PRELIMINARY OBSERVATIONS ON MALTING QUALITY OF OKLAHOMA GROWN BARLEYS

PRELIMINARY OBSERVATIONS ON MALTING QUALITY OF OKLAHOMA GROWN BARLEYS

By

ERNEST LEE MADER

BACHELOR OF SCIENCE

OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE

1936

SUBMITTED TO THE DEPARTMENT OF AGRONOMY

OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE

1945

APPROVED BY:

Chairman, Thesis Committee

Member of the Thesis Committee

Head of the Department

Dean of the Graduate School

ACKNOWLEDFMENTS

The writer wishes to express his sincere appreciation to Mr. C. B. Cross and Dr. H. F. Murphy for their encouragement and helpful criticism in connection with this research and in the writing of this thesis.

The writer also wishes to thank Mr. Lonnie Rose, of the Agronomy Department, and Dr. J. E. Webster, of the Agricultural Chemistry Department, for their assistance and cooperation.

CONTENTS

Page

INTRODUCTION

The purpose of this investigation is to determine the possibilities of producing malting quality barley under Oklahoma conditions. Little or no attention had been given to the production of barley for malting purposes in the Southwest until work was begun at Texas Technological College, Lubbock, Texas in 1937. (31) These investigations have proved that barley produced under irrigation is suitable for malting, providing the right varieties are used and irrigation water is applied at the proper time. Results from the Texas Panhandle have prompted similar tests in Oklahoma under ordinary farming conditions.

The production of barley for malt in the United States is confined to the states of the Upper Mississippi Valley and far Western States. Brewers of the Southwest must of necessity ship their malt from one of these two sources. With malting plants in the states of Oklahoma and Texas, farmers would be paid higher prices for the production of barley suitable for malting purposes, if suitable barley can be grown here.

Most of the barley produced in the state of Oklahoma is planted in the fall of the year, and yields from fall sown varieties are consistently higher than from spring sown varieties. For this reason several high yielding winter varieties were included in the investigation to determine their value for malting, along with some of the important spring varieties. Only spring varieties are used for malting in the Northern States.

Included in the investigation were barley varieties grown at three different locations in Oklahoma in order to have a survey in different areas of the state. Eight high yielding winter varieties grown in the crop year 1939-1940 at Stillwater, Oklahoma, were included along with ten fall sown varieties for the crop year 1940-1941. Spring sown varieties tested included only those seeded in the spring of 1941 at Stillwater. Fall sown varieties from Idabel in Mc Curtain county and Grove in delaware county were made a part of the investigation. these locations give a fair sample of the humid Eastern part of Oklahoma.

HISTORY

Maltsters and brewers have shown marked prejudices during the past forty years over the type, size and color of barley suitable for malting purposes. The Wyoming Experiment Station exhibited some barley samples in 1907 at the Louisiana Purchase Exposition at St Louis, Missouri. These barleys were of such quality that a representative of a Liverpool, England firm offered to pay a premium of fifty cents or more per bushel for the quality of brewing barley shown in the exhibit than for barley from anywhere else in the world. Nowell (32) states, "The high altitude, short season, absence of rain while in the shock and prevalence of sunshiny days in the growing season are just the conditions that make for the quality required". All samples exhibited were two rowed types. In 1914 Moor and Stone (30) wrote, "From reports received from the leading maltsters and brewers of the United States, no less than ninety-five percent of those reporting preferred the six-rowed, bearded barley".

The Coast type of barley introduced by Spanish settlers to California has played some part in formulating brewing practices on the Pacific Coast and in the British Isles. The introduction and development of Manchuria and Oderbrucker types of barley in the North Central United States assumed a major influence in the development and technique of the brewing industry of the United States during the period from 1900 to 1914.

Maltsters and brew masters in the United States, Canada and Europe differ greatly as to what constitutes a satisfactory malting barley. Each country differs as to the proper color requirement, kernel weight and protein content. All seem to agree that malting barley should have a high percentage of mellow or mealy kernels. Each of the above factors will be discussed from the viewpoint of different authorities and demands of different countries.

In the Upper Mississippi Valley the color of the barley is often considered as an index of steeliness. The United States maltsters demand a white kerneled variety with not more than five percent of black or Trebi type barley (Trebi has a blue color). On the other hand, Canadian brewers are fully satisfied with O.A.C. 21, a blue variety, which is used as an index for comparing all other varieties. Harlan and Martini (18) state,

> "It persists despite the fact that the only American barley that is bought at a premium on the English market is the blue barley of the Pacific Coast. Indeed, when Atlas was introduced many English buyers complained that it was not blue enough. The breeder, then, is confronted with local market prejudices. An infinitesimal amount of a harmless pigment is a layer of tissue that is not modified in brewing may add one more factor that he must consider in breeding malting barley. We have many varieties of both blue and white barley, and if it has to be done, we can meet the market requirement".

Protein content in barley is partly varietal and partly regional. In regions where malting quality barley is produced climatic and soil conditions play an important role on the amount of protein present in the barley kernel. "The outstanding factor of quality is the percentage of nitrogen in the grain. In general, the quality falls off with increasing nitrogen content. Values in excess of 1.5 to 1.6 percent are undesirable".[1] According to Grant, (16) "A high nitrogen content gives

> a low malt extract and causes fermentation trouble in the brewery. Barley kernels that appear hard and steely when split transversely are almost sure to be high in nitrogen. Nitrogen content seems to be associated, first with soil on which the barley is grown; second, climatic conditions during growth; third, type of barley. The low nitrogen requirements for malting barley eliminates the great bulk of the barley offered to the European importer interested in malting barley".

The barleys used in this country are of decidedly different types from those used abroad. European countries in the main like a very low protein barley of the two-rowed or plump six-rowed types. Our brewers and maltsters like malt from a barley running approximately twelvepercent protein with a relatively small plump kernel. English and German maltsters and brewers do not like the protein content to be above ten percent. Dupont (12) summarizes the American viewpoint in the following statement made at The Barley Improvement Conference held

---

[1] Summary of Report of Rothamsted (England) Conference on Malting Barley. p46, March 1928.

in 1933, "We, in the United States, can make use of the high protein barley, because in our method of production of beer, we can eliminate during the mashing these undesirable albuminoids and also have frequently been using malt adjuncts which do not furnish us with any protein. We, therefore, produce a smaller total amount of protein by the added percentage of protein less adjuncts."

The smaller kerneled varieties of barley, so much desired by maltsters in the United States, with high protein content give a higher diastatic power per gram than larger kerneled varieties.

During the period between 1918 and 1933, the malting brewing industry was in a very inactive state of production. The acreage planted to barley; however, was gradually increasing year after year. The increased acreage and production during the prohibition era was obviously used for feeding purposes. The chief concern of plant breeders during this era was to increase production per acre with little or no attention being given to the malting quality of new varieties. Oderbrucker, the chief malting barley prior to the prohibition era, 1918-1933, was largely replaced by Wisconsin No. 38 and by other smooth awned types. The quality of the newer varieties grown in different parts of the United States was determined in experimental malting laboratories at Madison, Wisconsin under the direction of J. G. Dickson and G.A. Weibe (10). On large scale field plantings in two counties in Wisconsin, Wisconsin No. 38 produced an increased grain yield per acre of 22.7 percent over Oderbrucker during the 1939 crop year and 19.6 percent more in the 1940 season. The malt and extract yield per acre was also higher for Wisconsin No. 38 over Oderbrucker both years.

Morey (31) concluded that malting barley could be produced on the Southern High Plains of Texas if irrigation water was applied at the proper times and that Wisconsin No. 38 and Velvet were of suitable quality to be considered malting barley. Spence (38) concluded that Wisconsin No. 38 and Afghan were the most suitable varieties for the production of malt in Western Texas. The quality of malt produced from Atlas, Manchuria and Velvet was lower than the above mentioned two varieties but could be considered malting barleys. Kern's work (22) in 1941, showed Velvet had the highest malting quality of the barley varieties grown at Lubbock, Texas. Manchuria was the only other variety suitable for malting. He also states that barley cut twenty-six to thirty-four days after heading was the most desirable for malting and maximum yield per acre.

Dickson, (10) and others, in reporting on regional tests of malting quality makes this statement regarding varieties grown at Lubbock, Texas during the crop year 1939.

"Three of the standard varieties, Wisconsin Barbless, Velvet, and Manchuria, were grown with Atlas and Afghan at Lubbock, Texas. The standard varieties compared favorably in quality to the results obtained at some of the more western stations in the northern spring barley area. The winter barley Wintex, was high in extract content of malt as is usually the case in winter barleys, relatively low in diastatic power of the malt, and produced a slightly hazy wort in the laboratory mashing procedure.

The ranking of the varieties grown at Lubbock was as follows; Manchuria 107, Odessa 102, Afghan 101, Velvet 100, Wisconsin Barbless 97, and Atlas 83."

EXPERIMENTAL METHODS AND PROCEDURE

The experimental work of this investigation was designed to study the physical factors which influence the grades and quality of malting barley. Chemical analysis was made on each sample to determine moisture and protein content. Duplicate determinations were made on all samples. Methods and procedure are discussed in the following paragraphs.

Test weight per bushel:

The standard Winchester test weight per bushel machine was used in making these determinations. Barley must test at least forty-three pounds to the bushel to grade "Malting Barley." The weight per bushel on a dry basis was calculated on each variety.

Broken and skinned kernels:

Approximately 30 grams of barley were used in making determination for broken and skinned kernels. The skinned and broken kernels were separated from the sample, weighed, and the percentage calculated. Broken kernels of barley are those that are cracked or fractured, regardless of the extent or size of the pieces. A skinned kernel of barley is any kernel of barley that has approximately one-third of the hull removed, or which has the germ end exposed in whole or in part. Malting barley, according to official standards, may contain not more than five percent of skinned and/or broken kernels.

Hull content of barley:

One hundred unselected kernels were placed in a flask in 0.2 percent ammonium hydroxide solution and heated to the boiling point in ten to fifteen minutes. The kernels were removed and washed immediately in cold water. Hulls were removed from the kernels by means of shapr forceps. Kernels and hulls were dried in an oven at 105 degrees centigrade for twelve hours and weighed and the hull content calculated on a percentage basis.

Endosperm texture:

Texture of the endosperm was determined by counting out one hundred unselected whole kernels. These kernels were cut lengthwise of the kernel with a razor blade. Texture of the kernels was considered as mealy, semi-steely and steely. Mealy kernels are those in which seventy-five percent or more of the kernel is mellow or starchy. Semi-steely kernels are kernels of barley which have between twenty-five and seventy-five percent of the kernel mellow or starchy. Steely kernels of barley are those which have seventy-five percent or more of the endosperm steely or glassy in texture.

Endosperm texture after steeping:

Approximately two hundred kernels of each variety were placed in a cheesecloth bag and steeped twenty-four hours in tap water at sixteen degrees centigrade or sixty degrees Fahrenheit. The samples were spread in a room with a temperature about ninety degrees Fahrenheit and with air circulating in order to dry the barley kernels to about the original moisture content. The air was kept circulating with an electric fan. The kernels were then cut longitudinally and classified as to texture.

Index of mellowness:

The index of mellowness was determined by adding the mealy and one half of the semi-steely kernels. The index is given in percentage.

Rate of water absorption:

A hundred-gram sample of each variety was weighed and placed in a mesh wire basket 6" X 6" X 5" with cheesecloth lining the inside. The sample in the basket was placed in a large galvanized pan with sufficient water to submerge the barley. Water in the large pan was kept at a constant temperature of 60.5 degrees Fahrenheit. All samples were steeped twenty-two to twenty-four hours, removed and all free water drained off. Fresh water was added, the samples re-steeped another twenty-two to twenty-four, removed and all free water again allowed to drain off. Weighings were made at twenty-two to twenty-four hours after steeping and forty-six to forty-eight hours after steeping. Weights of original sample and increases in weights were recorded.

Moisture content:

The moisture content was determined by grinding or pulverizing a sample of barley in a Wiley mill. The samples were weighed and placed in an oven between one hundred and 105 degrees centigrade for twenty-four hours. Samples were removed, reweighed and moisture percentage calculated.

Protein content:

Total nitrogen content of each sample was run by using the Kjeldahl method of nitrogen determination. These determinations were made by Dr. J. E. Webster, Agricultural Chemistry Department, Oklahoma Agricultural And Mechanical College. Total nitrogen was converted to protein by multiplying the crude nitrogen by 6.25.

Kernel weight of barley;

Samples were cut down to approximately one thousand kernels with a Boerner sampler. One thousand whole kernels were counted, without selection, weighed and the weight determined in grams.

RESULTS AND DISCUSSION

Stillwater Oklahoma Crop season 1939-1940.

The data on the physical and chemical analysis of winter barley varieties grown at Stillwater, Oklahoma during the crop year 1939-1940 are given in Table I. Bushel weight on all varieties ranged from 43.3 pounds for Club Mariout to 51.4 pounds for Ward. According to official standards (40) barley must test at least forty-three pounds to the bushel to grade "malting barley." All the varieties meet these requirements on test weight per bushel.

The percentage of broken kernels present in each of the samples was such that only two varieties, Michigan Winter and Wisconsin Winter, could not be classed into malting grades. Missouri Early Beardless was lowest with no broken kernels and Michigan Winter highest with nine percent. Five percent or less is allowed for malting barley.

Broken kernels are objectionable in barley intended for malting purposes because the broken kernels will not malt and must be removed to be sold as feed barley. If not removed in cleaning, the broken kernels absorb water more rapidly than the kernels which are normally covered. Irregularity or complete loss of germination occurs and the nongerminating kernels mold. Thus there is a serious reduction in both quality and quantity of malt.

Table I

PHYSICAL AND CHEMICAL ANALYSIS OF WINTER BARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop year 1939-1940*

Variety	Manchuria	Mich. Winter	Club Mariout	Brown Winter
Moisture content	8.94	8.92	8.93	8.94
Bushel weight (Air dry)	48.3	46.2	43.3	49.3
Bushel Weight (Dry basis)	44.0	42.0	39.4	44.9
Broken kernels	2.76	9.20	3.23	3.36
Skinned kernels	13.90	16.50	8.95	9.52
1000 kernel weight (Dry basis)	40.40	37.53	35.82	26.59
Hull content (Dry basis)	12.01	13.47	14.84	10.94
Endosperm texture (Dry grain)				
Mealy	39	25	61	68
Semi-steely	25	42	28	30
Steely	36	33	11	2
Index of Mellowness	51.5	46.0	75.0	83
Moisture absorbed				
22 to 24 hrs.	38.08	36.57	36.57	36.46
46 to 48 hrs.	42.96	42.69	4249	42.37
Endosperm texture (After steeping)				
Mealy	79	80	12	58
Semi-steely	20	19	43	42
Steely	1	1	45	0
Index of mellowness	89.0	89.5	33.5	79.0
Protein content	14.56	15.75	15.44	17.44

*Weights per bushel are in pounds, 1000 kernel weights in grams, all other notations in percentages.

(Continued)

Table I (cont'd)

PHYSICAL AND CHEMICAL ANALYSIS OF WINTER BARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop yeat 1939-1940*

Variety	Tenkow	Wis. Winter	Mo. Early Beardless	Ward
Moisture content	8.94	8.96	8.94	8.94
Bushel weight (Air dry)	45.8	46.7	43.6	51.4
Bushel weight (Dry grain)	41.71	42.52	39.7	46.8
Broken kernels	3.98	5.62	0	2.28
Skinned kernels	16.05	8.70	4.17	23.25
1000 kernel weight (Dry basis)	40.05	36.20	28.89	34.09
Hull content (Dry basis)	11.14	9.70	12.01	9.66
Endosperm texture (Dry grain)				
Mealy	46	66	44	28
Semi-steely	41	26	36	55
Steely	13	8	20	17
Index of mellowness	66.5	79.0	62.0	55.5
Moisture absorbed				
22 to 24 hrs.	35.18	35.91	34.28	35.79
46 to 48 hrs.	40.85	40.77	39.89	41.74
Endosperm texture (After steeping)				
Mealy	42	32	46	36
Semi-steely	56	52	48	44
Steely	2	16	6	20
Index of mellowness	70	58.0	70.0	58.0
Protein content	16.06	14.88	10.63	13.94

*Weights per bushelare in pounds, 1000 kernel weights in grams, other notations in percentages.

Skinned kernel percentages were exceedingly high in all samples except Missouri Early Beardless which contained only 4.17 percent, 0.83 percent less than the limit of 5 percent for malting barley. Ward had 23.25 percent of skinned kernels, which was the highest percentage of any of the varieties tested. Skinned kernels are even more objectionable than broken kernels because they cannot be screened out of barley intended for malting purposes, and because they do not convert properly during the malting process.

Malloch in Table II brings out the effect of skinned kernels on germination and acrospire growth.[1]

Table II

EFFECT OF SKINNING ON GERMINATION AND GROWTH

Sample	Germination percent	Acrospires escaped %
Good quality English malting barley	100	1
Ended and chipped grains from Australian Chevalier barley	100	20
Skinned grains with embryo exposed from Australian Chevalier barley	76	65

The official standards for barley provide a five percent limit of skinned and broken kernels in the grades for malting barley. As is shown in Table I, only

---

[1] Mallock, J. K., The Cleaning and Handling of Barley. Sci. Agri. 16: No. 6, 289-321, 1936.

one variety, Missouri Early Beardless, having 4.17 percent, contains less than five percent of skinned and broken kernels. Percentages in the other varieties range from 12.18 percent in Club Mariout to 25.70 percent in Michigan Winter. The high percentage of broken and skinned kernels are physical characteristics which are caused in threshing by (24) "high cylinder speed, concave teeth set too close to cylinder, too many concave teeth, worn and rounded teeth of the cylinder and the concave, unequal adjustment between concave and cylinder teeth, end play in the cylinder allowing it to rub the kernels too closely as they pass through." With proper adjustments, these physical conditions might be corrected and lower percentages of skinned and broken kernels obtained. Malloch (25) suggests that only two rows of teeth in concaves set well down from the cylinder be used.

The yield of malt from barley is influenced by the size of kernel or one thousand kernel weight. Analysis of the varieties in Table I, show a variation from 26.59 grams per thousand kernels for Brown Winter to 40.40 grams for Manchuria. In the American malting industry, a weight of thirty grams per thousand kernels is standard for malting varieties. California barley, most of which is exported to the British Isles, has exceptionally high kernel weights, and if the weight is over fifty grams per thousand kernel, it is considered of the finest quality. English brewers, with their malting procedure, prefer a large berry because it gives slightly more extract than a smaller one. On the other hand, American Maltsters prefer a small kernel because they feel a more complete conversion of starch to malt sugar is obtained by enzymatic action on the smaller kernel types. The weight of grain, or plumpness, is modified by variety, but to a greater extent by climatic and cultural conditions.

Although Brown Winter had the lowest 1000 kernel weight, the berries were plump and heavy as indicated by next to the highest test weight per bushel. The high kernel weight of Manchuria was also accompanied by a reasonably high weight per bushel. Missouri Early Beardless had a 1000 kernel weight of 28.89 grams. This low kernel weight was due to a low test weight per bushel and small shriveled kernels. All other varieties had reasonably high kernel weights.

Thin-skinned barleys are preferable, but a certain amount of hull is needed for drainage during the malting process. The hull content of the varieties in Table I, range from 9.66 percent for Ward to 14.84 percent for Club Mariout, a difference of 5.18 percent between the highest and lowest varieties. This difference is associated very closely with the test weight per bushel. Ward, which had the highest weight per bushel, had the lowest hull content. Club Mariout with the lowest test weight per bushel had the highest hull content. These figures bear

Table III

DAILY PRECIPITATION 1940, STILLWATER , OKLAHOMA

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	.03											
2							.42					
3		.21					1.36		.03	.08		
4	.27							.06	.11			
5									.49		.03	
6	.07	.07		.60				.12				
7	.29		.03	.92		.44						
8					.11							
9					.36	.36		1.58			.15	
10				.64		1.84				.19	T	
11				1.71		.04				.03		.20
12							.56	.03			T	.08
13								.03				
14	.01											
15								.28		.27		.87
16		.66			.04			.18				
17		1.07		.24				1.86				
18		.75			.02	T		.05				
19	T	T			.21							
20											1.11	
21											.68	
22											.10	
23	.02	.21			.25		.06		.37		.71	
24		.11	.06		.03	1.10	.03		.07		.25	
25					.04				T		.14	
26				.89					.05		1.93	.44
27												.51
28				1.02				.91		.21		
29			.10			.77				.12		
30									.05			
31					.16			.52		.23		
Total	.69	3.71	.19	6.02	1.22	4.55	2.43	5.62	1.17	1.13	5.10	2.10

out the fact that plump kernels have a low hull percentage and shriveled kernels have a high hull percentage.

The percentage of mealy kernels ranged from 25 percent in Michigan Winter to 68 percent in Brown Winter as shown in Table I. Official grain standards (40) for barley provide that malting barley shall contain 75 percent or more of mealy or mellow kernels. With ranges as shown in Table I, none of the varieties could be classed as malting barley. Brown Winter with 68 percent, Wisconsin Winter with 66 percent and Club Mariout with 61 percent were nearer malting grades than any of the other varieties tested. Manchuria, a type of varley at one time used extensively in the North Central States for malting, had 36 percent of steely kernels, the highest percentage of any of the varieties planted in 1939-1940. Michigan Winter had next to the highest percentage of steely kernels with 33 percent.

As shown by the index of mellowness, three of the varieties, Club Mariout, Brown Winter and Wisconsin Winter had an index of mellowness of 75 percent or more. These varieties had 75, 83 and 79 percent respectively. The index of mellowness figure is a method of evaluating and determining the actual percent of mealiness present in a barley sample. The varieties listed above on the basis of mealy kernels could be considered as suitable for malting purposes.

The differences in the percentage of mealy kernels in barley is due partially to varieties and partially to climatic conditions. Since steely or vitreous kernels are the opposite of mealy, the above factors would naturally have the same effect only in a reverse order. Elder (14) states, "There are four causes of steely unripe barley. They are premature cutting, lack of moisture due to being sown on poor land, late seeding which throws the maturing period into the hot weather, and lastly, continued hot dry weather during filling time." According to Petit (33), "Steeliness in barley is not of such great importance because it is possible, if the proper procedure is followed, to make malt from vitreous barley."

As shown in Table III, the 1940 growing season was very favorable for the development of barley kernels. The April and May distribution of rainfall was such that it favored slow, even ripening of the barley crop; however, this timely precipitation was accompanied by intermittent increases in temperature, which are not conducive to the production of malting quality barley. The last two days in March had a daily mean temperature of 69.7 degrees compared to the monthly mean temperature of 50 degrees. The first four days in April had a daily mean temperature of 69.8 degrees, compared to a monthly mean temperature of 59.4 degrees. These temperatures were high for that time of year. Warm periods also occurred during the remainder of April and all of May. The first ten days in June, at which time the barley crop was maturing, the average daily maximum temperature was 90 degrees. These high temperatures were accompanied by reasonably dry weather during the last ten days in May and first week in June. The vitreous or steely kernels could have formed during this warm, dry period.

The index of mellowness, after steeping, did not correlate with that of dry barley as is shown in Table IV. below. The percentage of mealy kernels increas markedly

Table IV.

RELATION OF INDEX OF MELLOWNESS BEFORE AND AFTER STEEPING OF BARLEY VARIETIES
Grown at Stillwater, Okla., during crop year 1939-1940.

VARIETY	INDEX OF MELLOWNESS	
	Dry grain	After Steeping
Manchuria	51.0	89.0
Michigan Winter	46.0	89.5
Club Mariout	75.0	33.5
Brown Winter	83.0	79.0
Tenkow	66.5	70.0
Wisconsin Winter	79.0	58.0
Mo. Early Beardless	62.0	70.0
Ward	55.5	58.0

in Michigan Winter and Manchuria after steeping; whereas, the other varieties, except Wisconsin Winter and Club Mariout, show little or no change in the percentage of mellow kernels. These varieties decreased from 66.0 to 32.0 and 61.0 to 12.0 percent respectively. It is difficult to explain these variations, since steeping over a twenty-four hour period should increase the percentage of mealy and semi-steely kernels.

Protein content of all varieties grown in 1940 was exceptionally high as shown in Table I, except for Missouri Early Beardless, which had the low percentage of 10.63 percent. Brown Winter with 17.44 percent contained the highest percentage of all the barleys tested. These figures present a range of 6.81 percent of protein among the eight varieties grown on the same type of soil and with the same cultural and climatic conditions. Graph I shows there is no correlation between the percentage of mealy kernels and protein content of the different varieties of barley grown at Stillwater in 1939-40.

Numerous factors might influence the protein content of barley kernels. The long rainless seasons of California and its relatively poor soil are both important in producing a low-protein malting barley. Gilmore and Fletcher (15) are of the opinion that a mealy consistency of the barley kernel usually indicates a lower protein content than a flinty kernel. Ehrich and Kneip (13) showed,

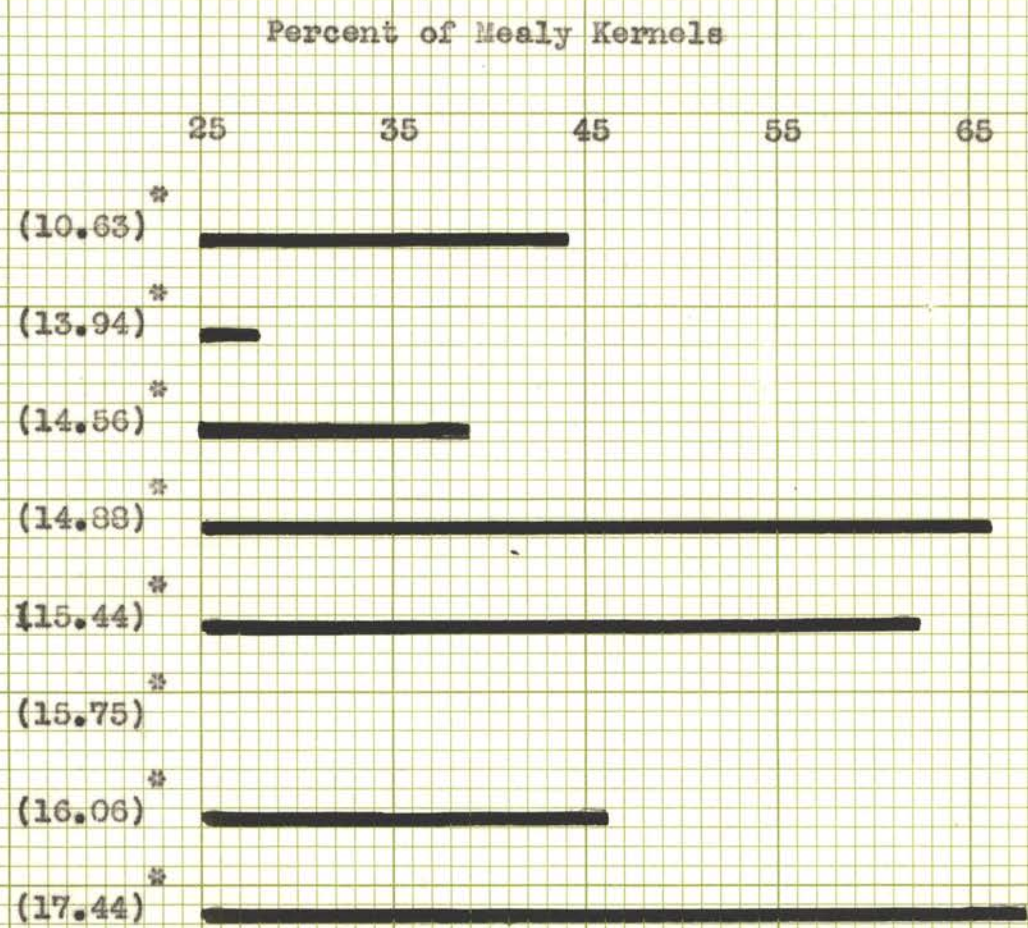
> "When a barley sample was separated into mealy, semi-steely and steely kernels, the protein content increased in the above order. During malting it was found that the steeping period was much shorter for the mealy portion of the sample than for the steely kernels."

As is evident in Table I and Graph I observations of this experiment do not coincide with those of the authors above.

Russell (36) in ten years of barley investigations at the Rothamsted Experiment Station of England makes

GRAPH I

PROTEIN CONTENT IN RELATION TO MEALINESS OF KERNELS



* Percent of Protein in Samples

the following statement regarding the possibility of controlling nitrogen content of barley, "It is easy to increase the nitrogen content of the grain beyond what is obtained by ordinary good cultivation and management but difficult to decrease it at will much below this level."

According to Leith (23) "Nitrogen seems to be the element most responsible for increasing the protein in the grain crop. Water evidently plays an important part in the retention of nitrogen in the soil as a considerable amount of rainfall washes out the soluble nitrate fertilizer and the plants will be short of nitrate in finishing out the ripening process, hence will show higher proportion of starch at maturity. In dry regions on black prairie soils which are high in organic matter, it seems evident that lack of rainfall plays a part in producing a high percentage of protein in the crop of grain. High protein alone may not be deleterious to malting, but the glassy kernel caused by heat at ripening time is very apt to result in kernels which will be slow in their rate of water absorption; hence quite undesirable for malting."

Some of the factors which may have been responsible for the high protein content of the barley varieties grown in 1939-1940 are; type of soil, warm temperatures during the later part of the growing season; varieties, date of maturity, the prevalence of stem rust, Puccinia graminis hordei, barley stripe disease, Helminthosporium gramineum, and the amount of available nitrogen in the soil.

In the malting process the barley kernel contains between 43 percent and 46 percent of moisture which is absorbed during a steeping period of 36 to 50 hours. If the desired percentage of moisture is not absorbed in the 50 hour steeping period, the quality and quantity of of malt produced is decreased as a result. Table I shows a range in moisture absorbed from 39.89 percent for Missouri Early Beardless to 42.96 percent for Manchuria. No significant differences occur between the highest and lowest percents of water absorbed, but none of the varieties absorbed moisture as rapidly as malting barleys should during the steeping period. The high percentages of proteins in the samples did not seem to inhibit the intake of moisture as is the belief of some investigators.

Results-Fall sown barley varieties grown at Stillwater, Oklahoma during the 1940-1941 growing season.

Data presented in Table V show lower average test weights per bushel for all varieties produced in 1941 as compared with those grown in 1940. The average test weight per bushel for the varieties grown in 1940 was 46.8 pounds and those grown in 1941 was 43.1 pounds, a difference of 3.7 pounds per bushel. Brown Winter had the highest test weight per bushel with 45.6 pounds and Missouri Early Beardless the lowest with 37.4 pounds per bushel.

As is evident from the data presented in Table V. the percentage of mealy kernels is low in all varieties ranging from 7 percent for Michigan Winter and Italiani to 27 percent for Cape and Missouri Early Beardless. When compared to a minimum of 75 percent to be classed as malting barley these percentages are very low. The 24 hour steeping period did not alter the percentage of mealy kernels in any of the samples grown at Stillwater this season to any marked degree. Tenkow, which was grown on the farm of Mr. C. O. Kienzie of Perkins, Oklahoma, had 74 percent of mealy kernels after steeping as compared to three percent in the dry grain.

The protein content of the varieties grown in the 1940-1941 crop year at Stillwater was unusually high,

Table V

PHYSICAL AND CHEMICAL ANALYSIS OF WINTER BARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop year 1939-1940*

Variety	Cape	Italiani	Manchuria	Brown Winter
Moisture content	10.62	10.63	10.35	10.32
Bushel weight (Air dry)	41.1	42.2	39.3	45.6
Bushel weight (Dry basis)	36.7	37.7	35.2	40.88
Broken kernels	4.78	5.61	5.89	6.45
Skinned kernels	6.94	6.13	6.33	5.23
1000 kernel weight (Dry basis)	29.63	27.71	28.37	25.62
Hull content (Dry basis)	14.60	12.64	16.08	13.10
Endosperm texture (Dry grain)				
Mealy	27	7	19	8
Semi-steely	50	36	46	53
Steely	23	57	35	39
Index of mellowness (Dry grain)	52.0	25.0	42.0	34.5
Moisture absorbed				
22 to 24 hrs.	38.86	37.39	3924	37.60
46 to 48 hrs.	42.16	42.11	43.79	41.33
Endosperm texture (After steeping)				
Mealy	46	24	28	6
Semi-steely	52	64	64	68
Steely	2	12	8	26
Index of mellowness	72.0	56.0	60.0	40.0
Protein content	15.38	16.25	16.50	16.74

* Weights per bushel are in pounds, 1000 kernel weights in grams, other notations in percentages.

(Continued)

Table V (cont'd)

PHYSICAL AND CHEMICAL ANALYSIS OF WINTER VARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop year 1939-1940*

Variety	Mich. Winter	Wis. Winter	Tenkow
Moisture content	10.61	10.51	10.18
Bushel weight (Air dry)	44.2	41.9	45.0
Bushel weight (Dry basis)	39.5	37.5	40.4
Broken kernels	7.54	4.85	4.56
Skinned kernels	7.44	3.90	8.42
1000 kernel weight (Dry basis)	27.27	29.23	32.78
Hull content (Dry basis)	13.55	12.59	11.61
Endosperm texture (Dry grain)			
Mealy	7	26	22
Semi-steely	54	49	47
Steely	39	25	31
Index of mellowness	34.0	50.5	45.5
Moisture absorbed			
22 to 24 hrs.	38.48	37.03	34.35
46 to 48 hrs.	43.08	43.16	37.04
Endosperm texture (After steeping)			
Mealy	0	34	30
Semi-steely	74	64	70
Steely	26	2	0
Index of mellowness	37.0	66.0	65.0
Protein content	16.25	16.06	15.19

*Weights per bushel are in pounds, 1000 kernel weights in grams, other notations in percentages.

(Continued)

Table V (cont'd)

PHYSICAL AND CHEMICAL ANALYSIS OF WINTER BARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop year 1939-1940*

Variety	Mo. Early Beardless	I-35-72 Okla. Sel.	(1) Tenkow
Moisture content	10.61	9.77	10.86
Bushel weight (Air dry)	41.8	44.0	49.1
Bushel weight (Dry basis)	37.4	39.7	43.77
Broken kernels	5.37	2.96	.63
Skinned kernels	13.05	5.70	3.21
1000 kernel weight (Dry basis)	25.74	32.60	36.29
Hull content (Dry basis)	12.05	12.26	10.60
Endosperm texture (Dry grain)			
Mealy	27	12	3
Semi-steely	54	46	34
Steely	19	42	63
Index of mellowness	54.0	36.0	20.0
Moisture absorbed			
22 to 24 hrs.	38.20	35.39	32.18
46 to 48 hrs.	42.63	37.41	36.88
Endosperm texture (After steeping)			
Mealy	28	22	74
Semi-steely	64	64	24
Steely	8	14	2
Index of mellowness	60.0	54.0	86.0
Protein content	16.06	15.38	11.63

*Weights per bushel are in pounds, 1000 kernel weights in grams, other notations in percentages.

1 Grown on C. O. Kinzie farm near Perkins, Okla.

ranging from 15.19 percent for Cape to 16.74 percent for Brown Winter. These high percentages can be attributed to the heavy type soil on which the crop was grown and the high percentage of organic matter in the soil. The low test weight and high percent of steely kernels are indicative of high protein in the barley kernel. The stem rust, Puccinia graminis, epidemic of the late spring retarded plant growth, thus prohibiting full growth and development of the barley kernels, possibly inhibiting proper translocation or infiltration of starch. As shown in Table VI the high rainfall during April, May and June of 1941 inhibited normal plant development, because the heavy soil prevented free drainage of water and free air circulation about the plant roots.

The sample of Tenkow grown on the C. O. Kinzie farm near Perkins had a higher test weight per bushel and 1000 kernel weight than Tenkow grown on the Experiment Station Farm at Stillwater. The percentage of mealy kernels in dry grain was higher in the Stillwater sample as well as the index of mellowness; however, the percent of mealy kernels in the Perkins sample after steeping was 74 percent and the Stillwater sample was 30 percent. The index of mellowness was 86 percent on the Perkins sample as compared to 65 percent on the Stillwater sample. The variations are probably due to differences in soil type and fertility as is indicated by the protein in the two samples. The Perkins sample containing 3.56 percent less protein than the Stillwater sample.

In Table VIII six varieties grown at Stillwater during the crop years 1939-1940 and 1940-41 are compared with respect to various uncontrollable factors. These six varieties were planted on the same soil seasons and had like cultural practices prior to planting. The data present certain positive and negative factors when each variety is compared and also when all varieties are compared during the two crop seasons. The test weight per bushel was higher for the 1940 crop season with an average of 4.0 pounds per bushel more for all varieties. Tenkow grown in 1940 weighed only .8 pounds more per bushel than that grown in 1941.

The 1000 kernel weight coincided with the weight per bushel. Brown Winter weighed only 0.97 grams per 1000 kernels more in 1940 than in 1941, which was the narrowest range of difference, while Manchuria weighed 12 grams more in 1940 than in 1941. Varieties grown in 1940 weighed an average of 6.75 grams more per 1000 kernel than those grown in 1941.

The hull content increased with higher test weights and lower 1000 kernel weights. Hull content averaged 1.60 percent greater in the 1941-grown varieties than

Table VII

DAILY PRECIPITATION STILLWATER, OKLA., 1941

Date	Jan.	Feb.	Mar.	April	May	June
1		.71				.73
2		.53		T	.10	
3						
4				T	.20	
5			T		1.53	
6	.02		.24		.25	.37
7	.02		.14	.29	.81	.63
8				.02		
9						.45
10					.99	.78
11						
12		.01	.15			
13	.22	.02				
14	.11		.04	.23		
15			T	1.04		
16	.10			.73		
17	.07					
18	T	.13		.20		
19		.10		.71		
20		.07			.68	
21		.02			1.77	
22		.01			.06	
23				.45	.65	
24	.10	.21				
25	.10					
26		.13	.03			.60
27			.08		.31	.11
28						.99
29				.03		
30	.03		.07	.55	.23	
31						
Total	.77	1.94	.75	4.25	7.58	4.66

those of the 1940 season. The widest difference in hull content occurred in Manchuria with an increase of 4.07 percent and the narrowest increase was .04 percent in Missouri Early Beardless.

Barley kernels were more mealy and had a higher index of mellowness in 1940 than 1941. The average increase in the index of mellowness for dry grain and steeped grain was 21.25 percent. Wisconsin Winter showed an increase of 8 percent in 1941 over 1940 for the after-steeping sample. No logical explanation can be given for such a reaction since the dry grain in 1940 contained a higher percent of mealy kernels than the steeped lot in 1941.

No significant differences occur between the two crop seasons with respect to the amount of moisture absorbed by the barley kernels. On the whole, the 1941 grown samples absorbed more moisture than those grown in 1940. The average percentage of increase for all six varieties was only 0.25 percent. Four of the varieties showed increases in moisture absorption in 1940, while two showed increases for the 1940 season. Tenkow showed the greatest difference of all the varieties, with the 1940 sample absorbing more moisture than the 1941.

Protein content was higher in four of the six varieties in 1941 and two of the varieties grown in 1940. The

Table VII

COMPARISON OF SIX WINTER BARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop years 1940 and 1941.

	Manchuria			Brown Winter		
	1940	1941	Difference	1940	1941	Difference
Bushel weight (Air dry)	48.3	39.3	9.0	49.3	45.6	3.7
1000 kernel weight	40.4	28.4	12.0	26.59	25.62	.97
Hull content	12.01	16.08	4.07	10.94	13.1	2.07
Index of mellowness (Dry grain)	51.5	42.0	9.5	83.0	34.5	48.5
Index of mellowness (After steeping)	89.0	60.0	29.0	79.0	40.0	39.0
Moisture absorbed	42.96	43.79	.83	42.37	41.33	1.04
Protein content	14.56	16.50	1.94	17.44	16.74	.70

*Weights per bushel are in pounds, 1000 kernel weights in grams, other notations in percentages.

(Continued)

Table VII (cont'd)

COMPARISON OF SIX WINTER BARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop years 1940 and 1941*

	Michigan Winter			Tenkow		
	1940	1941	Difference	1940	1941	Difference
						.8
Bushel weight (Air dry)	46.2	42.2	4.0	45.8	45.0	.8
1000 kernel weight	37.53	27.27	10.26	40.05	32.87	7.18
Hull content	13.47	13.55	.07	11.14	11.61	.47
Index of mellowness (Dry grain)	46.0	34.0	12.0	66.5	45.5	21.0
Index of mellowness (After steeping)	89.5	37.0	52.5	70.0	65.0	5.0
Moisture absorbed	42.69	43.08	.39	40.85	37.04	3.81
Protein content	15.75	16.25	.50	16.06	15.19	.87

*Weights per bushel are in pounds, 1000 kernel weights in grams, other notations in percentages.

(Continued)

Table VII (Cont'd)

COMPARISON OF SIX WINTER BARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop years 1940 and 1941*

	Wisconsin Winter			Mo. Early Beardless		
	1940	1941	Difference	1940	1941	Difference
Bushel weight (Air dry)	46.7	41.9	4.8	43.6	41.8	1.8
1000 kernel weight	36.20	29.23	6.97	28.89	25.74	3.15
Hull content	9.70	12.59	2.89	12.01	12.05	.04
Index of mellowness (Dry grain)	79.0	50.5	28.5	62.0	54.0	8.0
Index of mellowness (After steeping)	58.0	66.0	8.0	70.0	60.0	10.0
Moisture absorbed	40.77	43.16	2.39	39.89	42.63	2.74
Protein content	14.88	16.06	1.18	10.63	16.06	5.43

*Weights per bushel are in pounds, 1000 kernel weights in grams, other notations in percentages average protein content for all six varieties grown in 1940 was 14.89 percent, and for those grown in 1941 it was 16.13 percent, a difference of 1.24 percent more in 1941 than in 1940. The greatest increase in protein content occurred in Missouri Early Beardless, the 1941 sample containing 5.43 percent more than the 1940 sample.

It is evident from Table VII that certain positive differences exist between the 1940 and 1941 growing seasons, as shown by the measuring factors. These outstanding features are evident:

1. The average test weight per bushel was higher in 1940 than in 1941.
2. The 1000 kernel weight was higher in 1940 than in 1941, which indicates test weight and 1000 kernel weight closely correlate.
3. Hull ratio was greater on the 1941 crop than the 1940 crop. From these data it is evident that hull ratio is closely associated with lower test weight per bushel and low 1000 kernel weight.
4. A higher percentage of mealy kernels was produced in 1940 as indicated in the index of mellowness than in 1941. The index of mellowness of dry grain and steeped grain was higher in 1940 than 1941. This factor also correlates closely with test weight per bushel and 1000 kernel weight.

5. The difference in the amount of moisture absorbed was negligible when all varieties were compared for both years.

6. The average protein content was 1.24 percent higher on all six varieties in 1941 than in 1940. This factor seems to be associated with low test weight per bushel, low 1000 kernel weight and low percentage of mealy or mellow kernels.

Results- Spring sown barley varieties grown at Stillwater, Oklahoma during the 1941 growing season.

The barley varieties grown in the spring of 1941 had very unfavorable environmental conditions under which to grow and mature. The daily precipitation (Table VI) during the months of April, May and June was unusually high. Temperature and humidity were such as to favor the development of stem rust, *Puccinia graminis hordei*, and to prevent normal plant development.

The test weight per bushel and 1000 kernel weight was so low that none of the varieties could be considered for malting purposes. Test weights per bushel ranged from 33.5 pounds for Manchuria to 42.9 pounds for Spartan. The 1000 kernel weight indicated a high percentage of shriveled and immature kernels.

The immature and shriveled kernels are evidenced by the high percentage of hull. Manchuria with the lowest test weight per bushel had 17.30 percent of hulls, which was the highest and Spartan with the highest test weight per bushel had 14.37 percent of hulls, which was the lowest.

The percent of mealy kernels of dry grain ranged from none in Spartan and Tenkow to 16 percent for Velvet. The percentage of steely kernels developing under such environmental conditions as mentioned before would naturally be high. The range was 39 to 82 percent. The

Table VIII

PHYSICAL AND CHEMICAL ANALYSIS OF SPRING BARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop year 1941

Variety	Velvet	Club Mariout	Tenkow	Manchuria
Moisture content	11.52	10.78	10.62	10.39
Bushel weight (Air dry)	39.7	41.9	39.7	33.5
Bushel weight (Dry basis)	35.1	37.38	35.5	30.02
Broken kernels	3.60	1.65	1.31	1.67
Skinned kernels	16.88	8.29	12.31	6.96
1000 kernel weight)Dry basis)	27.2	34.25	28.77	23.93
Hull content (Dry basis)	15.4	14.57	16.16	17.30
Endosperm texture (Dry grain)				
Mealy	16	7	0	4
Semi-steely	45	37	30	17
Steely	39	56	70	79
Index of mellowness	38.5	26.5	15.0	12.5
Moisture absorbed				
22 to 24 hrs.	38.88	37.07	37.83	42.58
46 to 48 hrs.	41.91	40.07	40.58	46.52
Endosperm texture (After steeping)				
Mealy	22	44	20	30
Semi-steely	62	50	78	62
Steely	16.0	6	2	8
Index of mellowness	53.0	69.0	59.0	61.0
Protein content	14.94	13.88	14.94	17.08

*Weights per bushel are in pounds, 1000 kernel weights in grams, other notations in percentages.

(Continued)

Table VIII (cont'd)

PHYSICAL AND CHEMICAL ANALYSIS OF SPRING BARLEY VARIETIES
Grown at Stillwater, Oklahoma during the crop years 1941*

Variety	Cape	Timerick	Italiani	Spartan
Moisture content	10.39	10.51	10.86	10.99
Bushel weight (Air dry)	35.2	41.9	40.7	42.9
Bushel weight (Dry basis)	31.5	37.5	36.28	38.19
Broken kernels	1.44	1.50	1.06	1.43
Skinned kernels	8.38	14.50	10.59	26.58
1000 kernel weight (Dry basis)	24,95	26.78	28.31	31.92
Hull content (Dry basis)	15.83	14.87	14.80	14.37
Endosperm texture (Dry grain)				
Mealy	1	2	4	0
Semi-steely	33	39	27	18
Steely	66	59	69	82
Index of mellowness	17.5	21.5	17.5	9.0
Moisture absorbed				
22 to 24 hrs.	40.92	36.83	36.40	35.89
46 to 48 hrs.	48.05	41.06	40.55	39.73
Endosperm texture (After steeping)				
Mealy	16	32	22	20
Semi-steely	70	68	72	76
Steely	14	0	6	4
Index of mellowness	51.0	66.0	58.0	58.0
Protein content	16.56	14.88	15.69	17.06

*Weights per bushel are in pounds, 1000 kernel weights in grams, other notations in percentages.

steeping period had little or no effect in increasing the percentage of mealy kernels.

The rate and percentage of moisture absorption by the spring varieties grown in 1941 was more satisfactory from a malting standpoint than any of the other groups tested. The rate of moisture absorption might be attributed to the high hull content which would allow rapid imbibition.

As shown in Table VIII, high protein content is closely associated with small (shrunken and poorly filled) kernels, low test weight per bushel, and a high percentage of steely kernels. Such a condition exists with the spring sown barley varieties of 1941. Factors mentioned earlier are responsible for the high percentages of protein. Harlan (18) in discussing factors influencing protein content in barley states, "Barley grown on rich land contains more protein than barley grown on lands of moderate fertility. Thin barley has more protein than plump barley. Barley grown in the humid areas contains a higher percentage of protein than barley grown in the West." Russell and Bishop (36) found in their investigations that the following factors tend to increase nitrogen or protein content in barley: "Increasing beyond a certain point the supply of soluble nitrogen nutrients to the plant; growing the crop on soils righ in organic matter; dry weather during the spring months, especially April and May; late planting; sowing in wide rows; planting varieties containing a high percentage of nitrogen."

He also goes on to say that "a decreased nitrogen content in the barley kernel is brought about by wet weather during April and May; early planting; growing after a fallow."

<u>Results- Winter sown barley varieties grown at Grove, Oklahoma during the 1940-41 growing season.</u>

The test weight per bushel was not obtained on the three varieties grown at Grove, Oklahoma because the samples were too small. The 1000 kernel weight was higher on the three varieties (Manchuria, Tenkow and Michigan Winter) grown at Grove than on the same ones grown at Stillwater. Considering the size of kernels as an index to bushel weight, the Grove-grown samples would have higher test weights per bushel than the same varieties grown at Stillwater.

The percentage of mealy kernels in the dry grain of Manchuria was 8 percent and the index of mellowness was only 36 percent. Tenkow and Michigan Winter had 45 and 43 percent of mealy kernels. Index of mellowness percentages was high for these two varieties grown at Stillwater the same year. Michigan Winter grown at Stillwater had an index of mellowness of 34 as compared to 66.5 percent for the sample from Grove. Tenkow grown at Grove had an index of mellowness of 63 as compared to 45.5 percent for the Stillwater grown sample.

After the varieties were steeped twenty-four hours and mealiness determinations were made, the percentage of mealy kernels and index of mellowness was unusually high on all three varieties. Manchuria had 88 percent of mealy kernels and an index of mellowness of 94 percent, the

Table IX

PHYSICAL AND CHEMICAL ANALYSIS OF WINTER BARLEY VARIETIES
Grown near Grove, Oklahoma during the crop year 1940-41*

Variety	Manchuria	Tenkow	Mich. Winter
Moisture content	10.00	9.68	9.86
Bushel Weight (Air dry)	**	**	**
Bushel weight (Dry basis)	**	**	**
Broken kernels	1.93	1.97	4.73
Skinned kernels	6.65	6.76	5.44
1000 kernel weight (Dry basis)	42.64	37.29	33.08
Hull content (Dry basis)	10.50	11.29	11.05
Endosperm texture (Dry grain)			
Mealy	8	45	43
Semi-steely	56	36	47
Steely	36	19	10
Index of mellowness	36.0	63.0	66.5
Moisture absorbed			
22 to 24 hrs.	33.34	32.36	35.95
46 to 48 hrs.	34.83	37.07	38.32
Endosperm texture (After steeping)			
Mealy	88	82	62
Semi-steely	12	18	38
Steely	0	0	0
Index of mellowness	94.0	91.0	80.0
Protein content	9.81	9.19	10.44

*Weights of 1000 kernels in grams, other notations in percentages.

**Samples too small to take test weight per bushel.

Table X

DAILY PRECIPITATION GROVE, OKLAHOMA, JULY 1940 to July 1941

Date	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1	T						1.45	.36			.92	2.05
2	T		.04				.01	.76		.12		
3			2.69					.04			.05	.03
4			.34						T	T		.47
5		.10	.02									
6				.38			.03		.09		.01	1.30
7							.01		1.40	.39	.22	
8		.05										.01
9		.12			.37							.15
10		.40	.04	.03	.05	T						3.72
11	.02	.74			.10	.62						
12						.05	.20		.18	.05		
13		.05			.02	.10	.51					.02
14				1.30		.13	.31			.80		
15		.16				.80	.48		.19	1.14		
16	.04	.59					.23			2.97	.16	
17		1.09								.03		
18		.39				.01				2.10		
19	.01				T			.02		1.86		
20					1.54			.28				
21	T				.75						T	
22	1.05				.32		T	.18			.04	T
23	.62		.21		.55		.15	.22		.01		
24			.42		.03		.02	.39				
25			.04		.21		.28	T				.01
26		1.16			1.10	T	.05	.02				
27		.23		T			T					
28		.01		.89			T					
29		.08								T		
30		T					.18		.04	.29		
31				.10		.19	.71					
Total	1.74	5.17	3.80	2.70	5.04	1.90	4.26	2.27	1.90	9.76	1.40	7.76

highest percentage of any of the varieties tested from the different locations. Such percentages of mealy kernels as existed in each of the three varieties, warrant further investigations in this area with other fall sown varieties and some spring sown varieties known to be acceptable for malting purposes.

The data in Table IX also show the varieties to contain lower percentages of protein than varieties grown in other parts of the state where samples were tested. The low percent of protein in the samples from Grove is due largely to the high rainfall during the crop year 1940-41 as shown in Table X, and the relatively poor soil, or lack of available nitrogen during the growing season. As were the samples from Idabel, moisture absorption was at a very slow rate.

Results- Michigan Winter barley sown at different spacings with various fertilizer treatments at Idabel, Oklahoma during the crop year 1940-41.

The data presented in Table XI show that different fertilizer treatments and spacings have little or no effect on the test weight per bushel. The plot on which an application of 200 pounds of 4-12-4 was applied, and which was planted in 14 inch rows had a test weight of 50.1 pounds per bushel, while the 7 inch spacing with 100 pounds of treble super phosphate added per acre had a test weight of 48.1 pounds per bushel. The test weight per bushel correlates closely with the 1000 kernel weight. The plot to which 4-12-4 fertilizer was applied had a test weight per bushel of 50.1 pounds and a 1000 kernel weight of 34.74 grams. Where 100 pounds of treble superphosphate was applied the test weight per bushel was 48.1 pounds and 1000 kernel weight was 31.80 grams.

The broken and skinned kernels, if taken collectively on all samples, total more than 5 percent, the maximum allowed to grade as malting barley. The total percentages range between 7.66 and 10 percent, which are not so great that thresher adjustments could remedy them.

The percentage of mealy kernels varied with the different treatments. The two plots planted in 7 inch rows had 76 and 79 percents of mealy kernels, while those

Table XI

PHYSICAL AND CHEMICAL ANALYSIS OF MICHIGAN WINTER BARLEY
Sown at different spacings with various fertilizer treatments
grown at Idabel, Oklahoma during the crop year 1940-1941.*

Variety	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5
Moisture content	10.06	10.03	10.11	10.43	10.50
Bushel weight (Air dry)	50.1	48.9	48.9	48.1	49.0
Bushel weight (Dry basis)	45.06	44.0	44.96	43.08	43.86
Broken kernels	1.90	1.30	1.50	2.15	2.30
Skinned kernels	7.31	6.36	6.29	7.85	5.37
1000 kernel weight(Dry basis)	34.73	33.24	32.59	31.8	34.35
Hull content (Dry basis)	10.79	11.21	10.85	11.84	9.07
Endosperm texture (Dry grain)					
Mealy	49.0	48	79	76	59
Semi-steely	32	38	18	18	29
Steely	19	14	3	6	12
Index of mellowness	65.0	67.0	88.0	85.0	73.5
Moisture absorbed					
22 to 24 hrs.	31.82	33.28	31.87	33.32	33.50
46 to 48 hrs.	37.08	37.89	36.69	37.87	37.63
Endosperm texture(After steeping)					
Mealy	76	80	84	68	76
Semi-steely	24	18	16	32	24
Steely	0	2	0	0	0
Index of mellowness	88.0	89.0	92.0	84.0	88.0
Protein content	11.06	11.69	10.94	11.00	10.63

*Weights per bushel in pounds, 1000 kernel weights in grams, other notations in in percentages.

**No.1 200 lbs 4-12-4 in 14" rows.
**No.2 14" rows, check.
**No.3 Check & 7" rows.
**No.4 100 lbs. treble super phos. 7" rows.
**No.5 100 lbs. treble super phos. 7" rows.

planted in 14 inch rows had 48, 49 and 59 percent of mealy kernels. These figures would indicate that barley planted at wider spacings have higher percentages of steely and semi-steely kernels and narrow spacings are conducive to mealy or mellow kernels. The application of fertilizer did not seem to influence the percentage of mealy kernels.

The check plot planted in seven inch rows had 79 percent of mealy kernels, and the plot with 100 pounds of treble superphosphate planted in 7 inch rows had 76 percent of mealy kernels. These two samples were the highest in percent of mealy kernels and according to official standards would grade malting barley . The other samples could not be classed into malting grades.

The factors responsible for the high percentage of mealy kernels in two of the lots of barley grown at Idabel are: type of soil, width of row, climatic conditions, especially rainfall during the months of April and May which favored slow ripening of the barley kernels.

The index of mellowness percentage after steeping was high for all spacings and fertilizer treatments. The high index of mellowness, 84 to 92, would indicate a high percentage of conversion of vitreous kernels to mellow kernels.

The percentage of moisture absorbed by each of the

Table XII

DAILY PRECIPITATION, IDABEL, OKLAHOMA, JULY 1940 THRU JUNE 1941

Date	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1	.79						.17	.44			.02	
2	1.44	T						.40		T		3.56
3	.20									.13	.68	.10
4			.14		.03						.23	
5			T						.74		.41	
6		.04				.03	T		.32			
7				.24		.41			.02	.28		.81
8												.02
9		T			1.71							
10		.06			1.55						.03	.96
11						1.00						1.14
12						.26			.02			
13						.08				.14		
14						.26	.50					.21
15	T			.45		1.34	.03		.43	.95		
16										.05		.56
17						.11						
18		.19						.32		.17		
19	.03	T						.11		.18		
20	3.36							.35	.09	.08		
21	.30		T		.41							
22	.08		.03		1.88			T	.01	.18		
23			.08		2.39		.62		.61	1.86		
24			.80		.05		.16	.37		.19		
25			.05		.41	.06	.17		T			T
26					.21	1.35	.22					
27						.08			T			
28		.59		.11							.01	1.24
29		T		1.18							.01	
30									.08	2.96	T	
31				.83								
Total	6.20	.83	1.10	2.81	8.64	4.98	1.87	1.99	2.32	7.17	.78	8.60

five treatments was below the amount which should be imbibed over a 48 hour steeping period. It is difficult to explain such a reaction, since most authorities (2), (10), (36) have proved that with a high percentage of mealy kernels, a high percentage of moisture is absorbed in a relatively short period of time.

The percentage of protein present in the fertilizer and apacing tests with Michigan Winter barley was low as compared with the same variety grown at Stillwater, Oklahoma during the same crop year. The low percentage of protein in the Idabel samples may be attributed to the high rainfall during the months of April and May as shown in Table XII. The relatively warm ripening season with greater tendency to disease and the leaching out of a part of the available nitrogen supply could be other influencing factors.

Results- Summary of the results of all varieties grown at the different locations during 1939-40 and 1940-41.

Data presented in Table XIII show that none of the varieties grown in the crop years 1939-40 and 1940-41 at the different locations could be graded as malting barley. The factor for determining the grade on all the varieties was test weight per bushel, except for the sample of Michigan Winter grown in 1939-40. The grading factor on this lot was broken kernels. Samples 3 and 4 grown at Idabel in 1940-41 had more than 75 per-cent of mealy kernels and could not be classed as malting barley because of the high percentage of skinned and broken kernels. These physical characters are controllable by proper threshing.

Table XIII

MARKET GRADES OF BARLEY GROWN AT DIFFERENT LOCATIONS IN OKLAHOMA, DURING THE CROP YEAR 1939-40 and 1940-41.

Variety	Grade Class	Determining Factor or Factors
Stillwater, Winter 1939-40		
Manchuria	No. 1 Barley	-----------
Michigan Winter	No. 3 Barley	Broken Kernels
Club Mariout	No. 3 Barley	Test Weight
Brown Winter	No. 1 Barley	-----------
Tenkow	No. 3 Barley	Test Weight
Wisconsin Winter	No. 2 Barley	T. W. and broken kernels
Mo. Early Beardless	No. 3 Barley	Test Weight
Ward	No. 1 Barley	
Stillwater, Winter 1940-41		
Cape	No. 4 Barley	Test Weight
Italiani	No. 4 Barley	Test Weight
Manchuria	No. 5 Barley	Test Weight
Brown Winter	No. 3 Barley	Test Weight
Michigan Winter	No. 3 Barley	Test Weight
Wisconsin Winter	No. 4 Barley	Test Weight
Mo. Early Beardless	No. 4 Barley	Test Weight
Tenkow	No. 3 Barley	Test Weight
Okla. Sel. 1-35-72	No. 3 Barley	Test Weight
Tenkow (Perkins)	No. 1 Barley	Test Weight
Stillwater, Spring 1941		
Velvet	No. 5 Barley	Test Weight
Club Mariout	No. 4 Barley	Test Weight
Tenkow	No. 5 Barley	Test Weight
Manchuria	Sp. Gr. Barley	Test Weight
Cape	No. 5 Barley	Test Weight
Timirick	No. 4 Barley	Test Weight
Italiani	No. 4 Barley	Test Weight
Spartan	No. 4 Barley	Test Weight
Idabel, Winter 1940-41		
Sample 1	No. 1 Barley	
Sample 2	No. 1 Barley	
Sample 3	No. 1 Barley	
Sample 4	No. 1 Barley	
Sample 5	No. 1 Barley	
Grove, Winter 1940-41	*	

* Not graded because samples were too small to obtain test weight per bushel.

SUMMARY AND CONCLUSIONS

1. Malting tests were made on samples of eight winter barley varieties grown in 1939-40, nine winter varieties grown in 1940-41, and eight spring varieties grown in the spring of 1941, at Stillwater Oklahoma.

2. Tests were also made on Tenkow barley grown at Perkins, Oklahoma, Michigan Winter grown at Idabel, Oklahoma with different fertilizer treatments and width of row spacings, and three varieties grown at Grove, Oklahoma during the crop year 1940-41.

3. The Winter barley varieties grown in 1939-40 at Stillwater, Oklahoma had higher test weight per bushel and 1000 kernel weights than the winter varieties grown at the same location in 1940-41.

4. The percentage of broken and skinned kernels was too high in all of the samples tested for any of them to be considered suitable for malting purposes.

5. The 1000 kernel weight was too low on the fall varieties grown in 1940-41 and spring varieties grown in 1941 for them to be classed malting barleys.

6. Hull content correlates closely with 1000 kernel weights and test weights per bushel; as the hull content increases the test weight per bushel and 1000 kernel weight decreases and as the hull content decreases, the test weight per bushel and 1000 kernel weight increases.

7. Width or row planting seemed to influence the percentage of mealy kernels in Michigan Winter barley planted at Idabel, Oklahoma in 1940-41. Seven inch rows had higher percentages of mealy kernels than 14 inch rows.

8. The application of 4-12-4 fertilizer and treble superphosphate did not increase the percentage of mealy kernels in Michigan Winter barley grown at Idabel.

9. Endosperm texture is influenced by environmental conditions and is not an inherited characteristic of the varieties tested.

10. Mealy kernel percentages were higher in varieties with high test weight per bushel and high 1000 kernel weights.

11. Brown Winter and Wisconsin Winter had the highest percentages of mealy kernels of any of the varieties, winter or spring, grown at Stillwater, Oklahoma in the years 1939-40 and 1940-41.

12. Michigan Winter, a check plot planted in 7 inch rows at Idabel in 1940-41, had 79 percent of mealy kernels, the highest of all samples tested.

13. The next highest percentage of mealy kernels was 76 percent for Michigan Winter planted in 7 inch rows with 100 pounds of treble superphosphate applied per acre, grown at Idabel in 1940-41.

14. Protein content was lowest in samples from Grove and Idabel.

15. Protein content is closely associated with test weight per bushel, 1000 kernel weight and percentage of mealy kernels. High protein is indicative of low test weight per bushel, relatively low 1000 kernel weight, and low percentage of mealy kernels.

16. High rainfall, poorly drained soil, prevalence of stem rust, *Puccinia graminis*, and high organic matter in the soil were factors responsible for the poor quality of barley grown at Stillwater in 1940-41.

17. None of the samples tested were classed as malting barley; however, the two samples grown at Idabel in 1940-41 with 76 percent of mealy kernels were more nearly malting grades, than any other samples. The percentage of broken and skinned kernels prevented those two samples from grading malting barley. By adjusting the threshing machine it would be possible to cut down on the percentage of broken and skinned kernels, and raise the market grade to malting barley.

18. The writer is of the opinion that it would be difficult to produce malting barley in Oklahoma year after year, since climatic conditions are very uncertain. Excessive rainfall in Eastern Oklahoma accompanied by warm humid temperatures is not conducive to the production of malting barley. Central Western Oklahoma have climatic features favorable to the development of

hard steely kernels, which are not desirable in the malting industry.

19. More investigations should be conducted on different soil types throughout Oklahoma where the rainfall is higher than thirty inches annually. The northeastern part of the state, where small grain is one of the principle crops, should be given more careful study, especially with spring varieties.

BIBLIOGRAPHY

1. American Society of Brewing Chemists., Methods of Analysis of the American Society of Brewing Chemists. Chicago, Ill., 1940.

2. Anderson, J. A., and Meredith, W. O. S., Laboratory Malting. III. Steeping Equipment and Method. Cer. Chem., 17, No. 1: 66-72, Jan. 1940.

3. Anderson, J.A. and Rowland, Harry, Studies on Malting Quality. I. 1935 Variety Trials. Sci. Agri., 17, No. 10; 593-600, June, 1937.

4. Barbee, O.E., Barley Production in Washington. Wash. Agri. Expt. Sta. Bul. 382. 1939.

5. Cates, J. S., Brewing Barley. Country Gentleman, 104: 7, 72-3. March, 1934.

6. Coleman, D. A., Report of the Committee on Standardization of Methods for Brewing and Malting Control. Cer. Chem. 12: No. 6, 575-595, 1935.

7. Derr, H. B., Barley: Growing the Crop U. S. Dept. Agri., Farmers Bul.443, 1911.

8. Dickson, J. G., A Survey of Malting Quality of Barley Varieties Grown in the United States. Brewery Age, 6: No. 10, 61-66, 1938.

9. Dickson, J. G., Dickson, A.D., Shand, H.L. and Burkhart, B. A., Barley and Malt Studies. II. Experimental Malting of Barley Grown in 1935. Cer. Chem. 14: No. 3, 316-327, 1937.

10. Ibid., Seventh Annual Report of Barley Quality Studies Including the Investigations Conducted During 1939-1940 on the Barley Grown in 1939. U. S. D. A. Mimeographed Report, 1940.

11. Ibid., Barley and Malt Studies. I. Developing New Varieties of Barley for Malting and Their Properties. Cer. Chem. 12: No. 6, 596-609, 1935.

12. Dupont, F. M., Malting Values. Report of Barley Improvement Conference held in Minneapolis, Minn. Jan. 25-26, 1933.

13. Ehrich, E. and Kneip, E., Malze aus mehligen, halbglasigen und Gerstenkornen. Z. ges. Brauw., 54: 98, 1931 (English summary)

14. Elder, A. F. Quality Requirements of Western Canadian Malting Barley. (Type written article on file in Grain Division, Bur. Agri. Eco., U.S. Dept Agri.)

15. Gilmore, J. W. and Fletcher, L. J. Desirable Qualities of California Barley for Export. Calif. Agr. Expt. Sta. Cir. 246. 1922.

16. Grant, H. C. Barley Survey. Great Britian. Empire Marketing Board, Publication No. 62, 1933.

17. Harlan, H. V., Growing Barley for Malt and Feed. U. S. Dept. Agri. Farmers' Bul. 1732, 1934.

18. Harlan, H. V. and Martini, M. L., Problems and Results in Barley Breeding. U. S. Dept. Agri., Yearbook, 303-346, 1936.

19. Harlan, H. V. and Weibe, G. A., Growing Barley for Malt and Feed. U. S. Dept Agri. Farmers' Bul. 1732, 1940.

20. Harrison, T. J., A Basis for the Valuation of Malting Barley. Sci. Agri. 9: No. 9, 599-610, 1929.

21. Hulton, H.F.E, Report on the Relation of Nitrogenous Matter in Barley to Brewing Value. Jour. Inst. Brewing, 28: No. 1, Sup. 33-142, 1922.

22. Kern, H. James, The Relationship of Date of Harvest to the Malting Quality of Barley Grown in West Texas. Thesis, Texas Technological College, Lubbock, Texas, 1941.

23. Leith, B. D., Quality of Malting Barley as Affected by Soil, Climate and Harvesting Methods. Report of Barley Improvement Conference held at Minneapolis, Minn. January, 1933.

24. Leith, B. D., Shand, H.L. and Moore, R. A. , Quality Barley, Wis. Agri. Expt. Sta. Ext. Cir. 278, 1936.

25. Malloch, J. K., The Cleaning and Handling of Barley. Sci. Agri. 16: No. 6, 289-321, 1936.

26. Malt Research Institute. Industrial Evaluation of two Barley Varieties Grown in 1939. Pub. No. 1, 1941.

27. Ibid. Industrial Evaluation of Two Barley Varieties Grown in 1940. Pub. No. II, 1942.

28. Meredith, W. O. S., Rowland, H., and Anderson, J. A., Malting Quality of Canadian Barleys. II. Nineteen Varieties, 1936 and 1937 Trials. Sci. Agri., 19: No. 6, 389-403, 1939.

29. Miller, F. A., A Century of Progress in Malting and Brewing. Rahr Malting Co., Manitowoc, Wisc., 1935.

30. Moor, R. A. and Stone, A. L., Barley Culture in Wisconsin. Wis. Agri. Expt, Sta. Bul. 212, 1914.

31. Morey, D.D., Barley Investigations on the Southern High Plains of Texas with Particular Emphasis on the Production of Malting Barley. Thesis, Texas Technological College, Lubbock, Texas, 1938.

32. Nowell, Herbert T., Irrigation of Barley. Wyo. Agri. Expt. Sta. Bul. 77, 1908.

33. Petit, P., Les alteration du grain a la tempe. Brasserie et Malterie, 23: 369, 1934 (English Summary)

34. Rhode, H. W., Malting and Mashing. Cer. Chem., 12: No. 6, 610-620, 1935.

35. Rothamsted Conferences No. VII. Summary of Report of Conference held March 15, 1928. London, Ernest Benn, 1928.

36. Russel, Sir E. J. and Bishop, L. R., Institute of Brewing Research Scheme. Ten Years Investigations on Barley. Supp. to Journal of the Institute of Brewing, 39: 287-421, 1933.

37. Shellenberger, J. A. and Bailey, C. H., Biochemical Distinction Between Barley Varieties. Cer. Chem., 13: No. 6, 631-655, 1936.

38. Spence, O., Evaluation for Malt Production of Barley Varieties Produced on the Southern High Plains of Texas. Thesis, Texas Technological College, Lubbock, Texas, 1940.

39. U. S. D. A. How to Grade Barley (Class I) with Special Reference to Malting Barley. Mimeographed Report. Washington, D. C., 1938.

40. U. S. D. A. Handbook of Official Grain Standards of the United States. U. S. Printing Office, Washington, D. C., 1941.

41. Wahlgren, H. F., Climatological Data. Oklahoma Section. U. S. Department of Agriculture, Weather Bureau, 1939.

42. Ibid. Climatological Data. Oklahoma Section. U. S. Department of Agriculture, Weather Bureau, 1940.

43. Ibid. Climatological Data. Oklahoma Section. U. S. Department of Agriculture, Weather Bureau, 1941.

44. Whitlock, B. W., Barley Markets of United Kingdom. Paper read at the California Farm Bureau Federation Meeting held at Merced, California, November 16, 1931. Mimeographed.

Mrs. Ernest Mader, typist