of the Mediterranean type and are characterized by rapid, even germination and ready modification, even when high in nitrogen content. This type of barley can be used for brewing purposes, as it is the standard brewing barley in Canada and in the Central and Eastern States of the United States.

The varieties of barley used mainly for brewing in England are two-rowed and have large, plump kernels, so that direct comparison of the small kernelled Canadian barleys with them is disadvantageous to the Canadian barleys. However, it is possible, by a comprehensive breeding programme, that the qualities of the Manchurian varieties might be improved to a point where they would be comparable to the two-rowed types that are grown in Britain and Europe, but another factor must be considered.

In general, Canadian barleys are of too high nitrogen content to be used in the British brewing trade, which favours a low nitrogen content in barley. There are, however, some areas in Western Canada where barley having nitrogen contents within the range used by the British brewers can be grown. One phase of the barley improvement programme in Canada must therefore be the defining of these suitable areas. The production of varieties with improved quality and precise knowledge of the areas which produce nitrogen levels suitable to the British trade might then place Canada in a favourable position for exporting barley.

As stated before, most of the barley grown in Canada is intended for consumption as feed, and this point must be remembered when improvements in varieties are sought. Of the varieties now grown, those most suitable for malting purposes do not possess the desirable agronomic characteristics of the better feed varieties. The malting barleys are, in general, weaker strawed, less resistant to disease and lower yielding than the feed barleys. The suggestion made previously that improvements should be sought in the Manchurian type of barley does not mean that the other types should be disregarded. Trebi, which is the best known of the Mediterranean type in Canada, has certain characteristics, such as strong straw and neck, which are desirable, so that the plant breeders might be able, by suitable crossing procedures, to produce these characteristics in the Manchurian barleys. That is to say, although the main interest is centred around the Manchurian barleys, the other types should be considered as parent material and their desirable characters transmitted, if possible, to the Manchurian varieties.

At present, there are certain areas in Canada in which a farmer can be reasonably sure of producing barley of good malting quality each year. There are, however, marginal areas in which barley of malting quality can sometimes be grown. Thus a farmer in such areas is faced with the question of sowing feed or malting types of barley and leaving the results to the whims of the elements. If the season is favourable and he has sown malting barley, he can sell his crop at a premium. However, if the season is unfavourable, the barley will not be graded as malting quality and the quantity obtained would not be as great as would have been obtained from a feed type barley. Thus, considering the relatively poor agronomic qualities of the Canadian malting varieties now known, it is not difficult to understand the attitude of the farmers in their unwillingness to take a chance on the production of good malting barley from the presently accepted varieties.

The problems in the improvement of barley in Canada are very similar to those that have been met in the development of high quality wheat. The grower is anxious to obtain a high yield of grain, even under adverse conditions, while the processors emphasize the desirability of high quality. The plant breeder must therefore strive to produce new varieties which combine high yielding capacity with high quality and the cereal chemists are attempting to devise methods of measuring the quality of comparatively small samples of these new varieties.

<u>Barley Breeding and Improvement Programme</u>

All investigational work dealing with barley culture in Canada is co-ordinated by the National Barley Committee. This committee is an organization to utilize, for barley improvement, the resources of farmers, grain companies, malting companies, Provincial Departments of Agriculture, the Dominion Department of Agriculture, the Agricultural Colleges and the National Research Council. The various phases of the work are handled by sub-committees, and the improvement programmes are supervised by the Sub-committee on Breeding and Production. This sub-committee is composed of the plant breeders of the Canadian Universities and Experimental Farms that are interested in barley improvement.

Each member of this sub-committee has his own breeding programme and tests the strains and varieties in his own locality. The most promising strains, after several years' trials, are submitted to a large national test known as the Uniform Variety Trials. By means of this test new varieties are grown at various stations in order to compare their performances with that of O.A.C.21, which is the standard malting variety in Canada. This variety is of the Manchurian type and is rough-awned and six-rowed. General conclusions as to the value of the varieties are based on the results of these tests.

In addition to plant breeders' productions several phases of barley culture, such as the effect of fertilizer and effect of rotation on barley quality and quantity, are studied under the leadership of this sub-committee. The investigational work in Canada is therefore comprehensive and the results of the tests are useful in evaluating the varieties with respect to agronomic quality and defining the areas most suitable for barley production, as well as determining the cultural practices favouring the production of high quality.

It is obvious that many of the investigations outlined above can only be pursued advantageously with the aid of tests of the malting quality of the samples produced. These malting tests are carried out at the University of Manitoba. Unfortunately, the capacity of this laboratory is limited and the samples to be submitted for malting tests are selected by a Sub-committee of the Associate Committee on Grain Research of the National Research Council and the Dominion Department of Agriculture. This committee is known as the Sub-committee on Laboratory Malting Tests and is under the chairmanship of Dr. P. J. Olson, Professor of Plant Science, University of Manitoba. The other members represent the National Research Council, the Dominion Department of Agriculture and the three Prairie Universities.

The Laboratory Malting Test and Its Development

The problems of testing wheat for commercial quality have been solved by the use of the laboratory milling and baking tests; similarly, a laboratory test is being developed for assessing the malting quality of barley. By means of this test malting qualities of new barley varieties are compared with those of a standard variety. The practice of malting small samples of barley and determining the quality of the malts from them is an old commercial practice and is known as the "stocking maltings." This method, which has been described by Hind and Lancaster (27), was used to carry out pilot maltings and thus give the maltsters information on the potential malting quality of the barleys that they had available and also to enable them to determine the conditions under which the main bulk of the barleys should be malted. That is, by malting replicate samples under different conditions and analyzing the malts, the maltsters were able to choose the conditions that would produce the desired qualities in the malts. The plant breeders who wished to determine the malting quality of the various crosses that were being developed also found commercial stocking maltings useful for testing their new varieties and their work was greatly facilitated.

The stocking method of malting has certain limitations. The samples are carried with whatever barley is being malted and the malting conditions, under which the experimental samples are made, vary from time to time, depending on the conditions required for the main bulk. Thus it is impossible to guarantee that all the samples, even within one season, are malted under identical conditions. Another limitation is that all barley breeders are not within easy reach of a malt house, or in close touch with the men who would be required to supervise the maltings.

Thus the arrangement, collection and timing of samples to be malted by the stooking method present many difficulties.

Owing to these limitations it seemed advisable to devise some other method of small scale malting. Professor T. J. Harrison and Mr. H. Rowland undertook the development of suitable small scale malting equipment at the University of Manitoba. In 1927 they designed and installed laboratory equipment for malting small samples of barley under controlled conditions (25). The results of some of the studies conducted by means of this equipment were described by Harrison (24) and by Elders and Rowland (18). The value of such a test for studying varietal malting qualities was quickly realized and some years later malting laboratories were developed at the Universities of Wisconsin (16) and Minnesota (37) and at the United States Department of Agriculture, Washington (15).

In 1934 the National Barley Committee reorganized the barley investigational work in Canada and requested the Associate Committee on Grain Research of the National Research Council and the Dominion Department of Agriculture to consider means of widening the malting research programme and improving the malting test. This body appointed a Sub-committee on Methods of Experimental Malting and Malt Analysis and authorized the construction of equipment and the development of a malting laboratory in the Division of Biology and Agriculture, National

Research Council, Ottawa. They also arranged to finance the malting laboratory, Division of Plant Science, University of Manitoba. There is very close co-operation between these two laboratories in all phases of malting research and the methods that are used for malting and analysis are under the jurisdiction of the aforesaid sub-committee.

This sub-committee combines the experimental and commercial viewpoints and it at present consists of four members, as follows: Mr. W.O.S. Meredith, Division of Plant Science, University of Manitoba; Mr. P. J. Dax, Canada Malting Company Limited, Montreal; Mr. D. S. Kaufman, Dominion Malting Company Limited, Winnipeg; and Dr. J. A. Anderson (chairman), Division of Biology and Agriculture, National Research Council, Ottawa. This committee is also consulted when investigations dealing with various phases of malting research are being designed.

The investigations that were undertaken by the laboratories on the American Continent (3,4,15,16,37,38) gave rise to many useful suggestions for the improvement of malting equipment and methods. Advantage was taken of these developments and in January, 1937, a new steep tank and kiln were installed in the laboratory at the University of Manitoba. A number of changes were also made in the germination chamber, and the malting and analytical methods were modified in various ways (8). As a result, a much improved malting test was made available for Canadian plant breeders.

The malting tests that are available in Canada are not confined to the two laboratories, as the two commercial malting companies also malt small samples. The Canada Malting Company uses a cage method in conjunction with its Saladin system of malting and the Dominion Malting Company uses a stocking method in conjunction with its Galland drum system. The malting companies are very willing to assist the laboratories in the improvement of methods of malting and analysis and provide invaluable assistance to them by means of co-operative tests. The Manitoba laboratory is the main station in Canada for routine testing of barley samples and only such research work as can be conveniently fitted into its programme is attempted. The Ottawa laboratory is mainly used for research problems on methods of malting and analysis, but also co-operates in routine testing when necessary.

The tests now in use are not absolute but serve only to compare the malting qualities of the varieties being studied with those of a standard variety. Certain limitations are involved and of these Anderson and Rowland (7) write;- "The laboratory malting test measures the response of samples to a standard set of malting conditions which simulate the average conditions used in commercial practice in Canada. It follows that not all samples are malted to the best advantage. There is some reason to suppose, however, that when laboratory malting tests show that two varieties differ widely in malting quality, the difference is characteristic of the varieties and would persist, though possibly to a lesser extent, if each variety were malted to the best advantage. In addition, it seems probable that varieties which modify readily and can be malted to good advantage in the laboratory are better suited to the short (6-day) germination period used in commercial practice in Canada than varieties which react unfavourably under laboratory test conditions.

"While the laboratory malting test compares samples with respect to certain quantitative malting characteristics, it fails to elucidate many other important factors. For this reason, malting data must be interpreted conservatively and more weight can be placed on negative than on positive conclusions. Thus, if tests show that a variety is lacking in certain important malting qualities, then it may be assumed that it is inferior to the standard variety. On the other hand, if tests show a variety to be equal to a standard variety with respect to all factors measured, it would be unwise to assume that the variety is equal in malting quality to the standard since it may be lacking in some quality not measured in the test. In spite of these limitations, the laboratory malting test must be considered as a valuable means of studying barley varieties, for which there is at present no adequate substitute."

It is apparent that in order to be satisfactory, individual malting tests must give reproducible results and different tests should place a series of samples in the same order with respect to each malt quality. An investigation has shown that the four Canadian experimental malting tests fulfill these requirements satisfactorily (6). The errors due to differences between duplicate maltings, within tests, were insignificant in comparison with the errors caused by the differential effect of environment on varieties. The differential effect of malting method on varieties was small in comparison to the previously mentioned differential effect of environment on varieties, which was the limiting factor in varietal differentiation.

Another limitation of the laboratory malting test is that relatively few malt qualities are studied. However, each determination requires a certain amount of time and the laboratory staff is kept busy with the determinations that are at present carried out. In order to justify carrying out further determinations, such determinations would have to be shown as being useful and necessary. There are several determinations that could possibly be added, such as difference between fine and coarse grist extracts, index of protein modification, length of acrospire, mealiness, etc., but their value in defining malt quality is somewhat doubtful and the interpretation of the results of these determinations present considerable difficulty. For instance the difference between fine and coarse grist extracts is considered very important by some authorities (28), but its value in the differentiation of Canadian varieties with respect to modification has not as yet been demonstrated. Further, although Bishop's index of nitrogen modification (11)(that is, the ratio of the amount of permanently soluble nitrogen in the wort to the amount of nitrogen in the original barley) has received widespread attention and use in England it has been criticised by some writers (6,36,40). It has also been shown that there are no apparent relationships between the results of some of the determinations that are regarded as indicating the degree of modification (6,19). Several of these determinations, such as length of acrospire and mealiness, are purely objective. The results of any test of modification are therefore difficult to interpret, and it is obvious that no good purpose is served when determinations are carried out that do not provide useful and interpretable results. It would also be useful to assess the nature and amounts of enzymes present in malt, especially the proteolytic and saccharifying enzymes, but suitable methods for their identification and quantitative determination have not as yet been worked out. It therefore seems advisable to restrict the number of determinations that are carried out to those that are definitely important.

Even the few determinations that are carried out in the course of malting tests are not always easy to interpret and, as previously stated, more weight must be placed on negative than on positive results. Experienced commercial maltsters are frequently consulted in order that their experience may be used to good advantage in interpreting laboratory results.

Criteria of Malting Quality

Malting is undertaken with the object of making the barley constituents soluble and it is only that part of the finished malt, which can be extracted by mashing with water, that is used in the brewing, distilling and allied malt consuming industries. The quantity and quality of the malt extract therefore determine the value of the barley from which the malt is made. These, in turn, are dependent partly on the properties of the various barley constituents (starch, proteins, etc.) and partly on kinds and amounts of enzymes liberated or developed during the malting process.

A complete and accurate evaluation of the malting quality of barley is not yet possible since methods for the determination of certain properties have not yet been developed and since the significance of many properties of barley and of the malts made from them is not yet fully understood.

In these circumstances, and because of limitations of staff and time, the number of determinations made in the course of the malting test now in use at the University of

Manitoba is confined to fifteen. These determinations can be conveniently divided into three groups, viz. (1) those qualities measured in the barley, (2) those qualities measured during malting, and (3) those qualities measured in the finished malt. The qualities that are measured in the finished malt are most important and of these extract yield, diastatic power and permanently soluble nitrogen in the wort are at present considered the most useful criteria of malt quality and these determinations are carried out in all malts. The qualities measured in the barley and during malting are important in their relationships to extract yield.

In discussing the qualities measured in the finished malt it must be remembered that extract yield, which has been previously mentioned, is most important. The extract yield of a malt represents the total forces of the enzymes on the available substrates and measures the quantity of soluble substances that can be derived from the malt by the mashing process. The measurement of the enzyme forces in malt has long been recognized as a complicated problem and the method of assessing the total enzymatic forces of malt by measuring its diastatic power in degrees Lintner has been severely criticized. This method has also been criticized as a measure even of diastatic power (i.e. power of saccharification) but no method to replace it has been approved so that it is retained at present as the standard method. Investigational work on the value of the Lintner determination is under way in several laboratories and it is hoped that the question of its utility as measures of diastatic power and of total enzyme power will be decided. In order to assist the assessment of the enzyme forces of malt the determination of permanently soluble nitrogen in the wort from the extract determination is carried out. This determination is not an accurate measure of proteolytic power as the amount of nitrogen made permanently soluble is dependent on the original nitrogen content of the barley, that is, the final amount of soluble nitrogen and not the rate of solubilisation is measured in this determination. The interpretation of the data for this determination presents some difficulty as the limits for the desirable proportions of soluble nitrogen in wort have not been defined for Canadian malts. However, low wort nitrogen indicates inadequate proteolytic activity and thus a deficiency of enzymes. When high amounts of nitrogen appear in wort it is advisable to view the samples with suspicion as the ratio of proteins to carbohydrates in the extract is different from normal.

The main criteria for a malt of good quality are therefore that it should produce a high extract and be rich in saccharifying and proteolytic enzymes as represented by diastatic power and permanently soluble nitrogen in wort. It is unlikely that there would be upper limits in diastatic power but high amounts of permanently soluble nitrogen in wort might be best viewed with suspicion. It is always advisable, however, to consider the qualities of the barley and its responses during malting before summing up the malt evaluation. The next stage for discussion is therefore the examination of barley properties.

The importance of the nitrogen content of barley and malt has been recognized for a long time (14) and the relationship of nitrogen content to malting quality has been investigated in England. It was shown that within varieties increases in nitrogen content are accompanied by decreases in extract yield (10, 12, 13). For this main reason high nitrogen barleys are undesirable, but nitrogen content is important for other reasons. The barley nitrogen content is closely related to wort nitrogen content and it was considered that high nitrogen barleys were undesirable in that they caused many difficulties in the fermentation of the wort and adversely affected the keeping qualities and stability of the beer. Low nitrogen content barleys did not provide sufficient food for proper yeast growth and ensuing fermentation, so they were also undesirable. The optimum nitrogen content for British barleys is assumed to be between 1.2% and 1.5% (28). No such investigational work has been undertaken on this continent, although higher nitrogen contents than those considered optimal in Britain can be tolerated in the brewing process.

The physical properties of high nitrogen barleys may also prove obstacles in malting and militate against their use. Hard, steely kernels which will not produce a mellow, friable malt are usually associated with excess of nitrogen. Because of these effects of nitrogen on malting quality it is generally accepted that varieties much higher or much lower than the standard in nitrogen content are less suitable for malting.

The size of the barley kernel is also important in commercial malting and, as Bishop (10,12,13) has shown that plump kernels produce more extract than thin kernels, well filled, plump kernels are preferred. This preference is also looked upon, from the chemical viewpoint, as providing a proper balance between starch and hull and at the same time presents an attractive looking malt. Uniform sized kernels are desired because they will grow uniformly and produce an even, well finished malt. The malt houses are equipped with standard cleaning and grading machinery, so that as well as being uniform in size within lots, the barleys should conform fairly closely with respect to kernel characteristics between lots. The barleys for malting should produce a high yield of heavy grade barley, as high cleaning losses are undesirable, with fairly high thousand kernel weight.

The above requirements for malting barley can be appreciated for still another important reason. It is the common practice in Canada to bulk all the varieties that are accepted into the same grades, so uniformity of kernel characters can be further emphasized, and a third barley character has also to be considered. If two varieties are bulked that require different lengths of steep considerable difficulty will be encountered in producing an evenly grown lot of malt. The bulk will be steeped to the necessary moisture content, but this figure will represent a value intermediate between the moisture contents of the two varieties. One variety will therefore be understeeped and the other oversteeped. This will result in very ragged growth on the floor and will also be reflected in the quality of the malt. It has been shown that changing the length of steep results in changing the extent of nitrogen modification (30), oversteeping producing too vigorous nitrogen degradation and understeeping causing the reverse. The malt from a mixture of types would likely cause considerable trouble in brewing. For these reasons it is desirable that varieties accepted in the same malting grades should require approximately the same length of steep.

The amount of growth that takes place during the malting process is also important, as in commerce a high malt yield is required; that is, it is preferable that the production of as great amounts of enzymes as is possible should be accomplished with as little loss of material as possible. If growth is carried on very far much valuable soluble material is lost through roots and respiration. The determinations of sprouts and malt yield therefore measure the growth forces of the barley. The laboratory malting test compares the growth forces of the various varieties under identical conditions and varieties that appear to grow strongly are those that are likely to be rich in enzymes. Such varieties, when malted commercially, are likely to produce the desirable changes in kernel constituents with minimum losses due to growth. The determinations of sprouts and malting loss are therefore important and assist materially in interpreting the reactions that have taken place in the production of the final malt qualities.

The previously mentioned determinations are carried out on all the samples submitted for malting tests and several others of minor importance are carried out in conjunction with the extract determination. These are malt moisture, odour of mash, time of conversion, speed of filtration, clarity of wort, and colour of wort.

EXPERIMENTAL

PART I

UNIFORM VARIETY TRIALS, 1936 CROP

This investigation is part of the National Barley Committee's programme for barley improvement in Canada and is directed by Mr. P. R. Cowan, Cereal Specialist, Central Experimental Farm, Ottawa, and carried out by the workers at the various Experimental Farms and Agricultural Colleges. The varieties are grown at the various stations throughout the Dominion from seed of authentic pedigreed stock supplied by the Central Experimental Farm, Ottawa. The barleys are grown under strictly comparable conditions, at each station, in plots of five rod-rows arranged in a modified balanced block, each variety being grown in quadruplicate. In order to minimize marginal errors only the three centre rows in each plot are harvested and all the data are obtained from these rows.

By means of this test the agronomic qualities of the various old and new varieties are compared over a wide area and a general picture of their relative agronomic values is obtained. It is not practical to carry out malting tests on all the samples that are obtained, as the investigation usually compares twenty-four varieties at twenty-three stations, so that a number of varieties and stations are annually selected from which samples are submitted for malting tests. This section reports the results of malting tests made at the University of Manitoba on samples representing eight varieties grown in 1936 at six points in Canada.

MATERIALS

The varieties included in this investigation and the stations at which they were grown are listed below.

Varieties	Stations
O.A.C.21	Brandon, Man.
Olli	University of Alberta, Alta.
Peatland	Melfort, Sask.
[i]Pontiac	Gilbert Plains, Man.
[o]Nobarb	Beaverlodge, Alta.
[o]Regal	Ste.Anne de la Pocatiere, Que.
[o]Velvet	
[xo]Rex	

[o]Smooth-awned varieties, all others rough-awned.
[x]Two-rowed variety, all others six-rowed.
[i]Since the malting tests were completed for the investigation a report has been received that the samples representing Pontiac were not the authentic variety.

METHODS

The standard methods for malting and analysis which were described by Anderson And Rowland (8) were used and one more determination was added. This is the determination of the amount of permanently soluble nitrogen in the wort from the extract determination. The method for this determination was described by Anderson and Meredith (5).

DISCUSSION OF RESULTS

The results of the minor determinations that are carried out in conjunction with the extract determination showed that the differences between samples were negligible and not sufficient to warrant discussion, but the approximate values for these determinations are given in Table I. The data for all the other determinations were analyzed statistically and are summarized in the various Tables and Figures. The results of the analyses of variance are reported and discussed in the final section.

TABLE I

Mean Values, over all Samples, for Various Minor Determinations

Determination	Mean
Malt moisture %	3.3
Odour of mash	very aromatic
Time of conversion, minutes,	5
Speed of filtration	normal
Clarity of wort	clear
Colour of wort, Lovibond units.	1.6

Differences between Varieties

The mean values, over six stations, for each variety are given, for nine determinations, in Table II. Each figure represents the difference between the mean values for O.A.C.21 and the variety listed in the first column. A positive sign indicates that the varietal mean was higher than the mean for O.A.C.21 and a negative sign that it was lower. The differences between means necessary for a 5% level of significance were calculated by statistical methods and are included in the table.

For convenience in discussion the various determinations are divided into the three groups already proposed. The first group consists of qualities that are measured in the barley, viz. nitrogen, 1,000 kernel weight, and percentage plump barley. The second group deals with the actual malting of the samples, that is, the length of steep required, sprouts, and malt yield. The determinations making up the third group are those characteristics that are measured in the malt and are extract percent, diastatic power, and permanently soluble nitrogen.

The barley qualities are secondary to those of the malt, in varietal evaluation, but as they are determined first they offer a suitable starting point for discussion. Since low nitrogen content is desirable in barley for malting, it is evident that Peatland, Velvet, and Rex can be faulted for tending to produce nitrogen contents that

TABLE II

Differences between Mean Values, over all Stations, for O.A.C.21 and other Varieties.

Variety	Nitrogen %	1000 K.wt. gms.	Plump barley %	Hours steep	Sprouts %
O.A.C.21	2.39	30.2	68.9	80	2.4
Olli	+0.14	-3.8*	-19.3*	-27*	+0.6*
Peatland	+0.35*	-3.0*	-17.1*	-1	-0.1
Pontiac	+0.05	+0.6	+1.1	0	+0.1
Nobarb	+0.01	+2.7*	+11.3*	+9*	-0.7*
Regal	+0.06	+0.8	+2.5	+10*	-0.3
Velvet	+0.27*	-0.6	+1.7	-1	-0.3
Rex	+0.27*	+6.4*	+8.1	+12*	-0.5*
Necessary difference	0.15	2.0	10.0	7	0.4

	Malt yield %	Extract %	D. P. °L.	P.S.N. %
O.A.C.21	92.0	73.5	145	1.14
Olli	-0.6*	+1.8*	+42*	+0.20*
Peatland	+0.4	-1.3*	+15	+0.07
Pontiac	0	-0.8	+6	-0.03
Nobarb	+1.2*	-1.1	-28*	-0.18*
Regal	+0.7*	-1.9*	-49*	-0.07
Velvet	+0.7*	-2.3*	-7	+0.02
Rex	+0.6*	-0.1	0	+0.10*
Necessary difference	0.6	1.2	15	0.10

*Denotes significant differences.

are higher than that of the standard. Olli, Pontiac, Nobarb and Regal can be considered about equal to the standard in nitrogen content. In 1,000 kernel weight Olli and Peatland are faulted, as they were considerably lower than O.A.C.21 in that character. Nobarb and Rex produced higher kernel weights than the standard and such performances can be regarded as favourable. The data for percentage plump barley show the same tendency as those for kernel weight. Olli and Peatland were much inferior to the standard in this respect, while Nobarb produced a higher percentage of plump barley than O.A.C.21.

Of the six varieties compared with O.A.C.21, it is apparent that only three, Pontiac, Nobarb and Regal, possess barley properties that compare favourably with those of O.A.C.21. Olli is low in 1,000 kernel weight and yield of plump barley, Peatland is faulted in all three properties, and Velvet and Rex possess undesirably high nitrogen contents.

The varieties studied in this investigation are divided by agronomic characteristics into two main groups, rough-awned and smooth-awned, and it is interesting to note that the groups, with minor exceptions, seem to possess different malting characteristics. The smooth-awned group of Nobarb, Regal, Velvet and Rex, in general, required longer length of steep than the rough-awned group and at the same time produced more malt than the latter.

In the rough-awned group Peatland and Pontiac could not be differentiated from O.A.C.21 in any of the three determinations concerning malting. Olli absorbed water faster than O.A.C.21 and its production of less malt and more sprouts indicates that it also grew more rapidly. The smooth-awned, six-rowed varieties showed some variability from each other. Nobarb and Regal required longer steeping than O.A.C.21, while Velvet could not be differentiated from the standard in this respect. Nobarb, of the six-rowed varieties, produced significantly less sprouts than the standard, but all three varieties, however, produced more malt than O.A.C.21. Rex, the two-rowed variety, was different from O.A.C.21 in all three determinations, requiring longer steep and producing more malt and less sprouts. It may therefore be concluded that the smooth-awned varieties under discussion did not grow as rapidly as the rough-awned varieties.

From these data it is evident that the rough-awned varieties were able, in general, to produce more growth and show greater activity during malting than the smooth-awned varieties. However, it does not necessarily follow that these are group characteristics and this point will be discussed more fully later.

Examination of the results for extract, diastatic power and permanently soluble nitrogen indicates that the differentiation between the smooth-awned and rough-awned varieties persists. The smooth-awned varieties are, in general, lower in extract and diastatic power than the rough-awned varieties. In the rough-awned group Pontiac was about equal to O.A.C.21 in all three characteristics. Peatland was about equal to the standard in diastatic power and permanently soluble nitrogen although it was lower in extract. Since it has been shown that increases in nitrogen, within a variety, are accompanied by decreases in extract (7,10,12,13), the low yield of extract for Peatland can be attributed, at least in part, to its high nitrogen content. Olli was higher than O.A.C.21 in all three characteristics, and these facts require consideration. There is no reason to suppose that a variety would be faulted for possessing a high diastatic power but, as stated before, a high permanently soluble nitrogen in wort may prove objectionable and the tendency of Olli to produce a high permanently soluble nitrogen should be viewed with suspicion until its significance is established. (Investigations are already planned which may clarify this situation. In this connection, Bishop's work is of interest, as he says (11): "Six-rowed barleys differ from two-rowed chiefly in the smaller amount of peptide nitrogen which they give, suggesting that, from the nitrogen standpoint, they differ not so much in yeast feeding properties, but chiefly in giving less palate fulness and less tendency to protein haze." The suspicion with which Olli's tendency to produce high amounts of nitrogen in wort is regarded is based largely on the difficulties encountered with two-rowed barleys that produce high amounts of nitrogen in wort. It is possible, in view of Bishop's suggestion, that the difference between Olli and O.A.C.21 in amounts of wort nitrogen may not be critical. However, in the meantime, it is advisable to view varieties that differ from the standard with suspicion, as has been suggested previously.) Moreover, it is interesting to note that Olli was 0.20% higher than O.A.C.21 in permanently soluble nitrogen which, when calculated to protein basis, is 1.25% soluble substances in the wort. As Olli was 1.8% higher than O.A.C.21 in extract yield, it is not improbable that the apparent advantage of Olli over O.A.C.21 may be almost wholly due to increases in soluble nitrogen in the wort and if this is the case it represents a situation that is not desirable as the ratio of nitrogen to carbohydrate in wort would be much different from that for a normal malt. Taking these points into consideration it is evident that although Olli appears to have some desirable qualities, some real differences exist between Olli and O.A.C.21 with respect to malting quality.

The smooth-awned varieties again showed considerable variation from each other. Nobarb was lower than O.A.C.21 in diastatic power and permanently soluble nitrogen, while Regal was lower in extract and diastatic power than the standard, and Velvet was exceptionally low in extract. It is therefore apparent that these smooth-awned varieties are lacking in some essential characteristic necessary for malting quality and the evidence indicates that they are deficient in enzymes.

Before discussing the results for Rex, which is a two-rowed variety, several points must be considered. It has been generally accepted that the two-rowed varieties possess different characteristics, malting as well as agronomic, from the six-rowed varieties and it is the custom to germinate them for a longer time than the six-rowed varieties. That is, they grow much more slowly on the floor than do the six-rowed varieties, thus taking a longer time to reach their optimum yields of extract and enzymes.

It therefore seems inadvisable to compare two-rowed varieties, which at present are assumed to be unsuited to six-day germination periods, with O.A.C.21, which is generally recognized to be well suited to this short growing period. The two-rowed varieties known at present produce higher extract contents than O.A.C.21, no doubt due to their larger kernels, but they have not been malted to any great extent in Canada owing to their slow rate of growth. It may therefore be inadvisable to submit two-rowed varieties to the same malting test as for six-rowed varieties, as the results are difficult to interpret. However, the plant breeders use two-rowed varieties as parents in some of their crosses and it is possible that some of the segregates might have the malting characteristics of the six-rowed varieties even though two-rowed. If this occurs then it might be advisable to compare such new types directly with O.A.C.21 and ignore the fact that they are two-rowed. For this reason, the results for Rex may be discussed from two angles viz. (1) comparison with the trend of two-rowed varieties, (2) direct comparison with O.A.C.21. However, the latter method of comparison is very risky, as two-rowed varieties have certain characters that differ from the six-rowed varieties (11) and there may be other differences that are not assessed in the malting test. For these reasons, Rex will be discussed as a two-rowed variety, although it can be said that it compares favourably with O.A.C.21 in the qualities measured in the malting test, although it tended to be high in permanently soluble nitrogen content in wort and this might be objectionable.

That Rex failed to show the customary characteristics of the two-rowed class is shown by the fact that it was only about equal to O.A.C.21 in extract yield. It was also about equal to the standard in diastatic power and was higher in permanently soluble nitrogen. Because it was grown for only six days, these results cannot represent its optimum qualities and with a longer growth period this variety might well show to much better advantage. However, in comparison with the results of previous investigations (7) in which two-rowed varieties produced much higher extract yields than O.A.C.21, even with a six-day germination period, Rex does appear to possess attractive malting quality. It seems logical, by analogy with the six-rowed varieties, to ascribe its lack of quality to some functions that are associated with its smooth-awned characteristics.

It is unwise, however, to condemn the smooth-awned group as being unsuitable for malting on the basis of the four smooth-awned varieties studied in this investigation. The smooth-awned varieties were developed to meet the demand of farmers who wished to obtain higher yields of grain and also to use the straw for feeding purposes. Most of the present smooth-awned varieties were developed from a variety known as Lion which must have been very deficient in enzymes and thus likely to produce a malt of very inferior quality.[1] The genetic linkage between poor quality and smooth awns may be very close, but that does not mean that it is not possible to produce a high yielding, smooth-awned barley with good malting quality. New smooth-awned barleys are being developed and owing to the size of sample required for malting, the malting tests on these crosses are several years behind the field work. It is therefore advisable to consider the data on smooth-awned varieties as representing

[1]Personal communication to the writer from Dr. G. P. McRostie, Professor of Field Husbandry, O.A.C., Guelph, formerly Professor of Agronomy, University of Manitoba.

stages of advance from Lion and not as final conclusions on the malting quality of the whole group.

The discussion has been confined so far to average differences, over six stations, between the varieties, and the varieties have been considered from the viewpoint of general comparisons of their malting qualities. Varietal means were considered to be about equal unless their differences could occur by chance only once in twenty times. The values necessary for significant differences were calculated from the mean squares due to the differential response of varieties to environment. When varieties differed in their mean values by the required amount it is considered that some real differences between the varieties were operating to spread the means and the variety having the higher mean will show higher values at the majority of stations. When differences between varietal means could not be considered statistically significant it is evident that the varieties were not placed in exactly the same relative positions at all stations.

These differential responses of varieties to change in environment are illustrated by histograms in Figure 1. The columns in each histogram represent four varieties, O.A.C.21, Nobarb, Olli and Peatland, and each separate histogram represents the results obtained for each station. Data for nitrogen, extract, diastatic power and permanently soluble nitrogen, are presented. Previous

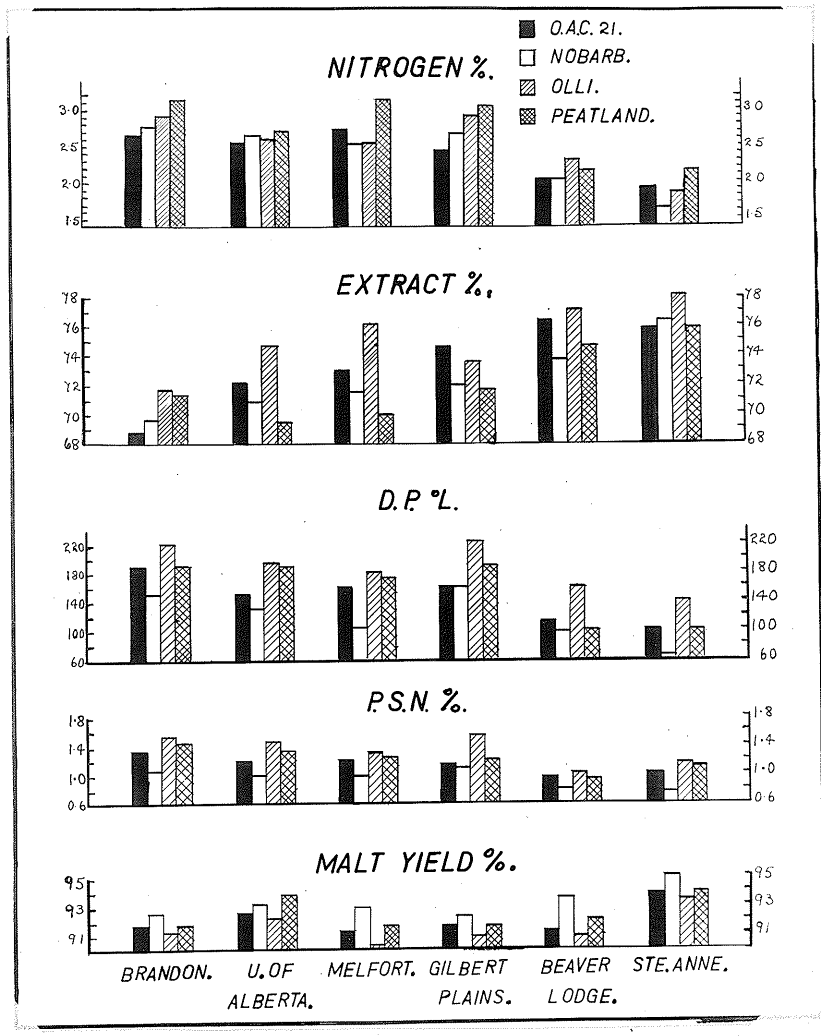

Figure 1.

Histograms illustrating the magnitude of the differential effect of environment on varieties.

investigations have shown (6,7) that the differential effect of environment is a serious limiting factor in the differentiation of varieties, and this conclusion is substantiated by the data for the present investigation.

The data for nitrogen content show that Nobarb was higher in nitrogen content than O.A.C.21 in three of the six stations and lower than it in the other three, so it is not surprising that their mean values for nitrogen content, as given in Table II, were indistinguishable. The data for Olli show somewhat similar characteristics as it was higher in nitrogen content than O.A.C.21 at four stations and lower than it at the other two, and as a result the mean nitrogen content of Olli was not significantly different from that for O.A.C.21. Peatland was consistently higher than O.A.C.21 in nitrogen content, particularly at Brandon, Melfort and Gilbert Plains. Thus its mean nitrogen content was significantly higher than that for O.A.C.21.

The histograms dealing with extract yield also show changes in the placing of the varieties from station to station. Olli was consistently highestin extract yield and this is reflected in its mean value for this quality being significantly higher than that for O.A.C.21. Nobarb was higher in extract than O.A.C.21 at Brandon and Ste. Anne de la Pocatiere, though lower than it at the other four stations. As a result, its mean difference from O.A.C.21 failed to attain the significant level. Peatland was higher than O.A.C.21 in extract yield at the same two stations as Nobarb, but it was considerably lower than O.A.C.21 at the other four points, so that the mean values of the two varieties are significantly different. It is interesting to note that at Brandon Peatland was much higher in extract yield than O.A.C.21 and this can probably be accounted for by the fact that Brandon was heavily infested with rust in 1936. Peatland is rust resistant and it stood up much better and produced higher quality grain than did O.A.C.21. The fact that Peatland was equal to O.A.C.21 in extract yield at Ste. Anne de la Pocatiere is also of interest, in that the mean nitrogen level for that station was low.

The figures for diastatic power again show that the differentiation of varieties depends on the changes in relative position from station to station. Olli was consistently higher than O.A.C.21 and Nobarb was consistently lower than O.A.C.21 in diastatic power and the resultants are that the mean value for the former is significantly higher than that for O.A.C.21 and the mean value for the latter is significantly lower than that for the standard. Peatland was higher than O.A.C.21 at four stations and lower than it at the other two, the mean effect being that Peatland is barely significantly higher than O.A.C.21 in diastatic power.

With respect to percentage permanently soluble nitrogen the differences between O.A.C.21 and Olli and

O.A.C.21 and Nobarb are quite clear cut, as these two varieties maintain their positions relative to O.A.C.21 at all stations. Peatland, however, maintained its average relative position at all points but one, namely Beaverlodge, and as a result its mean difference from O.A.C.21 is not quite significant.

The six histograms for malt yield exhibit the same general shapes for O.A.C.21, Nobarb and Olli, and the mean differences from O.A.C.21 for these varieties are significant, Nobarb producing more malt than O.A.C.21 and Olli less. Peatland again exhibits a tendency to alter its relative position at different stations and its mean value is not significantly different from that for O.A.C.21.

These histograms serve to indicate the difficulty of interpreting results of the laboratory malting test and emphasize the point, which will be referred to again later, that the limiting factor in varietal differentiation is that the varieties are not placed in the same relative positions with respect to malt quality at all points. That is, changes in environment affect different varieties differently with respect to malt quality. It is of interest to note that Peatland exhibited the greatest change in position of all the varieties. Some explanation of this tendency may lie in the factors controlling its nitrogen content, as Peatland seems to have a tendency to develop a high nitrogen content. At Ste. Anne de la Pocatiere, where the nitrogen level is low, Peatland was close to O.A.C.21 in nitrogen content and all other determinations. When the nitrogen was high, as at Gilbert Plains, Peatland increased its nitrogen content over that for O.A.C.21 considerably and the other qualities varied accordingly, extract decreasing and diastatic power increasing.

When summing up the results of the various determinations for malt qualities, the more important malt qualities are considered first. Varieties that compare unfavourably with the standard in two of the three main qualities or are seriously deficient in even one quality are faulted. Should a variety compare favourably with the standard in the three main qualities, the barley qualities are then considered before final evaluation is made. That is to say, a variety may be equal to the standard in yield of heavy grade barley, 1,000 kernel weight, nitrogen content, etc. but if faulted in the malt qualities its favourable barley qualities do not counteract its deficiencies in malt qualities.

Examination of the data for extract yield, diastatic power and permanently soluble nitrogen show that two varieties, Nobarb and Regal, are faulted in two main qualities. Nobarb was low in diastatic power and permanently soluble nitrogen, while Regal was low in extract and diastatic power. Velvet was much lower than O.A.C.21 in extract yield and is thus faulted. These varieties did not grow as rapidly as the standard, as is indicated by the data for malt yield, and it is apparent that they are deficient in enzymes. There are thus good grounds for considering them definitely inferior to O.A.C.21 in malting quality.

Of the rough-awned varieties Pontiac could not be differentiated from O.A.C.21 and may be considered equal to it in malting quality. Peatland has smaller kernels than O.A.C.21 and is lower in extract, so that these two varieties can hardly be considered equal in malting quality. Peatland may well compare favourably with O.A.C.21 under conditions which tend to produce a low nitrogen content and the fact that Peatland produces reasonably good malt qualities under rust epidemic conditions is a point in its favour. The third rough-awned variety, Olli, though it has smaller kernels than O.A.C.21, possesses some desirable characteristics in that it is high in enzymatic activity and produces a higher extract and diastatic power than O.A.C.21. However, its characteristics seem to be different from O.A.C.21 in some respects and it also produces a high amount of permanently soluble nitrogen in wort. The significance of this last characteristic is not yet clear but, in the meantime, Olli can be classed as a promising variety.

It is extremely difficult and perhaps inadvisable to draw conclusions with respect to the malting quality of Rex, which is a two-rowed variety. The information on the malting characteristics and qualities of Canadian two-rowed varieties is extremely scant and no good purpose is served by drawing conclusions from such inadequate information and experience. Under the six-day germination system used in this investigation, which is not likely to produce optimum results from two-rowed varieties, Rex was about equal to O.A.C.21 in extract yield and diastatic power and higher than it in permanently soluble nitrogen in wort. It has been shown that the two-rowed varieties, even under a six-day germination period, are likely to produce more extract than O.A.C.21 (7), so it is therefore evident that Rex does not compare favourably with the general characteristics of its class. Although it does compare favourably with O.A.C.21 in the qualities measured (except for being high in permanently soluble nitrogen, the significance of which is not yet known), the validity of direct comparison of Rex with O.A.C.21 is extremely questionable. No definite conclusions as to the malting quality of Rex may therefore be drawn until it has been tested further and more adequate information on the malting characteristics of two-rowed varieties is available.

Effect of Environment

The means for each station, over all varieties, for all determinations are given in Table III. The geographic positions of the stations indicate that the barleys were grown under varied environmental conditions and the effect

TABLE III

Mean Values for each Station over all Varieties

Station	Nitrogen %	1000 K.wt. gms.	Plump barley %	Hours steep	Sprouts %
Brandon	2.94	23.9	26.8	66	2.1
University of Alberta	2.72	32.0	76.4	84	1.7
Melfort	2.77	28.4	61.2	84	2.4
Gilbert Plains	2.78	29.7	61.0	79	2.9
Beaverlodge	2.09	33.2	85.2	79	2.4
Ste.Anne de la Pocatiere	1.90	36.2	97.8	91	1.7
Necessary difference	0.13	1.8	8.5	6	0.3

Station	Malt yield %	Extract %	D. P. °L.	P.S.N. %
Brandon	92.2	69.3	176	1.36
University of Alberta	92.8	71.2	160	1.22
Melfort	91.7	71.9	152	1.20
Gilbert Plains	91.6	72.7	165	1.21
Beaverlodge	91.9	75.4	106	.95
Ste.Anne de la Pocatiere	94.3	76.1	95	1.00
Necessary difference	0.5	1.1	13	0.09

on malt quality of these changes in conditions is demonstrated. Each figure is a mean value over eight varieties so that the data can be interpreted as representing the average effect on malting quality of varying the climatic conditions.

The enormous effect of environment on quality is readily realized from the ranges between stations in the values for the various determinations. The two extremes in the main qualities are Ste. Anne de la Pocatiere and Brandon, Ste. Anne representing the comparatively cool humid climate of Eastern Canada with a long growing period and Brandon representing a hot dry climate with shorter growing period. These conditions are primarily reflected in nitrogen content, with Ste. Anne samples being more than 1% lower than the Brandon samples in this quality. Similarly Ste. Anne samples are highest in 1,000 Kernel weight and plump barley percent, while the Brandon samples are lowest in these respects.

These differences between stations in kernel characteristics may therefore be attributed to the environmental conditions under which the samples were grown and these differences are reflected in malting quality also. Ste. Anne samples are highest in extract and lowest in diastatic power, while Brandon samples are complementary to them. The environmental conditions under which barley is grown therefore plays an important role in determining its eventual malting quality, as has been previously recognized (6,7,17,26,32). From these facts it is evident that the production of choice malting barley in Canada is dependent on two factors, variety and environment. The defining of areas favourable to the production of high class malting barley is thus a necessary step in the Canadian barley improvement programme dealing with barley for malting purposes.

Although the data are of interest in making quantitative comparisons with respect to malting quality between localities they are also of particular interest since they illustrate the relationships between nitrogen content and malt qualities. That is, a direct and simple method for a preliminary assessment of possible malting value is desirable, and there seems to be some constant relationships between nitrogen content and malt qualities. Considerable investigational work on these relationships has been carried out in England (10,12,13) and data on these points are gradually being accumulated in Canada.

The data for this investigation are limited, as samples from only six points were studied, but they serve to indicate the general relationships between nitrogen content and extract yield, diastatic power and permanently soluble nitrogen. The data for these three characteristics are plotted against nitrogen content to form scatter diagrams, in Figure 2. Of course, more extensive data are

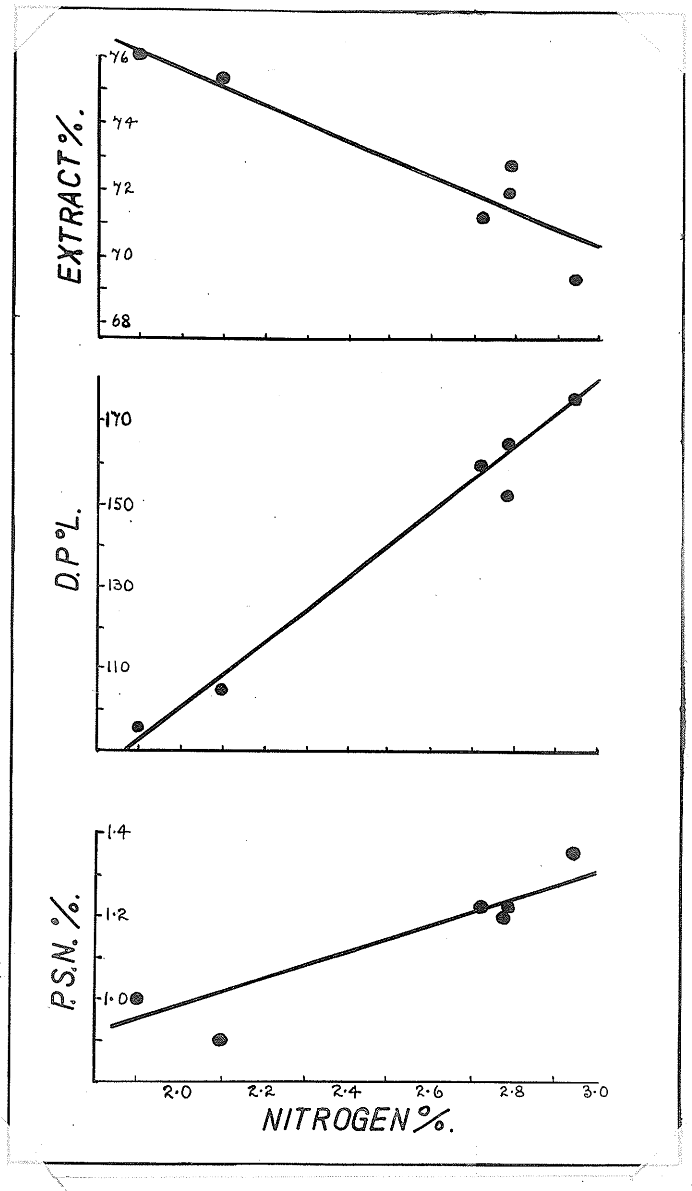

Figure 2.

Scatter diagrams illustrating the relationships between the main malt qualities and barley nitrogen content (mean values for six stations, over eight varieties).

required before final quantitative relationships, as have been established by Bishop (10,12,13), can be determined for Canadian varieties.

The diagram for nitrogen content and extract yield indicates that there is a linear relationship between these characteristics and moreover, the relationship is inverse, as extract yield decreases with increasing nitrogen content. Thus the results are in line with those of the English investigations, as was to be expected. The relationship between diastatic power and nitrogen content was also linear, and increases in nitrogen were accompanied by increases in diastatic power, so that the Canadian varieties are similar to the British varieties in this relationship also.

It is apparent from the diagram for nitrogen and permanently soluble nitrogen that as the nitrogen content increases, the amount of permanently soluble nitrogen also increases. However, it is also evident that the rates of increase of total nitrogen and permanently soluble nitrogen are not equal, and thus as the total nitrogen increases the proportion of it which appears in soluble form in the wort decreases. These results support the conclusions of Menzel (36), and cast some doubt on the usefulness of Bishop's Index of Nitrogen Modification (11). Bishop has proposed that a malt is properly modified (i.e. has attained its optimum qualities) when the proportion of permanently soluble nitrogen in wort to total nitrogen in barley attains a fixed value (35% for English barleys) irrespective of variety or nitrogen content. It is, of course, recognized that the optimum indices for Canadian and British barleys would not necessarily be the same, but this investigation supports Menzel's contention that the proportion of nitrogen made permanently soluble in a properly modified malt decreases with increasing nitrogen content. Moreover, the investigations of Anderson and Meredith (6) and Thunaeus and Schroderheim (40) suggest the probability that the proportion of nitrogen which can be made permanently soluble by malting is a varietal characteristic. It must be borne in mind, however, that the samples studied by Bishop would not represent such wide ranges of environmental conditions as found in Canada and also that the British varieties of malting barley are closely related genetically and are thus likely to have very similar malting characteristics.

It is therefore apparent that the variations in nitrogen content of a barley are closely associated with variations in the important malting qualities. Increases in nitrogen content are accompanied by decreases in extract yield and increases in diastatic power and permanently soluble nitrogen. The increase in permanently soluble nitrogen, though proportional to the increase in nitrogen, is not equal to it, so that an increase in nitrogen is accompanied by reduction in the proportion of barley nitrogen that is degraded by malting and mashing and is permanently soluble in the wort.

That the malting quality of a barley is more or less predetermined by its nitrogen content is definitely proven by numerous investigations (6,7,9,10,11,12,13,14,29) and the similarity between barley and wheat problems is again evidenced. The nitrogen standards for high quality malting barley are, however, complementary to those for high quality baking wheat, as low nitrogen contents are desirable in the former. The relationships between nitrogen content and baking quality of wheat, under Canadian conditions, have been thoroughly investigated by various workers (1,31,33,34) and good use has been made of the results of their investigations. Protein surveys of Western Canada are undertaken annually (22) and the results of these surveys have been utilized to indicate the areas that consistently produce wheat of high nitrogen content. Although nitrogen is not the sole quality determining factor, these high nitrogen level areas are those most likely to produce high quality baking wheat. Similar zoning of Western Canada with respect to the production of high quality malting barley may therefore be possible.

The collection of adequate data on nitrogen levels of barley grown in the various districts in Western Canada is an enormous task, but annual surveys have been conducted for several years to date (23). The wheat protein surveys may however prove useful in the evaluation of areas with respect to barley quality, as areas which produce wheat that is faulted mainly on account of low nitrogen content are likely to be able to produce malting barley of good quality. Geddes has already carried out investigations on the relationship between the nitrogen levels of wheat and barley grown in the same areas (21). Continuation of these investigations are likely to prove valuable, as the data for wheat nitrogen levels, for areas where only scant information is available on barley nitrogen levels, may therefore be utilised for the prediction of the malting quality of barley from these areas.

From the preceding paragraphs the suggestion is advanced that the determination of the quantitative relationships between barley nitrogen content and malting quality is an important task and one of great practical value. However, it must be borne in mind that the value of malt is determined by the purpose for which it is intended to be used. Some trades require a high extract yield, as in brewing, with medium enzymatic strength, while other trades, such as distilling, require high enzymatic power and are prepared, within limits, to sacrifice a certain amount in extract in order to obtain the high concentration of enzymes. The relation between nitrogen and extract being the reverse of that between nitrogen and enzymatic power, balance must be struck between potential extract and amount of enzymes, depending on the purpose for which the malt is intended. The investigational work on the nitrogen levels of the various areas in Canada may therefore provide preliminary information as to the uses to which the barleys grown in them are best suited.

Statistical Treatment and Interpretation

The data for each determination were subjected to separate analyses of variance and the variance in each case was separated into portions due to (1) average differences, over all stations, between varieties; (2) average differences, over all varieties, between stations; (3) differences in the relative performances of the varieties at different stations; and (4) differences between duplicate maltings. The complete data for the analyses of variance on extract yield are given in Table IV, and a summary of the results of the analyses of variance for all determinations are given in Table V.

In determining whether variances can be considered significant the ratio of the mean square in question to the mean square for the factor contributing the greatest error to differentiation is determined (20). This ratio is known as the F value and tables have been prepared giving the F value necessary for significance, taking into account the degrees of freedom (one less than number of variants in the group) for each mean square (39). These values have been calculated for two levels of significance, that is, when such F values would occur by chance alone once in twenty trials, and once in a hundred trials. It is usually assumed that when the magnitude of a variance is such that it could occur by chance alone only once in twenty trials (5% level), the variance is due to significant differences between the samples. The 1% level, then, represents highly significant differences between samples. The various F values have been included in the table.

TABLE IV

Analyses of Variance on Extract Yield

Variance due to	D.F.	Sum of squares	Mean squares	F Values		
				Found	Required	
					F=.05	F=.01
Varieties	7	136.8495	19.5499	8.60	2.30	3.30
Stations	5	535.2292	107.4584	47.30	2.48	3.59
Varieties x stations	35	79.5105	2.2717	38.57	1.48	1.75
Duplicates	47	2.77	.0589			

The magnitude of the mean square due to differences between duplicate malting tests is so small that laboratory errors are almost negligible in this investigation. The mean square due to stations is large and thus indicates that the average performance of the varieties at the various stations was very different. However, since this mean square represents that portion of the variance that affected all varieties equally it can be eliminated from further consideration of the comparative behaviour of the varieties. The remaining variance is divided into portions which represent differences in the average performance of varieties over all stations and variations due to differences in the relative behaviour of the varieties at different stations. If the varieties behaved in exactly the same way at each station this last portion of the variance would be reduced to a negligible quantity. The fact that it is by no means negligible indicates that the varieties responded in different ways at different stations, or in other words there was an interaction between varieties and stations and this error is therefore the standard against which the mean squares for varieties and stations are tested for significance.

The point may be raised that the samples of barley for the malting test are bulked from quadruplicate plots and thus the field error is not taken into account when differentiating varieties. That is to say, the interaction between blocks and varieties is used as error in comparing the agronomic qualities of the varieties within stations and there may be similar interactions with respect to malting qualities, that are lost when the samples are bulked. It is possible to malt a sufficient number of samples to determine the quantitative effect on varietal evaluation of this interaction between blocks and varieties, but this would seriously lessen the number of investigations carried out annually. The field error is caused mainly by the soil heterogeneity within the field, while the interaction between varieties and stations is caused mainly by differences between stations in soil type and climate and it seems logical to assume that the interaction between stations and varieties would be much greater than the interaction between blocks and varieties, or field error, within stations. As the two interactions have similar effects on varietal differentiation, the field error, though it does not appear in the malting results, is satisfactorily accounted for when the varieties are differentiated on the basis of the interaction between varieties and stations. The necessary differences between varieties and between stations in Tables II and III were calculated from the mean squares due to interaction for all determinations except sprouts and malt yield, in which cases the mean squares due to duplicates were used.

This differentiation of varieties by comparing their performances over wide ranges in environmental conditions such as were encountered in this investigation may be open to criticism. It is generally recognized in all cereal investigations that different varieties are unlikely to respond equally to changes in environment and thus their relative values would differ in different areas. However, only those varieties that are consistently superior (or inferior) are differentiated from the others by the method used in this investigation. The varieties that interchange their positions at different stations are not differentiated, but are considered equal in their average behaviour. The differentiation of such varieties can only be carried out by comparing their performances within smaller areas and thus determining the varieties most suitable for each area. That is to say, investigations dealing with samples representing wide ranges of environment separate only the inferior and superior varieties, and other investigations, within zones, are required to fully evaluate the better quality varieties. The investigation reported in this paper represents the first stage in the evaluation of Canadian barley varieties with respect to malting quality, so that the differentiation of varieties on the basis of their average behaviour over widely differing environmental conditions seems justified.

Despite the large comparative magnitude of the interaction effect, the fact that there were significant differences between varieties in extract yield is demonstrated. The mean square due to varieties is significantly greater than that due to interaction, as is evidenced by the F value, which is twice that required for the 1% level of significance. That is to say, even though the relative performances of the varieties differ at different stations, the average performances of the varieties, over all stations, differ significantly. In effect, then, the extract yield is a varietal characteristic.

The mean square due to stations is also significantly greater than that due to interaction, the F value being very much higher than that required for a 1% level of significance. This can be interpreted as showing that there were wide differences between stations with respect to average extract yield, so that the conditions under which the barley is grown also have marked effect on extract yield.

It is interesting to note that in this investigation the F value for stations is much higher than that for varieties, showing that the areas in which the barley were grown caused greater variations in extract yield than did the varietal characteristics. However, these data must be interpreted cautiously as the extract yield is not the sole characteristic by which malts are evaluated. Even though a sample of barley from one district has a higher extract than a sample of another variety grown in a different district it does not follow that the higher extract barley is superior to the other in malt quality. The ultimate goal in obtaining good malting barley is the production of good varieties in areas most conducive to the production of good quality.

The results of the analyses of variance for the other eight determinations are reported in Table V and the data show similar trends to those for extract yield. The mean squares for varieties and for stations are significantly greater than those for errors in every determination. The mean square for interaction is significantly greater than that due to duplicates in all but two determinations, showing that the differential effect of environment is a limiting factor in the differentiation of varieties, and stations, in practically all malt qualities. (The field error, or interaction between blocks and varieties, does not appear in this analysis of variance, but, as suggested before, it is unlikely to be greater than interaction between varieties and stations. In any case, the field error is due to differences in "local" environment.) The two cases in which the interaction effect is not significant are sprouts and malt yield and this is probably a reflection on the precision of these determinations. The precision of all the other determinations, as shown by the low values of mean squares due to duplicates, reached a satisfactory level.

The comparative magnitude of the interaction effect might be reduced when varieties are compared within small areas, but it is doubtful that the mean squares for the differential effect of environment on varieties, for the important malt qualities measured, would attain the small magnitudes of the mean squares due to duplicate maltings.

The malting and analyses are carried out under controlled conditions, and the variations introduced into the data from these sources are certainly much smaller than those introduced by factors that cannot be controlled and result in interactions.

TABLE V

Analyses of Variance

Variance due to	D.F.	Mean squares: Nitrogen %	Mean squares: 1000 K.wt. gms.	Mean squares: Plump barley %	Mean squares: Hours steep
Varieties	7	.2135 ++	123.124 ++	383.83 +	1861.58 ++
Stations	5	2.9339 ++	207.592 ++	4880.88 ++	1153.28 ++
Varieties x stations	35	.0358 **	6.146 **	146.04 **	74.23 **
Duplicates	47	.0009	.094	.43 °	7.65

Variance due to	D.F.	Mean squares: Sprouts %	Mean squares: Malt yield %	Mean squares: D. P. °L.	Mean squares: P.S.N. %
Varieties	7	1.9840 ++	3.6165 ++	6800.9 ++	.1552 ++
Stations	5	3.2860 ++	16.7651 ++	18125.9 ++	.3674 ++
Varieties x stations	35	.2339	.4768	329.1 **	.0150 **
Duplicates	47	.1594	.3410	24.5	.0004

° Approximate value of errors for this determination.

++ Significantly greater than the mean square due to varieties by stations.

** Significantly greater than the mean square due to duplicates. Double signs denote that the mean square attains a 1% level of significance, single signs denote a 5% level.

PART II

SUMMARY OF INFORMATION, COLLECTED DURING 1936 AND 1937, ON VARIETAL DIFFERENCES IN THE MALTING QUALITY OF BARLEY

The first part of this paper deals with the results of only one investigation on the malting quality of barley varieties. This investigation is typical of all those that are submitted for malting tests and they are all studied by the same malting, analytical and statistical methods. Information on varietal differences in malting quality, collected in ten investigations made during the past two years, is summarized in this section.

LIST OF INVESTIGATIONS

Investigation No.	Investigation	No. of samples
	Variety Trials, 1936 Crop	
1.	Uniform Variety Trials	48
	Varieties - 8 - O.A.C.21, Olli, Peatland, Pontiac, Nobarb, Regal, Velvet, Rex.	
	Stations - 6 - Brandon, Man.; University of Alberta; Melfort, Sask.; Gilbert Plains, Man.; Beaverlodge, Alta.; Ste. Anne de la Pocatiere, Que.	

2. Alberta U.G.G. 36

Varieties - 6 - O.A.C.21, Brio, Lapland, Olli, Peatland, Regal.

Stations - 6 in Alberta - Athabasca, Beaverlodge, Bon Accord, Fallis, Mellowdale, Warburg.

3. Manitoba Wheat Pool 96

Varieties - 3 - O.A.C.21, Mensury, Gartons.

Stations - 32 in Manitoba - Osborne, Solsgirth, Ipswich, Otterburne, Dugald, Shoal Lake, Gordon, Fannystelle, Marquette, Moorepark, Graysville, Roblin, Fortier, Newdale, High Bluff, Dauphin, Norgate, Elie, Benito, Thornhill, Strathclair, Dropmore, Gilbert Plains, Portage, Swan River, Oakville, Clanwilliam, Rackham, Makaroff, Arborg, Boissevain, Minitonas.

4. Saskatchewan Wheat Pool 66

Varieties - 5 - O.A.C.21 & Regal from each station. Hannchen & Peatland from 8 stations each. Olli from 6 stations.

3 varieties from each station.

Stations - 22 in Saskatchewan -

Grand Coolee, Qu'Appelle,
Rowlette, Govan, Raymore,
Tugaske, Neville, Danwelle,
Invermay, Middle Lake,
Kelvington, Watson, Annaheim,
Leacross, Melfort, Birch Hills,
Norquay, Star City, Bjorkdale,
Armley, White Fox, Paddockwood.

Effect of Cultural Practices, 1936 Crop

5. Manitoba U.G.G. 60

Varieties - 5 - O.A.C.21, Gartons, Bearer,
Mensury Ott.60, Wisconsin 38.
Each variety grown with and
without fertilizer at each of
3 dates of seeding.

Stations - 2 - Swan River, Fort Garry.

Variety Trials, 1937 Crop

6. Uniform Variety Trials 144

Varieties - 12- O.A.C.21, Charlottetown 80,
Hannchen, Mensury Ott.60, Nobarb,
Olli, Peatland, Pontiac, Regal,
Velvet, Victory, Wisconsin 38.

Stations - 12 - Ste.Anne de la Pocatiere, Que.; Beaverlodge, Alta.; Nappan, N.S.; Lethbridge, Alta.; O.A.C., Ont.; Brandon, Man.; Macdonald College, Que.; Fredericton, N.B.; Lacombe, Alta.; M.A.C., Man.; Ottawa, Ont.; Gilbert Plains, Man.

7. Peace River District 36

Varieties - 6 - O.A.C.21, Newal, Olli, Peatland, Regal, Trebi.

Stations - 6 - Fairview, Baldonnel, High Prairie, Pouce Coupe, Dreau, Beaverlodge.

8. Alberta U.G.G. 36

Varieties - 6 - O.A.C.21, Brio, Newal, Olli, Peatland, Regal.

Stations - 6 - Fallis, Olds, Beaverlodge, Bon Accord, Warburg, Mellowdale.

9. Manchurian Varieties 24

Varieties - 4 - O.A.C.21, Mensury Ott.60, Olli, Peatland.

Stations - 6 in Ottawa Valley - Westboro, Lochiel, Ottawa, Kinburn, Kemptville, Navan.

10. Manitoba Wheat Pool 36

Varieties - 4 - O.A.C.21, Gartons,
Mensury Ott.60, Peatland.

Stations - 9 - Moore Park, Neepawa, Rackham,
Holland, Killarney, Thornhill,
Elie, High Bluff, Marquette.

Total 532

RESULTS

In all these investigations O.A.C.21 was used as a reference or standard variety, and the mean values for it, for eight qualities, for each investigation, are given in Table VI. The mean value, over all investigations, for each determination, was calculated and is also reported. The differences between varieties that can be considered significant (to 5% level) were calculated for each investigation and are given in Table VII. These necessary differences between varietal means were calculated from the mean squares due to the differential effect of environment on varieties for all determinations except those for malt loss and sprouts. In these two determinations necessary differences were calculated from the mean squares due to differences between duplicate maltings since they were greater.

TABLE VI

Mean Values, by Investigations, for O.A.C.21

Invest-igation No.	No. of samples	Barley			Malting		Malt		
		N. %	1000K. wt.gm.	Plump %	Loss %	Sprouts %	Extract %	D.P. °L.	P.S.N. %
1	6	2.39	30.2	69	8.0	2.4	73.5	145	1.14
2	6	2.31	32.7	83	7.6	1.8	73.3	116	--
3	32	2.45	--	55	9.9	2.8	71.9	165	--
4	22	2.39	--	75	8.0	2.4	73.1	158	--
5	12	2.47	--	62	8.2	2.0	71.0	157	--
6	12	2.24	31.0	74	7.4	2.2	73.9	127	1.10
7	6	2.24	--	83	8.1	2.6	73.6	111	0.93
8	6	2.60	--	93	8.4	2.7	72.6	152	1.27
9	6	2.36	--	67	8.2	2.5	74.5	141	1.30
10	9	2.30	29.7	56	9.2	2.9	73.4	143	1.17
Mean	117	2.39	30.8	68	8.6	2.5	72.8	145	1.15

TABLE VII

Necessary Differences, for 5% Level, between Means of Varieties, for each Investigation

Investigation No.	Barley			Malting		Malt		
	N. %	1000 K. wt. gm.	Plump %	Loss %	Sprouts %	Extract %	D. P. °L.	P.S.N. %
1	0.15	2.0	10	0.6	0.4	1.2	15	0.10
2	0.15	2.0	4	0.4	0.3	0.9	11	--
3	0.11	--	4	0.2	0.2	0.8	6	--
4	0.13	--	4	0.2	0.1	0.8	7	--
5	0.22	--	20	0.8	0.4	1.5	15	--
6	0.08	1.5	5	0.4	0.2	0.6	11	0.05
7	0.10	--	5	0.6	0.3	1.7	12	0.07
8	0.13	--	6	0.4	0.3	1.0	19	0.10
9	0.07	--	9	0.4	0.3	1.2	12	0.09
10	0.14	2.0	10	0.8	0.6	1.2	7	0.07

The collected data for these investigations yield information on the malting quality, relative to O.A.C.21, of nineteen varieties. These varieties have been listed in Table VIII. The first column of the table contains the names of the varieties studied. The second column identifies the investigation by means of the numbers given in the list of investigations. The third column gives the number of samples in each investigation for each variety. The remaining eight columns contain the data for varietal differences from O.A.C.21. The differences from the standard that are considered significant, on the basis of the necessary differences listed in Table VII, are marked with an asterisk. A negative sign indicates that the mean was lower than that for O.A.C.21; when no sign is given the mean was higher.

TABLE VIII

Malting quality of barley varieties grown in Canada. Differences between variety means for each investigation and corresponding mean for O.A.C.21.

Variety	Investigation No.	No. of samples	Barley: Nitrogen %	Barley: 1000 K. wt. gm.	Barley: Plump %	Malting: Loss %	Malting: Sprouts %	Malt: Extract %	Malt: D. P. °L.	Malt: F.S.N. %
O.A.C.21, mean over all samples			2.39	30.8	68	8.6	2.5	72.8	145	1.15
Six-rowed varieties admitted to malting grades										
Gartons	3	32	0.36+	--	-3	-0.7+	-0.6+	-1.0+	8+	--
	5	12	0.41+	--	8	-0.3	-0.2	-0.7	6	--
	10	9	0.34+	0.8	10+	-1.5+	-0.9+	-1.2+	5	0.05
Mensury	3	32	0.01	--	1	-0.3+	-0.2+	0.3	7+	--
Mensury Ott.60	5	12	0.16	--	-2	-0.2	-0.2	-0.5	8	--
	6	12	0.06	1.0	3	-0.1	-0.1	0	1	0.03
	9	6	-0.01	--	6	-0.3	-0.1	-0.2	1	-0.06
	10	9	0.06	1.1	2	0.1	0.1	-0.1	10+	0
Peatland	1	6	0.35+	-3.0+	-17+	-0.4	-0.1	-1.3+	13	0.07
	2	6	0.36+	-6.8+	-21+	0.6+	0	-1.7+	6	--
	4	8	0.57+	--	-22+	0.6+	0	-2.2+	28+	--
	6	12	0.23+	-2.5+	-8+	-0.3	-0.3+	-0.7+	-7	-0.02
	7	6	0.25+	--	-19+	-0.2	-0.6+	-1.8+	-2	0.04
	8	6	0.32+	--	-16+	0	0.3+	-1.5+	-10	0.07
	9	6	0.22+	--	0	-0.8+	-0.9+	-0.8	-14+	-0.07
	10	9	0.30+	-0.2	6	-0.9+	-0.7+	-0.8	-2	0

TABLE VIII (cont'd)

Variety	Investigation No.	No. of samples	Barley: Nitrogen %	Barley: 1000 K. wt. gm.	Barley: Plump %	Malting: Loss %	Malting: Sprouts %	Malt: Extract %	Malt: D. P. °L.	Malt: F.S.N. %
Six-rowed varieties, not admitted to malting grades.										
(a) Rough-awned varieties										
Bearer	5	12	0.34+	--	5	-0.4	-0.2	-0.9	5	--
Brio	2	6	-0.13	-3.1+	-1	-0.2	-0.4+	2.0+	-12+	--
	8	6	-0.16+	--	0	-0.5+	-0.6+	2.4+	-32+	-0.01
Lapland	2	6	-0.17+	-5.2+	-18+	0.6+	0.1	3.4+	15	--
Olli	1	6	0.14	-3.8+	-19+	0.6+	0.6+	1.8+	42+	0.20+
	2	6	-0.12	-2.2+	-3	1.1+	-0.4+	3.5+	26+	--
	4	6	0.08	--	-11+	0.6+	0.2+	1.1	18+	--
	6	12	-0.02	-1.5+	-8+	0.4+	-0.1	2.1+	26+	0.11+
	7	6	-0.04	--	-2	0.2	-0.2	1.6	17+	0.04
	8	6	-0.15+	--	-7+	0.1	0.1	3.9+	12	0.02
	9	6	0.06	--	-7	-0.2	-0.5+	0	14+	0.20+
Pontiac	6	12	0.04	1.3	5+	-0.5+	-0.2+	-1.3+	4	-0.05+
Trebi	7	6	-0.09	--	8+	-2.5+	-1.0+	-4.0+	-29+	-0.27+
(b) Smooth-awned varieties										
Newal	7	6	0.19+	--	10+	-1.3+	-1.0+	-2.5+	44+	-0.03
	8	6	0.12	--	3	-1.6+	-0.8+	-1.2+	39+	-0.03
Nobarb	1	6	0.01	2.7+	11+	-1.2+	-0.7+	-1.1	-28+	-0.18+
	6	12	-0.05	2.7+	6+	-1.0+	-0.6+	-1.0+	-27+	-0.21+

TABLE VIII (cont'd)

Variety	Investigation No.	No. of samples	Barley: Nitrogen %	Barley: 1000 K. wt. gm.	Barley: Plump %	Malting: Loss %	Malting: Sprouts %	Malt: Extract %	Malt: D. P. °L.	Malt: P.S.N. %
Regal	1	6	0.06	0.8	2	-0.7+	-0.3	-1.9+	-49+	-0.07
	2	6	0.08	0.9	1	-1.2+	-0.4+	-2.8+	-58+	--
	4	22	0.06	--	0	-0.7+	-0.6+	-2.0+	-50+	--
	6	12	0.11+	0.5	2	-0.4+	-0.5+	-2.7+	-41+	-0.06+
	7	6	0.09+	--	-5+	-2.0+	-0.8+	-5.0+	-45+	-0.13+
	8	6	0.18+	--	-4	-1.3+	-0.9+	-4.4+	-49+	-0.06
Velvet	1	6	0.27+	-0.6	2	-0.7+	-0.3	-2.3+	-7	0.02
	6	12	0.15+	0.1	2	-0.8+	-0.5+	-1.6+	-3	0
Wisconsin 38	5	12	0.19	--	17	-0.3	-0.4+	-3.0+	-26+	--
	6	12	0	1.3	12+	-0.8+	-0.6+	-2.7+	-31+	-0.26+
Two-rowed varieties										
(a) Rough-awned varieties										
Hannchen	4	6	0.15+	--	3	-0.9+	-0.6+	0.9	-12+	--
	6	12	-0.02	4.6+	9+	-0.3	-0.3+	3.0+	-11+	-0.07+
Charlottetown 80	6	12	0.06	4.0+	8+	0.2	-0.1	2.2+	-27+	-0.11+
Victory	6	12	-0.01	5.0+	10+	-0.3	-0.1	2.0+	-24+	-0.18+
(b) Smooth-awned varieties										
Rex	1	6	0.27+	6.4+	8	-0.6+	-0.5+	-0.1	0	0.10+

+ Denotes significant difference.

DISCUSSION

The data on varietal differences can be conveniently and briefly discussed by groups of varieties.

Six-rowed varieties admitted to malting grades

Four varieties, as well as O.A.C.21, are included in this group and the data on these varieties are adequate to justify conclusions with respect to their malting quality. Only two of this group, Mensury and Mensury Ott.60 (which is a selection of Mensury), compare favourably with O.A.C.21 in all malting qualities. The results for Gartons and Peatland suggest that these varieties are less suitable for malting than O.A.C.21, as both varieties are higher in nitrogen and lower in extract yield than the standard. Peatland is also faulted for its small kernels and low yield of heavy grade barley.

Six-rowed varieties not admitted to malting grades

(a) Rough-awned varieties

This group consists of six varieties but only one of them, Olli, has had sufficient testing to warrant conclusions, but even then the evaluation of Olli is a difficult problem. The data indicate that Olli is higher than O.A.C.21 in extract yield and in diastatic power and both of these characters are considered favourable. Under some conditions it also tends to produce higher amounts of permanently soluble nitrogen in wort than the standard. The interpretation of this characteristic is not yet possible, but in the meantime it may be viewed with suspicion as a high nitrogen content in wort might be objectionable. However, Olli can be classed as promising as its desirable properties are always evident, despite its low 1,000 K. weight and low yield of plump barley, and the quality that is questionable, namely high amounts of permanently soluble nitrogen in wort, is only evident under some conditions. Olli when grown in Alberta appears to be about equal to O.A.C.21 in permanently soluble nitrogen in wort, as well as being higher than it in extract yield and diastatic power.

The information on the other varieties studied is insufficient to provide definite evaluation of their worth, but the indications are as follows: Trebi is unsuitable for malting as its extract yield is extremely low and it is also deficient in enzymes as is evidenced by its low diastatic power. Bearer is faulted as its nitrogen content tends to be high, and Pontiac is faulted as its extract yield tends to be low. Of the remaining varieties Brio seems to exhibit unusual characteristics, as its extract is higher than O.A.C.21, and its diastatic power much lower than the standard. Lapland appears to be somewhat similar to Olli, as it possesses a high extract yield and high diastatic power. Both these varieties are similar to Olli in that they possess small kernels. Under the circumstances of their similarity to Olli in extract yield, Brio and Lapland might therefore for the present be considered promising, at least as parent material for breeding.

(b) Smooth-awned varieties

The information on most of the varieties in this group is inadequate for conclusions to be drawn, and the characteristics of these varieties, which represent stages of advance in quality from Lion, should not be taken as representing the optimum qualities of this class. Regal was studied in six investigations and it can be concluded that this variety, owing to its lower extract and lower diastatic power than O.A.C.21, is less suitable than the standard for malting purposes.

The data for the other four varieties of this class that were studied are not as numerous as those for Regal and the result should therefore be interpreted as indications rather than conclusions. Wisconsin 38 appears to be similar in character to Regal and can probably be classed the same as it in malting quality. These two varieties, Regal and Wisconsin 38, are the most commonly grown smooth-awned varieties and the three other varieties, Nowal, Nobarb, and Velvet, may be regarded as later stages in breeding. Nowal appears to be an advance from Regal in both extract and diastatic power, in fact its diastatic power is exceptionally high; Nobarb also represents an advance in extract and diastatic power, while Velvet appears to show improvement mainly in diastatic power.

While none of the smooth-awned varieties can at present be regarded as equal to O.A.C.21 in malting quality, some of the newer varieties represent definite improvements over the older varieties in that respect and it is not improbable that further improvements in quality might be obtained.

Two-rowed varieties

The malting test at present in use is not particularly suitable for testing two-rowed varieties, as they grow more slowly than six-rowed varieties. They are thus unlikely to attain their optimum qualities in the short germination period. For this reason it is not advisable to compare their results with those for O.A.C.21. However, it is possible to obtain fair comparisons between the two-rowed varieties. As Hannchen seems to compare fairly favourably with O.A.C.21 in the important malt qualities, it is used as the standard against which the other two-rowed varieties in this test are compared.

(a) Rough-awned varieties

Only one investigation included the three varieties in this group and the results show that Charlottetown 80 and Victory produced less extract than Hannchen and they also tended to be lower than it in diastatic power and permanently soluble nitrogen in wort. Owing to these facts, these two varieties are probably less suitable for malting than Hannchen.

(b) Smooth-awned varieties

The investigation in which a variety of this class, Rex, was studied did not include Hannchen and the difficulties encountered in evaluating Rex with respect to malting quality were discussed in Part I of this paper. Rex does not exhibit the high extract yields that are generally associated with two-rowed varieties but more investigational work is necessary before it can be finally evaluated.

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