INFLUENCE OF PERIODIC SHADING ON THE LENGTH AND SOLIDNESS OF THE INTERNODES OF RESCUE WHEAT¹

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ABSTRACT

Shading at the initiation of elongation shortened the internodes of Rescue wheat whereas shading later in the elongation period caused the internodes to elongate as much as or more than if they had not been shaded.

The solidness of the bottom Internode, 1, was reduced mainly by shading from the 2-leaf to the boot stage, while that of Internodes 2 and 3 was reduced mainly by shading from the 4-leaf to the boot stage. The solidness of Internode 4 was reduced mainly by shading from the boot to the heading stage. The solidness in the lower 3 internodes was affected by reduction in light intensity even after the boot stage. Severe lodging occurred only in stems shaded from the boot to the heading stage.

Two methods were used for rating stem solidness, namely, measurement in the split stem of proportion of the internode filled with pith, and classification of solidness of cross-sections at designated points in each internode. They were strongly correlated and appeared to give equally accurate estimates of solidness, although their degrees of sensitivity varied with the amount of stem solidness present.

INTRODUCTION

Farstad (1) found that the stem solidness of certain lines of *Triticum aestivum* L. emend Thell., including S-615, which is one of the parents of Rescue wheat, is affected by environment. When these lines were grown under cages or in the greenhouse, their solidness was reduced. Platt (6) concluded that reduction in light intensity is the major factor in reducing stem solidness in S-615. He also stated that June is the critical month in determining stem solidness in the field, although in some cases the effect may extend into July.

The importance of stem solidness in host resistance to the wheat stem sawfly, *Cephus cinctus* Nort., has been shown (1, 3, 7). The present study was conducted to determine the effect of shading during several periods in the growing stage on the solidness of each internode of Rescue, a sawfly-resistant bread wheat. In addition there was a need for a comparison of two techniques of measuring stem solidness, one based on the diameter and the other on the length of the pith cavity.

METHODS AND MATERIALS

The experiment was conducted on dry land at Lethbridge, Alberta, in 1956. Rescue wheat was seeded on May 16 in rows spaced 7 inches apart in six blocks. Each block consisted of six randomized plots. The blocks and the plots were separated by 10 feet. Each plot was covered during a specified period with a cage approximately 2 feet square and 3 feet high. The top, east, and west sides of each cage were completely covered with heavy, unbleached cotton sheeting. To allow air movement within the cage, the north side was not covered and the south side was covered to within 6 inches of the base of the cage.

¹Contribution from the Entomology Section.

The ripe wheat from each plot was collected and divided at random into two lots. Ten main stems from the first lot were split longitudinally. The length of each of the internodes, which were numbered consecutively from the base, and of its pith cavity were used to obtain percentage solidness. The data were converted by the angular transformation and subjected to the "F" test (2). Ten main stems from the second lot were rated for solidness by Larson's method (4, 5). Cross-sectional cuts were made at the centre in all five internodes as well as at 1 cm. from the top in Internodes 1 and 2 and at 2 cm. from the top in Internodes 3 and 4, and at 5 cm. from the top in Internode 5. The population shaded from boot to heading stage was not examined as the stems were too brittle. The solidness was rated by index numbers ranging from "1" for thin-walled hollow to "5" for completely solid cuts. The means for the various cuts were calculated to 0.01. Only data from the centre cuts were included in Table 3, as they were generally representative of the data from the other cuts.

RESULTS AND DISCUSSION

Internode Length

Shading the plants during different periods in their development did not exert a uniform effect on the length of the various internodes; some were elongated as expected, but others were shortened (Table 1). Hence, it appeared that stage of development of the stems during shading may have been an important factor. The mean lengths in millimeters of 10 unshaded main stems at each stage were:—

Date	Stage	Internode				
		1	2	3	4	5
June 18	4-leaf	18	4	1	0.3	—
July 6	Boot	45	90	110	23	7
Sept. 4	Mature	59	85	147	242	483

Shading before the 2-leaf stage had no effect on internode length (Table 1). Shading from the 2-leaf to the 4-leaf stage shortened Internodes 1 to 4; all of these internodes started elongating during this period (see leader table above). Shading from the 4-leaf to the boot stage lengthened Internodes 1, 2, and 3 and shortened Internodes 4 and 5; during this period elongation was completed in Internodes 1 and 2, about 75 per cent completed in Internode 3, about 10 per cent completed in Internode 4, and just started in Internode 5. Shading from emergence to the boot stage had a similar effect except that it shortened Internode 3; during this period Internode 3 was shaded during initial elongation but, apparently, not long enough during its later development to overcome the initial shortening effect. Shading from the boot to the heading stage did not affect the length of Internodes 1, 2, and 3 but it did lengthen Internode 4 and shorten Internode 5; during this period Internode 4 completed its elongation while Internode 5 had not finished when the cages were removed.

Hence, shading during the initiation of elongation of an internode reduced its elongation whereas shading later in the elongation period caused the internode to elongate as much as or more than if it had been unshaded.

Internode Solidness

Shading up to the 2-leaf stage had no effect on internode solidness (Table 2 and 3). The most critical period in the determination of solidness in Internodes 1, 2, and 3 was from the 4-leaf to the boot stage (June 18 to July 6), although the solidness of these internodes continued to be affected by shading even after the boot stage. The most critical period in the determination of solidness in Internode 4 and probably Internode 5 was from the boot to the heading stage (July 6 to 17). Shading from the 2-leaf to the 4-leaf stage (May 29 to June 18) increased the length but not the diameter of the pith cavity of Internode 1 and increased the effect on Internodes 1 and 2 of shading continued to the boot stage. Shading between the 4-leaf and boot stages increased the solidness in the middle of Internode 4 (Table 3), and decreased the solidness in the upper part. The mean solidness indices of the upper cuts in this internode of stems shaded from emergence to the boot stage and from the 4-leaf to the boot stage were 2.95 and 2.65, which were both significantly more hollow at the 1 per cent level

TABLE 1.—THE EFFECT OF SHADING ON INTERNODE LENGTH (MM.) IN RESCUE

Dates shaded	Stage of plant shaded	Internode				
		1	2	3	4	5
None (check)	None	59	85	147	242	483
May 23 to May 29	Emergence to 2-leaf	56	84	147	246	484
May 29 to June 18	2-leaf to 4-leaf	39**	72**	119**	231*	457
June 18 to July 6	4-leaf to boot	71†	124††	161††	157**	416**
May 23 to July 6	Emergence to boot	68	120††	117**	171**	406**
July 6 to July 17	Boot to heading	61	92	148	252†	423**

*Significantly lower than check

†Significantly higher than check

TABLE 2.—THE EFFECT OF SHADING ON PERCENTAGE SOLIDNESS BASED ON LONGITUDINALLY SPLIT STEMS OF RESCUE

Stage of plant shaded	Internode				
	1	2	3	4	5
None (check)	88	95	91	18	3
Emergence to 2-leaf	94	97	97	19	4
2-leaf to 4-leaf	66**	93	84	25	3
4-leaf to boot	30**	25**	12**	24	19††
Emergence to boot	14**	7**	16**	20	14††
Boot to heading	72*	85**	61**	3**	0

*Significantly lower than check

†Significantly higher than check

TABLE 3.—THE EFFECT OF SHADING ON THE SOLIDNESS INDICES OF THE CENTRE CROSS-SECTIONAL CUTS IN THE INTERNODES OF RESCUE

Stage of plant shaded	Internode				
	1	2	3	4	5
None (check)	4.96	4.95	4.90	3.26	2.28
Emergence to 2-leaf	4.98	5.00	4.98	3.14	2.27
2-leaf to 4-leaf	4.92	4.97	4.90	3.48	2.20
4-leaf to boot	4.42**	4.10**	3.52**	3.74†	3.20††
Emergence to boot	3.82**	3.42**	3.88**	3.85††	2.76†

*Significantly lower than check

†Significantly higher than check

than the check. Shading between the 4-leaf and boot stages also increased the solidness of Internode 5, while shading from the boot to the heading stage completely reduced the solidness of this internode, although the check was so hollow that a significant difference could not be obtained. There appeared to be no consistent relationship between length of an internode and its solidness.

Normally, in Rescue, the pith cavity extends down from the upper node in each internode, but when Rescue was shaded from the boot to the heading stage, a large cavity developed in the lower part of Internode 3. This occurred because approximately 75 per cent of Internode 3 had already developed at the boot stage and the lower 25 per cent developed after the cage was placed over the plants.

Shading from the boot to the heading stage greatly increased the brittleness of the stems. Almost all of the stems that received this treatment were broken near the third internode at maturity whereas most of the stems from the other treatments were still in good condition. This suggests that the period from the boot to the heading stage may be the most critical period in determining the characteristics of the straw that are associated with lodging resulting from excessive reduction in light intensity.

Comparison of the Two Techniques for Measuring Solidness

The data obtained independently by the two methods were very similar (Tables 2 and 3). A correlation coefficient of 0.89, significant at the 1 per cent level, was obtained between the data from the cuts made in the middle of the internodes and the percentage solidness of the internodes. Similarly, the correlation coefficient of 0.91 between the cuts at the top of the internodes and the percentage solidness was equally significant. Thus, the diameter of the pith cavity is significantly related to the length of the pith cavity and the measurement of either should give a good index of the solidness of an internode. However, cross-sectional cuts can be made much more quickly than the more laborious method of measuring the length of the internode and of the pith cavity. In a few cases significant differences between the treatments and the control were obtained with one method and not the other. Internode 4 showed a significant difference from the control only in the diameter of the pith cavity in plants shaded from the 4-leaf to the boot stage and from emergence to the boot

stage. However, the cavity at the top of Internode 4 was significantly more hollow, while that at the middle was significantly more solid than at the same locations in the unshaded stems. Thus, the amounts of solidness at the two locations appear to nullify each other in respect to the sawfly resistance of the internode, and the failure of the longitudinal measurements to pick out this effect is probably not too serious. In the treatment where the plants were shaded from the 2-leaf to the 4-leaf stage, Internode 1 was significantly more hollow only in the length of the pith cavity (Table 2). It appears that the method of measuring the length of the pith cavity is more sensitive at the upper levels of solidness, as a decrease in the cross-section index of about 25 per cent was accompanied by a drop in the longitudinal index of about 80 per cent. Conversely, the cross-sectional method is more sensitive at the lower levels of solidness. This indicates that the pith cavity starts to lengthen before it increases in diameter but that after the cavity has reached about its maximum length, its diameter continues to enlarge.

Whichever method is used to determine the solidness of the various internodes, the lumping together of all the ratings to obtain a single rating for the whole stem is of doubtful value. Most of the sawfly eggs are generally laid in the lower three internodes. As sawfly larvae can complete their development in one internode, individuals from eggs laid in the lower three internodes of solid stems may tunnel only in these internodes. However, larvae from eggs laid in the upper internodes must tunnel through the lower internodes. Thus, the lower internodes are generally more important in the resistance of a stem to sawflies. Combining the solidness ratings of the upper internodes with that of the lower internodes may give a false picture of the sawfly resistance. This applies in particular to the rating by the cross-sectional method, which includes three cuts in the top internode and two cuts in each of the other internodes.

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