



Methods of planting to best determine inherent differences in yield components and quality characteristics of barley
by Gerald H Ellis

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University
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Abstract:

A planting method study was conducted with three 2-row barley varieties. The planting methods ranged from 4-row solid drilled plots to single 2 feet x 2 feet hill planted plots. Plant characteristics studied included protein content, per cent plump and thin kernels, 100 kernel weight, tiller number, and yield. The types of planting methods chosen to determine inherent differences in plant characteristics could be based on the least variation within a method. On this basis, a 96 pound per acre 1-row drilled plot distinguished varieties for protein content. This method also produced low variance in per cent plump kernels. A 1-foot x 1-foot spacing method with solid borders of Vantage barley produced the least variation in tiller number per four square feet of plot. This method distinguished Betzes greater tillering capacity from that of Carlsberg II and Compana. Differences between varieties were observed in a head row method of planting for per cent plump kernels. A space planted 1-foot x 1-foot, 15 seed per hill method, although higher in variance than several other methods, separated varieties for 100 kernel weight. The latter was considered to be the most generally satisfactory method for simultaneous evaluation of all characteristics studied.

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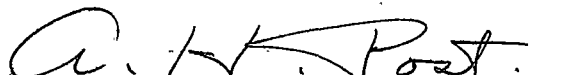
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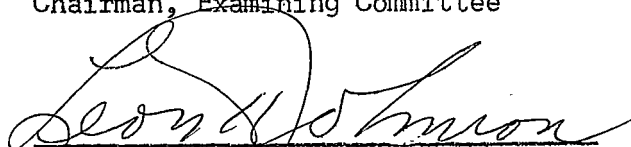
at

Montana State College

Approved:


Head, Major Department


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Bozeman, Montana
June, 1961

ACKNOWLEDGEMENT

I wish to express my appreciation to Professor R. F. Eslick and Dr. E. A. Hockett for their assistance in choosing, planning and conducting this study. I also wish to thank Dr. C. J. Mode, Assistant Professor of Statistics and Experiment Station Consultant, for his valuable advice in analyzing the data. Clifford Watson, Assistant Chemist, has also aided my work by his encouragement and sincere advice.

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ABSTRACT

A planting method study was conducted with three 2-row barley varieties. The planting methods ranged from 4-row solid drilled plots to single 2 feet x 2 feet hill planted plots. Plant characteristics studied included protein content, per cent plump and thin kernels, 100 kernel weight, tiller number, and yield. The types of planting methods chosen to determine inherent differences in plant characteristics could be based on the least variation within a method. On this basis, a 96 pound per acre 1-row drilled plot distinguished varieties for protein content. This method also produced low variance in per cent plump kernels. A 1-foot x 1-foot spacing method with solid borders of Vantage barley produced the least variation in tiller number per four square feet of plot. This method distinguished Betzes' greater tillering capacity from that of Carlsberg II and Compana. Differences between varieties were observed in a head row method of planting for per cent plump kernels. A space planted 1-foot x 1-foot, 15 seed per hill method, although higher in variance than several other methods, separated varieties for 100 kernel weight. The latter was considered to be the most generally satisfactory method for simultaneous evaluation of all characteristics studied.

INTRODUCTION

One of the problems facing the plant breeder is how to grow segregating plant materials in the field to most effectively measure genetic differences in plant characteristics.

It is an obvious fact that barley plant characteristics such as kernel plumpness, kernel weight, tiller number, protein content and yield may vary greatly in a single field. This variation is the result of numerous environmental influences interacting with, or modifying, the effects of the expression of plant genotype. Some environmental influences are deleterious in that they lead to non-uniformity or low quality crops.

Quality barley production is probably smaller than it should be. The major objectives of barley breeders are higher yield, better malting and feed quality, and new uses for barley. Basic research is a necessity in order to achieve these goals. Fundamental studies can assist the plant breeder in his effort to approach variety improvement more objectively.

Quality in barley is a relative term. No sound barley can be judged either good or poor except in comparison with some standard and when evaluated for some definite use. Barley has a number of characteristics by which it may be judged in relation to its intended use and quality. No barley variety has all the characteristics that might be desired. Intense selection for one characteristic may decrease the plasticity of a population and generally lower the overall fitness of the desired plant selections. (5)

Throughout the past half century, plant breeders have developed certain techniques for the selection of plant material. Planting methods have been numerous and vary according to the material under observation, the amount of seed available, knowledge of the breeder, and equipment available for planting.

It was the objective of this study to investigate the variation of plant characteristics as they would occur with several methods of planting that have been used in plant breeding work. The characteristics investigated included tiller number, kernel weight, kernel plumpness and thinness, per cent protein, and yield.

If plant characteristics do differ, the problem is to select a method or methods of planting that express the genetic differences between varieties. The method should be one that shows the least buffering of characteristics by the environment. Differences in protein percentage, for instance, could exist at one mean level with thickly planted populations; whereas, in thinly spaced plantings or conditions of minimum competition, protein differences could be expressed at another level.

LITERATURE REVIEW

It is generally conceded that the inheritance of economic characteristics, such as yield and quality in plants, is extremely complex. This necessitates the individual study of yield and quality components and their inter-relationship. If agronomic characteristics that are genetically and simply inherited can be isolated, selection for a particular amount of that element would be facilitated.

Den Hartog and Lambert (4) studied the relationship between protein per cent and yield, bushel weight, and floret fertility; all of which are considered to be multigenically controlled. These workers found several significant correlations of low magnitude.

Certain visible morphological characters of known inheritance were associated with barley nitrogen per cent in an inheritance study conducted by Day and Dickson (3). They found nitrogen content was associated with the 2-row vs. 6-row character. Nitrogen content was generally lower in 6-row genotypes. They stated that genes controlling barley nitrogen are located in linkage group I for the 2-row vs. 6-row character.

Since nitrogen content is (1) one of the most important measures of malting quality of a variety or strain (2), (4), (7), it would be of interest to observe the expression of this characteristic under the influence of several methods of planting.

According to Thayer and Rather (12), rates of seeding small grain has relatively little influence on yield but may materially influence the expression of certain plant characters such as tillering, number of heads per plant and length of head.

Sprague and Ferris (11), using various plant spacings of Alpha barley, found a similar effect, in that reducing the plant spacing modified the individual plant development but had little effect on yield.

Engledow and Wadham (6) indicated that tillering changes are sensitive to variations in plant spacing, but varieties differ greatly in their response to the space available.

These studies point to the fact that barley plants have considerable ability to modify their development in response to the soil and other environmental resources available. If yield is not considerably altered, then one component of yield must develop to balance the modifying effect of competition of plants for moisture, nutrients and sunlight (8) on another component.

MATERIALS AND METHODS

In the spring of 1959, an experiment involving methods of planting was designed and planted at the Agronomy Farm, five miles west of Bozeman, Montana. The design consisted of plots 10 feet long arranged in a split-plot within a 9x9 latin square. This arrangement provided for a minimum amount of within planting method variation, as the main plots were methods of planting. The sub-plots were varieties of barley which provided increased precision for the varietal comparisons. All plots were bordered by a similar method of planting. A list of the nine planting methods including rates of seeding, type of plot, and manner of sampling each plot is shown in Table I.

The sub-plot units consisted of three 2-row barley varieties; Betzes, Compana and Carlsberg II. These varieties were chosen because of known differences in such characteristics as protein content, seed weight and size, and tiller number. Carlsberg II has generally exhibited a lower protein content and has a lighter seed weight and smaller kernels than Compana, and a lower protein content than Betzes. Betzes has a lower protein content and smaller kernels than Compana.

Precipitation during the spring and summer period was below normal in 1959. Two additions of water were applied by an overhead sprinkler system during the growing period. This did not prevent hot-drying winds, in mid to late July, from drying the barley, and thus resulting in less than complete filling.

Heading dates were taken during the growing period and per cent stand was observed at harvest time. On the average, Carlsberg II

first headed nine and five days after Compana and Betzes, respectively.

At harvest, one square foot samples were harvested at random within a single plot. Four one-foot samples were then combined to provide the yield and tiller number data, or averaged for protein content, per cent plump and thin kernels, and 100 kernel weight.

The original plan included the bulking of the remaining sub-plots and comparing data thus obtained with the performance of the four foot samples. Due to incomplete stands, the bulk data was not included in the analysis.

At harvest, tiller number was determined for each of the four square foot harvest samples and totaled. Tillers that supported immature heads were not counted.

In the laboratory, each sample was weighed to the nearest tenth of a gram to obtain yield data. Other data obtained in the laboratory included 100 kernel weight, kernel size assortment, and protein content. The dye ion-binding method of protein estimation, established by Udy (13) for protein determinations was employed.

The completed data was based on four square foot of area from the ten foot plots and included 81 individual samples from each of the three varieties.

The analysis of variance, on which most of the conclusions in this text are based, was calculated individually for each character and each method of planting. The F-values were computed on the assumption that the variables were fixed as described by Ostle (9).

The data for the nine methods were not combined because preliminary analysis indicated that the methods of planting were not of the same population. Thus a complex analysis was not valid for this study due to the lack of a common variance for the planting methods.

Table I. Approximate rate of planting, plot type and sampling technique used in the planting method study grown at Bozeman, Montana in 1959.

Method	Approximate Rate	Plot Type	Sampling Technique
1	96 pounds per acre	4 row drilled	4 samples each 1 foot in length (2 samples from each center row)
2	96 pounds per acre	1 row drilled	4 samples each 1 foot in length
3a	Varies with variety	5 foot head row	4 samples each 1 foot in length*
3b	15.4 pounds per acre (16 seed per 5 square feet)	5 foot head row	4 samples each 1 foot in length*
4	4.8 pounds per acre (1 seed per square foot)	1 foot x 1 foot spacing	4 plants
5	19.2 pounds per acre (4 seed per square foot)	1 foot x 3 inch spacing	4 samples containing 4 plants per foot
6	24 pounds per acre (5 seed per square foot)	1 foot x 1 foot spacing	4 hills
7	72 pounds per acre (15 seed per square foot)	1 foot x 1 foot spacing	4 hills
8	4.8 pounds per acre (1 seed per square foot)	1 foot x 1 foot spacing, solid drilled Vantage border rows	4 plants
9	1.2 pounds per acre (1 seed per 4 square feet)	2 foot x 2 foot spacing	2 hills, averaged

* Method 3 represented an average of 3a and 3b harvested samples

RESULTS AND DISCUSSION

The variety means data and the planting method mean data accompanied by the standard error of the mean for each method of planting are shown in the even numbered tables from II through XII. The analysis of variance for individual methods of planting for each characteristic studied is shown in the odd numbered tables from III through XIII. The year 1959 was unusually dry throughout the season. The generally high per cent thin kernels and protein content is an indication of lack of available moisture for all methods tested.

There was some evidence of the virus disease, yellow dwarf of barley, especially in the Compana plots. This may have reduced yields in that variety to some extent. The effects of the disease were observed more often in the thinner planting methods. A stand observation indicated Compana established fewer plants in this experiment.

Varietal Differences Within Methods of Planting

With the aid of Scheffe's (10) method for comparing treatment means, it was possible to calculate at a selected probability, the differences between varietal means within each planting method. The letter superscripts used in the even numbered tables II through XII indicate significant differences between variety means. For example, if the letter superscripts a, b, and c all occur within a method, the method of planting has separated all varieties for the character involved.

The treatment means for protein content, table II, show that method 2 ranked the barley varieties, Compana, Betzes, and Carlsberg II from high to low respectively. Methods 4 and 5 separated Betzes from Carlsberg II, but did not place Compana. Method 6 ranked Betzes above Compana and Carlsberg II in protein content.

Method 2 did not separate varieties completely from kernel plumpness and thinness or other characteristics as shown in table XIV. This method (96 pounds per acre, 1 row drilled plots) was competing with adjoining varieties for available moisture and soil nutrients. Method 1 (96 pounds per acre, 4 row drilled plots) did not distinguish between varieties completely for any characteristic measured. This phenomena could indicate competition within a variety does not allow a complete expression of a characteristic, while competition between varieties permits expression. A single variety must compete for essentially the same nutrients and other factors in the environment. Conversely, a mixture of varieties could aid one another by merely emerging at slightly different times, tillering at different levels and heading at different dates. The effect could be either detrimental or favorable to the variety.

As indicated by table XIV, other complete differentiations of varieties were established by method 3 for per cent plump kernels, by method 7 for 100 kernel weight and by method 5 for tiller number. Measurements on Betzes and Carlsberg II were generally similar in magnitude for kernel plumpness and 100 kernel weight throughout all planting methods. Except by method 8, Compana always had the

heavier kernels. Comana showed plumper kernels by methods 1, 3, 4, 5, and 6, than Betzes and Carlsberg II. Betzes generally ranked first in tiller number and yield by all methods of planting.

Variance Differences Between Methods

After examining the tabulated data and preliminary analysis, it was assumed the methods were not of the same population. Application of Bartlett's test of homogeneity of variances (9) confirmed these assumptions. One of the main objectives of the study was to find those methods of planting that had the least within variation for a characteristic and that would at the same time, differentiate varieties. Application of Bartlett's test was followed by establishing which one method or group of methods resulted in the lowest within variability for a characteristic. Table XV depicts the confidence limits for estimating the variance within methods and includes confidence brackets to show differences between method variances for the six characteristics under discussion. The confidence limit for each method of planting was based on 95 per cent probability that the true population variance occurred within the designated boundaries, L_1 and L_2 .

For this particular point of the discussion, all methods were removed from the confidence limit data that did not show significant differences between at least two varieties. The fewer variances included for each variable, the more confident is each statement. Most of the material analyzed included overlapping intervals.

The protein data of table XV indicates a similar variance for methods 2, 4, and 5. Another similarity in variances occurred for methods 4, 5, and 6. This indicates a higher variance for method 6 than for method 2. These statements are based on 80 per cent confidence $[100 - (5 \text{ per cent probability} \times 4 \text{ methods})]$ or more that the true population variance of each method will be included within a bracket.

The analyses of per cent plump and thin kernel data, table XV, separated two methods from the others with reference to the magnitude of the variance. Method 2 is distinctly different and has less within method variation than the other methods included in the study. Method 1 has been separated from the others within the group by a higher variance within the planting method. These statements are based on 55 and 75 per cent respectively, of being correct.

The examination of 100 kernel weight data indicates a separation of variances into four categories with only a 55 per cent probability of the groupings being correct.

The analysis of tiller number data separated method 8 into a lower category of variance than other methods of planting. The confidence bracket's for tiller number and yield are based on a 60 per cent probability. The analysis of yield data has separated method 5 from the other methods compared.

These results are valid for choosing either high or low within planting method variances. Definite separations in magnitude of variance was established for four characteristics. These included

low variances for per cent plump kernels and tiller number in method 2 and 8 respectively. High variances were found for per cent thin kernels and yield within methods 1 and 5 respectively.

Although methods of planting showing no significant distinction between varieties were not included in table XV, a similar study of the complete data could similarly separate variances for methods not included. For instance, the complete data for protein content separates method 9 from all other lower variances, while methods 1, 3, 7, and 8 have similar variances.

Table II. Average protein per cent and standard error of the method mean for three barley varieties grown at Bozeman, Montana in 1959, including nine planting methods with nine replications.

Method of Planting	Per cent protein per 4 square feet			Method	
	Betzes	Compana	Carlsberg II	Mean	S.E. $\bar{x}$
1. 96# per acre, 4 row drilled plot	15.3 ^{a*}	15.6 ^a	15.0 ^a	15.3	0.31
2. 96# per acre, 1 row drilled plot	15.8 ^b	16.5 ^a	14.7 ^c	15.6	0.14
3. 5 foot head row; 5 foot, 16 seed	17.0 ^a	16.5 ^a	16.3 ^a	16.6	0.21
4. 1 foot x 1 foot spacing, 1 seed	17.9 ^a	17.2 ^{ab}	16.7 ^b	17.3	0.21
5. 1 foot x 3 inch spacing, 1 seed	16.9 ^a	16.6 ^{ab}	15.9 ^b	16.5	0.20
6. 1 foot x 1 foot 5 seed per hill	16.4 ^a	15.6 ^b	15.6 ^b	15.9	0.22
7. 1 foot x 1 foot 15 seed per hill	15.5 ^a	15.6 ^a	15.3 ^a	15.5	0.20
8. 1 foot x 1 foot drilled borders	16.5 ^a	16.7 ^a	16.2 ^a	16.5	0.24
9. 2 foot x 2 foot spacing, 1 seed	17.9 ^a	18.2 ^a	18.4 ^a	18.2	0.37
Variety Mean	16.9	16.5	16.0	16.4	

* Those values within a method followed by the same letter are not significantly different from each other at the 5 per cent level of probability.

Table III. Individual analysis of variance for protein content of nine planting methods including three barley varieties per method.

Source of Variation	Degrees of Freedom	Method 1		Method 2		Method 3	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	0.8655 ^{ns}		7.5545**		0.2565 ^{ns}	
Within varieties	24	0.3869	0.6219	0.1791	0.4232	0.3808	0.6171
Total	26						

Source of Variation	Degrees of Freedom	Method 4		Method 5		Method 6	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	3.0415**		2.2159**		1.8945*	
Within varieties	24	0.4012	0.6334	0.3729	0.6106	0.4207	0.6487
Total	26						

Source of Variation	Degrees of Freedom	Method 7		Method 8		Method 9	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	0.1745 ^{ns}		0.5211 ^{ns}		0.6678 ^{ns}	
Within varieties	24	0.3605	0.6004	0.5266	0.7257	1.2080	1.0991
Total	26						

* Denotes significance at the 5 per cent level of probability.

** Denotes significance at the 1 per cent level of probability.

ns Denotes no significance.

Table IV. Average kernel plumpness per cent and standard error of the method mean for three barley varieties grown at Bozeman, Montana in 1959, including nine planting methods with nine replications.

Method of Planting	Per cent plump kernels* per 4 square feet			Method	
	Betzes	Compana	Carlsberg II	Mean	S.E. $\bar{x}$
1. 96# per acre, 4 row drilled plots	20.8 ^{b**}	46.5 ^a	25.3 ^b	30.9	2.73
2. 96# per acre, 1 row drilled plots	27.0 ^a	32.5 ^a	28.0 ^a	29.2	1.53
3. 5 foot head row; 5 foot, 16 seed	40.9 ^c	76.3 ^a	52.4 ^b	56.5	3.08
4. 1 foot x 1 foot spacing, 1 seed	57.9 ^b	75.0 ^a	58.5 ^b	63.8	3.11
5. 1 foot x 3 inch spacing, 1 seed	42.5 ^b	65.3 ^a	44.9 ^b	50.9	3.04
6. 1 foot x 1 foot 5 seed per hill	43.8 ^b	73.3 ^a	40.1 ^b	52.4	3.04
7. 1 foot x 1 foot 15 seed per hill	41.2 ^{ab}	44.4 ^a	32.2 ^b	39.3	2.82
8. 1 foot x 1 foot drilled borders	18.8 ^b	39.7 ^a	32.0 ^a	30.2	3.56
9. 2 foot x 2 foot spacing, 1 seed	66.5 ^{ab}	80.9 ^a	62.9 ^b	70.1	4.20
Variety Mean	39.9	59.3	41.8	47.0	

* Plump kernels are those remaining on a 6/64 x 3/4 inch sieve.

** Those values within a method followed by the same letter are not significantly different from each other at the 5 per cent level of probability.

Table V.. Individual analysis of variance for per cent plump kernels of nine planting methods including three barley varieties per method.

Source of Variation	Degrees of Freedom	Method 1		Method 2		Method 3	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	1693.26**		77.18*		2464.47**	
Within varieties	24	67.14	8.19	20.97	4.58	85.08	9.22
Total	26						

Source of Variation	Degrees of Freedom	Method 4		Method 5		Method 6	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	845.82**		1416.36*		2981.85**	
Within varieties	24	86.87	9.32	83.25	9.12	83.07	9.11
Total	26						

Source of Variation	Degrees of Freedom	Method 7		Method 8		Method 9	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	362.52*		1273.08**		816.84*	
Within varieties	24	71.56	8.46	113.77	10.67	158.70	12.60
Total	26						

* Denotes significance at the 5 per cent level of probability.

** Denotes significance at the 1 per cent level of probability.

Table VI. Average per cent thin kernels and standard error of the method mean for barley varieties grown at Bozeman, Montana in 1959, including nine planting methods with nine replications.

Method of Planting	Per cent thin kernels*			Method	
	per 4 square feet			Mean	S.E. _x
	Betzes	Compans	Carlsberg II		
1. 96# per acre, 4 row drilled plots	24.0 ^{a**}	13.4 ^b	25.3 ^a	20.9	1.89
2. 96# per acre, 1 row drilled plots	18.5 ^a	20.7 ^a	23.2 ^a	20.8	1.41
3. 5 foot head row; 5 foot, 16 seed	9.2 ^a	4.0 ^b	8.9 ^a	7.4	1.26
4. 1 foot x 1 foot spacing, 1 seed	5.8 ^a	3.5 ^a	5.7 ^a	5.0	1.34
5. 1 foot x 3 inch spacing, 1 seed	8.1 ^a	7.3 ^a	9.2 ^a	8.2	1.14
6. 1 foot x 1 foot 5 seed per hill	5.7 ^b	4.8 ^b	13.4 ^a	8.0	1.19
7. 1 foot x 1 foot 15 seed per hill	8.7 ^b	13.1 ^{ab}	17.5 ^a	13.1	1.39
8. 1 foot x 1 foot drilled borders	17.2 ^a	16.1 ^a	13.9 ^a	16.5	3.20
9. 2 foot x 2 foot spacing, 1 seed	3.7 ^a	3.1 ^a	8.1 ^a	5.0	1.94
Variety Mean	11.2	9.6	13.9	11.6	

* Thin kernels are those going through a 5/64 x 3/4 inch sieve.

** Those values followed by the same letter are not significantly different from each other at the 5 per cent level of probability.

Table VII. Individual analysis of variance for per cent thin kernels of nine planting methods including three barley varieties per method.

Source of Variation	Degrees of Freedom	Method 1		Method 2		Method 3	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	367.59**		66.64*		77.98*	
Within varieties	24	32.16	5.67	17.94	4.24	14.22	3.77
Total	26						

Source of Variation	Degrees of Freedom	Method 4		Method 5		Method 6	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	14.82 ^{ns}		57.89*		198.47**	
Within varieties	24	16.27	4.03	11.76	3.43	12.75	3.57
Total	26						

Source of Variation	Degrees of Freedom	Method 7		Method 8		Method 9	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	173.36**		20.57 ^{ns}		67.22 ^{ns}	
Within varieties	24	17.50	4.18	92.09	9.60	33.75	5.81
Total	26						

* Denotes significance at the 5 per cent level of probability.

** Denotes significance at the 1 per cent level of probability.

ns Denotes no significance.

Table VIII. Average 100 kernel weight and standard error of the method mean for three barley varieties grown at Bozeman, Montana in 1959, including nine planting methods with nine replications.

Method of Planting	100 kernel weight in grams per 4 square feet			Method	
	Betzes	Compana	Carlsberg II	Mean	S.E.x
1. 96# per acre, 4 row drilled plots	3.15 ^{b*}	3.69 ^a	2.92 ^b	3.26	0.086
2. 96# per acre, 1 row drilled plots	3.25 ^b	3.59 ^a	3.14 ^b	3.33	0.047
3. 5 foot head row; 5 foot, 16 seed	3.71 ^b	4.95 ^a	3.85 ^b	4.17	0.061
4. 1 foot x 1 foot spacing, 1 seed	3.87 ^b	4.79 ^a	3.99 ^b	4.22	0.060
5. 1 foot x 3 inch spacing, 1 seed	3.71 ^b	4.47 ^a	3.74 ^b	3.99	0.062
6. 1 foot x 1 foot 5 seed per hill	3.76 ^b	4.67 ^a	3.61 ^b	4.01	0.077
7. 1 foot x 1 foot 15 seed per hill	3.64 ^b	3.98 ^a	3.27 ^c	3.63	0.064
8. 1 foot x 1 foot, drilled borders	3.24 ^b	3.73 ^b	3.41 ^{ab}	3.46	0.126
9. 2 foot x 2 foot spacing, 1 seed	3.99 ^b	4.83 ^a	4.24 ^b	4.35	0.141
Variety Mean	3.59	4.30	3.82	3.82	

* Those values followed by the same letter are not significantly different from each other at the 5 per cent level of probability.

Table IX. Individual analysis of variance for 100 kernel weight of nine planting methods including three barley varieties per method.

Source of Variation	Degrees of Freedom	Method 1		Method 2		Method 3	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	1.3974**		0.4968**		4.1271**	
Within varieties	24	0.0670	0.2588	0.0213	0.1458	0.0337	0.1837
Total	26						

Source of Variation	Degrees of Freedom	Method 4		Method 5		Method 6	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	2.2332**		1.6612**		3.0038**	
Within varieties	24	0.0579	0.2407	0.0343	0.1852	0.0529	0.2299
Total	26						

Source of Variation	Degrees of Freedom	Method 7		Method 8		Method 9	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	1.1344**		0.5565*		1.6556**	
Within varieties	24	0.0366	0.1915	0.1436	0.3789	0.1791	0.4232
Total	26						

* Denotes significance at the 5 per cent level of probability.

** Denotes significance at the 1 per cent level of probability.

Table X. Average tiller number and standard error of the method mean for three barley varieties grown at Bozeman, Montana in 1959, including nine planting methods with nine replications.

Method of Planting	Tiller number per 4 square feet			Method	
	Betzes	Compana	Carlsberg II	Mean	S.E. $\bar{x}$
1. 96# per acre, 4 row drilled plots	320 ^{a*}	291 ^b	256 ^b	289	10.2
2. 96# per acre, 1 row drilled plots	304 ^a	258 ^b	248 ^b	270	11.8
3. 5 foot head row; 5 foot, 16 seed	113 ^a	74 ^b	107 ^a	98	7.7
4. 1 foot x 1 foot spacing, 1 seed	95 ^a	53 ^b	101 ^a	83	6.8
5. 1 foot x 3 inch spacing, 1 seed	159 ^a	94 ^c	126 ^b	126	13.2
6. 1 foot x 1 foot, 5 seed per hill	151 ^a	116 ^b	137 ^{ab}	135	8.2
7. 1 foot x 1 foot, 15 seed per hill	246 ^a	211 ^b	219 ^b	225	8.8
8. 1 foot x 1 foot, drilled border	39 ^a	28 ^b	27 ^b	31	2.9
9. 2 foot x 2 foot spacing, 1 seed	44 ^a	20 ^b	20 ^b	28	6.0
Variety Mean	163	127	138	143	

* Those values followed by the same letter are not significantly different from each other at the 5 per cent level of probability.

Table XI. Individual analysis of variance for tiller number of nine planting methods including three barley varieties per method.

Source of Variation	Degrees of Freedom	Method 1		Method 2		Method 3	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	9249.88**		8269.79**		5618.92**	
Within varieties	24	934.58	30.57	1254.96	35.43	532.19	23.07
Total	26						

Source of Variation	Degrees of Freedom	Method 4		Method 5		Method 6	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	6037.45**		9540.12**		1991.25 ^{ns}	
Within varieties	24	420.71	20.51	1570.83	39.63	60.09	24.51
Total	26						

Source of Variation	Degrees of Freedom	Method 7		Method 8		Method 9	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	3035.11*		384.92*		1736.04*	
Within varieties	24	698.49	26.43	77.15	8.78	322.70	17.96
Total	26						

* Denotes significance at the 5 per cent level of probability.

** Denotes significance at the 1 per cent level of probability.

ns Denotes no significance.

Table XII. Average yield and standard error of the method mean for three barley varieties grown at Bozeman, Montana in 1959, including nine planting methods with nine replications.

Method of Planting	Yield in grams per 4 square feet			Method	
	Betzes	Compana	Carlsberg II	Mean	S.E. $\bar{x}$
1. 96# per acre, 4 row drilled plots	160.7 ^{a*}	150.3 ^a	138.6 ^b	149.9	4.25
2. 96# per acre, 1 row drilled plots	153.4 ^a	119.9 ^b	128.0 ^b	133.8	6.08
3. 5 foot head row; 5 foot, 16 seed	82.3 ^a	57.3 ^b	77.2 ^b	72.3	6.38
4. 1 foot x 1 foot spacing, 1 seed	76.5 ^a	37.2 ^b	82.0 ^a	65.2	5.50
5. 1 foot x 3 inch spacing, 1 seed	113.6 ^a	66.3 ^b	82.9 ^{ab}	87.6	10.52
6. 1 foot x 1 foot; 5 seed per hill	115.5 ^a	84.6 ^b	92.0 ^b	97.4	6.55
7. 1 foot x 1 foot, 15 seed per hill	159.6 ^a	116.7 ^b	127.5 ^b	134.6	5.78
8. 1 foot x 1 foot drilled border	20.8 ^a	18.6 ^a	15.6 ^a	18.4	2.24
9. 2 foot x 2 foot spacing, 1 seed	32.5 ^a	13.0 ^b	16.2 ^b	20.6	5.46
Variety Mean	101.7	73.8	84.5	86.6	

* Those values followed by the same letter are not significantly different from each other at the 5 per cent level of probability.

Table XIII. Individual analysis of variance for yield of nine planting methods including three barley varieties per method.

Source of Variation	Degrees of Freedom	Method 1		Method 2		Method 3	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	1107.96**		2749.53**		1565.02*	
Within varieties	24	162.71	12.75	332.89	18.24	366.42	19.14
Total	26						

Source of Variation	Degrees of Freedom	Method 4		Method 5		Method 6	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	5327.76**		5189.88*		2334.75**	
Within varieties	24	272.48	16.51	996.94	31.58	386.67	6.55
Total	26						

Source of Variation	Degrees of Freedom	Method 7		Method 8		Method 9	
		M.S.	s	M.S.	s	M.S.	s
Between varieties	2	4471.54**		61.28 ^{ns}		983.08*	
Within varieties	24	300.74	17.34	44.99	6.71	268.73	16.39
Total	26						

* Denotes significance at the 5 per cent level of probability.

** Denotes significance at the 1 per cent level of probability.

ns Denotes no significance.

Table XIV. Effect of planting methods on the arrangement of six barley characteristics as measured in three varieties; Compana, Betzes and Carlsberg II.

Method	Per cent Protein	Per cent Plump Kernels	Per cent Thin Kernels	100 Kernel Weight	Tiller Number	Yield
1.	<u>Co</u> <u>Be</u> <u>Ca</u>	Co <u>Ca</u> <u>Be</u>	<u>Ca</u> <u>Be</u> <u>Co</u>	Co <u>Be</u> <u>Ca</u>	Be <u>Co</u> <u>Ca</u>	<u>Be</u> <u>Co</u> <u>Ca</u>
2.	Co <u>Be</u> <u>Ca</u>	<u>Co</u> <u>Ca</u> <u>Be</u>	<u>Ca</u> <u>Co</u> <u>Be</u>	Co <u>Be</u> <u>Ca</u>	Be <u>Co</u> <u>Ca</u>	Be <u>Ca</u> <u>Co</u>
3.	<u>Be</u> <u>Co</u> <u>Ca</u>	Co <u>Ca</u> <u>Be</u>	<u>Be</u> <u>Ca</u> <u>Co</u>	Co <u>Be</u> <u>Ca</u>	<u>Be</u> <u>Ca</u> <u>Co</u>	Be <u>Ca</u> <u>Co</u>
4.	<u>Be</u> <u>Co</u> <u>Ca</u>	Co <u>Ca</u> <u>Be</u>	<u>Be</u> <u>Ca</u> <u>Co</u>	Co <u>Be</u> <u>Ca</u>	<u>Be</u> <u>Ca</u> <u>Co</u>	<u>Be</u> <u>Ca</u> <u>Co</u>
5.	<u>Be</u> <u>Co</u> <u>Ca</u>	Co <u>Ca</u> <u>Be</u>	<u>Ca</u> <u>Be</u> <u>Co</u>	Co <u>Be</u> <u>Ca</u>	Be <u>Ca</u> <u>Co</u>	<u>Be</u> <u>Ca</u> <u>Co</u>
6.	Be <u>Co</u> <u>Ca</u>	Co <u>Be</u> <u>Ca</u>	<u>Ca</u> <u>Be</u> <u>Co</u>	Co <u>Be</u> <u>Ca</u>	<u>Be</u> <u>Ca</u> <u>Co</u>	Be <u>Ca</u> <u>Co</u>
7.	<u>Co</u> <u>Be</u> <u>Ca</u>	<u>Co</u> <u>Be</u> <u>Ca</u>	<u>Ca</u> <u>Co</u> <u>Be</u>	Co <u>Be</u> <u>Ca</u>	Be <u>Ca</u> <u>Co</u>	Be <u>Ca</u> <u>Co</u>
8.	<u>Co</u> <u>Be</u> <u>Ca</u>	<u>Co</u> <u>Ca</u> <u>Be</u>	<u>Be</u> <u>Co</u> <u>Ca</u>	<u>Co</u> <u>Ca</u> <u>Be</u>	Be <u>Co</u> <u>Ca</u>	<u>Be</u> <u>Co</u> <u>Ca</u>
9.	<u>Ca</u> <u>Co</u> <u>Be</u>	<u>Co</u> <u>Be</u> <u>Ca</u>	<u>Ca</u> <u>Be</u> <u>Co</u>	Co <u>Ca</u> <u>Be</u>	Be <u>Co</u> <u>Ca</u>	Be <u>Ca</u> <u>Co</u>

Varieties; Compana (Co), Betzes (Be) and Carlsberg II (Ca) are listed in order of magnitude.

Significant differences are indicated by those varieties that are not underscored by the same line.

Table XV. Confidence intervals for the estimation of variance within methods and confidence brackets to indicate differences within method variances for six barley characteristics.

Per cent Protein ²		
Method 2:	$L_1 = 0.1171$,	$L_2 = 0.2959$
Method 5:	$L_1 = 0.2492$,	$L_2 = 0.6296$
Method 4:	$L_1 = 0.2679$,	$L_2 = 0.6766$
Method 6:	$L_1 = 0.2966$,	$L_2 = 0.7492$

Per cent Plump Kernels ⁵		
Method 2:	$L_1 = 14.02$,	$L_2 = 35.40$
Method 1:	$L_1 = 44.86$,	$L_2 = 113.35$
Method 7:	$L_1 = 47.83$,	$L_2 = 120.82$
Method 6:	$L_1 = 55.52$,	$L_2 = 140.25$
Method 5:	$L_1 = 55.64$,	$L_2 = 140.55$
Method 3:	$L_1 = 56.87$,	$L_2 = 143.64$
Method 4:	$L_1 = 58.06$,	$L_2 = 146.66$
Method 8:	$L_1 = 76.04$,	$L_2 = 192.08$
Method 9:	$L_1 = 106.07$,	$L_2 = 267.95$

Per cent Thin Kernels ³		
Method 5:	$L_1 = 7.86$,	$L_2 = 19.85$
Method 6:	$L_1 = 8.61$,	$L_2 = 21.53$
Method 3:	$L_1 = 9.50$,	$L_2 = 24.01$
Method 2:	$L_1 = 11.99$,	$L_2 = 30.29$
Method 1:	$L_1 = 21.50$,	$L_2 = 54.30$

100 Kernel Weight ⁵		
Method 2:	$L_1 = 0.0142$,	$L_2 = 0.0359$
Method 3:	$L_1 = 0.0225$,	$L_2 = 0.0569$
Method 5:	$L_1 = 0.0229$,	$L_2 = 0.0571$
Method 7:	$L_1 = 0.0245$,	$L_2 = 0.0619$
Method 6:	$L_1 = 0.0354$,	$L_2 = 0.0893$
Method 4:	$L_1 = 0.0387$,	$L_2 = 0.0978$
Method 1:	$L_1 = 0.0448$,	$L_2 = 0.1131$
Method 8:	$L_1 = 0.0960$,	$L_2 = 0.2424$
Method 9:	$L_1 = 0.1197$,	$L_2 = 0.3024$

Tiller Number ⁴		
Method 8:	$L_1 = 51.60$,	$L_2 = 130.34$
Method 9:	$L_1 = 251.69$,	$L_2 = 544.82$
Method 4:	$L_1 = 281.12$,	$L_2 = 710.27$
Method 3:	$L_1 = 355.71$,	$L_2 = 898.52$
Method 7:	$L_1 = 466.86$,	$L_2 = 1,179.29$
Method 1:	$L_1 = 624.67$,	$L_2 = 1,577.89$
Method 2:	$L_1 = 838.82$,	$L_2 = 2,118.83$
Method 5:	$L_1 = 1,050.03$,	$L_2 = 2,652.34$

Table XV. (Continued)

Yield ⁴

Method 1:	$L_1 = 108.75$,	$L_2 = 274.70$
Method 9:	$L_1 = 179.61$,	$L_2 = 453.70$
Method 4:	$L_1 = 182.12$,	$L_2 = 460.03$
Method 7:	$L_1 = 201.02$,	$L_2 = 507.74$
Method 2:	$L_1 = 222.50$,	$L_2 = 562.02$
Method 3:	$L_1 = 244.91$,	$L_2 = 618.64$
Method 6:	$L_1 = 258.55$,	$L_2 = 652.82$
Method 5:	$L_1 = 666.33$,	$L_2 = 1,683.14$

1. Denotes a 95 per cent confidence that a true population variance will be in the interval (L_1, L_2) .
2. Denotes at least 80 per cent confidence that a true population variance will be included within the brackets.
3. Denotes at least 75 per cent confidence that a true population variance will be included within the brackets.
4. Denotes at least 60 per cent confidence that a true population variance will be contained within the brackets.
5. Denotes at least 55 per cent confidence that a true population variance will be within the brackets.

Any precise statement concerning the choice of a particular planting method for a certain use should be based on several years of experimental data. The data has indicated that average differences of the three varieties grown under two different methods was often greater than differences between the two most extreme varieties of either method. Certain trends relating varietal differences to planting rates were observed.

A general trend indicated an increase in protein content as seeding rates were decreased. In thin stands Betzes barley generally ranked higher than Carlsberg II in protein content.

The outstanding differences in kernel plumpness were observed in Compana barley. This large seeded 2-row variety was reduced in plumpness by the more competitive, thicker seeded plantings. Although method 8 was seeded as a one foot x one foot spacing, the solid borders of Vantage 6-row barley, seeded at the rate of 96 pounds per acre reduced plumpness of all three varieties. This could indicate the high variances for the other characteristics measured under method 8 are associated with plants with highly competitive conditions.

The method of planting for selection of one characteristic in a variety is not an indication of good selection for all characteristics of that variety. The one-row drilled plot could be selected as the best for determining varietal protein differences. This method is not the most satisfactory for determining differences in yield, tiller number, kernel plumpness, and weight.

Selection for several desirable characteristics simultaneously within one planting method could decrease the expression needed for effective selection and thus increase the possibility of obtaining good quality barley. Method 7 (one foot x one foot, 15 seed hill) is a reasonably good choice. The 100 kernel weight of varieties are distinctly different. It classes the malting barley, Betzes, well below the average in protein content and per cent thin kernels, while per cent plump kernels are above average.

SUMMARY AND CONCLUSIONS

A planting method study was conducted with three 2-row barley varieties at Bozeman, Montana.

Compana, Betzes and Carlsberg II were chosen for the study because of known inherent differences in protein content, kernel size and weight, and tiller number per plant. The nine planting methods ranged from 4-row solid drilled plots to single 2 feet x 2 feet hill planted plots. Plant characteristics studied included protein content, per cent plump and thin kernels, 100 kernel weight, tiller number, and yield. The data were based on four square feet of area from 10-foot plots with nine replications per method.

Generally higher within method variance occurred for per cent protein, per cent plump kernels, and 100 kernel weight within the thinner plant population methods of planting. Tiller number and yield within method variance was similar or less with thinly populated plots as compared to densely populated plots.

Few of the methods studied differentiated varieties completely. Those methods of planting which showed the lowest variances and still separated varieties for the characteristics under study were assumed to be the most useful methods.

Per cent protein of the three varieties was best differentiated in a 1-row drilled plot. This method ranked the varieties; Compana, Betzes and Carlsberg II, from high to low respectively.

Observations from treatment mean data reveal some interesting trends concerning Betzes barley. They are listed as follows:

1. Betzes exhibited a higher protein level than Compana and Carlsberg II in most thin plantings.
2. Betzes produced slightly lower per cent plump kernels at thicker planting rates than Carlsberg II.
3. Betzes showed higher tiller numbers per four square foot of row than Compana.

The results of this study indicated that selection for a combination of characteristics in barley is a difficult task. Favorable selection conditions for protein content resulted in unfavorable conditions for selection of kernel plumpness and kernel weight. A compromise by selecting a method of planting that shows fairly good characteristic differentiation for all the plant characteristics would be the most desirable.

Method 7 (1 foot x 1 foot, 15 seed per hill) is a reasonable compromise. The 100 kernel weight of varieties are distinctly different. It classes the malting barley, Betzes, well below the average in protein content and per cent thin kernels, while per cent plump kernels are above average. The method differentiated at least one variety for all characteristics except protein content. The magnitude of the differences for protein content were typical for these three variables.

LITERATURE CITED

1. ANDERSON, J.A., MEREDITH, W.O.S., and SALLANS, H.R., Malting quality of Canadian barleys. IV. Sci. Agr. 23: 297-314. 1943.
2. ANDERSON, J.A., SALLANS, H.R., and AYRE, C.A. Varietal Differences in Barleys and Malts II. Correlations between nitrogen and saccharifying activities. Canad. Jour. Res. C., 16: 456-466. 1938.
3. DAY, A.D., and DICKSON, A.D., Association between nitrogen percentage and certain morphological characteristics in barley, Agron. Jour. 49: 244-245. 1957.
4. DEN HARTOG, G.T., and LAMBERT, J.W., The relationship between certain agronomic and malting quality characters of barley. Agron. Jour. 45: 208-212. 1953.
5. ELLIOTT, F.G., The significance of recombination in plant breeding. Plant Breeding and Cytogenetics. McGraw-Hill Book Co., Inc. Chapter 3, pp. 95. 1958.
6. ENGLEADOW, F.L., and WADHAM, S.M., Investigations on Yield in Cereals. I. Appendix III. The problem of "tillering." Jour. Agr. Sci. 14: 80-85. 1924.
7. HARRIS, R. H., and BANASIK, O.J. Effects of environment, variety and season on barley quality. Cereal Chem. 29: 148-155. 1952.
8. HARRISON, T.J., Causes of variation in protein content of barley. Worlds Grain Exhibition and Conference Proc. Regina, Canada. 1933.
9. OSTLE, B., Statistics in Research. The Iowa State College Press. Ames, Iowa. 1954.
10. SCHEFFE, H., A method for judging all contrasts in the analysis of variance. Biometrika 40:87. 1953.
11. SPRAGUE, H.G., and FERRIS, N.F., The effect of uniformity of spacing seed on the development and yield of barley. Jour. Am. Soc. Agron. 23: 516-533. 1931.
12. THAYER, J.W., Jr., and RATHER, H.C., The influence of rate of seeding upon certain plant characters in barley. Jour. Am. Soc. Agron. 29: 754-760. 1937

13. UDY, D.C. Estimation of protein in wheat and flour by ion-binding. Cereal Chem. 33: 190-197. 1956.



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