



The agronomic characteristics and the reaction to attack by the wheat stem sawfly of a series of foreign wheat introductions
by Eugene G Eckroth

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:

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Many correlations were calculated between the plant characters and the methods of infestation sampling and percent cutting.

Date of heading was found to be negatively correlated with infestation in the spring planting but not in the fall planting. This correlation was considered to indicate that the later the variety the less the infestation, which results in a variety avoiding the peak of the sawfly flight. Plant height was found to be negatively correlated with infestation in both spring and fall plantings with the exception of the hollow stemmed wheats in the fall planting. This correlation indicates that the taller the variety the less the infestation.

Stem diameter did not appear to be correlated with infestation or cutting.

Regression coefficients were calculated and used for predicting amount of cutting when the degree of infestation was known.

Some multiple correlations were computed involving characters showing association.

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ABSTRACT

The following factors: date of heading, date of ripening, date of planting, plant height, stem diameter and stem solidness were studied in relation to attack by the wheat stem sawfly on selected wheat varieties.

Many correlations were calculated between the plant characters and the methods of infestation sampling and percent cutting.

Date of heading was found to be negatively correlated with infestation in the spring planting but not in the fall planting. This correlation was considered to indicate that the later the variety the less the infestation, which results in a variety avoiding the peak of the sawfly flight.

Plant height was found to be negatively correlated with infestation in both spring and fall plantings with the exception of the hollow stemmed wheats in the fall planting. This correlation indicates that the taller the variety the less the infestation.

Stem diameter did not appear to be correlated with infestation or cutting.

Regression coefficients were calculated and used for predicting amount of cutting when the degree of infestation was known.

Some multiple correlations were computed involving characters showing association.

INTRODUCTION

The wheat stem sawfly, Cephus cinctus Norton, is a species native to the United States. It has come into prominence since the beginning of the present century, as a result of the change in its larval feeding habits. This insect originally lived in the tall, hollow, native grasses of Western North America, but with the increase of cereal grains in the northern Great Plains area, the sawfly has transferred to these grains, particularly wheat.

The sawfly increased from an almost unknown insect to a major pest of wheat in Montana during the period 1940 to 1945.

Rescue, a variety of hard red spring wheat, has been tested in Canada and Montana under sawfly conditions. These tests indicate that the resistance of Rescue to sawfly cutting is probably due to the solidness of stem, which is characteristic of this variety. However, the degree of stem solidness is apparently modified to a great extent by weather and other environmental conditions as shown in a study by Platt (9).

In view of the lack of sawfly resistance in varieties of wheat now being grown commercially it seems desirable that a search for new sources of resistance be made. The study reported here was undertaken to determine if there are characters, other than solidness of stem, which will provide additional sources of resistance to sawfly attack.

A grouping study was also made with the varieties of wheat being divided into nine groups, based on their morphological characteristics.

REVIEW OF LITERATURE

(The sawfly was first observed in 1890 in the stems of native grasses in the vicinity of Alameda, California (2).) In 1895, adults were collected in the Canadian Northwest Territories and in the same year larvae were found feeding in wheat near Kulm, in south-central North Dakota.) By 1908, the sawfly was beginning to cause alarm in central Manitoba and Saskatchewan, and (in 1909 losses of 5 to 25 percent were reported from the area around Minot and in the Red River Valley, near Fargo, North Dakota. The North Dakota infestation reached epidemic proportions in 1916, but then it receded and by 1920 the sawfly was a pest of slight importance. The infestation in the western Canadian provinces continued and as new wheat acreages were brought into production, the losses mounted. This explains why the Canadian government has been interested in sawfly research for many years.

(In Montana, the first adult sawfly was collected near Bozeman in 1900. In 1910, the first infested wheat stems were found in northeastern Montana, near Bainville.) No further sawfly activity was reported until 1923, but from 1923 to 1941 sporadic reports of its occurrence were received from widely scattered areas throughout the state. (In 1941, the sawfly began to cause concern in the northeastern counties and the western part of the Triangle, and by 1943, it was a major pest in wheat growing areas. It has increased in severity almost every year since 1943.)

The adult is wasp-like in appearance, black, with yellow

rings on the abdominal segments and legs. The egg is laid within the stem of the host plant by means of a sawlike ovipositor with which the adult insect easily penetrates the tough outer wall of the stem. The egg, although very thin and delicate, is strong enough to be safely lifted and moved with the aid of a fine brush. The egg always lies free within the stem of the host plant, either in the stem cavity or in a hollow excavated by the ovipositor of the female. Hatching occurs in about one week.

The larva feeds within the stem, moving up and down in its gallery, until about the time the wheat begins to ripen (1). The larva traverses its gallery several times swallowing repeatedly the same fragments of tissue that have already been devoured during the first excavation of the stem. It is also believed that the larva which finally reaches maturity has devoured its rival larvae or eggs. Measurements of larvae gave a range of 8 to 14 millimeters in length and 1 to 2 millimeters in width. The length of the larval period is probably about 60 days, varying more or less with the warmth of the summer and the state of maturity of the host stems. When mature the larva always seeks the extreme base of the stem, where it begins its preparations for hibernation. Here it cuts a neat V - shaped groove entirely around and inside the stem, usually at or a little above ground level. This groove does not sever the stem completely, but so weakens it that the upper stalk, swayed by the wind, will break off completely

when dry, leaving a stub that is very characteristic of the work of this insect. In this simple manner the larva provides the adult with a means of escape from the stub the following summer. After cutting its characteristic groove within the stem the larva forces a mass of the frass into the bore just below the groove and in this manner plugs the upper end of the stub that is to be left in the ground after the upper stalk has been broken away. Late in the summer or in the fall the larva within the stub spins for itself a delicate membranous cocoon and hibernates. During the winter the larvae are frozen or are chilled into immobility and show no signs of life when disturbed. As soon as the temperature rises in the spring they become active and move freely up and down within the limits of the hibernation chamber until the time of pupation arrives.

Duration of the pupal period is dependent upon temperature and moisture. Pupation usually begins in late May or early June and two distinct periods are recognized. The early pupa is creamy white and the late pupa is dark colored. Emergence of the adult from the pupal case generally occurs within a few days after the late pupa is recognized. The adult remains for a short while in the cell before forcing its way upward through the plug or frass to emerge. After emerging, the adult is able to take instantly to wing without any preliminary drying or other preparation.

A few adults die within the cell, possibly because of the

lack of vitality needed to break through the stopper of frass above them. In cases where the girdling of the stem is inefficiently done, so that the wheat stalk does not break off during the winter season, the adult dies.

The female is noticeably larger than the male. The adults seem to be partial to sunshine and are rarely seen abroad on a cloudy day. They are considered weak fliers and seldom travel to any great distance at one time. The adults are not at all timid and can often be easily taken from the grass stems with the fingers. When conditions are favorable the female is usually too intent on oviposition to be easily annoyed but if disturbed beyond endurance she quickly disappears.

Copulation is very brief, usually lasting less than a minute. The species is single brooded with the first adults usually appearing during the spring and the last some time about midsummer.

✓ (The female gives evidence of being in search of a particular point for oviposition and has her head downward, looking towards the base of the stem during oviposition. When satisfied with a location, she halts and slowly arches her abdomen and, clasping her hind pair of feet around the stem as far as they will reach, begins to drive the ovipositor into the hard outer coating of the stem. She makes an opening so small that it is almost impossible to find the scar.)

(Normally but one egg is placed in each stem. However, no

attention is paid to previous oviposition by other sawflies, and consequently numerous eggs have been taken from a single stem.) As was stated before, only one of the larvae can possibly survive until fall. Injury to the wheat crop is due primarily to breaking of the straw before or at harvest time rather than from the quantity of food that the insect removes from the plant. This causes much of the grain to fall to the ground or lodge so that it can be harvested only with great difficulty.

(Several partially effective cultural methods have been tried in attempts to control the sawfly. Plowing the infested stubble under in such a manner that the entire slice is inverted, prevents the adults from emerging (1). When this is properly done it shows some success in control. Occasionally, larvae may live over in the stubs for more than one season, although very little is known about the larva when it goes through this diapause stage. In some locations, cultural conditions are not favorable for burying stubble by plowing. In North Dakota, spring wheat is followed in many cases by winter rye which is disked into the wheat stubble after harvest. The wheat stubble seems to be necessary in this region to hold the winter snow for the protection of the young rye seedlings.

Larvae can be killed by tillage methods which lift and expose the stubble to thorough drying (9). Some reduction in population can be expected from very shallow surface tillage soon

after harvest.

Under ordinary conditions the burning of the infested stubble in the fall or spring does not seem to heat the ground sufficiently to kill the larvae in the stubs.

— Early harvesting of the crop eliminates some loss, since the plants do not fall until they are ripe and the straw is dry (8). This early harvesting is usually accomplished by swathing or binding the grain just prior to ripening. Pickup reels attached on combines are used to pick up grain that has been swathed or windrowed.)

Munro (9) found that the application of present day insecticides are impractical in control of the wheat stem sawfly.

(Wheat may be protected somewhat against sawfly by delayed seeding (9).) To what extent this advantage is offset by decreased yields still needs to be determined.

Flax is readily infested, but the sawfly mortality is quite high (3). The sawfly appears to be of little importance as a potential pest in flax.

Farstad and Platt (4) tested a number of barley varieties throughout the sawfly area in Canada. Significant varietal differences in infestation were established in all nurseries and in cutting in all but one. Trebi was found to be most resistant with Flush, Prospect and Newal almost equally so. Hannoeh and Rex were most susceptible. None of the barleys sustained damage to the same extent as adjacent plots of Thatcher and Marquis

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wheats. Unpublished data from the Entomology department of Montana State college indicates that the barley variety, Compana, is highly resistant to the sawfly.

Farstad and Platt (5) found that durum varieties had high resistance in wet years and variable reactions in other years.

Where practical, rotation of crops is recommended with such resistant crops as flax, oats, barley, corn, mustard, and sweetclover (7). This should prove effective in reduction of sawfly damage.

The latest and present recommendation in Montana is to plant Rescue wheat in all sawfly areas. Rescue is a hard red spring wheat with a solid stem which appears to be the source of resistance. It has proven beneficial in the sawfly areas, but like all varieties of wheat it has certain limitations. The solidness of the stem is modified to a great extent by weather conditions. If the weather conditions are variable, Rescue may be expected to give high resistance one year and practically no resistance another. Platt (10) has demonstrated that shading in the field will cause solid stemmed wheats to become hollow. He found that with few exceptions solid stemmed wheats always have hollow stems when grown in the greenhouse. However, he found that Golden Ball, a solid stemmed durum, remained solid under all conditions. It was more resistant to cutting than any solid stemmed vulgare wheats tested. In view of Platt's study it seemed desirable to attempt a transfer of

the solid stem character of Golden Ball to hollow stemmed varieties of Triticum vulgare Vill. by hybridization. This project was started by Platt (11) before Yamashita's work was made available. According to Yamashita there is a gene for hollowness in the C genom of Triticum vulgare Vill. that is epistatic to the genes for solidness in the A and B genoms. Yamashita's work may have influenced Platt since he was unable to accomplish this breeding objective. Platt's failure to obtain solid stem vulgare segregates lends support to Yamashita's hypothesis.

MATERIALS AND METHODS

Two thousand varieties of foreign wheat introductions were obtained from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, and seeded October 1, 1948. These wheats were seeded in single five foot rows in a sawfly infested area northeast of Choteau, Montana. This was the beginning of an extensive screening project with the State of Montana and the United States Department of Agriculture cooperating. Since the spring and winter growth habit was not known, these same 2000 varieties were replanted May 5, 1949.

It was thought that a diversity of plant characters might have an influence on infestation. Wheat varieties were divided into groups having different characteristics with 25 to 30 varieties selected for each group. The groups were as follows: Tall, Short, Early, Late, Large Stems, Slender Stems, Solid Stems, Durums, and Clubs.

Agronomic notes taken included date of heading, date ripe, plant height, and growth habit. A variety was considered fully headed when 75 percent of the row was headed. The early group headed out between June 21 and June 30, whereas the late group headed out between July 12 and July 15. Varieties in the short group varied in height from 19 to 26 inches at the end of the flight period, whereas those in the tall group ranged in height from 27 to 33 inches. Varieties assigned to the slender stem

group and large stem group were those which appeared either large or slender in the field. This material was measured in the laboratory using calipers to measure the diameter of the lowest internode. The slender stem group ranged in diameter from 2.2 mm to 2.5 mm and the large stem group 3.2 mm to 3.8 mm. The solid group included varieties which were variable in the expression of solid stems. Mr. D. J. Ward, who sent the seed from Sacaton, Arizona, included a list of varieties showing stem solidness. This list was the basis for this grouping. Only those varieties showing more than 50% solidness were included. No variety in this group was as solid as Rescue. Varieties for the durum and club groups were selected on the basis of morphological characters. No cytological study was made, therefore, it is possible that a few varieties do not belong in these two groups.

The sawfly flight period lasted from June 10 to July 15 with some appearing before and after this period but not in great enough numbers to be of importance.

Material from the fall planting was collected on July 9, 1949 and from the spring planting on August 1, 1949. Ten stems were taken at random from each variety in each series. This material was stored in a refrigerator at Montana State College the same day it was collected in order to prevent excessive drying out of the stems.

In the field, the remaining stems of each row were tied into two or three bundles while still standing to insure greater

accuracy in checking infestation and cutting. Tying the plants in the row prevented the cut stems from entangling or mixing with adjoining rows.

Field infestation notes were taken by counting all the stems in the row including the ones cut off by the sawfly. The number of cut stems were counted and the stems not cut by sawfly were cross-sectioned through the middle of the internodes and if frass or evidence of tunneling was noticeable they were considered infested. For total infestation, the cut stems plus the infested stems were divided by the total number of stems in the row. For percent cutting the cut stems were divided by the total number of stems in the row.

During the fall and winter of 1949-50 this material was studied in the laboratory. Each group was assigned 20 varieties from the fall planted series and 15 varieties from the spring planted series. Since growth habit was not known prior to selection of wheats for the nine groups, some winter wheats were selected for spring planted series. This reduced the number of varieties available for the spring planted series since the winter wheats did not head.

Infestation was checked by splitting all stems longitudinally. Percent stems with larvae were computed for each variety. It was done by dividing the number of stems infested with larva by ten. Percent stems with larvae or eggs was figured for each variety. It was figured the same way as for percent stems

with larvae. Larvae per stem was calculated by dividing the total number of larvae in each variety by the ten stems checked. The number and location of eggs and larvae were listed by internode. The internodes were numbered from the bottom to the top of the plant as one to four. Approximately 3000 stems were split in the fall planted and spring planted series of which only about 30 stems had five internodes at the stage in which this material was collected.

Mean infestation location on the stem was computed for each variety to determine whether it had any effect on cutting. This was done by assigning each internode a numerical value. Internode 1, which is the bottom internode, was assigned a value of .5, internode 2 a value of 1.5, internode 3 a value of 2.5, and internode 4 a value of 3.5. The total number of larvae and eggs in each of the internodes was multiplied by the appropriate values shown above. This total sum was divided by the total number of larvae and eggs, giving the mean infestation location on the stem for each variety.

The data was first analyzed on the basis of the groups as previously set forth. An examination of this analysis indicated that a population study with larger numbers would be desirable. For this portion of the study these wheats were divided into three groups: (1) all wheats in the above groups, (2) hollow stemmed wheats, and (3) solid stemmed wheats and durum wheats.

The basic information used in this study was recorded on

punch cards and run through an IBM machine.

One hundred and eighty-eight correlation coefficients were computed, some of which were not directly applicable. Some multiple correlations, as well as regressions, were computed.

EXPERIMENTAL RESULTS

Varieties in the spring planted series were over two weeks later in heading than the same varieties in the fall planted series as shown in Table 1. For this reason the spring planted material was not collected until three weeks after the fall planted material had been collected.

Table 1. A comparison of the heading dates for different groups in the fall and spring planting.

Group	Average Heading Date	
	Fall planted	Spring planted
Tall	July 3	July 20
Short	July 6	July 20
Early	June 30	July 17
Late	July 13	July 31
Large Stem	July 8	July 24
Slender Stem	July 2	July 17
Solid Stem	July 8	July 27
Durum	July 8	July 23
Club	July 11	July 27

Upon checking infestation in the spring planted varieties, it was found that a large amount of larval tunneling had taken place through the nodes. For this reason, it did not seem justifiable to compute infestation data similar to that in the fall planting. This tunneling must have resulted in the destruction of other larvae and eggs and resulted in smaller infestation readings than had occurred. Infestation data for the spring plantings, therefore, consists only of percent stems with larvae

or eggs for each variety. Only seven eggs in over 1400 stems were found. Since the spring planted series had so much tunneling the more valuable data for this study was obtained from the fall planted series.

Many of the fall planted varieties did not germinate until the following spring due to very dry conditions. This condition should be considered because of its possible effect on results.

Infestation, as well as cutting, was higher in the fall planting than in the spring planting. The sawfly flight was considered uniform throughout the nursery.

Date of heading had no effect on any of the measures of infestation or cutting in the fall planted series. However, in the spring planting, heading date had a very pronounced effect on infestation and cutting. This is illustrated in Table 2.

Table 2. A comparison of infestation and cutting for different groups in the fall and spring plantings.

Group	Fall planted			Spring planted	
	field infestation	stems with larvae or eggs	cutting	stems with larvae or eggs	cutting
	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
Tall	56.6	70.0	37.2	46.0	33.3
Short	64.4	67.5	50.5	40.0	32.0
Early*	61.2	76.0	37.5	66.7	39.3
Late*	56.1	70.0	43.0	11.0	6.7
Large stem	54.3	56.0	39.6	32.7	10.0
Slender stem	53.1	65.5	33.1	35.3	20.7
Solid stem	43.0	70.5	16.3	45.3	5.3
Durum	29.4	30.0	5.4	4.0	1.3
Club	56.5	65.0	37.2	24.7	11.3

* Heading date

Since the maturity of varieties by groups differed considerably it was deemed undesirable to continue with the original analysis on the basis of these groups. In addition, each of these groups was affected by a number of factors which would give misleading results. For example, the tall group was influenced by date of heading, stem size, amount of stand and others, in addition to the plant height factor. Since these factors influencing the results could not be controlled in the group analysis, a population study was decided on.

Selectivity of the sawfly for different plants is also illustrated in Table 2. The durum group in the spring planting had only 4 percent of the stems infested as compared to a much higher infestation in the other groups. This selectivity is not so pronounced in the fall planted series where all groups had a high infestation. For the above reasons, it was deemed advisable to keep the durum and solid stem groups separate from the hollow stemmed varieties for the purpose of population study.

An attempt was made to devise a sampling method which would give an accurate prediction of percent cutting about six weeks prior to harvest. The methods used for sampling infestation were as follows: (1) percent stems with larvae, (2) percent stems with larvae or eggs, and (3) larvae per stem. These methods have been previously described. Percent field infestation was also taken for comparison with the above sampling methods.

These data are presented in Table 3.

Table 3. Correlation coefficients between infestation reading methods and cutting percentage.

Infestation reading methods	Types of wheat	N*	r
<u>Fall planted series</u>			
Field infestation	1. Solid stemmed and durums	40	.685**
	2. Hollow stemmed	140	.831**
	3. All wheats	180	.830**
Percent stems with larvae	1. Solid stemmed and durums	40	.690**
	2. Hollow stemmed	140	.329**
	3. All wheats	180	.553**
Larvae per stem	1. Solid stemmed and durums	40	.577**
	2. Hollow stemmed	140	.251**
	3. All wheats	180	.409**
Percent stems with larvae or eggs	1. Solid stemmed and durums	40	.588**
	2. Hollow stemmed	140	.383**
	3. All wheats	180	.496**
<u>Spring planted series</u>			
Percent stems with larvae or eggs	1. Solid stemmed and durums	30	.519**
	2. Hollow stemmed	105	.875**
	3. All wheats	135	.812**

** Denotes significance at the 1% level

* N= Number of varieties in each correlation

The types of wheat appear to have an effect on the correlation coefficients. In the fall planted series, the measures of infestation in all cases except field infestation show a higher correlation with percent cutting in the solid stemmed and durum wheats than in the hollow stemmed wheats. However, in the spring planting the measures of infestation of the hollow stemmed wheats

exhibit a higher correlation with percent cutting than the solid stemmed and durum wheats.

Percent stems with larvae appears to be the best method of predicting cutting in solid stemmed and durum wheats, whereas percent stems with larvae or eggs has a higher correlation with cutting in the hollow stemmed wheats. Field infestation had a higher correlation coefficient with percent cutting than any of the other infestation measures. This may be due to the fact that field infestation included cut stems which raised the correlation.

Only a small number of correlations were calculated in the spring planting because of the limited data.

Regression coefficients were determined for percent stems with larvae or eggs with percent cutting. These are presented in Table 4.

Table 4. Regression coefficients of percent stems with larvae or eggs with percent cutting in the fall and spring plantings.

Types of wheat	No. of varieties	Regression coefficients
Fall planted series	N	b
1. Solid stemmed and durums	40	.231 $\pm$.517
2. Hollow stemmed wheats	140	.326 $\pm$.669
Spring planted series		
1. Solid stemmed and durums	30	.128 $\pm$.039
2. Hollow stemmed wheats	105	.729 $\pm$.040

** Denotes significance at 1% level.

Table 6. Mean infestation location for each group in the fall planted series.

Group	Average mean infestation location
Tall	2.77
Short	2.60
Early	3.00
Late	1.81
Large Stem	2.45
Slender Stem	2.95
Solid Stem	2.64
Durum	3.26
Club	2.05

Mean infestation location is lower on the stem in later maturing varieties. The late group and the club group, a comparatively late group, illustrate this. Infestation location was higher on the stem in the durum and early groups. See appendix tables 1 to 9 for detailed data.

Mean infestation location was highly correlated with cutting, especially in the solid stemmed and durum wheats. The correlation within the hollow stemmed wheats were significant at the 5% level, but not at the 1% level. Since the correlations are of a negative value this indicates that the lower the infestation on the plant the more liable the plant is of becoming cut, particularly in the solid stemmed wheats. Table 7 shows the correlation coefficients between mean infestation location and percentage cutting and percent stems with larvae or eggs in the fall planting.

Since regression coefficients are known, it is possible to predict the amount of cutting by knowing the percent stems with larvae or eggs. This is demonstrated by using examples in Table 5.

Table 5. Examples of predicted cutting percentages assuming infestation percentages of 30, 50, and 70, and using the regression coefficients in Table 4.

Types of wheat	Percent stems with larvae or eggs	Predicted percent cutting
Fall planted series		
1. Solid stemmed and durums	30	6.1
	50	10.7
	70	15.4
2. Hollow stemmed	30	27.6
	50	34.1
	70	40.6
Spring planted series		
1. Solid stemmed and durums	30	4.8
	50	7.3
	70	9.9
2. Hollow stemmed	30	26.5
	50	41.1
	70	55.7

Data on infestation location are presented in Table 6.

Table 7. Correlation coefficients of mean infestation location with percent cutting and percent stems with larvae or eggs in the fall planted series.

Characters correlated	Types of wheat	N ⁺	r
Mean infestation location x percent cutting	1. Solid stemmed and durums	40	-.556**
	2. Hollow stemmed	140	-.172*
	3. All wheats	180	-.343**
Mean infestation location x percent stems with lar- vae or eggs	1. Solid stemmed and durums	40	-.515**
	2. Hollow stemmed	140	-.055
	3. All wheats	180	-.244**

- * Denotes significance at the 5% level
 ** Denotes significance at the 1% level
 + Number of varieties in each correlation

Most of the larvae were observed in the third internode with internodes two and four following in that order. However, this was not true in the case of eggs observed. Most of the eggs were observed in internode four with internodes three and two following respectively. These data are presented in Tables 8 and 9. Only in the case of the durum group were there more eggs found than larvae observed. This may be due to the fact that the eggs were more noticeable in pithy stems.

Table 8. Number of larvae in the internodes of each group and percentage of the total observed in the fall planted series.*

Group	Internodes								Total
	1		2		3		4		
	no.	%	no.	%	no.	%	no.	%	
Tall	0	+0	26	18.7	49	35.3	64	46.0	139
Short	0	+0	45	26.8	91	54.2	32	19.1	168
Early	0	+0	9	4.5	83	41.5	108	54.0	200
Late	7	4.2	99	59.6	50	30.9	2	1.2	166
Large stem	0	+0	44	34.9	55	43.7	27	21.4	126
Slender stem	0	+0	32	20.0	68	42.5	60	37.5	160
Solid stem	1	+7	60	40.0	59	39.3	30	20.0	150
Durum	0	+0	2	13.3	5	33.3	0	53.3	15
Club	4	2.6	86	55.5	59	39.1	6	3.9	155
Total	12	+9	403	31.6	527	41.2	337	36.3	1279

* 200 stems checked in each group.

Table 9. Number of eggs in the internodes of each group and percentage of the total observed in the fall planted series.*

Group	Internodes								Total
	1		2		3		4		
	no.	%	no.	%	no.	%	no.	%	
Tall	0	+0	1	2.2	5	10.9	40	87.0	46
Short	0	+0	0	+0	7	21.2	26	78.8	33
Early	0	+0	2	6.3	4	12.5	26	81.3	32
Late	0	+0	1	4.8	10	47.6	10	47.6	21
Large stem	0	+0	5	18.5	1	3.7	21	77.8	27
Slender stem	0	+0	0	+0	11	32.4	23	67.6	34
Solid stem	0	+0	3	2.9	28	27.2	72	69.9	103
Durum	0	+0	1	1.5	6	9.1	59	89.4	66
Club	1	5.0	1	5.0	7	35.0	11	55.0	20
Total	1	+3	14	3.7	79	20.7	280	75.3	382

* 150 stems checked in each group.

Correlation coefficients calculated on the internode data are presented in Table 10. Computations were made for the hollow stemmed wheats only. Table 10 shows that percent cutting is significantly associated with percent stems with larvae or eggs and percent stems with larvae in internodes two and three. There is also association of internode infestation with heading date and plant height and these correlations substantiate the association of heading date and plant height with infestation.

Table 10. Correlation coefficients of percent cutting, heading date and plant height with internode data for the hollow stemmed wheats in the fall planted series. (N=140)

Correlation coefficients			
	% cutting	Heading date	Plant height
	r	r	r
Percent stems with larvae or eggs at internode			
1	.024	.291**	.245**
2	.227**	.573**	.125
3	.196*	-.070	-.341*
4	-.031	-.718**	-.471**
Percent stems with larvae at internode			
1	.007	.275**	.239**
2	.200*	.623*	.207*
3	.222**	.081	-.338**
4	.001	.679**	-.398**
Percent stems with eggs at internode			
1	.049	.107	.146
2	.108	.039	.001
3	-.027	.019	-.042
4	-.035	-.296**	-.315**

* Denotes significance at 5% level.

** Denotes significance at 1% level.

Stem diameter does not seem to be associated with cutting or infestation, although in the field the sawfly appears to be looking for a specific place or specific size stem for oviposition. The correlations involving stem diameter include only the 40 varieties which make up the large stem and slender stem groups. These correlations are presented in Table 11.

Table 11. Correlation coefficients of stem diameter with various observations in the fall planted series. (N=40)

Observations correlated with stem diameter	r
% cutting	.272
% stems with larvae or eggs	-.215
% stems with larvae	-.213
Larvae per stem	-.152
Heading date	.675**
Plant height	.363*
Mean infestation location	-.478**
* Denotes significance at the 5% level.	
** Denotes significance at the 1% level.	

Table 12 shows a high negative correlation in the fall planting between plant height and infestation in the solid stemmed wheats and durums and no significant correlation in the hollow stemmed wheats. This correlation means that the taller the plant the less the amount of infestation. However, this does not hold true for the hollow stemmed wheats since they showed no significant correlation. It appears that the durums are affecting this correlation.

Table 12. Correlation coefficients between percent cutting, percent stems with larvae or eggs and heading date and plant height in the spring and fall plantings.

Characters	Types of wheat	% cutting	% stems with larvae or eggs
Fall planted series			
Heading date	1. Solid stemmed and durums	.275	.057
	2. Hollow stemmed	.164	.019
	3. All wheats	.111	.013
Plant height	1. Solid stemmed and durums	-.265	-.574**
	2. Hollow stemmed	.044	.120
	3. All wheats	-.131	-.183*
Spring planted series			
Heading date	1. Solid stemmed and durums	-.181	-.374*
	2. Hollow stemmed	-.567**	-.617**
	3. All wheats	-.525**	-.568**
Plant height	1. Solid stemmed and durums	-.376*	-.597**
	2. Hollow stemmed	.216*	-.269**
	3. All wheats	-.300**	-.398**

* Denotes significance at the 5% level

** Denotes significance at the 1% level

Most of the spring planting correlations were significant which shows that heading date and plant height are associated with cutting and infestation. This was true in all cases but one, where heading date and cutting were not significantly associated in the solid stem and durum groups.

Some multiple correlations were calculated in order to determine the effect of more than one character in combination on cutting and infestation. The multiple correlations of interest

are presented in Table 13. Infestation in this table refers to percent stems with larvae or eggs.

Table 13. Multiple correlations of various observations with percent cutting in the fall and spring plantings.

Observations correlated with percent cutting and types of wheat	No. varie- ties correlated	Multiple correlations
	N	R
<u>Fall planted series</u>		
Heading date and plant height		
Hollow stemmed	140	.173
Heading date and stem diameter		
Solid stemmed and durum	40	.301
Heading date and mean infestation location		
Solid stemmed and durum	40	.559**
All wheats	180	.401**
Heading date and infestation		
Hollow stemmed	140	.636**
Heading date and % stems with larvae at internode 2		
Hollow stemmed	140	.206*
Heading date and % stems with larvae or eggs at internode 2		
Hollow stemmed	140	.231*
Plant height and stem diameter		
Solid stemmed and durum	40	.272
<u>Spring planted series</u>		
Heading date and plant height		
Solid stemmed and durum	30	.731**
Hollow stemmed	105	.666**
All wheats	135	.663**

* Denotes significance at the 5% level

** Denotes significance at the 1% level

Another multiple correlation of interest but not included in Table 13 is heading date and plant height x infestation with a correlation of .593 in the solid stemmed and durum wheats.

All wheat varieties in this study were hollow stemmed except those in the solid stem group and some in the durum group. A few of the hollow stemmed wheats had a cutting percent low enough to warrant further testing. These varieties are: (1) Tall group, 100, 1318, and 1398, (2) Short group, 1508, (3) Early group, 289, (4) Slender stem group, 303, 1312, 1422, (5) Club group, 93, and 517. Appendix tables 7 and 8, the durum and solid stem groups, show considerably more varieties with a low cutting percent. It is believed these varieties had a low cutting due to the presence of a solid or pithy stem.

DISCUSSION

Varieties with solid or pithy stems and durums were the only wheats that showed considerable mechanical resistance to the wheat stem sawfly in this study. Some of the characteristics looked for in the laboratory study, in addition to those previously presented, were the following: (1) a hard, thick stem wall sufficient to prevent oviposition of the eggs, (2) nodes, hard enough to prevent the larvae from passing through to the bottom of the stem, (3) long, narrow nodes which would prevent the larvae from passing through, (4) sufficient pubescence on the stem to interfere with oviposition of the eggs. Since all the varieties studied were cut to some extent in the field, it can be assumed that the above characteristics may not have been present, or if they were, did not inhibit cutting to any appreciable extent. It was disappointing to find only a few varieties out of the original 2000 with pubescence on the stems and that in minute quantity.

Of the methods described for sampling infestation prior to harvest to predict amount of cutting, it appears that percent stems with larvae or eggs is the best measure of ultimate cutting in sampling hollow stemmed wheats. However, percent stems with larvae appears to be better in sampling solid stemmed or durum wheats. This is shown by the relatively high correlation coefficient of .690 between cutting and percent stems with larvae.

The correlation coefficients between percent cutting and infestation were twice as high for the solid stemmed and durum wheats as for the hollow stemmed wheats. Infestation in the fall planting varied from 56% to 76% for the hollow stemmed wheats and 70.5% and 30% for the solid stemmed and durum wheats respectively. Infestation in the spring planting varied from 14% to 67% in the hollow stemmed wheats with 45% for the solid stemmed wheats and 4% for the durum wheats. In the hollow stemmed wheats about 50% of the infested stems were cut in both the fall and spring plantings. The solid stemmed and durum wheats were cut 22% and 18% of the infestation respectively in the fall planting. In the spring planting the solid stemmed and durum wheats were cut 12% and 33% of the infestation respectively. So the solid stemmed and durum wheats show more resistance to cutting as compared to the hollow stemmed wheats.

Regression coefficients are valuable in predicting amount of cutting if the degree of infestation is known. If a farmer knew he could expect 50% cutting, he might start harvest operations somewhat earlier or even consider windrowing. The regression coefficients for the hollowed stemmed wheats and the solid stemmed and durum wheats were significant in the spring planting. This means that more accurate predictions can be made for the spring planted wheats. Since this datum consists of only one years work, its value is limited. It would be desirable to have more than one years information in order to more accurately predict amount of cutting since it is not known

whether or not the regression values remain relatively constant in all years or under all conditions.

Date of heading had no effect on cutting or infestation in the fall planting, but it did in the spring planting. The fall planting did not germinate until the following spring which resulted in this series being early as a whole and making the comparatively late varieties early enough for the sawfly flight. The early group in the spring planting had the highest infestation and cutting percent. Since the spring planting was more than two weeks later in heading it probably caused the early group's high cutting and infestation to be so pronounced. In spring wheat it appears that a late variety can avoid the peak of the sawfly flight period, but it does not appear possible for a variety to be early enough to avoid this flight period. Correlation coefficients in the spring planting between infestation and heading dates were $-.617$ for the hollow stemmed wheats and $-.374$ for the solid stemmed and durum wheats. The correlation with the solid stemmed and durum wheats was lower than with the hollow stemmed wheats because of the influence of the durums. The sawfly did not prefer the durums, resulting in a very low infestation. There is indication that some factor of the durums, possibly the coarseness of the durum stems or the thinness of the durum stands due to lack of tillering, and subsequent exposure of the sawfly to the wind, was the principal influencing factor. It is also possible that some other

durum plant characteristics may have been influencing factors.

Plant height is associated with cutting and infestation. A taller variety generally has less infestation and cutting than a short variety. This was especially true for the solid stemmed and durum wheats in the correlations with infestation. The correlations were over twice as high as for the hollow stemmed wheats. Plant height is more highly correlated with infestation than with cutting.

Stem diameter does not appear to be correlated with cutting or the different measures of infestation, but is correlated with date of heading, plant height and infestation location. Stem diameter is correlated only with those factors that are not of too much importance in this study. The fact that sawflies vary in size and that stems vary in diameter on the same stem possibly explains the lack of significance in correlations with cutting and various measures of infestation. Stem diameter shows a relatively high negative correlation with mean infestation location which means that the larger the diameter of the stem the lower down on the plant will be the infestation location. Stem diameter was negatively correlated with percent stems with larvae at internodes 3 and 4. This indicates that the larger the diameter of the stem the less is the amount of infestation at these two internodes. Stem diameter showed a relatively high positive correlation with percent stems with larvae or eggs at internode 2 which means that the larger the diameter of the stem the higher

the amount of infestation at this internode.

Correlation coefficients between cutting and mean infestation location were over three times higher for the solid stemmed and durum wheats than for the hollow stemmed wheats. This means that the location of the infestation in the solid stemmed and durum wheats is of much more importance. To illustrate this, infestation on the lower part of the stem will result in more cutting than infestation towards the top of the stem in solid stemmed and durum wheats. Generally, location of infestation in hollow stemmed wheats does not seem too important in affecting the amount of cutting, since the larva has no obstacle other than the nodes to pass through in order to reach the bottom of the plant.

Infestation location at the different internodes shows association with cutting, heading date and plant height. In the infestation measurements, cutting is associated with internodes 2 and 3 in percent stems with larvae and percent stems with larvae or eggs. This means that more cutting occurred when the infestation was observed at internodes 2 and 3. Percent stems with eggs was not associated with cutting at any of the internodes. However, all three of the infestation measures are correlated with date of heading at one or more internodes. Date of heading was highly associated with percent stems with larvae at internodes 1, 2, and 4. This means that the later the variety, the higher is the infestation at internodes 1 and 2 and since

internode 4 has a negative correlation, it means that the later the variety the less is the infestation at this internode. Plant height is also associated with the different measures of infestation at the various internodes. But in plant height, internodes 3 and 4 show negative correlations. This means that the taller the variety the less will be the infestation at these two internodes. However, percent stems with larvae or eggs at internode 1 has a positive correlation with plant height which means that a taller variety will have a higher infestation at this lower internode. Three times more larvae than eggs were observed.

The multiple correlations showed marked differences between the fall and spring plantings. For example, in the fall planting, date of heading and plant height versus percent cutting showed no significance, but the multiple correlation of these characters was highly significant in the spring planting.

SUMMARY

The plant characteristics of 180 varieties of wheat in both a spring and fall planting were studied in relation to attack by the wheat stem sawfly. The plant characters studied were the following: date of heading, date ripe, plant height, stem diameter and stem solidness.

An attempt was made to devise a method for sampling infestation about six weeks prior to harvest which would give an accurate prediction of percent cutting at harvest time. Percent stems with larvae or eggs appeared to be the best method of sampling infestation in hollow stemmed wheats, and percent stems with larvae seemed the better method in the solid stemmed and durum wheats.

Varieties with solid stems and durums were the only wheats that showed considerable resistance to the sawfly.

✓ Date of heading showed a relatively high negative correlation with cutting and infestation in the spring planted series, with the exception of the solid stemmed and durum wheats, and no significant correlation in the fall planting. A negative correlation indicates the later the heading date the less the infestation and cutting.

✓ Plant height showed a negative correlation with cutting only in the spring planting but was negatively correlated with infestation in both the spring and fall plantings, with the exception of the hollow stemmed wheats in the fall planting. This negative correlation indicates that the taller the variety the less the

cutting and infestation.

Stem diameter was not found to be correlated with either cutting or infestation. However, stem diameter showed a relatively high negative correlation with mean infestation location, indicating that the larger the stem diameter the lower down on the stem will be the infestation location. Stem diameter was negatively correlated with percent stems with larvae at internodes 3 and 4, indicating that the larger the stem diameter the less the infestation at these two internodes. Stem diameter exhibited a relatively high positive correlation with percent stems with larvae or eggs at internode 2, indicating that the larger the stem diameter the higher the infestation at this internode.

Mean infestation location had a relatively high negative correlation with cutting and infestation, especially in the solid stemmed and durum wheats. This negative correlation suggests that infestation on the upper part of a solid stem or durum stem will result in less cutting than infestation on the lower part of the stem.

The regression coefficients between infestation and percent cutting were highly significant in the spring planting but were not significant in the fall planting.

In the spring planting, date of heading and plant height in combination were highly correlated with both percent cutting and infestation, but these same multiple correlations exhibited no association in the fall planting.

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APPENDIX

Table 1. Fall planted tall group.

Variety No.	% cut	% field infestation	% stems with larvae	% stems with larvae or eggs	Larvae per stem	Mean in- festation location
82	28	63	20	50	.4	2.8
99	15	45	80	80	1.0	3.2
100	10	26	80	90	1.0	3.1
557	64	77	50	80	.5	2.5
558	62	84	70	80	.9	2.9
571	50	55	70	70	.9	3.2
1009	46	74	60	80	.7	2.5
1177	50	65	50	70	.7	2.8
1182	45	60	50	55	.7	2.2
1266	66	83	90	90	1.1	3.3
1318	10	15	40	80	.4	3.1
1319	18	35	50	80	.5	2.7
1328	38	42	30	40	.3	3.0
1366	55	80	70	70	.8	2.1
1367	47	59	10	50	.1	3.3
1371	25	52	90	90	1.1	3.1
1375	33	45	40	50	.8	2.9
1398	10	41	60	60	.6	3.2

Table 2. Fall planted short group.

Variety No.	% cut	% field infestation	% stems with larvae	% stems with larvae or eggs	Larvae per stem	Mean infestation location
51	52	76	80	80	1.4	3.0
303	63	90	70	90	.9	2.5
470	70	79	90	100	1.1	2.3
559	36	53	30	40	.3	3.3
561	33	44	40	50	.7	2.5
1219	35	50	50	50	.9	2.7
1220	53	66	50	60	.7	2.4
1291	50	73	90	90	1.4	2.2
1293	70	92	100	100	1.6	2.1
1499	31	58	30	40	.8	2.5
1508	10	25	30	40	.3	3.0
1516	31	40	50	50	.9	2.3
1601	65	78	80	80	1.5	2.4
1634	80	84	50	50	.5	2.9
1635	95	99	90	100	1.3	2.6
1638	50	85	60	70	.6	2.8
1652	60	70	60	60	.7	2.2
1653	56	66	60	60	.7	2.2
1707	44	44	30	60	.3	3.1

Table 3. Fall planted early group.

Variety No.	% cut	% field infestation	% stems with larvae	% stems with larvae or eggs	Larvae per stem	Mean infestation location
288	30	63	100	100	1.8	2.7
289	10	50	100	100	1.6	2.9
290	20	59	100	100	2.5	2.9
570	60	67	50	70	.6	3.1
877	48	73	70	80	.8	2.8
879	27	51	40	40	.6	2.8
1216	22	58	90	100	1.4	2.8
1258	25	49	40	40	.3	3.3
1259	40	76	50	60	.6	3.1
1268	50	82	80	90	1.2	3.1
1269	55	86	90	90	1.4	3.1
1270	50	85	90	100	1.3	3.1
1271	54	87	90	100	1.3	3.0
1295	45	78	90	100	1.1	3.1
1297	35	66	50	70	.7	3.2
1373	23	41	30	50	.5	3.2
1377	33	45	40	50	.7	2.1
1423	50	68	60	80	.8	3.2
1500	35	51	60	60	.8	3.2
1716	37	48	0	40	.0	3.3

Table 4. Fall planted late group.

Variety No.	% cut	% field infestation	% stems with larvae	% stems with larvae or eggs	Larvae per stem	Mean infestation location
115	40	61	60	60	.7	1.9
214	75	83	100	100	1.8	2.2
307	35	61	100	100	1.4	2.1
533	43	48	70	70	.9	1.8
546	55	74	50	70	.8	2.1
576	20	38	40	40	.4	1.9
577	40	51	90	90	1.0	1.7
579	21	56	80	80	.9	2.1
580	20	28	70	90	.9	2.3
1314	60	65	60	60	.6	1.7
1522	45	52	50	60	.5	1.8
1523	50	54	60	70	.7	1.8
1526	52	59	50	60	.5	2.2
1528	50	61	60	60	.6	1.7
1530	38	46	70	70	1.0	1.7
1534	30	36	60	60	.6	1.5
1536	59	80	60	80	.8	2.2
1538	47	56	60	60	.9	1.8
1650	52	74	70	80	1.2	1.8

Table 5. Fall planted large stem group.

Variety No.	% cut	% field infestation	% stems with larvae	% stems with larvae or eggs	Larvae per stem	Mean in- festation location
491	40	53	100	100	1.4	2.5
529	68	87	50	90	.9	2.9
530	70	88	70	70	.9	2.1
563	33	45	50	50	.6	2.1
565	17	26	30	30	.3	2.5
566	30	50	50	60	.6	2.5
567	46	48	60	70	1.0	2.5
572	50	57	60	60	.7	2.2
1104	31	69	30	40	.3	2.5
1106	22	32	30	30	.3	2.2
1107	25	39	30	40	.4	2.3
1108	38	49	30	40	.3	2.5
1109	25	31	30	40	.3	2.3
1166	23	42	50	50	.5	2.9
1172	71	85	10	40	.1	2.7
1173	30	51	40	60	.5	1.9
1517	27	32	30	30	.3	2.5
1637	39	51	60	70	.7	2.5
1649	56	69	80	80	1.5	2.8
1667	50	82	60	70	1.0	2.7

Table 6. Fall planted slender stem group.

Variety No.	% cut	% field infestation	% stems with larvae	% stems with larvae or eggs	Larvae per stem	Mean infestation location
302	35	54	60	70	.6	2.8
303	5	38	70	70	.7	2.3
441	32	62	100	100	1.7	2.4
467	32	59	100	100	1.1	2.6
710	45	59	70	70	.7	2.9
1292	74	99	80	80	1.5	2.4
1312	5	17	0	20	.0	3.5
1403	57	77	60	80	.8	2.7
1422	10	21	50	50	.7	2.9
1464	40	60	40	50	.6	3.2
1465	31	65	80	80	1.2	2.9
1466	34	54	60	60	.6	3.1
1467	36	61	80	90	1.0	3.0
1501	25	51	30	50	.3	3.2
1502	28	41	50	60	.5	3.5
1503	22	45	10	40	.1	2.9
1717	21	25	40	40	.4	3.0
1718	50	64	70	70	1.0	2.9
1883	50	71	100	100	1.6	2.5
1995	30	38	10	30	.1	3.3

Table 7. Fall planted solid stem group.

Variety No.	% cut	% field infestation	% stems with larvae	% stems with larvae or eggs	Larvae per stem	Mean in- festation location
287	16	41	70	70	1.1	2.9
292	1	34	60	70	.8	3.1
293	15	42	60	70	1.0	2.8
294	0	39	70	100	1.2	3.1
295	5	49	40	100	.4	2.9
305	10	33	0	70	.0	2.7
339	30	80	60	60	.8	1.9
417	40	62	90	90	1.1	2.2
443	10	49	30	60	.4	3.3
524	10	53	50	70	.5	2.1
542	20	30	70	90	.9	1.9
613	35	64	80	90	1.2	2.3
1754	7	29	10	40	.3	3.0
1762	20	37	30	50	.5	2.5
1826	16	41	40	70	.8	2.8
1844	19	50	40	70	.9	2.6
1852	17	27	20	40	.4	2.8
1875	20	42	40	70	.9	2.7
1913	10	28	30	60	.7	2.5
1966	24	45	60	70	1.2	2.6

Table 8. Fall planted durum group.

Variety No.	% cut	% field infestation	% stems with larvae	% stems with larvae or eggs	Larvae per stem	Mean in- festation location
438	0	30	20	40	.2	2.5
439	0	22	0	30	.0	3.2
442	15	78	10	50	.1	3.5
446	20	47	20	60	.2	3.4
450	20	55	50	70	.5	3.3
451	1	19	10	20	.1	3.2
452	10	17	0	20	.0	3.2
568	1	2	0	20	.0	3.5
1408	0	25	0	40	.0	3.5
1409	5	29	0	20	.0	3.0
1414	0	6	0	30	.0	3.5
1415	5	11	0	30	.0	3.5
1416	0	17	0	20	.0	3.5
1417	0	20	0	20	.0	3.5
1418	0	8	0	20	.0	3.5
1419	10	58	10	20	.1	3.0
1420	15	76	20	50	.2	3.3
1625	5	12	0	10	.0	3.5
1627	0	31	10	20	.1	2.0
1658	1	25	0	10	.0	3.5

Table 9. Fall planted club group.

Variety No.	% cut	% field infestation	% stems with larvae	% stems with larvae or eggs	Larvae per stem	Mean in- festation location
89	54	86	100	100	1.4	1.9
90	40	80	70	70	1.0	2.4
91	25	31	50	50	.8	2.1
93	10	33	40	40	.4	3.0
111	45	65	50	50	.6	2.8
308	20	58	60	60	.9	1.8
517	10	48	50	60	.5	2.0
522	39	51	80	80	.9	2.1
795	60	74	70	70	.9	2.8
987	50	54	70	70	.7	1.6
1186	37	47	60	60	.7	1.6
1236	61	67	70	70	1.0	2.2
1237	50	50	100	100	1.8	1.9
1247	45	61	90	90	1.2	1.7
1267	39	60	60	60	.7	2.3
1390	44	61	40	60	.4	2.5
1655	25	56	70	70	.8	1.6
1656	25	59	0	50	.0	3.1
1657	15	25	30	30	.3	1.8
1702	50	63	60	60	.8	1.8

Appendix Table 10. The correlations listed here are those which were calculated in conjunction with this study but have not been previously presented.

	Types of wheat	Percent stems with larvae	Percent stems with larvae or eggs	Larvae per stem
		r	r	r
Field infestation	1. Solid stemmed and durums	.578**	.580**	.310**
	2. Hollow stemmed	.469**	.550**	.359**
	3. All wheats	.598**	.617**	.435**
Percent stems with larvae	1. Solid stemmed and durums	-----	.856**	.878**
	2. Hollow stemmed	-----	.893**	.838**
	3. All wheats	-----	.895**	.850**
Larvae per stem	1. Solid stemmed and durums	.875**	.648**	-----
	2. Hollow stemmed	.838**	.727**	-----
	3. All wheats	.850**	.730**	-----
Date of heading	1. Solid stemmed and durums	.050	.057	.217
	2. Hollow stemmed	.115	.019	.090
	3. All wheats	.064	.013	.128
Plant height	1. Solid stemmed and durums	-.532**	-.574**	-.532**
	2. Hollow stemmed	.095	.120	.095
	3. All wheats	-.154*	-.183*	-.174*
Date ripe	1. Solid stemmed and durums	-.138	-.261	-.312*
	2. Hollow stemmed	.160	.061	.001
	3. All wheats	-.108	-.114	-.174*

* Denotes significance at 5% level.

** Denotes significance at 1% level.

Appendix Table II. The correlations listed here are those which were calculated in conjunction with this study but have not been previously presented.

	Types of wheat	Date of heading	Plant height	Date ripe	Mean infestation location
Field infestation	1. Solid stemmed and durums	-.039	-.246	-.061	-.419**
	2. Hollow stemmed	-.001	-.018	-.107	-.041
	3. All wheats	-.010	-.155*	-.233**	-.230*
Percent stems with larvae	1. Solid stemmed and durums	.050	-.532**	-.138	-.626**
	2. Hollow stemmed	.115	.095	.160	-.207*
	3. All wheats	.064	-.154*	-.108	-.388**
Larvae per stem	1. Solid stemmed and durums	-.217	---	-.312*	-.731**
	2. Hollow stemmed	-.090	-.324**	.001	-.153
	3. All wheats	-.128	-.591**	-.174*	-.359**
Date of heading	1. Solid stemmed and durums	---	.151	.643**	-.389*
	2. Hollow stemmed	---	.464**	.599**	-.658**
	3. All wheats	---	.390**	.582**	-.558**
Plant height	1. Solid stemmed and durums	.151	---	.373*	.065
	2. Hollow stemmed	.464**	---	.289**	-.343**
	3. All wheats	.390**	---	.361**	.179*
Date ripe	1. Solid stemmed and durums	-.138	.373*	---	-.044
	2. Hollow stemmed	.160	.289**	---	-.214*
	3. All wheats	-.108	.361**	---	-.048

* Denotes significance at 5% level
 ** Denotes significance at 1% level

Appendix Table 12. The correlations listed here are those which were calculated in conjunction with this study but have not been previously presented and are data for the hollow stemmed wheats in the fall planting.

	Stem diameter Mean (N=40)	infestation location (N=140)
Percent stems with larvae or eggs at internode		
1	----	-.309**
2	.505**	-.738**
3	-.217	-.102
4	-.201	-.690**
Percent stems with larvae at internode		
1	----	-.293**
2	.097	-.741**
3	-.318*	-.092
4	-.325*	.581**
Percent stems with eggs at internode		
1	----	.153
2	.213	-.055
3	.284	-.015
4	.517**	.374**
Total eggs per stem	-.061	.290**

* Denotes significance at 5% level

** Denotes significance at 1% level



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Eckroth, E. G

The agronomic characteristics and
the reaction to attack by the wheat
state sawfly a series of foreign
wheat introductions.

Luginbill, Philip
May 17, 58. Signal
US. M. Causino

R. 8 '54 28

Duane Arnsteden

2-9-64 Charles Evers

(S) 317 50.112

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