A STUDY OF METHODS OF INFLUENCING LODGING IN BARLEY

AND OF

THE EFFECT OF LODGING UPON YIELD AND VARIOUS QUALITY CHARACTERS

A Thesis

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INTRODUCTION

Many investigations have been carried out in an attempt to determine the cause of lodging. The problem has been approached from the point of view of soils and fertilizers, root structure, and stem morphology. Little work has been done to determine the specific effects of lodging on cereal crops although it has been assumed that it causes reduction in yield and kernel size.

The effect of lodging in test plots is also of great importance because of its probable effect upon quality. In a cereal breeding program in which quality factors are being considered, the lodging of some hybrids, due to their weak straw, may adversely affect their quality. This might result in very high quality hybrids, which would be of some use as parent material, being overlooked entirely. If information on the effect of lodging in cereals were available some adjustment of quality data could be made for plots which had lodged.

In order that accurate assessment of quality may be made, it is desirable to have test plots in which the various hybrids are as upright as possible. Therefore, techniques that may be applied to control lodging are valuable.

The first experiment in this study was designed to influence lodging in test plots by varying the rate of seeding, the spacing between rows and the type of guard row. It was thought that all these factors would have some effect on straw strength.

In the second experiment plots were lodged artificially at

various degrees and at several dates. The effect of such lodging upon yield and certain quality factors was determined.

REVIEW OF LITERATURE

Few data on the effect of rate of seeding and amount of spacing between rows on lodging in barley have been published. Numerous authors however refer in general terms to the effect of rate of seeding on lodging.

Welton and Morris (11) working with wheat and oats reported that heavier rates of seeding often lodged while lighter rates remained erect. Thayer and Rather (9) stated that at heavier rates of seeding "There was an increased tendency for the grain to lodge". Donald (1) reported that light seeding gave stronger strawed oats.

Leith and Delwiche (6) stated that oats seeded at higher rates lodged while those at lower rates did not. In 1919 they found that at a seeding rate of three bushels per acre 100 per cent of the crop lodged, at two bushels, 33 per cent lodged and at one bushel there was no lodging. In 1921 and 1922 similar results were obtained.

Percival (7) stated that lodging is "most frequently associated with weakness of straw due to the crowding of plants."

Thayer and Rather (9) also reported on yield as affected by rate of seeding. They found that the extent of tillering, length of head and number of kernels per head decreased as the rate of seeding increased from one-half to three bushels per acre. Yields at one and one-half, two and two and one-half bushels per acre varied little.

Rayns (8) found that barley seeded in rows three and one-half inches apart yielded more than that seeded in rows seven inches apart

the average increase being three bushels per acre. Harper (5) reported that oats in seven inch rows yielded more than those in fourteen inch rows seeded at half the rate per acre.

Harlan and Martini (4) stated that where there was early lodging of barley the development of the kernels was affected. Percival (7) reported that the lodging of a crop was of serious importance for it reduced the yield of grain.

Tysdal (10) lodged alfalfa plants artificially by gently forcing the stems over and holding them near the ground with wire staples. He found that the lodged plants gave a much reduced yield of seed.

Egorov (2) reported on the effect of lodging in wheat under irrigation. Two fields, one of 100 hectares and one of 110 hectares, were studied. Three samples were taken: the first from plants that were not lodged, the second from the top layer of lodged plants and the third from the bottom layer of lodged plants. Lowest values for head length, head diameter and weight of 100 heads were obtained from the sample taken from the bottom layer of lodged plants. These values decreased for the greater degrees of lodging. Thousand-kernel weight values were 47.9, 41.1 and 27.4. Yield was reduced by thirty-eight per cent in the plots in which the most lodging occurred. A measure equivalent to weight per measured bushel also decreased. Ratio of protein to starch in normal grain was 1 : 4 while in lodged grain it was 1 : 2.7. These results were attributed to changes in micro-climate.

MATERIALS AND METHODS

Six varieties of barley were used in both experiments. In selecting them an attempt was made to cover the range of straw strength as completely as possible. Sanalta was used to represent the strong strawed group; Montcalm, O.A.C. 21, Plush and 41-1522 (a hybrid developed at the University of Manitoba), the intermediate group and Wisconsin 38, the weak group.

In order to simulate weather conditions favorable to lodging a small overhead spray irrigation system was installed. In 1946 the equivalent of seven inches of rain was applied by irrigation. The natural rainfall during the growing season was 4.7 inches. In 1947, five and one-half inches were applied, the natural rainfall being 7.4 inches. Irrigation was stopped when the desired amount of lodging had been attained.

I. The effect of rate of seeding, spacing and type of guard row upon lodging in rod row plots

In this experiment the rate of seeding, the spacing between rows and type of guard row were varied in the test plots. The rates used were equivalent to one and one-half, two and two and one-half bushels per acre, at spacings of nine, twelve and fifteen inches. Three types of guard row were used: 1. the same variety as the test plots, 2. Sanalta barley and 3. Renown wheat.

All plots consisted of four rows. These were thirteen feet long,

one foot being cut off each end before harvesting. The two middle rows of each plot were used for making all determinations.

A split plot design was used, varieties being placed in the largest plots, guard row plots randomized within these plots and rates of seeding and spacing between rows randomized within the guard row plots. Only two replicates of the whole test were planted, but, as it was intended to attach little importance to varietal differences, each variety actually amounted to a replication.

Data on straw strength were obtained by multiplying the strength of straw recorded on a one to ten basis (one being flat on the ground, ten upright) by the percentage of the plot having that straw strength, summing the figures for each plot and dividing by 100.

Analysis of variance was performed on data obtained in 1946 and 1947 separately as well as over the two years. Methods described by Goulden (3) were used.

II. The effect of artificial lodging on yield and on various barley kernel characters

In the second experiment the same six varieties of barley were included. Plots consisted of six rows thirteen feet long, one foot being cut off each end before harvesting. All data were obtained from the middle two rows.

In 1946 two degrees of lodging were used; flat on the ground and upright. Complete lodging was accomplished by irrigating the plots for a number of hours and then gently pushing the plants down using a length of board which enabled all six rows of each plot to be lodged at the

same time. Care was taken not to damage the stems unduly or to disturb the roots. The lodging was performed at three dates; one week, two weeks and three weeks after heading. A split plot design was used; the varieties being placed in the larger plots and the different degrees of lodging carried out within them.

In 1947 another degree of lodging, namely an angle of approximately forty-five degrees, was included. The different degrees of lodging were accomplished by the following procedure: A piece of two inch mesh wire netting approximately the same size as the plot was supported horizontally at a level eighteen to twenty-four inches above the ground. The barley then grew up through this netting. The plots that were to remain upright were not disturbed. To obtain the forty-five degree angle the wire was pulled carefully so as to bend the plants the required amount. In the plots which were to be completely lodged, the wire netting was not placed above the plants. When the plots were to be lodged, the wire was rolled over them and secured to the ground by means of short wooden stakes.

This procedure was carried out at heading, ten days after heading and twenty days after heading. Satisfactory control of lodging was obtained by this method.

Yield, thousand-kernel weight, weight per measured bushel and nitrogen content of grain were determined.

A split plot design was used, varieties being placed in the larger plots and the degrees and dates of lodging in the smaller ones. This experiment could not be analyzed over two years because an additional treatment was included in 1947.

DISCUSSION OF RESULTS

I. The effect of rate of seeding, spacing and type of guard row upon lodging in rod row plots

TABLE I

VARIETAL DIFFERENCES IN YIELD
AND STRAW STRENGTH 1946 - 1947

Variety	Yield (bushels per acre)	Straw Strength (1-10)
Sanalta	50.17	6.28
O.A.C. 21	52.84	5.33
Plush	56.56	5.73
Montcalm	51.92	5.48
41-1522	51.47	5.29
Wisconsin 38	50.67	6.01
Necessary difference at the 5% point	9.01	1.68

From Table I it will be noted that there are no significant differences between the yields of the six varieties. This fact can be attributed to the design of the experiment. It was intended to attach little importance to varietal differences and they were placed in the largest plots. The error with which they were compared is therefore large.

Data on straw strength are given in the same table. The same

reasoning as above is applicable and differences are not significant although Sanalta appears to be the strongest strawed variety, 41-1522, the weakest.

TABLE II

EFFECT OF TYPE OF GUARD ROW ON YIELD AND STRAW STRENGTH 1946 - 1947

Type of Guard Row	Yield (bushels per acre)	Straw Strength (1-10)
Same as plot	47.89	5.22
Sanalta	48.44	5.65
Wheat	60.48	6.19
Necessary difference at the 5% point	3.50	0.76

In Table II figures for yield and straw strength obtained using different types of guard row are given. Guard rows of the same variety as the plot and Sanalta guard rows gave almost idential results. Wheat guard rows, on the other hand, gave a significantly higher value for both factors. Wheat generally has a stronger straw than has barley and this type of guard row tended to support the barley. The significant increase in yield from plots with wheat guard rows, may be attributed partly to the more upright position of the plants in these rows and partly to differences in the root habit of the two crops as the number of plants per row was the same for both cereals.

TABLE III

EFFECT OF VARIETY AND TYPE OF GUARD ROW
ON YIELD 1946 - 1947

	Type of Guard Row		
Variety	Same as Plot	Sanalta	Wheat
Sanalta	49.1	47.1	54.3
O.A.C. 21	49.0	48.4	61.2
Plush	53.3	53.2	63.1
Montcalm	46.1	50.2	59.4
41-1522	42.3	48.4	63.7
Wisconsin 38	47.5	43.3	61.2

Necessary difference for significance at the 5% point - 8.58 bushels per acre

From the above table it will be noted that although the wheat guard rows gave a significantly higher yield than the other types of guard row, they did not change the order of yield of the barley varieties significantly. However the increase in yield was greater for the weaker strawed varieties than for the stronger ones.

Yield and straw strength data obtained from different rates of seeding are given in Table IV. Yield decreased as the seeding rate increased, the differences being significant in all cases except between rates of one and one-half and two bushels per acre.

The straw strength also decreased significantly as the seeding rate increased from one and one-half to two to two and one-half bushels

TABLE IV

EFFECT OF RATE OF SEEDING ON YIELD
AND STRAW STRENGTH 1946 - 1947

Rate of Seeding (bushels per acre)	Yield (bushels per acre)	Straw Strength (1-10)
$1\frac{1}{2}$	54.03	6.13
2	52.56	5.76
$2\frac{1}{2}$	50.23	5.17
Necessary difference at the 5% point	2.18	0.24

per acre. The plots seeded at the heavier rates gave rise to plants with finer straw which tended to lodge more.

TABLE V

EFFECT OF ROW SPACING ON YIELD
AND STRAW STRENGTH 1946 - 1947

Spacing between Rows (inches)	Yield (bushels per acre)	Straw Strength (1-10)
9	56.48	6.04
12	51.45	5.67
15	48.88	5.34
Necessary difference at the 5% point	2.18	0.24

The effect of row spacing on yield and straw strength is given in Table V. Both yield and straw strength decreased significantly as the spacing between rows was increased from nine to twelve to fifteen inches. Since the rate of seeding per acre was the same regardless of row spacing, there were more plants per row at the wider than at the narrower spacings.

TABLE VI

EFFECT OF PLANT SPACING WITHIN ROWS ON
YIELD AND STRAW STRENGTH
(disregarding spacing between rows)
1946 - 1947

Number of Seeds per 13 foot Row	Yield (bushels per acre)	Straw Strength (1-10)
189	60.33	6.48
252	54.63	6.16
315	50.81	5.63
335	51.24	5.72
420	50.13	5.26
525	47.72	4.89

Data concerning spacing within rows are given in Table VI. These data are not strictly comparable as the figures for 252, 335, and 420 seeds per row were obtained from twice as many plots as the remainder. The trend shown in the table is quite apparent and it appears that the number of plants per row determines the yield and straw strength. Row

spacing was not considered in this table as the results were identical at each of the different row spacings.

TABLE VII

EFFECT OF ROW SPACING AND SEEDING RATE ON YIELD (BUSHELS PER ACRE) 1946 - 1947

Spacing between Rows	Rate of Seeding $1\frac{1}{2}$ bushels per acre	2 bushels per acre	$2\frac{1}{2}$ bushels per acre
9	60.33	55.94	53.19
12	53.33	51.24	49.78
15	48.44	50.49	47.72

Necessary difference at the 5% point - 3.79 bushels per acre

Tables VII and VIII show the effect of seeding rate and spacing between rows on yield and straw strength. An increase in either seeding rate or spacing between rows or an increase in both resulted in a decrease in yield and straw strength.

The results indicate that plots seeded at a rate of one and one-half bushels per acre in rows nine inches apart will give maximum yield and straw strength under the environment of this experiment.

TABLE VIII

EFFECT OF ROW SPACING AND SEEDING RATE ON STRAW STRENGTH (1-10) 1946 - 1947

Spacing between Rows	Rate of Seeding $1\frac{1}{2}$ bushels per acre	2 bushels per acre	$2\frac{1}{2}$ bushels per acre
9	6.48	6.03	5.61
12	6.28	5.72	5.00
15	5.64	5.51	4.89

Necessary difference at the 5% point - 0.42

II. The effect of artificial lodging on yield and on various barley kernel characters

The effect of date of complete lodging on yield, thousand-kernel weight, weight per measured bushel and nitrogen content are given in Table IX. Yield, thousand-kernel weight and weight per measured bushel decreased as the length of time the plots were lodged was prolonged. In the case of yield and thousand-kernel weight all differences shown are significant except those between plots lodged two weeks after heading and the check plots. All values obtained for weight per measured bushel are significantly different. Nitrogen content of the kernels increased as the period of lodging was prolonged. All differences are significant except that between plots lodged at the latest date and the check.

TABLE IX

EFFECT OF DATE OF LODGING ON YIELD PER ACRE, THOUSAND KERNEL WEIGHT, WEIGHT PER MEASURED BUSHEL AND NITROGEN CONTENT - 1946

Factor	Date of Lodging				Necessary difference at the 5% point
	At Heading	1 Week after Heading	2 Weeks after Heading	Check	
Yield (bushels per acre)	47.09	54.74	68.94	71.83	11.93
Thousand-kernel weight (grams)	33.22	35.87	38.43	39.23	1.28
Weight per bushel (pounds)	45.38	46.62	48.75	49.54	0.79
Nitrogen content (per cent)	2.37	2.30	2.20	2.15	0.06

TABLE X

EFFECT OF DEGREE OF LODGING ON YIELD PER ACRE, THOUSAND KERNEL WEIGHT, WEIGHT PER MEASURED BUSHEL AND NITROGEN CONTENT - 1947

Factor	Degree of Lodging			Necessary difference at the 5% point
	Flat on ground	45 Degree	Upright	
Yield (bushels per acre)	30.46	42.19	57.17	5.60
Thousand-kernel weight (grams)	28.08	31.51	34.54	1.50
Weight per bushel (pounds)	39.64	42.96	46.19	1.29
Nitrogen content (per cent)	3.07	2.82	2.62	0.10

The effect of degree of lodging is shown in Table X. As the degree of lodging was reduced from flat on the ground through forty-five degrees to upright, the values for yield, thousand-kernel weight and weight per measured bushel increased significantly. In the case of nitrogen there was a progressive significant decrease.

TABLE XI

EFFECT OF DATE OF LODGING AND DEGREE OF LODGING ON YIELD (BUSHELS PER ACRE) - 1947

	Date of Lodging		
Degree of Lodging	At Heading	10 Days after Heading	20 Days after Heading
Flat on ground	24.47	29.96	36.95
45 Degrees	33.88	44.94	47.75
Upright	58.34	55.16	58.01

Necessary difference at the 5% point - 6.86 bushels per acre

Table XI shows the effect of date of lodging and degree of lodging upon yield. At any date of lodging a significant increase in yield was obtained as the degree of lodging was reduced. In plots lodged to such an extent that they were flat on the ground all differences due to date of lodging are significant except that between plots lodged at heading and those lodged ten days after heading. An increase in yield was also

obtained in plots lodged to a forty-five degree angle at the various dates. The yields of 44.94 and 47.75 bushels per acre are not significantly different. Any degree of lodging carried out at any of the dates considered gave a significant decrease in yield as compared with the corresponding check plot. The percentage decrease in yield from an average of check plots varied from 16.5 per cent in plots lodged forty-five degrees twenty days after heading to 57.2 per cent in plots lodged flat at heading time.

TABLE XII

EFFECT OF DATE OF LODGING AND DEGREE OF LODGING ON WEIGHT PER MEASURED BUSHEL (POUNDS) - 1947

	Date of Lodging		
Degree of Lodging	At Heading	10 Days after Heading	20 Days after Heading
Flat on ground	39.71	38.17	41.01
45 Degrees	42.71	42.58	43.58
Upright	46.17	46.38	46.04

Necessary difference at the 5% point - 2.24 pounds

Table XII shows the effect of date of lodging and degree of lodging on weight per measured bushel. At any date of lodging the values for weight per measured bushel increased significantly as the degree of

lodging was reduced.

Date of lodging had little effect on weight per bushel at any degree of lodging. The values for plots lodged twenty days after heading were, however, slightly higher than those for plots lodged at earlier dates. Data for plots lodged ten days after heading are slightly lower than those for plots lodged at heading. This may be attributed to the fact that the plots lodged earlier were still in a very active growing stage and the heads tended to grow upright through the wire even though the culms were at the desired angle. This gave the kernels in these heads a better chance to fill than those on the heads of plants which were lodged at a later date and remained flat on the ground.

Decrease in weight per measured bushel would be expected as lodging tends to produce small kernels which have a large percentage of hull and hence have a lower weight per unit volume. The decrease varied from 5.7 per cent to 17.4 per cent.

Thousand-kernel weight data are shown in Table XIII. At any date of lodging the values for thousand-kernel weight increased as the degree of lodging was reduced. All these differences are significant except that between plots lodged to an angle of forty-five degrees twenty days after heading and the check plot. Date of lodging appears to have little effect on this character. Plots lodged twenty days after heading, however, had slightly higher values than those lodged at earlier dates. Figures for plots lodged ten days after heading are slightly lower than those for

TABLE XIII

EFFECT OF DATE OF LODGING AND DEGREE OF LODGING ON THOUSAND-KERNEL WEIGHT (GRAMS) - 1947

Degree of Lodging	Date of Lodging: At Heading	10 Days after Heading	20 Days after Heading
Flat on ground	28.10	27.08	29.05
45 Degrees	31.05	30.75	32.73
Upright	33.98	34.96	34.68

Necessary difference at the 5% point - 2.60 grams

plots lodged at heading. This may be explained in the same manner as were the corresponding figures for weight per measured bushel. (See Page 18). The percentage decrease from check plots varied from 5.2 per cent to 21.6 per cent.

Data concerning the effect of date of lodging and degree of lodging on nitrogen content of kernels are given in Table XIV. At all dates the values for plots lodged flat were significantly higher than the corresponding values for the check plots. In all cases the per cent nitrogen decreased as the amount of lodging was reduced. In the plots lodged to such an extent that they were flat on the ground, the per cent nitrogen decreased as the date of lodging was delayed.

This decrease in nitrogen content would be expected as in the final stages of development starch is the main product produced. The smaller,

TABLE XIV

EFFECT OF DATE OF LODGING AND DEGREE OF LODGING ON NITROGEN CONTENT OF KERNELS (PER CENT) 1947

Degree of Lodging	Date of Lodging: At Heading	10 Days after Heading	20 Days after Heading
Flat on ground	3.18	3.04	2.99
45 Degrees	2.92	2.71	2.83
Upright	2.56	2.60	2.70

Necessary difference at the 5% point - 0.17 per cent

less well developed kernels would therefore contain a higher per cent of nitrogen. The percentage increase in nitrogen varied from 3.4 per cent to 21.4 per cent above an average of the check plots.

It was not intended to study varietal reactions, and since none of the interactions involving varieties were significant, discussion of individual varieties has been omitted.

SUMMARY AND CONCLUSIONS

Two experiments were included in this study. The first involved an attempt to influence the amount of lodging in rod row test plots by varying the rate of seeding, the spacing between rows, and the kind of guard row. In the second a study was made of the effect of artificially induced lodging upon yield, thousand-kernel weight, weight per bushel, and nitrogen content of the kernels. Techniques for inducing lodging are described.

Degree of lodging was inversely proportional to rate of seeding. The rates used were one, one and one-half and two bushels per acre. Yield was also inversely proportional to seeding rate. The least lodging and highest yield were obtained in rows spaced nine inches apart and seeded at a rate of one and one-half bushels per acre. The number of plants per row was lowest at this spacing. The use of wheat guard rows gave stronger strawed plants and higher yield without significantly changing the order of yield of the varieties.

Complete lodging (flat on the ground) resulted in values for yield, thousand-kernel weight, and weight per measured bushel which were significantly lower than corresponding values for barley lodged to an angle of forty-five degrees or for that which remained upright. Values for plots lodged forty-five degrees were lower than those for plots which remained upright. A progressive significant increase of the nitrogen content of the kernels was obtained as the amount of lodging increased.

Earlier dates of lodging caused greater decreases in yield,

thousand-kernel weight, and weight per measured bushel than did later dates of lodging. Earlier lodging also gave increases in the nitrogen content of kernels.

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