The influence of environmental factors on the degree of stem solidness expressed by selections from crosses involving rescue wheat

by John J Kolar

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Abstract:
Fifteen selections from a N1750 (Pilot x Mida) x Rescue population, 15 selections from a Rescue x Golden Ball population, and Rescue were grown at Choteau, Montana in 1950 under four environmental conditions; namely, irrigated, irrigated-shaded, non-irrigated and non-irrigated-shaded. The test was repeated in 1951; however, moisture levels were omitted.

These same lines were grown at Bozeman, Montana in 1950 and 1951 under irrigated and non-irrigated conditions; however, the shading treatment was omitted.

Estimates of stem solidness were made according to a method of classification suggested by Miss Ruby Larson. Numerical estimates of stem solidness were analyzed statistically.

Analysis of the stem solidness data obtained at Choteau in 1950 revealed a highly significant reduction due to shading. The lack of difference between the irrigated and non-irrigated plots was presumed to be due to the prevalence of sufficient moisture until late in the growing season. However, highly significant differences between lines within population one and between lines within population two were indicated. In 1951, the data revealed highly significant 'differences between lines of population one but no differences between lines of population two. The shading treatment was not effective in reducing stem solidness.

Analysis of the data obtained at Bozeman in 1950 indicated significant differences due to moisture levels. Highly significant F values were obtained for lines of population one, lines of population two, populations, and the interactions of population x moisture level and lines of population 'one x moisture level. Significant differences were obtained in 1951 be-. tween moisture levels, between populations, and between lines of population one.

Line B49-106 was superior to Rescue in stem solidness while line B49-100 was less solid. As indicated by a combined analysis, none of the lines showed the stability of Golden Ball, which was grown at both locations in 1951.

THE INFLUENCE OF ENVIRONMENTAL FACTORS ON THE DEGREE OF STEM SOLIDNESS EXPRESSED BY SELECTIONS FROM CROSSES INVOLVING RESCUE WHEAT

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ABSTRACT

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Analysis of the data obtained at Bozeman in 1950 indicated significant differences due to moisture levels. Highly significant F values were obtained for lines of population one, lines of population two, populations, and the interactions of population x moisture level and lines of population one x moisture level. Significant differences were obtained in 1951 between moisture levels, between populations, and between lines of population one.

Line B49-106 was superior to Rescue in stem solidness while line B49-100 was less solid. As indicated by a combined analysis, none of the lines showed the stability of Golden Ball, which was grown at both locations in 1951.

INTRODUCTION

The development of Rescue Wheat (Triticum aestivum, T. vulgare) from an Apex x S615 cross and its subsequent wide use in sawfly areas has proved effective in reducing damage caused by the wheat stem sawfly (Cephus cinctus Nort.). The solid stem of this wheat is thought to provide mechanical resistance to the feeding larvae, causing increased mortality and consequently decreasing the amount of stem cutting.

Unfortunately, the degree of stem solidness exhibited by Rescue wheat is influenced greatly by environmental conditions prevailing during the growing season. Therefore, the resistance of Rescue wheat varies in different localities and in different seasons.

Golden Ball, a variety of Triticum durum, has offered very effective resistance to sawfly damage. Since the solidness of stem exhibited by Golden Ball remains relatively stable under most environmental conditions, this character would be very desirable in a wheat of the Triticum vulgare group.

In interspecific crosses of Golden Ball and vulgare wheats, little success has been realized in transferring the Golden Ball type of stem solidness to the progeny without the transfer of other undesirable durum characters. No progeny of the vulgare type have been found with the Golden Ball stem solidness stability.

This study was undertaken in an attempt to determine if derivatives of a N1750 (Pilot x Mida) x Rescue cross and of a Rescue x Golden Ball cross would prove superior to the Rescue parent in stem solidness. At the same time, it was desired to observe the effects of moisture and light on the degree and stability of stem solidness of these lines when grown in the field.

REVIEW OF LITERATURE

Percival (9) in his monograph on the wheat plant reported that most of the common and club wheats have culms that are thin-walled and hollow. The culms of Triticum durum, T. polonicum, and T. turgidum are usually smaller in diameter and filled with pith or are thick-walled with a very small lumen. Solidness of straw is not a common character in the vulgare wheats, but it has been found in some wheats from the Mediterranean Region (16). The solid stem vulgares are solid in all portions except for short distances below the spike and above and below the nodes. The solid stems of durums and other 28 chromosome wheats are solid throughout the upper internode, even immediately below the spike but may be somewhat hollow in the lower internodes (14) (20).

Platt and Larson (12) concluded that the type of solidness exhibited by the solid stem vulgares differ from Golden Ball, a solid stem durum, in two respects; first, the vulgare type of solidness is more easily modified by environment, secondly, when environmental conditions prevail that do not allow for the maximum expression of solidness, the vulgares become less solid below the spike while the durums are invariably solid at this point though they may show hollowness in one of the lower internodes.

The effect of environment on plant structure has been widely studied and numerous authors have reported varied results. Penfound's work (8) with Helianthus annuus and Polygonum hydropiper revealed that plants grown in full sunlight differed from those that were shaded in that the roots and hypocotyl of plants grown in full sunlight had a greater diameter, a greater area of xylem, and more and thicker-walled mechanical elements. Results of

Shirley's experiments (17) with sunflowers, buckwheat, tobacco, and tomatoes disclosed that the percentage of dry matter in tops, vigor of growth, strength of stem, and leaf thickness all increased as light intensity was increased. Arthur and Stewart (1) grew plants under several conditions of shading such that the transmission of light was respectively 100, 78, 58, and 35 percent of the total solar radiation. Tobacco plants reached maximum dry weight at 35 percent intensity, buckwheat and dahlia at 58 percent, and sunflowers at 78 percent intensity. Leaves of deciduous trees increased in thickness, intercellular spaces, size of cells and stomata, and layers of assimilating tissue in high light intensities (5). Studies of the effect of light intensity on the growth of soybeans by Popp (13) showed that the rate of elongation was more rapid during the period of initial growth under low light intensities, and that thickness of stem was directly proportional to light intensity.

Welton and Morris (23) grew soybeans under screens of single layers of cheesecloth. Results showed less dry matter in the shaded material as well as less carbohydrates, cellulose, and lignin. Since cellulose and lignin give strength to stems, the shaded material had a greater tendency to lodge. Oats and wheat grown under shading had less dry matter than plants grown under normal conditions (21).

Clements and Long (3) concluded that with sunflowers, water assumes the greater role in cell elongation and light the greater part in the production of dry matter. The amount of top growth of potatoes was not altered by soil moisture content as long as available moisture was present (19).

The effects of environment on the expression of stem solidness in wheat has been summarized by various workers. Platt and Farstad (4) observed that where stem solidness was decreased by environmental conditions prevailing during the growing season, the incidence of damage by the sawfly in solid stem vulgare wheats was increased. S-615, the solid stem parent of Rescue, was cut 73 percent by sawfly at Regina in 1945, the highest recorded damage for this variety in a field test. Climatic data revealed that there were 60 hours less sunshine during June for that particular test than for any other recorded test in which this variety was grown. Resistance of the solid stem vulgare wheats was modified by rainfall during the growing season, hours of sunshine, and prevailing temperatures during the early growth period. Most changes in stem solidness occurred during the period of stem elongation. The effects of environment were reflected in the wide variation in solidness of stem between locations and between years (6) (10).

The solid stem vulgare wheats were partially hollow when grown under field cages and completely hollow when grown in the greenhouse. Greenhouse experiments conducted to determine effects of moisture levels on stem solidness were unsuccessful because of the influence of some other factor which caused all plants to be hollow. This factor was presumed to be light intensity.

Spacing experiments reported by Platt (10) indicated that wheat plants, sown in the normal manner in the field and at a rate of 1-1/2 bushel per acre, were less solid than those plants which had been spaced within the rows with the rows one foot apart.

Golden Ball, a solid stem durum wheat, remained solid in all field tests. However, when Golden Ball was grown in the greenhouse during the winter, it had a tendency to be only partially solid. Summer greenhouse tests using Golden Ball showed that it retained its solidness (10).

The genetic factors involved in determining stem solidness vary with the species. Since most wheats are tetraploids or hexaploids, the study of inheritance of stem solidness is complicated by the fact that several chromosomes may be carrying genes which govern the expression of this character.

Early studies by Biffin (2) indicated that Triticum vulgare contained a dominant factor for hollowness expressing itself over the recessive factor, solid, which was found in Triticum turgidum.

Platt, Darroch, and Kemp (11) using crosses of hollow stem vulgares x solid stem vulgares, concluded that solidness was controlled by 3 factor pairs. Stem solidness was expressed only in those plants in which these factors were recessive. They suggested that the factors were cumulative in effect and that 4 or more dominant genes would produce plants that were phenotypically hollow stemmed.

Yamashita (23) concluded that the factor for hollow in the A genome was the most primitive of all and therefrom the factor for hollow or medullary in the B genome would have differentiated or mutated. The factor for hollow in the C genome probably would have differentiated from that of the more or less related B genome.

Platt and Larson (12) obtained solid stemmed derivatives from crosses between Golden Ball and two hollow stemmed vulgare wheats, R.L.1097 and

Regent. The derivatives had some of the seed characteristics and disease reactions of the vulgare wheats. The haploid chromosome number of these lines was the same as that of the durum parent. They concluded that the transfer of the durum type of stem solidness to the vulgare wheats was not practical.

Cytogenetic studies of interspecific crosses revealed the difficulty which is encountered in the attempt to transfer characters from a tetraploid to a hexaploid. Cytological examinations by Sax (15) of a cross between _T. vulgare_ and _T. durum_ revealed 14 bivalents and 7 univalents in the first meiotic division. In the second meiotic division, the 7 univalents did not divide but were distributed at random between the two poles. Some of these chromosomes were observed to lag and thus they sometimes were not included in the resulting gametes. The gametes formed by _T. vulgare_ x _T. durum_ contained between 14 and 21 chromosomes. The nearer the chromosome number approached the parental haploid number (14 or 21), the more likely it would be that the gametes would be functional. Thompson (18) observed from the F_3 of a cross between _T. durum_ and _T. vulgare_ that when the chromosome number was near 21, very few durum characters were evident; inversely, when the chromosome number was near 14, most durum characters were evident. Plants with intermediate chromosome numbers showed some characters of both parents.

MATERIALS AND METHODS

Two populations, consisting of 15 lines each, were grown under various environmental conditions in order to discover which of the lines, if any, were superior to the Rescue check in either stability or degree of solidness. At the same time, it was desired to find what effect moisture level and light intensity had on the expression of stem solidness.

Population one was composed of 15 F_7 lines from a N1750 (Pilot x Mida) x Rescue cross made at Bozeman, Montana. These derivatives had only Rescue as a solid stem parent and were selected in the early generations for this character.

Golden Ball and Rescue were the parental varieties of the 15 F_6 lines which made up population two. These lines were the result of crosses made at Lethbridge, Alberta and were selected for solid stem as well as other characters common to the vulgare type wheats. Since both parents are solid stemmed, it seemed possible that greater solidness may have been attained by these interspecific hybrids.

The lines of these populations and the Rescue check were planted in 5 foot rows spaced 1 foot apart at Choteau and Bozeman, Montana in 1950 and 1951. Golden Ball was also grown as a check variety in 1951 at both locations in order to observe the effect of environment on its stem structure.

The Choteau tests were conducted at the sawfly field nursery. The plants were grown under four environmental conditions; namely, irrigated, non-irrigated, irrigated-shaded, and non-irrigated-shaded in 1950. The two irrigated treatments were not applied in the 1951 tests. Three replications of each treatment were used.

Shading was obtained by erecting screens of a single layer of cheese cloth over the plots. These screens reduced light intensity by 1/3 according to Weston Light Meter readings.

Bouyoucos blocks were used at 6 and 18 inch depths to check soil moisture content in 1950. According to the block readings, the moisture level was ample during the early growth period. Irrigation was unnecessary until July 21 at which time the wheat was 25 to 50 percent headed.

The amount of stem cutting by the wheat stem sawfly was recorded both in 1950 and 1951. The percentage of cutting was obtained by dividing the number of cut stems by the total number of stems in the sample and multiplying by 100.

The same entries were also grown at Bozeman, Montana in 1950 and 1951 under irrigated and non-irrigated conditions; however, no shading treatments were provided at this location.

The field plots of all tests were planted in such a manner that the resulting data could be analyzed statistically. Treatments made up the main plots while the sub-plots were composed of lines.

The wheat plants from the inner portion of each row were pulled when fully matured and were classified for solidness during the autumn and winter months. The only exception to the above rule was the 1951 Choteau tests. In this test, it was desired to classify the wheats of one replication during the soft dough stage of kernel development when the stems were still green. This procedure was followed so that it could be ascertained how much change in solidness of stem occurred between the two stages of maturity.

Twenty stems were selected at random from each row to form the row sample. Only main tillers or culms were examined in order to eliminate variation due to differences that might have existed between the main culms and the secondary tillers.

The system of stem solidness classification used in this study was a modification of a method suggested by Miss Ruby Larson of the Dominion Experiment Station, Lethbridge, Alberta, Canada (7).

In the method of classification used in this study, the stems were cross-sectioned at designated points and estimates of the degree of stem solidness were made for each trans-section. The estimates were given numerical values ranging from 1 to 5, the former designating a thin walled, hollow, cross-section, while the latter indicated a completely solid cross-section. Estimates were made to the nearest whole numbers, and the sum of values of all the cuts made on the stem formed the stem solidness rating. The stem solidness rating of each row sample was the average of the values of the 20 stems within the sample.

Three cuts or cross-sections were made in the first or uppermost internode in order to distinguish the durum type of solidness. These cuts were made 2 inches below the base of the spike, 2 inches above the first node and at the center of the internode. All other internodes were cross-sectioned only at the point midway between the nodes. Only 4 internodes were used in determining the stem solidness ratings of a stem as this was the number of internodes common to the majority of the stems. Little variation was found in the fifth and sixth internode when they were present so these extra internodes were disregarded. Possible range of the stem solidness rating was from 6 to 30.

EXPERIMENTAL RESULTS

Analysis of the data of stem solidness ratings of the wheats grown at Choteau, Montana in 1950 was performed and the results are presented in Table I.

Table I. Analysis of variance of stem solidness ratings of lines grown at Choteau, Montana in 1950. 1/

Variance due to:	df	Variance	s
Replications	2	6.98	
Irrigated vs. non-irrigated	1	2.79	
Shaded vs. non-shaded	1	106.03**	
Population one vs. population two	1	9.32	
Moisture x shade	1	5.40	
Moisture x populations	1	2.08	
Shade x populations	1	1.21	
Moisture x shade x populations	1	8.42	
Error (a)	14	4.93	2.22
Lines within population one	15	18.44**	
Lines population one x shade	15	.76	
Lines population one x moisture	15	.93	
Lines population one x shade x moisture	15	1.28	
Error (B)	120	1.08	1.03
Lines within population two	2	1.26**	
Lines population two x shade	14	.37	
Lines population two x moisture	14	.55	
Lines population two x shade x moisture	14	.71	
Error (C)	112	.44	.67
Total	371		

**F value significant at the 1 percent level

1/ Rescue is included in population one.
L.S.D. lines of population one (P = .05) 1.68
L.S.D. lines of population two (P = .05) 1.10

The analysis indicated significant reductions in stem solidness due to the shading treatment. However, no significant difference due to moisture levels was revealed, this presumably being due to the fact that moisture was not a limiting growth factor until late in the season.

Highly significant differences between lines were evident in both populations. While differences between lines within population two were highly significant, none of these lines were significantly different from the Rescue check. On the other hand, some of the lines of population one were significantly different than Rescue. B49-106 was significantly higher in solidness than the check while B49-100 was significantly less solid. Variance due to populations was not significant.

Sawfly cutting data obtained from this test indicated that the shaded wheat plants were more heavily cut than the non-shaded plants. This higher percentage of cutting was attributed to the increased hollowness of the shaded lines.

The accuracy of the sawfly cutting data was questionable as the mixture of cut stems in the field made identity of the source of these stems difficult to determine. Consequently, no statistical analyses involving cutting percentages were employed. Nevertheless, it can be pointed out that B49-106, the most solid line, had an average cutting of 10 percent while B49-100, the most hollow line, had an average cutting of 24 percent as compared with 12 percent cutting recorded for the Rescue check.

Data of the stem solidness ratings of the wheats grown at Bozeman, Montana in 1950 and 1951 were analyzed and the results are presented in Table II.

Table II. Analyses of variance of stem solidness ratings of lines grown at Bozeman, Montana in 1950 and 1951. 1/

Variance due to:	df	1950 Variance	1950 s	1951 Variance	1951 s
Treatment (Moisture level)	1	206.71*		259.84*	
Error (A)	2	4.98	2.23	3.60	1.89
Lines	30	9.31**		3.25*	
Population one vs. population two	1	50.15**		10.42*	
Lines within population one	15	12.70**		4.17*	
Lines within population two	14	2.75**		1.76	
Lines x Moisture	30	1.25*		2.16	
Population one vs. population two x moisture	1	3.69*		.08	
Lines within population one x moisture	15	1.81**		2.46	
Lines within population two x moisture	14	.48		1.98	
Error (B)	60	.64	.80	1.91	1.38
Total	123				

* Significant at the 5 percent level
** Significant at the 1 percent level

1/ Rescue is included in population one.
1950 L.S.D. lines (P = .05) 1.60
1951 L.S.D. lines (P = .05) 2.76

The analysis of variance of the data obtained in 1950 revealed highly significant differences in stem solidness between lines while the difference between moisture levels and difference due to the interaction of lines x moisture were significant only at the 5 percent level.

Further breakdown of the variance attributed to lines indicated highly significant differences between lines within population one as well as between lines within population two.

When the variance due to the lines x moisture levels interaction was broken into its component parts, population x moisture levels interaction was revealed. The interaction of lines within population one x moisture level was highly significant thus indicating that these lines did not respond to the two moisture levels in the same manner.

Variation between lines, when measured by twice the standard error of the difference, showed 13 lines to be higher in stem solidness rating than the Rescue check while only one line, B49-100, was significantly lower. Of these 13 lines, only 3 were in population one (N1750 x Rescue) while the remainder were in population two (Rescue x Golden Ball).

Analysis of the Bozeman data of 1951, also presented in Table II, showed significant differences to exist between moisture levels and between lines. When the variance due to lines was attributed to its component parts, significant differences between populations and between lines within population one were evident but differences between lines of population two were not apparent. No interactions were significant in this analysis when measured by the F test. Error (B) in the 1951 analysis was approximately three times that of 1950. The greater error term was probably due to the large soil variation within plots.

Results from the analysis of data of stem solidness ratings of the wheats grown at Choteau, Montana in 1951 is presented in Table III.

Table III. Analysis of variance of stem solidness ratings of lines grown at Choteau, Montana in 1951. 1/

Variance due to:	df		Variance	s
Replications	2		121.01*	
Shaded vs. non-shaded	1		4.33	
Error (A)	2		3.20	1.78
Lines	30		4.25**	
Population one vs. population two		1	.13	
Lines within population one		15	7.88**	
Lines within population two		14	.64	
Lines x Shade	30		.59	
Population one vs. population two x Shade		1	.78	
Lines within population one x Shade		15	.63	
Lines within population two x Shade		14	.55	
Error (B)	120		.54	.74
Total	185			

* Significant at the 5 percent level
** Significant at the 1 percent level

1/ Rescue is included in population one
L.S.D. of lines (P = .05) = 1.21

Highly significant differences between lines were obtained which on further breakdown were revealed to be due to the lines within population one. Lack of a significant difference due to the shading treatment was noted.

This analysis also revealed a difference between replications in the test. The main factor influencing this difference can be assumed to be stage of maturity at which the respective replications were classified for stem solidness. The more mature plants had a lower stem solidness rating than those which were classified while still green.

In order to obtain an overall evaluation of all lines, the data of all trials were combined and the variance of each line was calculated. The overall mean and range in stem solidness rating, as well as the coefficient of variability, was obtained for each line. These data are presented in Table IV.

Large differences in coefficients of variability of lines were absent except for Golden Ball which was grown only in 1951. Its coefficient of variability of two percent gave evidence of its stability under all conditions encountered.

The mean solidness rating of B49-106 was higher than any of the other lines tested. Its rating of 25.8 most nearly approached that of Golden Ball which had a rating of 29.5. Rescue's rating of 23.4 was definitely inferior to that of B49-106 and Golden Ball. The stem solidness rating of B49-100 was consistently low in all tests and its instability was indicated by a coefficient of variability of 15.30 percent.

Table IV. Means, ranges, and coefficients of variability of stem solidness ratings, and the annual and average sawfly cutting percentages of all lines grown at Choteau and Bozeman, Montana in 1950 and 1951.

Line or Variety	Range of Solidness	Mean Solidness	C.V. (%)	Sawfly cutting percentage		
				1950	1951	Ave.
Population one (N1750 x Rescue)						
B49 - 94	15.9 - 25.8	22.7	12.47	18	28	23.0
- 95	16.5 - 27.5	23.0	13.91	16	23	19.5
- 98	16.0 - 26.9	22.2	14.36	18	24	21.0
-106	19.4 - 29.2	25.8	11.28	10	18	14.0
-101	17.2 - 26.7	23.2	11.16	19	23	21.0
Rescue	18.0 - 27.9	23.4	11.75	12	19	15.5
B49 -103	17.1 - 26.4	22.8	13.38	23	21	22.0
- 97	16.5 - 26.2	22.4	13.30	18	23	20.5
- 96	16.6 - 27.8	22.9	14.24	14	25	19.5
-100	15.3 - 24.2	20.0	15.30	24	27	25.5
-102	16.9 - 27.8	23.2	13.36	13	19	16.0
-108	16.6 - 25.7	22.6	11.86	11	26	18.5
-113	17.1 - 27.8	23.9	12.22	14	17	15.5
-109	17.8 - 26.8	23.4	11.37	14	17	15.5
-111	16.9 - 27.2	24.0	12.33	14	24	19.0
-112	18.2 - 28.6	24.0	12.63	17	30	18.5
Population two (Rescue x Golden Ball)						
4093 - 17	17.8 - 28.2	23.4	12.74	12	19	15.5
- 6	18.6 - 25.7	22.5	12.40	16	18	17.0
- 15	17.9 - 26.5	23.5	12.34	7	21	14.0
- 8	17.0 - 25.8	22.5	11.96	16	23	19.5
- 1	17.7 - 25.4	22.6	10.62	17	21	19.0
- 14	17.9 - 28.0	23.3	12.45	7	23	15.0
- 4	17.9 - 25.9	22.9	11.18	10	25	17.0
- 9	16.9 - 27.5	23.0	13.17	17	22	19.5
- 11	17.5 - 26.4	23.2	11.64	14	18	16.0
- 2	17.1 - 27.0	22.9	11.83	16	15	15.5
- 3	17.8 - 27.8	23.0	13.09	9	21	14.5
- 13	17.2 - 27.6	23.2	13.32	15	19	17.0
- 10	17.8 - 25.7	22.8	11.18	18	19	18.5
- 5	17.7 - 28.0	23.2	12.63	14	19	16.5
- 12	16.9 - 27.4	23.3	12.15	15	22	18.5
Golden Ball**	29.2 - 29.8	29.5	2.00	—	2	2.0

* Sawfly cutting data were obtained from the sawfly field nursery at Choteau, Montana.

** Golden Ball was grown only in 1951.