A STUDY OF THE ASSOCIATION OF CERTAIN AGRONOMIC CHARACTERS IN BARLEY

by

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A Thesis

Submitted to the Faculty of Graduate Studies and Research

In Partial Fulfilment of the Requirements

for the Degree of

Master of Science

THE UNIVERSITY OF MANITOBA

April 1952

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INTRODUCTION

The objectives in any cereal breeding program are the production of new varieties that equal or excel the standard varieties in quality and in yielding ability. It would be of great value in such a breeding program to establish more or less consistent associations between characters. These associations could be used in selecting for characters that are difficult to measure such as yield and quality, by selecting for an easily measured, associated character. Such association if known might make it possible to select for yield and quality on an individual plant or line basis. It would also bring out the difficulty of trying to combine two desirable characters when the two prove to be negatively correlated.

It is well recognized that quality characters and yielding ability are greatly influenced by environmental factors. They behave in inheritance as quantitative characters with many genes involved.

This investigation was conducted in an effort to determine if there is correlation between a number of the agronomic characters of barley, and to determine which characters if any, could be used as an aid in selecting those new barley hybrids which have superior quality and yielding ability.

REVIEW OF LITERATURE

Correlations of yield with various plant characters have been reported by a number of investigators for wheat, corn and oats, but very few have been reported for barley.

Sir Humphrey Davy (1) in 1821 remarked, "It is unfortunate that so many high yielding grains prefer to lie upon the ground."

Garber and Olson (2) reported that they found no significant correlation between yield and lodging in a study involving 15 strains of barley.

Kohls (6) as reviewed by Leasure (7), working with seventeen varieties of barley, found positive correlation between yield and test weight and between yield and height of plant.

At the Colorado experiment Station, Robertson and Koonce (10) found positive correlation between yield and test weight and between yield and height of plant in a test involving 41 barley varieties.

Kiesselbach et al (5) in a study on barley found no correlation of yield with either plant height or lodging, but they did find positive correlation between yield and test weight.

Leasure et al (7) calculated simple correlations in barley for yield with each of: plant height, length of head, breaking strength of straw, and test weight. They found that no character was associated closely enough to be of much value in selection.

Neatby and McCalla (8) in a study carried out on various test plots throughout Alberta found high negative correlation between yield

and protein content in both wheat and barley.

Quisenberry (9) observed positive correlations between yield in wheat and each of: the number of heads per unit area, the number of kernels per head, length of head and 1000 kernel weight.

Sprague (14) found positive correlation between yield and each of: length of spike, fertile florets per spike, test weight and straw yield per culm in bread wheats. He also found variations in the expression of characters under different climatic conditions.

Shaw and Loomis (11) obtained high correlations in corn between yield and each of: stalk height, stalk diameter and ear size.

Schildt and Akerberg (12) in an experiment with rye, obtained positive correlation between tillering and total number of flowers per spike and between the number of seeds per spike and the number of flowers per spike. They also found negative correlations between the number of sterile florets per spike and the total number of florets.

Warren and Hayes (15) working with rye polycrosses, found positive correlation between yield and each of: fall growth vigour, tillering, days to heading, test weight and percent fruitfulness. They also obtained negative correlation between yield and pollen sterility.

MATERIALS AND METHODS

This experiment was conducted in 1950 at Headingly, Manitoba, and repeated in 1951 in the field plots of the Division of Plant Science of the University of Manitoba, Fort Garry, Manitoba.

The lines of barley used in this study were taken at random from a Montcalm by Vantage cross, from which the stem rust susceptible lines had been eliminated. Selection for stem rust resistance had been made in the F_2 generation. The resistant lines had been bulked and continued through to the F_5 by the bulk method, at which time the material was re-selected for stem rust resistance and continued by the pedigree method to the F_6 generation, when these 200 lines were randomly chosen. The parent varieties were also included in the experiment.

The reason for using such closely related material was to have the genotypes of the lines differ by relatively few characters in order that most of them could be included within a manageable series of partial correlations. It was hoped also to bring out more accurately the relationship existing between the characters, than would be possible with material that was genotypically more diverse.

The experiment consisted of two tests with 100 lines in each. Each test was designed as a partially balanced lattice with four replicates. It later developed that the variation between blocks and tests was negligible and the two tests were therefore combined and analysed as a simple randomized block.

Each plot consisted of one rod row, with an extra foot at each end to minimize the border effect. The plots were spaced one foot apart

and seeded at the rate of 300 seeds per plot.

Drought in the spring of 1951 was responsible for uneven germination which resulted in an uneven stand in one half of the experiment.

Readings on the number of days from seeding to heading were taken at two day intervals. A plot was considered headed when 50% of the heads had emerged from the sheath.

The number of fertile florets and basal sterile florets per head was determined by the average count on ten random heads per plot.

For the determination of test weight per bushel an average was taken of two determinations on the seed from each plot.

The saccharifying values were determined by the laboratory of the Barley Improvement Institute, Winnipeg, Manitoba, on a composite of the four replicates for each line and reported for the 1950 crop only. The 1951 results are not available at the time of writing.

An analysis of variance was calculated to determine the significance of differences between lines for each of six of the characters studied, but was not possible for saccharifying activity as the determinations were made on a composite sample of each line.

Simple and partial correlation coefficients were calculated for both years for all possible combinations of the characters: yield, days to heading, plant height, the number of fertile florets per spike, basal sterility and test weight on the two hundred lines of barley. In order that the two years results might be comparable, the 1950 simple correlation coefficients involving saccharifying activity were not included when calculating the partial correlation coefficients, for as stated before the

1951 saccharifying values were not available at the time of writing. Multiple correlation coefficients for yield with the other characters were also calculated.

The simple correlation coefficients were determined by the method outlined by Hayes and Immer (3). The Doolittle method as outlined by G. B. Oakland*, Statistical Branch, Dominion Science Service, was employed in the calculation of the partial and multiple correlation coefficients.

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* Oakland, G. B. Unpublished.

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences between the lines during both years, for each of the characters studied. This high significance is indicated by the F. values which are given in Table 1.

TABLE 1

F VALUES AND MEANS OF THE CHARACTERS STUDIED IN 1950 AND 1951

Character	Year	F Value	Mean
Yield	1950	2.69 **	32.1
	1951	2.60 **	75.3
Basal Sterility	1950	2.99 **	11.3
	1951	3.55 **	9.0
Fertile Florets	1950	1.93 **	45.1
	1951	6.16 **	54.6
Plant Height	1950	2.19 **	29.5
	1951	12.84 **	35.2
Days to Heading	1950	1.35 *	57.9
	1951	16.29 **	57.2
Test Weight	1950	13.11 **	50.3
	1951	9.61 **	46.2
Saccharifying Activity	1950	---	155.5

* Significant at the 5% level
** Significant at the 1% level

Higher average values in 1951 for yield, fertility and plant height and lower averages for basal sterility and days to head are indications that 1951 was more favorable than 1950 for plant development.

The lower average bushel weight in 1951 was probably due to the longer awn retained by the grain.

Simple and partial correlation coefficients were calculated for all interrelationships of the seven characters studied. These are given in Table 11. The multiple correlation coefficients, indicating the dependence of yield on the other five characters were also calculated.

TABLE II.

SIMPLE, PARTIAL AND MULTIPLE CORRELATION COEFFICIENTS

	1950 Correlations		1951 Correlations	
	Simple	Partial	Simple	Partial
Yield x days to heading	+.005	+.053	-.413**	-.694**
" x plant height	+.296**	+.269**	+.138*	-.322**
" x fertile florets	+.103	+.063	-.015	+.564**
" x basal sterility	-.205**	-.275**	*.035	+.532**
" x test weight	+.134*	+.045	+.325**	+.381**
Days to head x plant height	-.040	-.290**	+.122	-.546**
" " " x fertile florets	+.584**	+.597**	+.673**	+.879**
" " " x basal sterility	+.297**	+.046	+.258**	+.765**
" " " x test weight	-.237**	-.180*	+.082	+.221**
Plant height x fertile florets	+.363**	+.404**	+.376**	+.644**
" " x basal sterility	+.131	+.089	+.272**	+.623**
" " x test weight	+.225**	+.170*	+.257**	+.247**
Fertile florets x basal sterility	+.428**	+.306**	-.181*	-.762**
" " x test weight	-.037	+.052	+.271**	-.105
Basal sterility x test weight	-.142*	-.111	-.071	-.227**
Saccharifying activity x yield	-.217**			
" " x days to head	-.217**			
" " x plant height	+.493**			
" " x fertile florets	-.238**			
" " x basal sterility	+.798**			
" " x test weight	+.004			
Multiple Correlation R1.23456		.3697**		.5414**

* Significant at the 5% level
** Significant at the 1% level.

The relationship between any two characters as revealed by the simple correlation coefficients is frequently influenced by other characters and does not therefore reveal their true relationship. With the calculation of the partial correlation coefficients by means of which the influence of the other characters is held constant, this masking effect is largely eliminated. The greater emphasis will therefore be placed on the partial correlation coefficients in interpreting these results.

Severe lodging in 1951 was probably responsible for the significant negative correlation between yield and days to head. During 1950, when no lodging occurred there did not appear to be any association between these two characters. In 1951 the plots lodged rather suddenly as the result of a rain storm during the time that the crop was reaching maturity. The later maturing lines were therefore more severely affected than the earlier maturing ones. These results were in agreement with those obtained by Sisler (13), who found a reduction in yield proportional to the length of time that the barley was lodged prior to maturity. Hot weather, which occurred at the time that the crop was maturing may also have had a more adverse affect on the later maturing lines.

The highly significant positive correlation coefficient which was obtained in 1951 between yield and test weight, indicated that these two characters were associated. This association was previously reported in barley by Kohls (6) Robertson et al (10) and Kiesselbach et al (5). Although the 1950 results did not indicate as pronounced a

relationship as the 1951 results, it does appear that the association between yield and test weight in barley could be of value in selecting towards yield.

The positive association between yield and the number of fertile florets per spike was indicated by the significant positive partial correlation coefficient obtained in 1951. The positive, though insignificant partial correlation obtained between these two characters in 1950, further substantiates this association. Similar results were reported by Quisenberry (9). The large differences between the simple and partial correlation coefficients suggests that other characters greatly influenced the relationship between yield and the number of fertile florets per spike.

The relationship between yield and plant height was greatly influenced by environmental conditions, as evidenced by the contradictory results obtained in the two years. The partial correlation coefficient was positively significant in 1950 and negatively significant in 1951. The simple correlation coefficient obtained in 1951 was positively significant, and therefore contrary to the conclusions drawn from the partial correlation. This indicates that other characters influenced the expression of the association between yield and plant height.

A similar contradiction in results between the two years was found in the partial correlation coefficients obtained between yield and basal sterility. The generally high degree of basal sterility noted in 1950 appeared to have an adverse affect on yield as indicated by the

significant negative correlation obtained. In 1951, on the other hand, the degree of basal sterility was rather low, and the adverse affect that the sterility would be expected to have on yield, was probably overshadowed by other factors. The specific factors involved were probably largely ones that were not included in this study, and therefore their specific affect could not be removed.

There is strong support for the view that the earlier maturing lines contained the tallest plants. This trend was evidenced by the significant negative partial correlation coefficients obtained in both years for the association of plant height and days to head. Little information concerning this association was available from the insignificant simple correlation coefficients of both years. This indicates that the other characters studied greatly influenced the association between plant height and days to head.

The later maturing lines were also the most fertile ones as revealed by the significant positive association between days to head and the number of fertile florets per spike. There was apparently no significant difference between the results obtained from the simple and partial correlation coefficients, indicating that other characters had little influence on this relationship.

It is difficult to understand, how the lower degree of basal sterility obtained in 1951 showed such a high positive association with days to head, when the comparatively high degree of basal sterility obtained in 1950 indicated practically no association with days to head. This apparent discrepancy, is probably the result of the greater adverse

affect that lodging had on the later maturing varieties, causing them to develop a higher degree of sterility than the earlier lines. That other factors influenced the expression of the relationship between days to head and basal sterility was also indicated by the differences between the simple and partial correlation coefficients.

The contradictory correlation coefficients between years for the association of days to head with test weight indicated that the associations observed are environmental rather than hereditary. The differences between the simple and partial correlation coefficients indicated that the expression of the association between days to head and test weight was also influenced by other factors.

Plant height indicated highly significant positive association with the number of fertile florets per spike and with test weight. The consistent results obtained between the two years indicated that variations in environmental conditions apparently did not influence the relationship between these characters, indicating that selection for tall plants would, on the average lead to superior material in terms of test weight and a greater number of kernels per spike.

The variation between the two years results for the association between plant height and basal sterility is an indication that this association was too greatly influenced by environmental conditions to indicate any hereditary relationship.

A similar situation is found in the association between the number of fertile florets per spike and basal sterility. The contra-

dictions between years in the association between these characters indicated that probably no hereditary relationship existed between them.

The insignificant correlation coefficients between the number of fertile florets per spike and test weight, for the two years, indicated t that this was probably an example of a lack of association between these characters.

It was observed that the spikes with the higher percentage of basal sterility also contained a larger proportion of smaller, incompletely developed seeds; which probably also were lower in test weight. This probably expains the negative correlations obtained for the two years between basal sterility and test weight.

The simple correlation coefficients which involved saccharifying activity, indicated, that it would be difficult to combine maximum saccharifying activity and maximum yield in one variety. Early maturity and plant height however could readily be retained in a line with high saccharifying activity. This is indicated by the highly significant negative association between saccharifying activity and days to head, and the high positive correlation between saccharifying activity and plant height. Since only one years data are available, caution should be exercised when drawing conclusions from these results.

The disagreement between years for some of the correlation coefficients can undoubtedly be attrbuted to environmental factors. The adverse weather conditions of 1950 had a different effect on these correlation coefficients than the more or less favourable conditions of 1951. A similar variation was reported by Immer and Ausemus (4) who

found differences in the correlations of the same characters at different locations and in successive seasons. The disagreement between years was most pronounced in the correlation coefficients involving yield. This is an indication that yield is probably influenced to a much greater degree by environmental factors than are any of the other characters studied. Yield is probably also influenced by a larger number of genes.

The multiple correlation coefficients indicated that only 13 and 29 per cent of the variability of yield in 1950 and 1951 respectively, could be accounted for by its association with the other characters that were studied. It is evident that other characters which were not included in this study, had a much greater affect on yield. The masking affect which those characters had on the correlation coefficients may have been quite large. It is quite possible therefore that more consistant results could have been obtained if more characters had been included in this study, so that a larger percentage of the variability in yield could have been accounted for. Some definite trends however, were in evidence, and in a few cases agreement between the two years was quite satisfactory.

More experimental evidence is required before any definite conclusions can be reached as to the use of these agronomic characters as an aid in selecting toward quality and yielding ability in barley hybrids. Some evidence was however obtained, indicating that the higher yielding lines could probably be selected for on the basis of the number of fertile florets per spike and test weight. The 1950 results indicated that probably the most convenient characters to use in selecting for lines with high saccharifying activity would be days to head and plant height.

SUMMARY

Measurements were made during two years on the yield, basal sterility, number of fertile florets per spike, plant height, days to head, and test weight on 200 lines of barley from a Montcalm by Vantage cross. Only in 1950 was a determination made of saccharifying activity.

The average performance of lines as regards saccharifyiny activity in 1950, and the other characters in each of two years was reported. These indicated more vigorous plant development in 1951 than in 1950.

The analysis of variance indicated that significant differences existed between lines for each of the characters studied.

Simple and partial correlation coefficiients were calculated for all of the interrelatioships of all the characters that were studied, except for those involving saccharifying activity, in which case only simple correlation coefficients were calculated.

Some evidence was obtained which indicated that the number of fertile florets per spike and test weight might be useful in selecting lines capable of producing high yields. Data limited to one year indicated that early maturity and tall plant type were probably the most convenient characters to use in selecting for lines with high saccharifying activity.

The multiple correlation coefficients indicated that only 13 and 29 per cent of the variability of yield in 1950 and 1951 respectively, could be accounted for by its association with the agronomic characters studied.

The contradictory results obtained between years for a number of the correlation coefficients are evidence of considerable fluctuation with environment. Further experimental results are required before definite conclusions are justified regarding these associations.

ACKNOWLEDGEMENTS

The writer wishes to express his thanks and appreciation to Mr. S. B. Helgason, Assistant Professor of Plant Science, University of Manitoba, under whose guidance the study was conducted and the manuscript prepared.

The author is indebted to Mr. A. B. Campbell, of the Dominion Laboratory of Cereal Breeding, Winnipeg, for the helpful suggestions and criticisms in preparing the manuscript.

Sincere appreciation is expressed to Mr. J. E. Dowd, Lecturer in Statistics, University of Manitoba, Winnipeg, for his helpful suggestions in connection with the statistical methods employed.

The author is grateful for the analyses of the saccharifying value performed by the staff of the Barley Improvement Institute, Winnipeg, Manitoba.

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