

THE EFFECT OF THE SPRING GENERATION OF
HESSIAN FLY (Phytophaga destructor (Say)) ON THE
YIELD OF STANDING CULMS OF THREE VARIETIES OF WHEAT

by

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INTRODUCTION

The hessian fly Phytophaga destructor (Say) ranks as one of our chief crop pests in the United States. Kansas, the leading wheat producing state, has an average yearly loss of millions of bushels of wheat from the presence of this insect (Kelly, 1946; Salmon et al., 1929). The hessian fly was first reported in Kansas in 1871, when it was found infesting wheat in a few of the eastern counties (McColloch, 1923). Since that time, it has played a position of high economic importance to the wheat grower for its frequent reduction of the wheat crop.

There are several types of injury to the wheat caused by the presence of the hessian fly. The extent of this injury varies from year to year. The two principal types of injury and their subdivisions as summarized by Painter¹ are as follows:

I. Its presence causes injury to the young plant in the fall.

A. It arrests the cell development in area of contact with the larvae which causes the shortening of the central leaf.

¹R. H. Painter, unpublished work.

B. The effect of its feeding spreads through the crown, stunting the plant and reducing the yield even in the absence of winter killing.

C. The infested plant may die before winter sets in.

D. The infested plant may be weakened so that death takes place during winter.

II. The presence of hessian fly in the spring causes injury to the mature plant.

A. The tiller may be stunted and prevented from heading.

B. The internodes may be shortened in length.

C. Lodging may occur at the point of infestation.

D. There may be a reduction in yield of the infested culms producing heads.

It is necessary to study all the types of injury in estimating the amount of damage or the loss each year from this insect. The study reported in this paper was made to analyze the damage sustained by the wheat due to the presence of the spring generation of hessian fly on standing culms and to determine whether there was any difference in reduction between varieties. Pawnee, Tenmarq and Red Chief were the varieties used in this study. Tenmarq wheat, one of the parents of Pawnee, has been in commercial trade channels for about 15 years (Johnson et al., 1947). Red Chief was chosen to see how the presence of fly would affect its usually high test weight. Pawnee wheat carries considerable resistance to the

hessian fly; with this in mind, it was desired to obtain data for the comparison of this variety with other less resistant varieties.

REVIEW OF LITERATURE

Some similar work on reduction of yield has been done in Pennsylvania and at Kansas State College, Manhattan, Kansas. In Pennsylvania, Hill and Smith, 1925, showed that the loss in yield due to the presence of hessian fly was variable from year to year and it also may vary according to locality. The average reduction in yield for a single flaxseed per culm was 16 percent. Painter¹ reported that in 1941 a single flaxseed reduced the yield of Tenmarq 22 percent and in 1942 there was a reduction of 32 percent.

Hill et al. (1943) made some further investigations, adding to the work of Hill and Smith, 1925, and obtained an average reduction in weight with one puparium present of 15.7 percent. From the data, they calculated a loss of 0.04 bushel per acre when only one percent of the productive culms were infested and 15.7 bushels per acre when 100 percent of the productive culms were infested. According to Painter et al. (1931, 1945), varieties differ in respect to the percentage of tillers infested and to the amount of injury caused by the hessian fly.

¹R. H. Painter, Unpublished work.

HISTORY OF VARIETIES

Pawnee variety of wheat was released to farmers in Nebraska in 1942 and to Kansas growers in 1943, and has been known for its tolerance to hessian fly. Pawnee was bred by the Kansas and Nebraska Agricultural Experiment Stations in co-operation with the Division of Cereal Crops and Diseases, United States Department of Agriculture. It is a selection from the cross Kawvale x Tenmarq made in 1928 at the Kansas Agricultural Experiment Station. Pawnee is a bearded, hard red winter wheat variety that appears to be well adapted to Kansas. Its superior characteristics, according to Reitz and Laude (1943), are high yield and high test weight, short stiff straw, high resistance to loose smut, and moderate resistance to leaf rust, stem rust, bunt and hessian fly. However, it is susceptible to speckled leaf blotch (*Septoria*) and may shatter slightly more than Tenmarq.

Tenmarq was produced from a hybrid between Marquis spring wheat and P 1066 winter wheat, the latter, being a sister selection of Kanred, made from Crimean wheat. The cross was made at Manhattan, Kansas, in 1917 by M. N. Levine. Tenmarq is a result of a selection from this cross made by John H. Parker in 1921 (Quisenberry and Clark, 1938; Salmon and Laude, 1932). Tenmarq is about two days later in maturity than Pawnee and somewhat taller. It has moderately stiff straw, some resistance to leaf rust, but is very susceptible to hessian fly.

In the fall of 1940, Earl G. Clark, Sedgwick, Kansas, released Red Chief to Kansas farmers. The variety is beardless,

has red chaff, and the grain is dark red in color and high in test weight. The exact origin of the variety is not known but it may be a selection from a natural Redhull x Chiefkan hybrid (Quisenberry et al., 1944). Of the three varieties studied, it is the latest to mature.

MATERIALS AND METHODS

The wheat used in this study was collected from two different localities and in different years. Part of the wheat was obtained in the Manhattan Fly Nursery from a block of three rows each, of Pawnee and Tenmarq, growing side by side. It had been harvested June 28, 1944, and stored especially for this kind of study. These plots were planted on October 5, 1943, after the fly free date. Infestation was induced in the nursery by bringing in infested stubble as described by Painter et al. (1931, 1940). Because of the late date of planting, almost no infestation or injury took place in the fall in the plants studied.

The other samples of wheat were taken from the Rice county variety test plots located one half mile north of Lyons, Kansas. The variety tests are co-operative experiments of the Department of Agronomy, Kansas State College, Manhattan, Kansas, the County Agriculture Agents and farmers.

The different varieties of wheat used in the variety tests were planted, under field conditions, in plots $13\frac{1}{2}$ feet by 500 feet on September 20, 1945. This is several days ahead

of the fly free date, which is October 5 for the county. A small amount of infestation is known to have been present in the plots but detailed records were not taken. The samples were taken June 14, 1946, in several points along the outside of the plots where the wheat appeared to be most uniform.

In the Manhattan Nursery, rust readings were not made on the particular rows that were studied. However, leaf rust readings were recorded on other rows of Tenmarq and Pawnee. The Nursery average for Tenmarq was 35 percent, which was probably a little low, and the average for Pawnee was 26 percent.

The percent of stem rust was not taken for these two varieties. When the culms were examined for fly, there seemed to be a fairly high infection of stem rust present which probably would influence the yield.

Readings on leaf rust on the Rice county variety tests were made by C. O. Johnston, Plant Pathologist, Bureau of Plant Industry. Pawnee had the least amount of leaf rust with 25 percent, Tenmarq and Red Chief were estimated to have 40 percent and 60 percent respectively. There was no evidence of stem rust present.

All of the other environmental factors were considered to be approximately equal in the wheat used for this study.

In harvesting the wheat at the Manhattan Nursery, all three rows of each of the two varieties were pulled from the ground and tied in separate bundles. At the Rice county test plots, random samples were taken from the three varieties. The size of the samples necessary was estimated from the pre-

liminary fly count that was made May 3, 1946. The down or lodged straw was cut off and discarded in the field so that only the standing culms were collected. The heads of wheat in each of the bundles were wrapped carefully to help eliminate any shattering that might occur in handling. The wheat was stored at the Insectary until it could be inspected for fly.

The methods used for the inspection of the culms were the same in both the Manhattan and the Rice county material. The plants were examined separately and only culms with uninjured heads were used.

The leaf sheath was stripped from each culm and each internode was inspected for the presence or absence of flaxseeds of the hessian fly. When an infested culm was found, the head was placed in a coin envelope. The number of flaxseeds and the internode in which they occurred were recorded on the same envelope. The length of the infested internode was measured in millimeters and it likewise was recorded on the envelope.

The procedure that was followed as near as possible was to do one plant at a time and when an infested culm was found, the head from the next uninfested culm was saved. The internode from this uninfested culm, corresponding in number to the infested internode, was measured and recorded.

If there were more infested culms in a plant than uninfested, the above procedure was changed, in that there would be less uninfested heads saved from that particular plant. The reason for doing one plant at a time was to eliminate, if possible, some of the plant to plant variation.

The culms that were used to provide the data were inspected at the same time for wheat straw worm, Harmolita grandis (Riley). A short length above each node was split open with a razor blade and if wheat straw worm could be found or if the stem showed evidence of having been infested, the heads were discarded and not used in the data reported here.

The number of the internode was determined by its distance from the head, number one, being the one immediately below it, and each successive internode numbered down to the crown of the plant. The usual number of internodes occurring in the three varieties was found to be five.

After all the culms had been inspected, the heads were threshed individually. For threshing, the head was placed in a rubber tube about five inches long with an inside diameter of about three-fourths of an inch. The ends of the tube were held shut with the thumb and forefinger of each hand and a vigorous rubbing motion was used to thresh the heads. The contents were then emptied into a wire household strainer. This was held over an electric fan, which quickly blew out the chaff, leaving the kernels in the bottom. The kernels were counted and placed back in the same coin envelope. The number of kernels was recorded on the outside with the other data.

Fifty of the heads from the uninfested material were picked at random by the use of a table of random numbers, Fisher and Yates (1943). These heads were also threshed individually and the kernels counted and recorded by the method described above.

Following the completion of the threshing, the kernels from each of the coin envelopes were weighed on a Roller-Smith Precision balance and the total weight was recorded. At the same time, the kernels were recounted to check for any possible errors in counting. The total weight of the kernels was divided by the number of kernels to get the average weight for each one.

EXPERIMENTAL RESULTS

A preliminary hessian fly count was made, as previously described in this paper. The purpose in taking the samples was to get some information on the amount of fly infestation. It was made, also, to obtain some idea on the size of a sample that would be necessary to collect which would represent an array of culms infested in the various internodes.

Table 1 gives the results of the preliminary hessian fly count made on the three varieties of wheat from the Rice county test. On this particular count, out of 100 tillers examined, Tenmarq had 47 with heads and 28 of these were infested with fly, in comparison with 38 with heads for Pawnee and only five of these being infested. Pawnee had a larger number of tillers without heads but only 13 percent of these were infested, whereas, Tenmarq had 60 percent of its tillers without heads infested. One of the characteristics of Pawnee is that it stools out considerably. Of all the tillers examined, Tenmarq had the highest infestation with 68 percent, Red Chief second with 50 percent, and Pawnee the lowest, with only 10 percent infested.

Table 1. Results of the preliminary hessian fly count made on Pawnee, Tenmarq, and Red Chief from samples taken May 3, 1946, at the Rice county variety test plots.

	: Pawnee		: Tenmarq		: Red Chief	
	: Num-	: Per-	: Num-	: Per-	: Num-	: Per-
	: ber	: cent	: ber	: cent	: ber	: cent
Plants examined	10	---	12	---	7	---
Plants infested	6	60	12	100	7	100
Tillers examined	100	---	100	---	50	---
Tillers infested	10	10	68	68	25	50
Total flaxseeds found	19	---	251	---	49	---
Tillers with heads	38	38	47	47	19	38
Infested	5	13	28	60	8	42
Uninfested	33	87	19	40	11	58
Tillers without heads	62	62	53	53	31	62
Infested	5	8	40	76	17	55
Uninfested	57	92	13	24	14	45

Table 2 gives the comparison of the hessian fly infestation on Tenmarq and Pawnee from the 1944 Manhattan Fly Nursery. Results of the investigations show that 16 percent of the standing culms of Tenmarq were infested as compared to seven percent for Pawnee. However, in these data, the unjointed tillers were not included. According to Painter and Jones (1945), Pawnee in general has about one-fourth as high a tiller infestation as does Tenmarq. The infestation occurred most commonly on the third internode in the case of both Pawnee and Tenmarq.

Figure 1 is a bar graph showing the relationship of the fly infestation between the various internodes of Tenmarq and Pawnee. In general, they both have about the same ratio in the various internodes. Pawnee, which is a few days earlier than Tenmarq, had a higher percentage of infested culms in the second internode than did Tenmarq.

Table 2. A comparison of the hessian fly infestation on Tenmarq and Pawnee from the 1944 Manhattan Fly Nursery.

Condition of Culms	: Total		: Percentage	
	: Tenmarq	: Pawnee	: Tenmarq	: Pawnee
Total culms examined	779	1189		
Culms not infested with flaxseed or W.S.W.	617	1091	79.2	91.8
Culms infested with flaxseed only	126	84	16.2	7.1
Culms with flaxseed and W.S.W.	36	14	4.6	1.2
1 flaxseed in 1st inter.*	6	4	0.8	0.3
1 flaxseed in 2nd inter.*	12	14	1.5	1.2
1 flaxseed in 3rd inter.*	50	31	6.4	2.6
1 flaxseed in 4th inter.*	28	20	3.6	1.7
1 flaxseed in 5th inter.*	2	0	0.3	0
1 flaxseed per culm*	98	69	12.6	5.8
2 flaxseeds per culm*	21	12	2.7	1.0
More than 2 per culm*	7	3	0.9	0.3

*Culms with flaxseeds only.

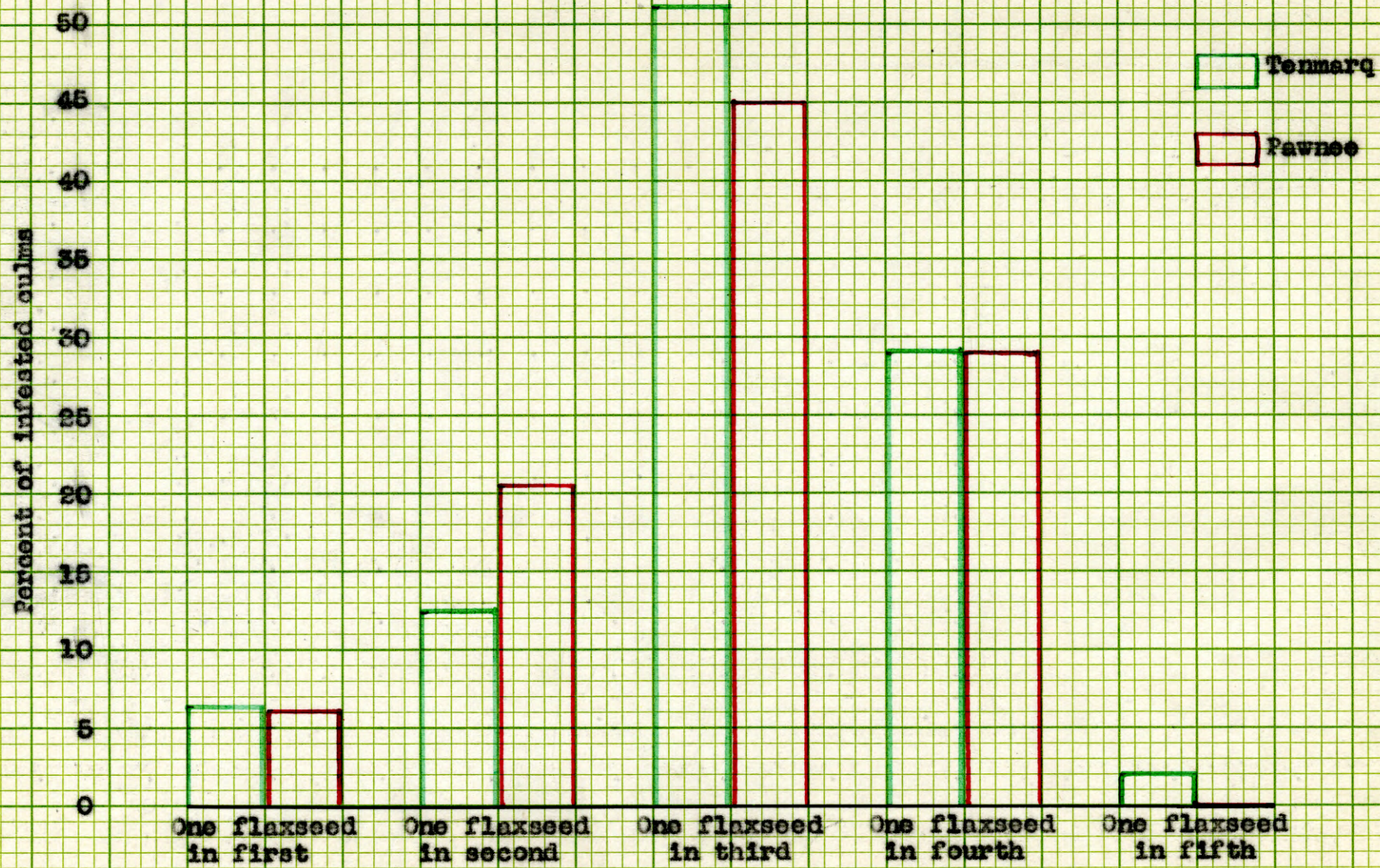


Fig. 1. The hessian fly infestation between the various internodes of Tenmarq and Pawnee from the 1944 Manhattan Nursery material.

Table 3 gives some comparisons of the hessian fly infestation between Pawnee, Tenmarq and Red Chief from the 1946 Rice county variety tests. Only the standing culms with heads are included in these data. No attempt was made to examine or keep a record of the unjointed tillers. The results show that Tenmarq had the highest infestation with approximately 54 percent of the culms infested, while Red Chief and Pawnee had 49 and 20 percent respectively. The percentage of infested culms on Pawnee is less than half the infestation on Tenmarq and Red Chief, thus showing its greater resistance to hessian fly. It was necessary to examine considerable more culms of Pawnee in order to get enough data on infested material to match with the other varieties of wheat. The table also shows comparisons of more than one flaxseed per culm. It is of particular interest to note that in Pawnee, out of 774 culms examined only 12 were infested with more than two flaxseeds per culm. Tenmarq had 68 culms with more than two flaxseeds from a total of only 444 culms.

Figure 2 is a bar graph depicting the relationship of the infestation in the various internodes in terms of the percent of infested culms. In general, the percentage of infested culms in the various internodes was about the same in all three varieties. Pawnee, as was discussed previously had slightly more in the third internode than the other varieties. Red Chief, which is the latest to mature, had more culms infested in the fifth internodes.

Table 3. A comparison of the hessian fly infestation on Pawnee, Tenmarq and Red Chief from the 1946 Rice county variety test plots.

Condition of culms	Total No. of culms			Percentage of culms		
	Pawnee	Tenmarq	Red Chief	Pawnee	Tenmarq	Red Chief
Culms examined	774	444	540			
Culms not infested	618	206	274	79.8	46.4	50.7
Number infested culms	156	238	266	20.2	53.6	49.3
Culms with 1 flaxseed in 2nd	5	8	3	0.7	1.8	0.6
Culms with 1 flaxseed in 3rd	32	27	29	4.1	6.1	5.4
Culms with 1 flaxseed in 4th	57	64	80	7.4	14.4	14.8
Culms with 1 flaxseed in 5th	8	6	18	1.0	1.4	3.3
Culms with 2 flaxseeds in 3rd	17	11	9	2.2	2.4	1.7
Culms with 2 flaxseeds in 4th	13	15	25	1.7	3.4	4.6
Culms with other combinations	24	107	102	3.1	24.1	18.9
1 flaxseed per culm	102	105	130	13.2	23.7	24.1
2 flaxseeds per culm	42	65	58	5.4	14.6	10.7
More than 2 flaxseeds per culm	12	68	78	1.6	15.3	14.5



Fig. 2. A bar graph showing the relationship of the position of the flaxseeds on the culms in the 1946 Rice county material.

Table 4 records some data on the reduction in length of the various internodes when they are infested with hessian fly. These data were derived from the Rice county material.

This table shows the reduction in length of the infested internodes for the three varieties. The internodes of Pawnee are affected the least by the presence of the fly. Pawnee, however, is not as tall as the other varieties and this, with its known tolerance to fly probably accounts for the smaller percentage of reduction. The latter, however, is probably the biggest factor in the smaller reduction.

Figure 3 is a bar graph showing the average length of the uninfested and infested internodes of each of the varieties.

Further study should be made on this particular injury to see if there may be some relationship between the reduction in length of the internodes and the percent of reduction in yield. This may help to throw some light on estimating the reduction of yield caused by the hessian fly.

Table 4. The relationship of the length of the internodes between Pawnee, Tenmarq and Red Chief from the 1946 Rice county tests.

Infestation	P A W N E E					T E N M A R Q					R E D C H I E F				
	No.	Avr. length of internode in mm.	Percent	reduction		No.	Avr. length of internode in mm.	Percent	reduction		No.	Avr. length of internode in mm.	Percent	reduction	
	of		of			of		of			of		of		
	culms	not inf.	infested			culms	not inf.	infested			culms	not inf.	infested		
1 flaxseed in 2nd	5	180.0	117.0	63.0	35	8	192.8	78.1	114.7	59.5	3	218.3	76.6	141.7	64.9
1 flaxseed in 3rd	32	97.6	65.5	32.1	32.9	27	119.4	64.3	55.1	46.1	29.	129.6	76.4	53.2	41.0
1 flaxseed in 4th	57	79.4	51.1	28.3	35.6	64	93.2	61.2	32.0	34.3	80	108.4	77.6	30.8	28.4
1 flaxseed in 5th	8	53.5	36.6	16.9	31.6	6	47.8	36.3	11.5	24.1	18	79.0	57.4	21.6	27.3

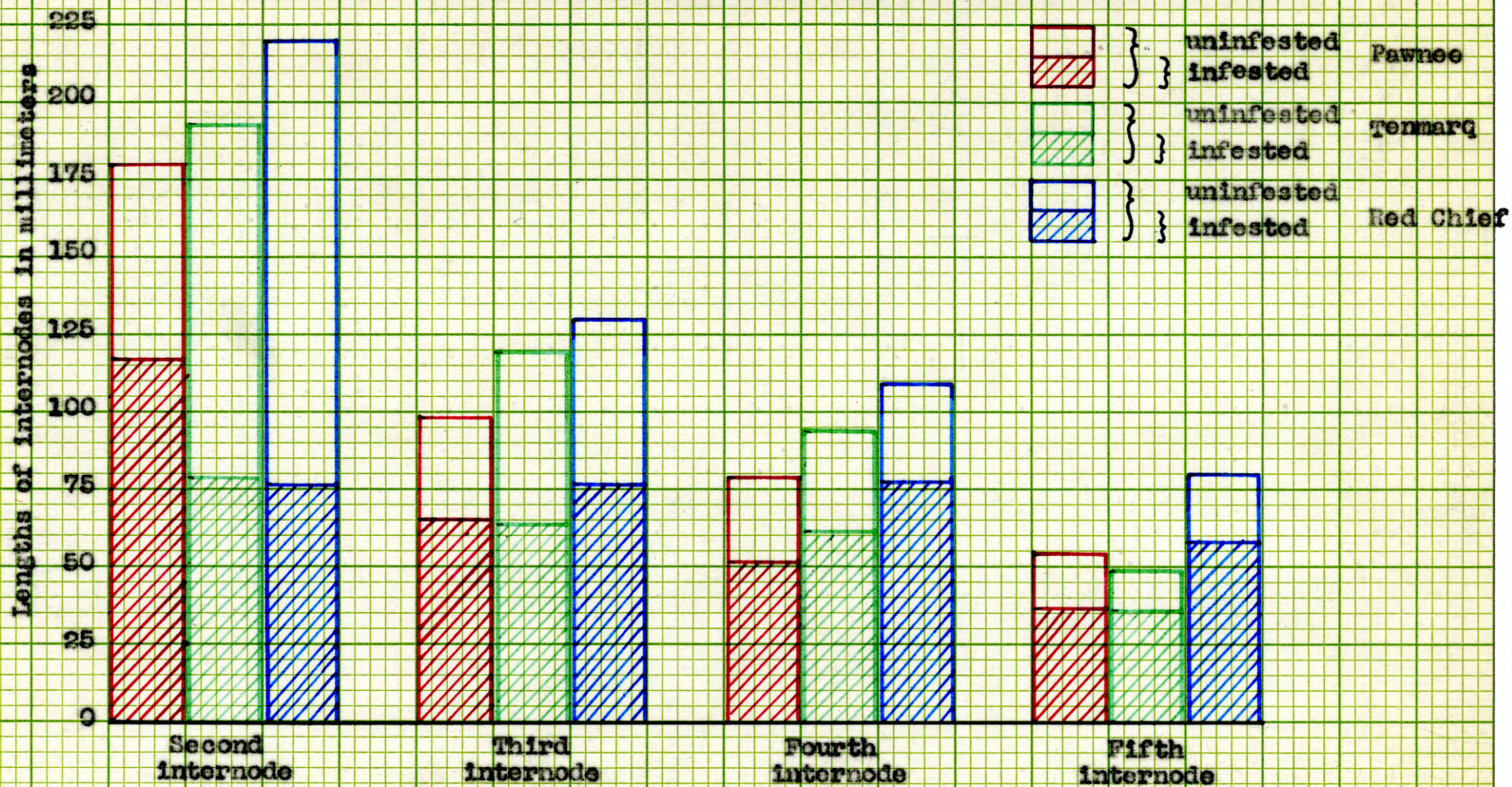


Fig. 3. A bar graph showing the relative lengths of the uninfested and infested internodes in the 1946 Rice county material.

Table 5 gives a summary of the results of the investigations upon Pawnee and Tenmarq from the 1944 Manhattan fly nursery. Results showed that in the uninfested material, Tenmarq had a higher average number of kernels per head than did Pawnee. The latter, however, had a greater weight per kernel than did Tenmarq, which resulted in a higher weight per head. In these particular data, Pawnee appeared to be more affected, both in the number of kernels and in the weight per kernel, when the culms were infested. When the two varieties were infested with one flaxseed per culm Pawnee showed an average reduction in the weight per kernel of 44.6 percent in comparison with 27.7 percent for Tenmarq. The percent of reduction in yield was approximately the same for both varieties when the culms were infested with two flaxseeds per culm. Tenmarq, however, with more than two flaxseeds per culm showed a greater loss than Pawnee did. These data showed that, in general, there was a greater reduction in yield when the infestation was towards the top of the culm.

Table 5. The relation of the hessian fly infestation to the yield of Pawnee and Tenmarq from the 1944 Manhattan Fly Nursery.

Condition of culms	T O T A L						A V E R A G E				PERCENT REDUCTION IN AVERAGE					
	No. of heads		No. of kernels		No. of kernels		Weight		Weight of grain		No. of kernels		Weight		Weight of grain	
	per kernel		per head		per kernel		per kernel		per head		per kernel		per kernel		per head	
	Pawnee	Tenmarq	Pawnee	Tenmarq	Pawnee	Tenmarq	Pawnee	Tenmarq	Pawnee	Tenmarq	Pawnee	Tenmarq	Pawnee	Tenmarq	Pawnee	Tenmarq
Flaxseed absent	50	50	1098	1179	22	23.6	26.0	21.3	577.8	515.5						
1 flaxseed in 1st	4	6	31	82	7.8	13.7	15.3	13.4	111.8	192.7	64.5	41.9	41.2	37.1	80.7	62.6
1 flaxseed in 2nd	14	12	144	128	10.3	10.7	16.5	12.5	174.4	153.7	53.2	54.7	36.5	41.3	69.8	70.2
1 flaxseed in 3rd	31	50	404	762	13.0	15.2	17.6	15.0	264.7	258.4	40.9	35.6	32.3	29.6	54.2	49.9
1 flaxseed in 4th	20	28	305	559	15.3	20.0	18.4	18.5	294.4	393.1	30.5	15.3	29.2	13.1	40.0	23.7
1 flaxseed per culm	69	98	884	1548	12.8	15.8	14.4	15.4	213.2	276.1	41.8	33.1	44.6	27.7	63.1	46.4
2 flaxseeds per culm	12	21	130	257	10.8	12.2	13.9	11.5	159.3	139.8	50.9	48.3	46.5	46.0	72.4	72.9
More than 2	3	7	50	49	16.7	7.0	20.5	12.4	374.6	82.1	24.1	70.3	21.2	41.8	35.2	84.1

Analysis of variance tests were made on the data to see if there was any significant difference in the amount of reduction when the flaxseeds were at different positions on the culms. These data are summarized in Tables 6 and 7. Tests made on Tenmarq, both on the number of kernels and on the weight per kernel, gave a highly significant F with a probability of less than one percent. Pawnee, however, showed no positional effect on the weight per kernel, but it did show a significant difference in the number of kernels. The probability for Pawnee is greater than 20 percent for the weight per kernel and less than five percent for the number of kernels.

Table 6. Analysis of variance on the effect of the position of the flaxseed on Pawnee from the 1944 Manhattan Nursery.

Number of kernels				:	:	Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	:	:	Source	D/f	Sum of sq's	Est. of var.
Total	68	2566.6				Total	68	2915.0	
Group	3	312.3	104.1			Group	3	51.1	17.03
Within	65	2254.3	34.7			Within	65	2863.9	44.06

: :

F - 3.00 D/f - 3 and 65; P less than 5% F-- .39 D/f - 3 and 65; P greater than 20%

Table 7. Analysis of variance on the effect of the position of the flaxseed on Tenmarq from the 1944 Manhattan Nursery.

Number of kernels				:	:	Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	:	:	Source	D/f	Sum of sq's	Est. of var.
Total	95	5950.7				Total	95	3809.6	
Group	3	842.6	280.9			Group	3	395.2	131.7
Within	92	5108.1	55.5			Within	92	3414.4	37.1

: :

F - 5.06 D/f - 3 and 92; P less than 1% F - 3.55 D/f - 3 and 92; P less than 1%

When there are one or more flaxseeds per culm the reduction in yield from the uninfested is high. Tests made on the effect of the number of flaxseeds are shown in Table 8 for Pawnee and Tenmarq in Table 9. The probability for both varieties was less than one tenth percent.

Table 8. Analysis of variance on the effect of the number of flaxseeds on Pawnee from the 1944 Manhattan Fly Nursery.

Number of kernels				Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	Source	D/f	Sum of sq's	Est. of var.
Total	133	6757.6		Total	133	7059.4	
Group	3	2796.8	932.3	Group	3	2617.7	872.6
Within	130	3960.8	30.5	Within	130	4441.7	34.2
F - 30.6; D/f - 3 and 130; P less than .1%				F - 25.5; D/f - 3 and 130; P less than .1%			

Table 9. Analysis of variance on the effect of the number of flaxseeds on Tenmarq from the 1944 Manhattan Fly Nursery.

Number of kernels				Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	Source	D/f	Sum of sq's	Est. of var.
Total	175	11361.4		Total	175	8709.2	
Group	3	3473.5	1157.8	Group	3	1890.9	630.3
Within	172	7887.9	45.9	Within	172	6818.3	39.6
F - 25.2; D/f - 3 and 172; P less than .1%				F - 15.9; D/f - 3 and 172; P less than .1%			

As discussed previously in this paper, there was considerable rust present. It is known that leaf rust may reduce the number of kernels per head while stem rust, which occurs later, may affect the weight of the kernels. In this material the high reduction in yield may be due to a combination of factors between the hessian fly and rust. The fly infested culms may have been retarded in growth so that they were exposed to greater rust infection.

Three varieties of wheat were studied from the 1946 Rice county variety plots and the results are somewhat different from those reported for Manhattan. The results of this study are summarized in Table 10. The average number of kernels for the uninfested wheat is approximately the same for the two localities. This agrees with some previous work done by Painter¹, in that the number of kernels per head does not vary as much from year to year as does the average weight per kernel.

In the uninfested material from Rice County, Red Chief had the highest average number of kernels per head with 25.2, while Tenmarq and Pawnee had 22.7 and 19.0 kernels, respectively. Tenmarq had the highest average weight per kernel with 36.8 mg. in comparison with 35.8 mg. for Red Chief and 33.1 mg. for Pawnee. In general, the material showed no particular trend or pattern when the culms were infested in the various internodes.

Statistical tests made on the three varieties showed that there was no significant difference in regard to the internode on which the flaxseed occurred. The probability was more than

¹R. H. Painter, unpublished data.

20 percent in the case of all three varieties. The results of these tests are shown in Tables 11, 12 and 13.

Table 10. The relation of the hessian fly infestation to yield on the three varieties of wheat from the 1946 Rice county variety test plot.

Condition of culms	TOTAL									AVERAGE		PERCENTAGE REDUCTION OF AVERAGE												
	No. of heads			No. of kernels			No. of kernels			Wt. per kernel		Kernel	Wt. of grain per hd.			No. of kernels			Weight per kernel			Wt. of grain per hd.		
	Paw-	Ten-	Red	Paw-	Ten-	Red	Paw-	Ten-	Red	Paw-	Ten-		Red	Paw-	Ten-	Red	Paw-	Ten-	Red	Paw-	Ten-	Red	Paw-	Ten-
	nee	marq	Chief	nee	marq	Chief	nee	marq	Chief	nee	marq	Chief	nee	marq	Chief	nee	marq	Chief	nee	marq	Chief	nee	marq	Chief
Flaxseed absent	50	50	50	950	1135	1261	19	22.7	25.2	33.1	36.8	35.8	631.2	841.2	906.3									
1 flaxseed in 2nd	5	8	3	91	150	68	18.2	18.8	22.7	31.1	35.1	31.3	575.0	654.6	789.1	4.2	17.2	9.9	6.0	4.6	12.6	8.9	22.2	12.9
1 flaxseed in 3rd	32	27	29	545	566	629	17.0	21.0	21.7	31.7	35.5	34.4	544.3	746.8	749.4	10.5	7.5	13.9	4.2	3.5	3.9	13.8	11.2	17.3
1 flaxseed in 4th	57	64	80	960	1250	1719	16.8	19.5	21.5	31.7	35.0	34.1	538.4	678.3	739.3	11.6	14.1	14.7	4.2	5.0	4.7	14.7	19.4	18.4
1 flaxseed in 5th	8	6	18	131	112	413	16.4	18.7	22.9	31.3	33.3	34.6	523.8	629.4	802.3	13.7	17.6	9.1	5.4	9.5	3.4	17.0	25.2	11.5
2 flaxseeds in 3rd	17	11	9	276	203	173	16.2	18.5	19.2	31.2	34.6	33.6	510.8	647.8	656.1	14.7	18.5	23.8	5.7	6.0	6.1	19.1	23.0	27.6
2 flaxseeds in 4th	13	15	25	237	300	526	18.2	20.0	21.0	31.6	32.9	31.4	582.1	667.7	702.5	4.2	11.9	16.7	4.5	10.6	12.3	7.8	20.6	22.5
1 flaxseed per culm	102	105	130	1727	2078	2829	16.9	19.8	21.8	31.7	35.0	34.2	540.9	691.3	751.4	11.1	12.8	13.5	4.2	4.9	4.5	14.3	17.8	17.1
2 flaxseeds per culm*	42	65	58	705	1188	1200	16.8	18.3	20.7	31.4	33.7	32.6	531.7	622.0	685.1	11.6	19.4	17.9	5.1	8.4	8.9	15.8	26.1	24.4
More than 2	12	68	78	182	1156	1373	15.2	17.0	17.6	29.9	32.4	32.9	458.1	549.8	628.1	20.0	25.1	30.2	9.7	12.0	8.1	27.4	34.6	30.7

*Contains some culms other than those given above.

Table 11. Analysis of variance on the effect of the position of the flaxseed on Pawnee from the 1946 Rice county variety test plots.

Number of kernels				:	:	Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	:	:	Source	D/f	Sum of sq's	Est. of var.
Total	101	1063.5				Total	101	680.5	
Groups	3	11.2	3.73			Groups	3	2.8	.93
Within	98	1052.3	10.74			Within	98	677.7	6.92
				:	:				
F - .35; D/f - 3 and 98; P more than 20%						F - .13; D/f - 3 and 98; P more than 20%			

Table 12. Analysis of variance on the effect of the position of the flaxseed on Tenmarq from the 1946 Rice county variety test plots.

Number of kernels				:	:	Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	:	:	Source	D/f	Sum of sq's	Est. of var.
Total	104	2203.4				Total	104	1096.0	
Group	3	57.7	19.2			Group	3	23.7	7.9
Within	101	2145.7	21.2			Within	101	1072.3	10.5
				:	:				
F - .91; D/f - 3 and 101; P more than 20%						F - .75; D/f - 3 and 101; P more than 20%			

Table 13. Analysis of variance on the effect of the position of the flaxseed on Red Chief from the 1946 Rice county variety test plots.

Number of kernels				:	:	Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	:	:	Source	D/f	Sum of sq's	Est. of var.
Total	129	2191.6				Total	129	1097.0	
Group	3	53.8	17.9			Group	3	28.9	9.63
Within	126	2137.8	17.0			Within	126	1068.1	8.48
				:	:				

F - 1.05; D/f - 3 and 126; P more than 20%

F - 1.14; D/f - 3 and 126; P more than 20%

An analysis of variance was made on the three varieties to test the reduction in yield when the culms were infested with one or more flaxseeds. The results of these tests are given in Tables 14, 15 and 16. In every case, the reduction in yield over the uninfested is highly significant (P is less than one tenth percent).

Table 14. Analysis of variance of the effect of the number of flaxseeds on the weight and number of kernels on Pawnee from the 1946 Rice county test plots.

Number of kernels				Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	Source	D/f	Sum of sq's	Est. of var.
Total	205	2542.3		Total	205	1377.7	
Group	3	224.0	74.7	Group	3	135.1	45.0
Within	202	2318.3	11.5	Within	202	1242.6	6.2

F - 6.50; D/f - 3 and 202; P less than .1% F - 7.26; D/f - 3 and 202; P less than .1%

Table 15. Analysis of variance of the effect of the number of flaxseeds on the weight and number of kernels on Tenmarq from the 1946 Rice county test plots.

Number of kernels				Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	Source	D/f	Sum of sq's	Est. of var.
Total	287	7810.6		Total	287	4096.3	
Group	4	1223.9	306.0	Group	4	713.3	178.3
Within	283	6586.7	23.3	Within	283	3383.0	12.0

F - 13.1; D/f - 4 and 283; P less than .1% F - 14.9, D/f - 4 and 283; P less than .1%

Table 16. Analysis of variance of the effect of the number of flaxseeds on the weight and number of kernels on Red Chief from the 1946 Rice county test plots.

Number of kernels				:	:	Weight per kernel			
Source	D/f	Sum of sq's	Est. of var.	:	:	Source	D/f	Sum of sq's	Est. of var.
Total	315	6950.0				Total	315	3034.6	
Group	4	1385.1	346.3			Group	4	451.7	112.9
Within	311	5564.9	17.9			Within	311	2582.9	8.3
				:	:				
F - 19.3; D/f - 4 and 311; P less than .1%						F - 13.6; D/f - 4 and 311, P less than .1%			

As shown in Table 10, there is a reduction both in the number of kernels and in the weight per kernel, in the infested culms of all three varieties. When there was one flaxseed per culm, Red Chief had the greatest reduction in the number of kernels with 13.5 percent as compared with 12.8 and 11.1 percent for Tenmarq and Pawnee, respectively. Tenmarq had the greatest reduction in the weight per kernel with 4.9 percent, while Pawnee had the least amount of reduction with 4.2 percent. When the culms of Tenmarq and Red Chief were infested with two flaxseeds per culm the reduction in yield was considerably greater than when they were infested with one flaxseed per culm. Pawnee, when infested with two flaxseeds per culm, showed only a slight increase in reduction. This difference in reduction of yield between one flaxseed per culm and two flaxseeds per culm was tested statistically to see if there was any significant difference between the two, in the different varieties. The results of the "t" tests are shown in Table 17. The results from these tests point out that Pawnee had very little additional reduction when it was infested with two flaxseeds per culm. This may be an added factor showing its tolerance to the hessian fly. The probability for Pawnee was more than 40 percent, while that for Tenmarq was less than five percent. Similar results were found in the Manhattan material.

Table 17. The results of the "t" tests between one flaxseed per culm and two flaxseeds per culm on the Rice county data.

	Pawnee	Tenmarq	Red Chief
No. of kernels	.16	2.03*	1.67
Wt. per kernel	.67	3.27**	3.47**

* P less than 5%.

**P less than 1%.

DISCUSSION

Investigations show that the results can be highly variable from year to year and from different localities. This is especially true for the weight per head whether infested or not. The average number of kernels does not vary as much from year to year as does the average weight per kernel. Various environmental factors may enter in to influence the relation between the hessian fly and the yield. The Manhattan material had a greater reduction in the weight per head, when infested, than did the Rice county material. In general, in the 1944 Manhattan material Pawnee showed a greater reduction in yield than did Tenmarq. In part, this may have been due to a combination of rust and fly injury, or in part, to different strains of hessian fly. It is known that Pawnee grown in the eastern third of the state is much less resistant to the hessian fly than when grown in central and western Kansas. The infestation on the Manhattan

material was fairly high in 1944, which probably means that there was present in the nursery a considerable number of the strain of fly that was able to injure Pawnee. The data on the Manhattan material showed some effect due to the position of the flaxseed on the culm. The total effect probably was not entirely due to fly. When tested statistically, the Rice county wheat did not show any significant difference in the reduction in yield resulting from the different positions of the flaxseed on the culm. In the material studied from Rice county, Pawnee showed no significant difference in the reduction in yield when infested with one flaxseed and when infested with two flaxseeds per culm. These results tend to show some of the resistance to hessian fly found in Pawnee wheat. Since the results from the two experiments do not agree in regard to the variety showing the greatest injury to the developing grain, it is considered that more tests under various conditions are needed to determine this point.

CONCLUSIONS

Due to the high variability in the material taken from different localities and from different years, more data should be studied before conclusive results can be made. In general the reduction in the average number of kernels does not vary as much from year to year as does the average weight per kernel. There is a definite reduction in yield, which differs among varieties studied, when the culms are infested with hessian fly.

The amount of reduction from the uninfested is highly significant in all cases. The Rice county material does not show any significant difference in the reduction in yield due to the position of the flaxseed on the culm. Pawnee showed no significant difference in reduction in yield when infested with one flaxseed and when infested with two flaxseeds per culm.

SUMMARY

Three varieties of wheat collected in two different years and from two different localities were used in the data reported here. A total of 3,726 culms were examined for the presence or absence of hessian fly. Only standing culms with heads are included in these data. Of these, 870 culms were infested out of the total number examined. The data reported here were taken from approximately 1120 heads, from which the grain was threshed and weighed individually. There was a total of 20,979 kernels handled in this study.

Results of the investigations show that in all three varieties the reduction in yield, from the uninfested culms, caused by one or more flaxseeds is highly significant.

The infestation was found to be higher in the Manhattan material than in the Rice county material.

In general, in the Rice county material, Pawnee showed less reduction both in the number of kernels and in the weight per kernel, when infested, than did the other two varieties. The reverse was found to be true in the Manhattan material.

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