

A 19416 of the United States Government



Issued November 25, 1908.

U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF PLANT INDUSTRY—Circular No. 16.

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A NEW BASIS FOR BARLEY VALUATION  
AND IMPROVEMENT.

BY

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57291—Cir. 16—08

WASHINGTON GOVERNMENT PRINTING OFFICE



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# A NEW BASIS FOR BARLEY VALUATION AND IMPROVEMENT.

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## INTRODUCTION.

In planning for the improvement of barley crops there are among many other things two of great importance: (1) The means of clearly recognizing the best grades of barley and (2) the knowledge of what factors or qualities in barley it is especially desirable to improve.

A great many tests for distinguishing different grades of barley have been in use. Of these the simpler ones, and therefore those that should be most useful, have not been found to be reliable. Conclusions based upon such external signs as color, fineness and wrinkling of hull, smooth or toothed condition of the nerves, long or short haired basal brush, and size and shape of grain are serviceable, but have proved so inaccurate that it is evident they can not be depended upon as a basis for scientifically accurate conclusions. The test made by cutting the grain across so as to see the relative mealiness of its starch contents is also very unsatisfactory, because there are two different but similar appearing states of glassiness, one that injures the malting qualities of the grain, while the other has no such effect. Even the more difficult and expensive chemical analyses leave much to be desired. For example, they indicate the percentage of nitrogen contained in a sample, but distinguish with great difficulty between the different kinds of nitrogenous contents; and, what is still more unfortunate, though they accurately determine the chemical composition of a given sample they have no testimony to offer showing why one variety has more of a certain substance than another, where the different constituents are located in the grain, or how superior grades of barley may be recognized and still better grades developed. Therefore, although chemical analysis in barley determinations is indispensable, there is great need for a trustworthy structural test.

In undertaking the improvement of American barleys the Bureau of Plant Industry therefore decided to attempt the solution of some

of these questions along new lines. Mr. David Fairchild has believed for some time that a thorough study of the internal structure of the barley grain should afford better knowledge than that hitherto secured of the location of the various constituents of the grain and especially of the location within the grain of those energies that bring about the changes included in the artificial process called malting and the natural process called germination. The valuable discoveries made by Dr. N. A. Cobb in his morphological studies of wheat <sup>a</sup> strengthen the belief that the functions of barley, included in its malting processes, however complicated, are referable to some structural parts as their source and are correlated with definite organs. The writer therefore undertook a careful study of the internal mechanism of the barley grain as to the structural changes that take place during its successive steps in malting.

To do this, modifications in laboratory technique have had to be worked out and methods discovered that would give the best results in killing, fixing, sectioning, staining, etc., this refractory material so as to fit it for microscopic study. The object of this article is merely to give a brief sketch of the work so far accomplished and to announce a new basis for barley valuation.

The first task undertaken was to investigate anew the work performed by the different parts of the grain. This was necessary because, although an enormous amount of study has been given to this subject, there is no unity of opinion to be found in the reports published. To take an example: It has long been known that the peculiar part of the embryo barley plant called the scutellum is an absorbing organ, which seizes upon the food supply stored in the rest of the grain and transfers it to the growing parts, the young root system and the stem. The shape and position of this organ suggest such a use to even an untrained observer. Its broad, flat surface is pressed close against the large, stored-up mass of starch, called the endosperm, which forms the bulk of the grain; and when germination, or its modified form called malting, has been going on for three or four days it is easy to see that the starch endosperm, especially that portion lying nearest the scutellum, is disappearing and that at the same time the embryo plant has commenced growth. It is evident that the scutellum is absorbing the starch and transferring it to the plant. But this can not be effected without certain preliminary changes. The walls of the starch-containing cells must first be broken down and the starch grains must then be changed into a liquid state by conversion into sugar, dextrin, or some such soluble correlative before the scutellum can absorb this supply and convey it to the plant.

<sup>a</sup> Published by the Department of Agriculture of New South Wales under the title "Universal Nomenclature of Wheat."

It is therefore important to know where the ferments or enzymes necessary to bring about these changes are secreted. Are they the product of the scutellum, making it thereby not only an absorbing but a secreting organ? Or are they located elsewhere? This is one of the questions about which there is much diversity of opinion. Some investigators hold that the necessary enzymes, diastase and cytase, are to be found in the cells of the starch endosperm itself, and that if, as is probable, the scutellum also secretes these enzymes it is supplementary to the stored-up supply of the starch cells. Others believe all or a considerable part of the supply is secreted by the cells of the aleuron layer, which invests the entire starch endosperm except at the end of the grain occupied by the plantlet. Certain authors hold that both this layer and the scutellum supply these ferments. It was such discordant testimony on this and other points that made necessary at the outset a thorough study of the morphology of the barley grain, so as to fix, as far as possible, the locations of these important functions.

These investigations have proved that the enzymes already mentioned, the diastatic and cytatic starch ferments, are wholly the product of the scutellum and are secreted by its outer layer, called the epithelial layer; that although a minute trace of them is to be found in the starch cells (as in all starch-containing tissue), it plays so slight a part in the normal starch conversion that it is practically negligible; that, furthermore, the aleuron layer has nothing whatever to do with this process. The scutellum can therefore be called the "malting organ" of the barley grain and its epithelial cells the "malting glands." This organ, together with the size and quality of the endosperm, is therefore of the highest importance in all questions concerning the food value, malting value, and germinating value of barley.

By a comparative study of this important organ in the leading varieties of cultivated barley, it was soon discovered that its shape varies greatly. At least two distinct types exist, with many intermediate forms—one very broad, almost circular in outline, covering the lower end and reaching well over the shoulders of the grain (see fig. 1); the other narrow, elongated, with nearly parallel sides and rounded or pointed tip (see fig. 2). The broad scutellum is generally nearly flat or so slightly convex on its inner surface that it lies in a shallow depression of the starch endosperm, while the narrow scutellum is thick and tongue shaped and is sunken quite deep into the endosperm. Compare the depression shown on the left in figure 1 with that in figure 2; also the two scutellums.

Corresponding differences, though less strongly contrasted, were found to exist in the size and shape of the epithelial cells clothing the inner surface of these two types of scutellum. The broad, shallow

form has decidedly narrow and elongated cells, on an average five to six times as long as broad; those of the other type are shorter and relatively thicker, averaging three to four times as long as broad. It is easy to understand how the former will have a greater secreting power than the latter, since the number of cell units in a given space will be greater without any loss in the capacity of each cell.

A fact of especial importance is that the broad, circular, slightly convex type of scutellum having long, narrow epithelial cells is found to be characteristic of the best grades of malting barley, while the narrow, deep-sunken type, with short and broad epithelial cells, is characteristic of barley inferior for malting purposes. A

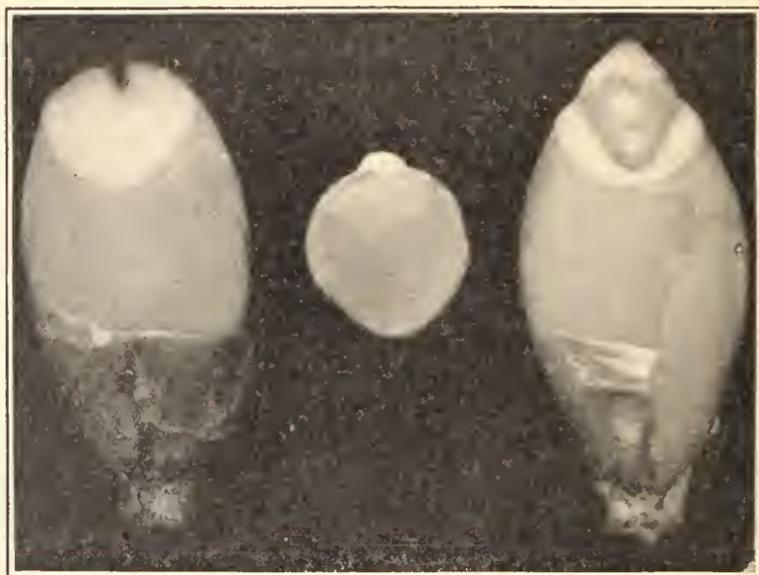


FIG. 1. High-grade Swedish pedigree barley. The hulls and outer membranes have been removed to show the ideal form of scutellum. Grain on the right entire; on the left with the scutellum removed, leaving a broad, shallow depression; scutellum in the center, seen from under side. Magnified 8 diameters.

good example of this fact is seen in figure 3. The value of this correlation is twofold: (1) It furnishes a means of recognizing the grade of any variety of barley by a test that is unquestionably more reliable than the external earmarks hitherto relied upon, such as character of the hull, basal bristle, shape of the grain, etc. For in the case of these external tests we have nothing more than an accidental and somewhat inconstant coincidence between form and physiological quality, while in the case of the scutellum we deal with a strictly vital correlation, a necessary and therefore fixed relationship between the organ and the malting efficiency. In the matter of its use the scutellum test is almost as easy as the above-mentioned external

tests, the general build of this organ being easily made out by merely removing the outside hulls of the grain. This is readily done even when the barley is dry, though it is better to soak the sample for a few hours. The examination of the epithelial layer is also a comparatively simple operation. A longitudinal section of a well-soaked grain, freed from its hulls, can be quickly made with a razor or sharp knife, and the microscope will then reveal the general form of this important glandular tissue. Of course, better sections can be secured with a microtome. Some of the new freezing microtomes are not only cheap but are easily operated. The one used in these investigations will enable a grain investigator to prepare excellent sections in five to eight minutes, and such sections give a

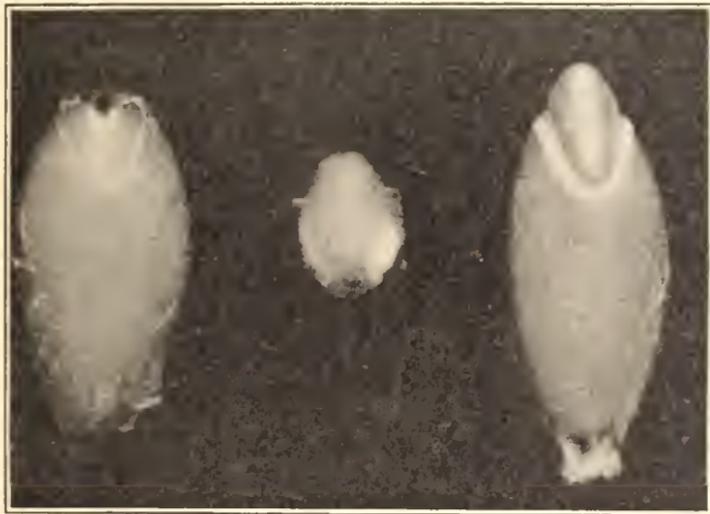


FIG. 2.—Low-grade barley sold on the Milwaukee market. Crop of 1907. The hulls and outer membranes have been removed to show the poor form of scutellum. Grain on the right entire; on the left with scutellum removed, leaving a narrow, deep-sunken depression; scutellum in the center, seen from under side. Magnified 8 diameters.

far better image of the starch body—its texture, mealiness, glassiness, etc.—than the crude method of cross-cutting the grain now practiced by grain buyers and malt experts.

It is to be seen by the foregoing that the first essential for barley improvement mentioned at the head of this article, namely, the means of recognizing the best grades of barley, is supplied by the structural differences of the scutellum.

(2) The second essential mentioned, a knowledge of what factors in barley it is especially desirable to improve, is also closely connected with the functions of the scutellum, for evidently any improvement in malting barley must include an improvement in the malting organ. Other factors are without doubt involved, the quality of the starch

endosperm, the percentage of nitrogen, etc., as well as some very weighty agricultural considerations having to do with yield, stiffness of straw, etc. But whatever other elements of quality enter into our work of American barley improvement, the scutellum, as the most potential part of the barley grain, is likely to be one.

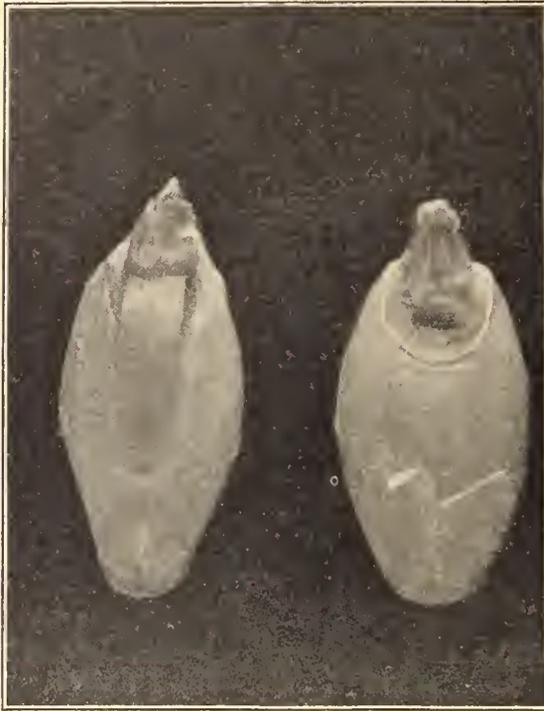


FIG. 3.—Malted barley from Pilsen, Austria. The grain on the right has the sprout removed to show the ideal form of scutellum. Magnified 8 diameters.

How far this is capable of modification is at present undetermined. But the opinions of those experimenters in grain breeding both here and in Europe who have been consulted on this point agree that there is no a priori reason why this particular form of plant structure should not be as plastic and capable of improvement as any other.

The general success in plant breeding, according to modern methods, leads us to expect that in our work of barley improvement now going on at St. Anthony Park, Minn., we shall secure results of distinct value to American agriculture.

Approved:

JAMES WILSON,

*Secretary of Agriculture.*

WASHINGTON, D. C., September 24, 1908.

[Cir. 16]

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