AGRICULTURAL EXPERIMENT STATION

KANSAS STATE COLLEGE OF AGRICULTURE
AND APPLIED SCIENCE
MANHATTAN, KANSAS

RESISTANCE OF VARIETIES OF WINTER WHEAT TO HESSIAN FLY

Phytophaga destructor (Say)

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SUMMARY

1. A detailed discussion is given of the methods used in studying the problem of resistance of wheat to Hessian fly.

2. Methods of measuring the differential infestations of varieties are analyzed.

3. The per cent of tillers infested, coupled with the rank of a variety in a single experiment or set of experiments probably constitutes the best measure of resistance. Under special conditions, estimations, per cent of plants infested, or number of flaxseed and larvæ present may be used to advantage.

4. Data on fly infestation are given for about 400 varieties, selections, and hybrids. Varieties and several pedigree selections of varieties are described in three groups: (1) Those which are highly resistant to fly from the hard-wheat belt. (Table IX.) (2) Those with medium infestation. (Table X.) (3) Very susceptible strains. (Table XI.)

5. Evidence is presented which indicates that varieties may be pure or homozygous so far as agronomic characters are concerned and impure or heterozygous for fly resistance factors.

6. Brief descriptions and pertinent agronomic data are given for a few of the varieties of special interest.

7. Resistance to fly of the hard-wheat belt is found in a marked degree in Fulhard, a hard wheat, and in the semihard variety Kawvale, as well as among the soft wheats. In the isolation of Kawvale and Fulhard by pedigree selection considerable progress has been made toward the ultimate object of this investigation; that is, the production of wheat varieties adapted to Kansas which will be equal or superior in agronomic characters to those now grown, and in addition will be resistant to Hessian fly.

8. Evidence is presented which shows that factors for resistance are inherited and that fly resistance may be combined with other desirable characters.

9. Suggestions are made concerning five characteristics which affect the resistant qualities of wheat varieties. These are: (1) A decided difference in the number of flies which develop on the several varieties; (2) a kind of tolerance as found in Blackhull wheat, permitting fly to develop without material damage to the plant; (3) the ability of some varieties of wheat to develop fly better and faster than other varieties; (4) the ability of wheat to produce tillers after infestation; and (5) the stiffness of straw in relation to Hessian fly damage.

10. Detailed information is given concerning the evidence for the presence of distinct biological strains or populations of Hessian fly, one in the hard-wheat belt of central and western Kansas, and one in the soft-wheat area of eastern Kansas.

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RESISTANCE OF VARIETIES OF WINTER WHEAT TO HESSIAN FLY.

Phytophaga destructor (Say)[1]

REGINALD H. PAINTER, S. C. SALMON[2] AND JOHN H. PARKER

That phase of biological control of insects which has to do with host resistance has been studied only to a relatively small extent. The data presented here, which were gathered over a period of eight years, have to do with the possibility of preventing or reducing Hessian fly injury in this way.

HISTORICAL STATEMENT

A review of the literature on the general subject of host resistance has been prepared by McColloch *(15)* and by Wardle *(24)*. The literature relating to the resistance of wheat varieties to Hessian fly has been reviewed by McColloch and Salmon *(12)*.

Marston *(10) (11)* has shown that in a cross between Maize Amargo, resistant to the European corn borer, and various susceptible local varieties, the resistance factor is inherited as a simple Mendelian recessive.

The results reported by McColloch and Salmon *(12) (13)*, Haseman, Sullivan, and McLane *(6)*, Packard *(16)*, Davis *(5)* and others supply abundant evidence of a differential infestation of wheat *(Triticum vulgare* Host) varieties both under field and experimental conditions. McColloch and Salmon *(12) (13)* and McColloch *(14)* have shown that while there is considerable variation in the number of eggs laid by the Hessian fly on different varieties, selective oviposition is not sufficient to explain the differences in resistance in all cases. The data in Table I reported by McColloch *(14)* give pertinent information of this kind regarding some varieties to be discussed later.

Evidence was also supplied by these investigators to show that resistance probably is due to physiological rather than gross mor-

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1. Contribution No. 385 from the Department of Entomology and No. 202 from the Department of Agronomy. This paper embodies some of the results obtained in the prosecution of Purnell project No. 164, the Departments of Entomology and Agronomy coöperating. The plant-breeding phases of this project are carried on in coöperation with the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture.

2. Principal agronomist, in charge of wheat investigations, Division of Cereal Crops and Diseases, United States Department of Agriculture; formerly professor of farm crops, Kansas State College of Agriculture and Applied Science.

phological characters and that in the young plants it resides at the base of the leaf sheaths, that is, at the crown of the plant. A large per cent of the larvæ are able to reach this region, but they are unable to develop on the resistant varieties.

TABLE I.—EGGS AND FLAXSEED ON WHEAT VARIETIES.

VARIETY.	Total number per 100 plants.	
	Of eggs.	Of flaxseed.
Kanred	550	140
Red Winter (Kan. No. 2132)	720	30
Dawson Golden Chaff	795	3
Illini Chief	590	0

Of the other small grains, oats has proved immune in all tests reported, while barley, rye, durum wheats, etc., have given varying results in different cases.

Packard *(16)* has shown that it is possible by choosing uninfested plants from succeeding generations to select fly-resistant strains of wheat from a variety which is usually susceptible.

Painter *(17)* has given evidence to show that different populations of fly may differ in ability to attack wheat varieties, and that a variety may be highly resistant to one and susceptible to another. He has also shown that the fly of any one locality may consist of a mixture of biological strains, characterized by their ability to infest different wheat varieties. With respect to the former statment, the fly usually found in southeastern Kansas is different from that in central and western Kansas. Kawvale and Superhard Blackhull show some resistance to the population of fly in both places, but certain other varieties show very different reaction to the two strains of fly. Painter *(18)* has also shown that there exists a difference in the survival of fly from eggs laid on different leaves of the same plant. This fact may be of importance in relation to certain resistance phenomena. Sapehin *(22)* and Sapehin *(23)* of Odessa, U. S. S. R., have shown that the fly resistance of a variety of T. *durum* can be combined with other desired characters found in varieties of T. *vulgare.*

METHODS USED

The methods used in the studies of the resistance of wheat varieties to Hessian fly have undergone a gradual change during the progress of the investigation. Those described here have been among the most successful.

The data presented in this bulletin were secured from field tests and from plantings in the greenhouse. In one test, in 1921, the plants were grown in the field and covered with muslin to confine

the fly. Many of the field data were secured from special Hessian fly nurseries. These usually consisted of eight-foot rows planted a foot apart. There were usually two rows of each variety or strain and frequently there were check rows of one or more well-known varieties at regular intervals. The principal Hessian fly nursery was located at Manhattan, but others have been located in various parts of the state from time to time. These nurseries for the most part have been uniform with respect to the varieties included, these having been chosen for the purpose of differentiating between populations of fly. As opportunity offered, use has also been made of varietal tests conducted in various parts of the state by the Department of Agronomy. Artificial infestation by importing infested stubble or volunteer wheat, always from the hard-winter-wheat belt, has been resorted to when infestation could not otherwise be secured. Flaxseed which have been secured in the course of dissecting plants from preceding tests have sometimes been used. These have been placed uniformly in the alleyways between plats and sprinkled with water occasionally. Suitable infestations, in most cases, have been secured by these means.

In the greenhouse tests the plants have been grown in four-inch clay pots. As soon as they were well tillered they were transferred to a small inclosure in the insectary where adult fly were allowed to oviposit. After a varying but usually short period of time, depending on the emergence of the fly, they were transferred to their former greenhouse location until the fly had reached the flaxseed stage, when the plants were dissected and the infestation recorded. Except for the brief period during which they were exposed to the fly for oviposition, the plants were grown at temperatures comparable to those which usually prevail in the field in the early fall. The temperature of the insectary was somewhat higher. However, there seems to be no reason to assume that these higher temperatures affected the results in any material way, although they were not the most favorable for normal growth of the host plant. Mildew and aphids developed to some extent on the wheat plants while in the insectary, but so far as observed did not materially affect the development of the Hessian fly larvæ on the several varieties.

In some of the experiments involving single pairs of Hessian fly, seeds from two different varieties were planted on opposite sides of the same pot. When the plants reached the desired size, the female flies were caged on these plants by means of a small mesh wire cone placed on the pot. (Fig. 1.)

In the greenhouse tests infestation has usually been secured by the use of flaxseed which have previously been removed from wheat plants. These flaxseed were kept on damp plaster paris in the bottom of a vial (fig. 1) or lamp chimney for about ten days previous to use. This gave a fairly uniform emergence which could be controlled rather closely. This method was also used in the experiments with individual strains of fly. Flaxseed may be stored in a cool dry place for several months.

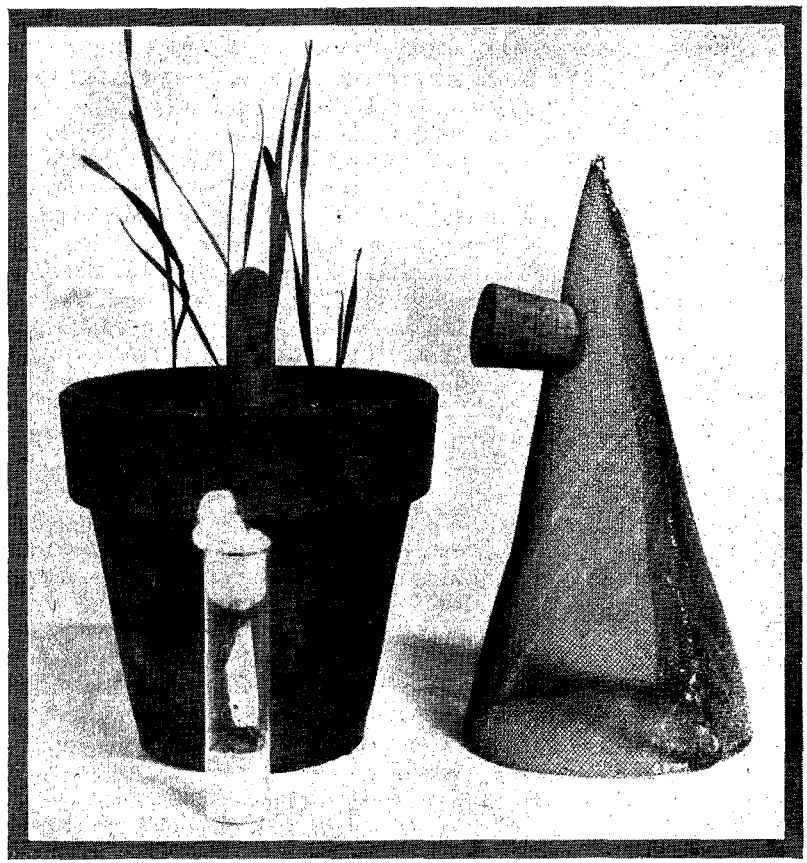

FIG. 1.—Equipment used in breeding experiments involving individual pairs of Hessian fly.

MEASURING DIFFERENTIAL INFESTATION OF VARIETIES

Measuring the infestation of a series of varieties in a given number of tests offers a number of problems which are not encountered in time-of-planting tests or others where a single variety is used. Hence a discussion of several possible methods of meeting these problems is of value here. The problems concerned with plat heterogeneity have been discussed by Larrimer *(8)* Larrimer and Cartwright *(9)*, and Cartwright and Larrimer *(1)*, whose studies apply here to some extent. The presence of biological strains of fly and the necessity of using rather small samples of a large number of strains of wheat bring in other complications. No two tests are ever quite equivalent in intensity of infestation and very few tests contain the same number of varieties or strains.

The particular way in which data are secured and recorded is a problem of some importance. Estimating the numbers or per cents of infested plants has proved useful in examining large numbers of varieties where the object is to find new resistant varieties or strains, and where there is no need for measuring relative resistance. The plants may be examined in the late fall without removal from the ground and the estimated number of infested plants recorded. A thorough search is made in those rows which are apparently uninfested or but slightly infested. Thus in 1929, when the agronomy nursery was rather heavily infested, more than 700 strains were examined. Over 100 which were apparently free of infestation were examined more thoroughly than the others. It would not have been practical to have accurately determined the per cent of infestation of all strains. In this case the method of procedure used was inexpensive, simple, and gave all the information that was required.

The per cent of plants infested as determined by actual count has perhaps been used most frequently. It is especially useful when the infestation is light. For reasonable accuracy a large number of plants is necessary, more, in fact, than are usually available, especially in greenhouse work. There is also a tendency to give too high a value to an infestation when only a minor tiller[3] is infested and if only a small number of plants are examined. When the infestation is heavy as in greenhouse tests it is easy to approach 100 per cent infestation of plants of susceptible varieties, and if it is desired to differentiate between such varieties it is necessary to use other criteria.

The per cent of infested tillers is a better measure of infestation when there are few plants or when the infestation is heavy, since the number of tillers is usually greater than the number of plants. This method of measurement takes into consideration the ability of a variety to stool under given conditions and this factor is an important one in resistance studies. In general for medium or heavy infestations the per cent of tillers infested is considered to be the best measure of a single infestation on one variety. In counting the number of tillers those are disregarded which had not separated from the parent leaf sheath and which were therefore not available for oviposition.

The number of flaxseed and larvæ present per plant has sometimes been used as a measure of infestation. This has been spoken of as intensity of infestation by Larrimer *(8)*. It may be stated either as the number of insects for a given number of plants or the average number for each infested plant. When the per cent of tillers infested reaches 100, as it may do on susceptible varieties, a further increase in infestation will not be shown if the former criteria are used, but will be shown if intensity of infestation is used as the measure of infestation.

3. The term tiller is applied to all branches of the wheat plant, including the first sprout. In the spring count there are included under this term both the jointed culms and the unjointed nonfertile branches.

In studying light infestations on varieties susceptible to only a part of a mixed population of fly, intensity of infestation should be used with care owing to the frequent habit which the females have of laying several eggs on one plant.

TABLE II.—SUMMARY OF INFESTATION OF CHECK ROWS IN THE 1929 FLY NURSERY AT MANHATTAN AS DETERMINED BY DIFFERENT METHODS OF RECORDING INFESTATIONS.

(Based on 50 plants in each of five series.)

	Per cent of tillers infested.	Per cent of plants infested.	Av. number of fly on 50 plants.	Av. number of fly on each infested plant.
Kanred	32.0±3.06	57.2±2.78	61.6±5.87	2.12±.16
Tenmarq	29.0±1.32	61.6±4.12	78.0±9.79	2.64±.30
Blackhull	12.8±1.96	19.2±2.07	20.6±2.68	2.16±.13
Early Blackhull	8.2± .90	17.2±2.11	19.4±2.87	2.24±.15
Superhard	7.4±1.34	14.0±2.17	14.6±2.98	1.92±.25
Fulhard	2.8± .33	4.8± .54	4.0± .85	1.66±.21
Illini Chief Sel. No. 223415	2.6± .27	5.2± .54	3.2± .65	1.30±1.30
Kawvale	2.2± .74	4.4±1.31	3.6±1.44	1.14± .09
Av. P. E.	1.24	1.96	3.39	0.20

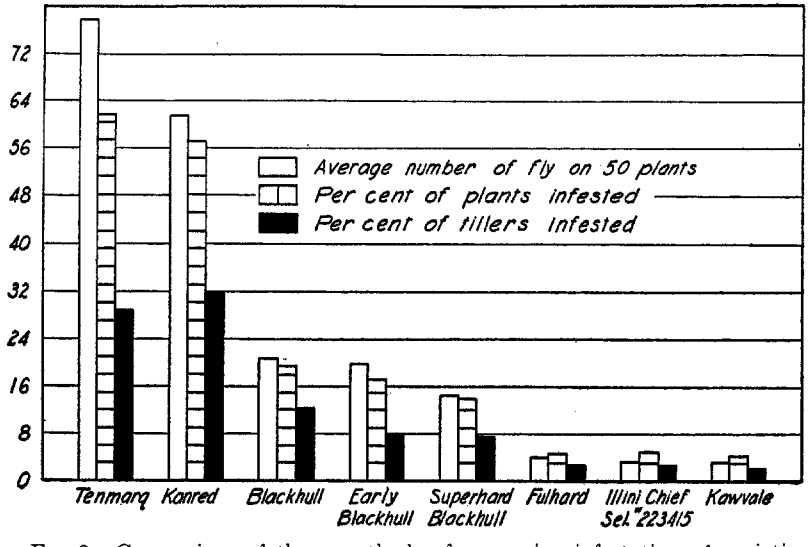

FIG. 2.—Comparison of three methods of measuring infestation of varieties of winter wheat with fly from the hard-wheat belt, Manhattan, Kan., 1929.

A comparison of several methods of recording infestations for eight check varieties in the 1929 fly nursery at Manhattan is given in Table II, and is shown graphically in figure 2. The varieties in the table are arranged in order of per cent of tillers infested and fall into three infestation groups: A lightly infested group, a heavily infested one, and an intermediate group. It will be apparent that the main conclusions will be the same regardless of which method of comparison is used. It may be noted, however, that the differences are much less when number of fly per infested plant is used as a criterion than when the other methods are used. For that reason this method is perhaps the least satisfactory of any of those employed, except when the infestation is very heavy. Thus in some of the greenhouse tests more than 500 flaxseed and larva have been removed from a single half-grown plant. Where infestation is so heavy the per cent of infested plants or tillers may fail to show differences that really exist.

Considering the remaining three methods, it is evident that the probable errors are least for the per cent of infested tillers and greatest for the average number of fly on fifty plants. The range of infestation between the least susceptible and the most susceptible varieties is less when stated as per cent of tillers infested than when per cent of infested plants is considered. Since the real test of utility often is the ratio between observed differences and the probable error of the difference, it would appear that from the statistical viewpoint the per cent of infested plants may be the best criterion, at least in some cases.

EXPERIMENTAL RESULTS WITH FLY FROM THE HARD_ WHEAT BELT

As will be shown later there appear to be biological strains of Hessian fly, and in conducting experiments and in presenting experimental data this fact must be recognized. When many of the experimental tests here reported were conducted this fact was not known, but nevertheless the possibility was recognized, and especially in securing material for infestation care was taken to use fly from the hard-wheat belt. The first and most extensive tests of different varieties were made at Manhattan. A brief discussion of the results follows.

INFESTATION OF VARIETIES

Tables III and IV give in detail the results of varietal infestation studies made at Manhattan since the publication by McColloch and Salmon *(13)*. For convenience the data are given in several sections. Table III gives the data for about 120 varieties and strains which have been in fly nursery tests two or more times. The data are given as per cent of plants infested, owing to the fact that counts of infested tillers were not taken in some of the earlier tests. Early Blackhull and Crimean Sel. No. 50, recently named

Cheyenne, from the Nebraska Agricultural Experiment Station, although in only one test, are included in this table for ready comparison with other related varieties. The varieties are arranged alphabetically except among the closely related ones, which are grouped together for ease of comparison. The number of plants dissected for each determination varied from 20 to 50, according to the year and in some cases according to the variety. Thus varieties used as checks usually were represented by 250 plants or more, in rows distributed throughout the nursery. The more important of these checks are indicated by small capitals, but it should be pointed out that all of the checks were not used as such in every test, although Kanred and Illini Chief selection have been used as checks in every test.

The table includes also tests of selections of several varieties and crosses between varieties of approximately equal susceptibility. Those involving crosses between resistant and susceptible varieties will be discussed later. The different tests recorded in this table varied greatly in the intensity of infestation and hence the averages are not strictly comparable in all cases.

Those varieties or selections which have been tested only once are listed in Table IV. Among these are many varieties and selections which appeared on first test to be completely susceptible, others which were discarded after a single test because not promising as to agronomic characters or because of loss of the seed, complete winterkilling, etc. A few were available for testing for the first time in 1929-'30. The data given in Table IV are not of the same significance as those in Table III but may be taken as an indication of the reaction of the fly on the varieties and selections involved.

TABLE III.—INFESTATION OF WHEAT BY HESSIAN FLY—PER CENT OF PLANTS INFESTED.

(Varieties tested two or more times.)

Kansas or Sel. No. (a)	C. I. No. (b)	VARIETY OR STRAIN.	Fall, 1922.	Fall, 1924.	Spring, 1925.	Fall, 1925.	Fall, 1927 F. N. (c)	Fall, 1929 F. N.	Fall, 1929 A. N. (d)	Av. per cent of plants infested.	
										Variety named.	Kanred in same tests.
2048	5797	Altara	66.0	60.0	7.0	18.0	.....	.....	.....	37.7	32.8
2558	5380	American Bronze	.....	6.6	.0	.....	.....	.....	.....	3.3	39.3
326	6156	Bacska	23.0	60.0	.....	.....	.....	.....	.....	41.5	50.2
.....	5566	Beechwood	.....	.0	7.0	.....	3.0	2.0	.....	3.0	50.7
		Blackhull Group									
343	6251	BLACKHULL (check)	19.0	26.7	20.0	.0	27.0	19.2	9.8	18.8	39.7
470	8054	Superhard	.....	.....	.....	.....	20.0	14.0	.....	17.0	62.1
2610	.....	Darlington	.....	.....	.....	.....	45.0	20.0	.....	32.5	62.1
2611	8262	Sedgwick	.....	.....	.....	.....	10.0	30.0	.....	20.0	62.1
483	8856	Early Blackhull	.....	.....	.....	.....	.....	17.2	.....	17.2	57.2
2331	3330	Buffum No. 17	.....	26.6	7.0	4.0	.....	.....	.....	12.3	33.3
388	.....	Burbank Super	.....	.....	.....	.....	50.0	36.0	.....	43.0	62.1
237	5670	Councilman	.....	6.6	.0	6.3	.....	.....	.....	4.3	33.3
(e) 2–95	.....	Crimean × Poole	.....	13.3	.0	.0	.....	.....	.....	4.4	33.3
.....	3326	Currell	.....	26.7	.0	.0	.....	.....	.....	8.9	33.3
(e) 2–19	.....	Currell Prolific × Fultz	.....	6.6	8.0	.....	.....	.....	.....	7.3	39.3
(e) 2–54	.....	Currell Prolific × Fultz	.....	6.6	.0	.0	.....	.....	.....	2.2	33.3
(e) 2–53	.....	Currell Prolific × Fultz	.....	.0	.0	.0	.....	.....	.....	.0	33.3
2564	3342	Dawson Golden Chaff	.....	6.9	.0	.0	.0	2.0	.....	1.8	44.8
2559	6301	Early Oakley	.....	6.6	.0	32.0	35.0	.....	.....	18.4	41.7
2577	3393	Early Red Clawson	.....	6.6	.0	4.0	.....	.....	.....	3.5	33.3
2523	6691	Forward	.....	6.7	.0	.....	.....	.....	.....	3.3	39.3
2594	8257	Fulhard	.....	.0	.0	.0	.0	4.8	.0	.8	40.9
2548	6999	Fulhio	.....	13.3	.0	.0	25.0	.....	.....	9.6	41.7

TABLE III—CONTINUED.

Kansas or Sel. No. (a)	C. I. No. (b)	VARIETY OR STRAIN.	Fall, 1922.	Fall, 1924.	Spring, 1925.	Fall, 1925.	Fall, 1927 F. N. (c)	Fall, 1929 F. N.	Fall, 1929 A. N. (d)	Av. per cent of plants infested.	
										Variety named.	Kanred in same tests.
		(For Fulcaster selections see Table VII.)									
40	1923	Fultz	.....	.0	.0	.0	35.0	.....	.....	8.7	41.7
.....	3604	Fultz	.....	.0	.0	.....	15.0	.....	.....	5.5	45.2
.....	5575	Fultz Sel	.....	6.6	.0	.....	.....	.....	.....	3.3	39.3
.....	.....	Fultz Sel	.....	6.6	.0	.....	.....	.....	.....	3.3	39.3
2563	4811	Fultz—Mediterranean	.....	10.0	.0	8.0	.....	.....	.....	6.0	33.3
(e) 2-23	.....	Fultz × Poole	.....	6.6	.0	.0	.....	.....	.....	2.2	33.3
(e) 2-24	.....	Fultz × Poole	.....	6.6	.0	.0	.....	.....	.....	2.2	33.3
2545	.....	Gladden	.....	20.0	.....	.....	35.0	.....	.....	27.5	58.6
.....	5644	Gladden	.....	26.6	.....	.0	.....	.....	.....	13.3	35.7
2584	4856	Gluten	.....	.0	.0	.0	20.0	16.0	.....	7.2	44.8
2573	5578	Golden Chaff	.....	6.6	.0	.0	.....	.....	.....	2.2	33.3
.....	5180	Golden Cross	.....	6.6	7.0	.0	.....	.....	.....	4.5	33.3
2579	4876	Grand Prize	.....	16.6	.0	.0	.....	.....	.....	5.5	33.3
.....	5772	Gipsy No. 62	.....	.0	.0	.0	15.0	.0	.....	3.0	44.8
373	6205	Hard Winter Defiance	.....	53.0	33.0	.....	.....	.....	.....	43.0	39.3
19	6199	Harvest Queen	13.0	33.3	.0	12.0	33.0	20.0	.....	18.5	42.6
.....	.....	Hedge Prolific	.....	.0	.0	.0	.....	.....	.....	.0	33.3
.....	4859	Hedge Prolific	.....	.....	.....	.....	5.0	16.0	.....	10.5	62.1
2522	6161	Honor	.....	.0	.0	.0	.0	4.0	.....	.8	44.8
2519	4843	Hussar	.....	86.5	60.0	22.0	75.0	.....	.....	63.2	41.7
223415	.....	ILLINI CHIEF SEL. (check)	.....	.0	.0	.0	3.3	5.2	.....	1.7	44.8
		(For Illini Chief selections, see Table VI.)									
		(For crosses involving Illini Chief, see Table XV.)									
2588	5338	Imperial Amber	.....	.0	.0	.0	15.0	12.0	.....	5.4	44.8
2382	5592	Improved Turkey	.....	86.7	60.0	18.0	.....	.....	.....	54.7	33.3
		(For Indiana Swamp, see Kawvale.)									
431	6934	Iobred	.....	66.7	.0	.0	90.0	.....	.....	39.1	44.8
307	5580	Iowa No. 404	.....	53.3	.....	4.0	.....	.....	.....	28.6	35.7
2557	6203	Jones Climax	.....	66.6	.0	16.0	25.0	.....	.....	26.9	44.8
2401	5146	KANRED (check)	31.4	50.2	28.5	21.2	67.0	57.2	21.8	39.7	39.7

TABLE III—CONTINUED.

Kansas or Sel. No. (a)	C. I. No. (b)	VARIETY OR STRAIN.	Fall, 1922.	Fall, 1924.	Spring, 1925.	Fall, 1925.	Fall, 1927 F. N. (c)	Fall, 1929 F. N.	Fall, 1929 A. N. (d)	Av. per cent of plants infested.	
										Variety named.	Kanred in same tests.
		Crosses and Selections Involving Kanred									
2529	.....	Kanred sel.	.....	80.0	.....	14.0	.....	.....	.....	47.0	35.7
2531	.....	Kanred sel.	.....	86.7	.....	.0	.....	.....	.....	43.3	35.7
2626	.....	Kanred × Hard Federation	.....	.....	.....	.....	80.0	40.0	.....	60.0	62.1
2627	.....	Kanred × Hard Federation	.....	.....	.....	.....	28.0	34.0	.....	31.0	62.1
254990	.....	Kanred × Hard Federation	.....	.....	.....	.....	85.0	40.0	.....	62.5	62.1
440	6937	Kanmarq	.....	53.3	.....	.....	50.0	58.0	.....	53.7	58.1
2640	.....	Kanred × Marquis	.....	.....	.....	.....	.....	56.0	30.1	43.0	39.5
2641	.....	Kanred × Marquis	.....	.....	.....	.....	.....	72.0	21.8	46.9	39.5
2642	.....	Kanred × Marquis	.....	.....	.....	.....	.....	44.0	34.1	39.1	39.5
439	6936	Tenmarq	.....	60.0	.....	.....	85.0	61.6	27.0	58.4	49.0
2637	.....	Tenmarq sel.	.....	.....	.....	.....	.....	48.0	32.0	40.0	39.5
285870	.....	Tenmarq sel.	.....	.....	.....	.....	.....	68.0	27.1	47.5	39.5
285944	.....	Tenmarq sel.	.....	.....	.....	.....	.....	54.0	23.4	37.7	39.5
285991	.....	Tenmarq sel.	.....	.....	.....	.....	.....	64.0	24.4	44.2	39.5
2628	8886	Prelude × Kanred	.....	.....	.....	.....	85.0	46.0	30.1	53.8	48.7
2652	.....	Prelude × Kanred	.....	.....	.....	.....	.....	46.0	24.0	35.0	39.5
263786	.....	Prelude × Kanred	.....	.....	.....	.....	.....	54.0	35.1	44.5	39.5
2593	8180	KAWVALE	.....	6.6	.0	.0	.0	4.4	0.45	1.9	41.0
382	6206	Kharkof	52.0	53.3	.....	8.0	.....	.....	.....	56.6	34.2
.....	4898	Malakof	.....	.....	.....	.....	.0	.0	.....	.0	62.1
2517	.....	Mammoth Red	.....	6.6	.0	.0	.....	.....	.....	2.2	33.3
36	2008	Mammoth Red	.....	23.3	7.0	8.0	20.0	.....	.....	14.6	41.7
.....	5686	Mealy	.....	6.6	.0	.....	.....	.....	.....	3.3	39.3
69	.....	Mealy	.....	.....	.....	12.0	35.0	.....	.....	23.5	44.1
427	.....	Mediterranean No. 30	.....	.0	.....	.....	5.0	6.0	.....	3.7	58.1
.....	5303	Mediterranean No. 30	.....	13.3	.0	4.0	.0	2.0	.....	3.8	44.8
496	.....	Menno	.....	.....	.....	.....	80.0	68.0	.....	74.0	62.1
2533	.....	Michigan Wonder	.....	.0	.0	.0	.0	.....	.....	.0	41.7
2534	.....	Michigan Wonder	.....	.0	.0	.0	.0	.....	.....	.0	41.7
2535	.....	Michigan Wonder	.....	.0	.0	.0	.....	.....	.....	.0	33.3
.....	5589	Michigan Wonder	.....	6.6	.0	4.0	.....	.....	.....	3.5	33.3
2525	6990	Michikof	.....	28.6	.0	4.0	75.0	26.0	.....	26.7	44.8
2448	6155	Minturki	.....	56.7	53.0	40.0	40.0	.....	.....	47.4	41.7

TABLE III—CONTINUED.

Kansas or Sel. No. (a)	C. I. No. (b)	VARIETY OR STRAIN.	Fall, 1922.	Fall, 1924.	Spring, 1925.	Fall, 1925.	Fall, 1927 F. N. (c)	Fall, 1929 F. N.	Fall, 1929 A. N. (d)	Av. per cent of plants infested.	
										Variety named.	Kanred in same tests.
321	6249	Nebraska No. 6	42.0	80.0	60.0	.0	.....	.....	.....	45.5	32.8
322	6250	Nebraska No. 60	47.0	73.3	60.0	32.0	.....	.....	.....	53.0	32.8
2667	8885	Nebraska Crimean No. 50 (Cheyenne)	.....	.....	.....	.....	.....	.....	20.8	20.8	21.8
34	5147	Nebraska No. 28	13.0	60.0	.0	24.0	75.0	.....	.....	34.4	39.7
459	5366	Nigger	.....	13.3	.0	4.0	5.0	14.0	.....	7.2	44.8
400	6962	Nittany (Penn. No. 44)	.....	6.6	.0	1.5	10.0	2.0	.....	4.0	44.8
.....	4475	Odessa	.....	6.6	.0	.....	.....	.....	.....	3.3	39.3
2546	7002	Ohio No. 9920	.....	6.6	27.0	.0	10.0	.....	.....	9.4	41.7
495	8220	Oro	.....	.....	.....	.....	80.0	40.0	.....	60.0	62.1
.....	6695	Pioneer	.....	.0	13.0	.0	.....	.....	.....	4.3	33.3
2576	3488	Poole	.....	13.3	.0	.0	15.0	.....	.....	7.0	41.7
2544	.....	Portage	.....	13.3	.....	.....	15.0	.....	.....	14.1	58.6
.....	5370	Portage No. 6400	.....	13.3	.....	.0	.....	.....	.....	6.6	35.7
2612	8381	Purkof	.....	.....	.....	.....	3.0	2.0	.....	2.5	62.1
2572	6384	Red Chaff	.....	6.6	.0	.....	.....	.....	.....	3.3	39.3
.....	3393	Red Clawson	.....	.0	.0	.....	.....	.....	.....	.0	39.3
61	3570	Red Cross	.....	6.6	.0	.0	.....	.....	.....	2.2	33.3
359	5597	Red Rock	.....	.....	.0	.0	.0	.0	.....	.0	44.8
2570	3500	Red Wave	.....	16.6	13.0	.0	55.0	.....	.....	21.1	39.3
2132	.....	RED WINTER	28.0	17.7	10.0	4.0	13.0	14.0	.....	14.4	42.6
.....	5870	Red Wonder	.....	6.6	.0	4.0	20.0	.....	.....	7.6	41.7
2589	6401	Reed Winter	.....	6.6	.0	.....	.....	.....	.....	3.3	39.3
2583	4873	Rudy	.....	30.0	7.0	.0	40.0	.....	.....	19.2	41.7
2587	5737	Russian	.....	.0	.0	.0	10.0	2.0	.....	2.4	44.8
2565	5942	Schonacher	.....	.0	.0	.0	.....	.....	.....	.0	33.3
(e) 2-41	.....	Sel. 13838	.....	6.6	.0	16.0	.....	.....	.....	7.5	33.3
435	6163	Shepherd	.....	.0	.0	.0	5.0	4.0	.....	1.8	44.8
2270	4430	Sherman	.....	75.0	67.0	16.0	80.0	.....	.....	59.5	41.7
2585	2496	Silver-sheaf	.....	16.6	.....	4.0	15.0	.....	.....	11.8	58.1
47	2980	Stoner	.....	6.6	.0	.0	.....	.....	.....	2.2	33.3
2215	1561	Theiss	.....	6.6	.0	.....	35.0	.....	.....	13.8	45.2
2580	5332	Treadwell	.....	13.3	.0	.....	15.0	.....	.....	9.4	45.2
2547	.....	Trumbull	.....	20.0	.....	8.0	40.0	.....	.....	22.7	58.1
392	1571	Turkey	.....	93.3	.....	20.0	.....	.....	.....	56.6	35.7

TABLE III—CONCLUDED.

Kansas or Sel. No. (a)	C. I. No. (b)	VARIETY OR STRAIN.	Fall, 1922.	Fall, 1924.	Spring, 1925.	Fall, 1925.	Fall, 1927 F. N. (c)	Fall, 1929 F. N.	Fall, 1929 A. N. (d)	Av. per cent of plants infested.	
										Variety named.	Kanred in same tests.
570	1558	Turkey	82.0	86.7	57.0	36.0	75.0	58.0	.....	65.8	42.6
480	5829	Turkish Amber	.....	.....	.....	.....	5.0	6.0	.....	5.5	62.1
2574	4846	Wheedling	.....	.0	.0	.0	15.0	.....	.....	3.7	41.7
.....	5658	Valley	.....	6.6	.0	.0	10.0	.....	.....	4.1	41.7
2084	6211	Zimmerman	.....	33.3	.0	8.8	80.0	.....	.....	30.5	41.7
.....	2907	Zimmerman	.....	80.0	.....	16.0	.....	.....	.....	48.0	58.6

(a) All numbers in this column below 10,000 are Kansas accession numbers. All above that are Kansas selection numbers.
(b) C. I. numbers are accession numbers of the Division of Cereal Crops and Diseases, U. S. Dept. of Agriculture.
(c) F. N. refers to fly nursery.
(d) A. N. refers to agronomy nursery.
(e) Crosses and selections made by Dr. C. E. Leighty, Division of Cereal Crops and Diseases, U. S. Dept. of Agriculture, and reported under his Arlington Farm Nursery numbers.

TABLE IV.—INFESTATION OF WHEAT BY HESSIAN FLY—PER CENT OF PLANTS INFESTED. (a)

(Varieties in only one test.)

Kansas or Sel. No.	C. I. No.	VARIETY OR STRAIN.	Per cent of plants infested.	
			Variety named.	Kanred in same test.
385	1438	Alton (Ghirka Winter)	66.6	50.2
428	.....	Ashland	40.0	50.2
....	6692	Ashland	20.0	50.2
(b) 2-13	.....	Ashland Sel.	6.6	50.2
296736	.....	Avis	46.0	57.2
100	4886	Beechwood	16.0	31.4
2251	1667	Beloglina	40.0	50.2
2515	6835	Berkeley Rock	20.0	50.2
271	6184	Big Frame	.0	50.2
296731	.....	Bolau Sel.	38.0	57.2
2575	180	China	10.0	50.2
....	4888	China	20.0	50.2
....	5669	China	20.0	50.2
2557	6203	Climax	.0	50.2
....	6208	Crimean	53.0	31.4
(b) 2-22	.....	Crimean × Poole	53.3	50.2
....	3326	Currell	50.0	67.0
....	2906	Currell	60.0	50.2
2406	6216	Currell	24.0	31.4
27 FN195	.....	Currell × Fultz	30.0	67.0
(b) 2-51	.....	Currell Prolific × Fultz	13.3	50.2
(b) 2-52	.....	Currell Prolific × Fultz	6.6	50.2
(b) 2-21	.....	Currell Prolific × Fultz	20.0	50.2
78	.....	Dawson Golden Chaff	8.5	31.4
2624	8265	Denton	28.0	57.2
2175	.....	Diehl Mediterranean	26.6	50.2
1638	1395	Diehl Mediterranean	13.3	50.2
....	4851	Dunlap	13.3	50.2
506	8860	Durabel	42.0	57.2
498	8868	Eagle Chief	38.0	57.2
2551	.....	Early Harvest	13.3	50.2
(b) 2-33	.....	Early Harvest	40.0	50.2
2521	.....	Early Kanred	73.3	50.2
2549	.....	Early Kanred	93.3	50.2
484	.....	Early Kanred	90.0	57.2
72	5641	Early Ripe	20.0	50.2
102	4891	Egyptian Amber	20.0	50.2
177	4854	Enterprise	13.3	50.2
2566	5915	Extra Early Windsor	33.3	50.0
....	6307	Flint	66.6	50.0
358	.....	Florence	53.3	50.0
2523	6691	Forward	15.0	57.2
		(For Fulcaster selections see Table VII.)		
2561	3416	Fultz	13.3	50.2
2156	6215	Fultz	40.0	50.2
....	.....	Fultz Sel.	20.0	50.2
....	4809	Fultzo-Mediterranean	.0	50.2
....	5681	Jersey Fultz	6.6	50.2
....	5774	Jersey Fultz	13.3	50.2
....	5643	Fultz Mediterranean	13.0	28.5
2563	4811	Fultz Mediterranean	.0	28.5
(b) 2-56	.....	Fultz × Poole	33.3	50.2
(b) 2-57	.....	Fultz × Poole	20.0	50.2
(b) 2-58	.....	Fultz × Poole	33.3	50.2
(b) 2-97	.....	Giant Square Head × Fultz	20.0	50.2
(b) 2-96	.....	Giant Square Head × Fultz Mediterranean	.0	50.2
(b) 27-47	.....	Giant Square Head × Fultz Mediterranean	20.0	67.0
(b) 2-55	.....	Giant Square Head × Mealy	20.0	50.2
2567	2996	Gold Coin	40.0	50.2
2568	6317	Gold Drop	73.3	50.2
....	6316	Gold Drop	53.3	50.2
....	4857	Goens	40.0	50.2
....	.....	Grand Prize	26.6	50.2
2579	4876	Grand Prize	13.3	50.2
296761	.....	Grand No. 4	58.0	57.2
2569	6027	Grass	60.0	50.2
2581	3436	Gipsy	20.0	50.2
....	5679	Gipsy	7.0	50.2
2123	6214	Hard Winter Defiance	55.0	31.4
19	5314	Harvest Queen	13.3	50.2

TABLE IV.—CONTINUED.

Kansas or Sel. No.	C. I. No.	VARIETY OR STRAIN.	Per cent of plants infested.	
			Variety named	Kanred in same test.
....	6328	Homer	53.3	50.2
494	.....	Hostianum	42.5	57.2
....	3496	Hussar	13.3	50.2
		(For Indiana Swamp see Kawvale.)		
....	6676	Iowa No. 1946	60.6	50.2
2666	10017	Iowin	48.0	57.2
2665	.....	Ioturk	66.0	57.2
....	4468	Jones Fife	46.6	50.2
2586	5823	Jones Longberry	13.3	50.2
296751	.....	Jayhawker	40.0	57.2
		Crosses and Selections Involving Kanred		
2415	5879	P. 1066	40.0	50.2
2648	.....	Kanred × Hard Federation Sel.	58.0	57.2
243181	.....	Kanred × Hard Federation Sel.	52.0	57.2
254635	.....	Kanred × Hard Federation Sel.	23.5	21.8
254898	.....	Kanred × Hard Federation Sel.	40.0	57.2
254981	.....	Kanred × Hard Federation Sel.	75.0	57.2
254991	.....	Kanred × Hard Federation Sel.	75.0	67.0
254580	.....	Kanred × Hard Federation Sel.	52.0	57.2
255005	.....	Kanred × Hard Federation Sel.	90.0	67.0
255085	.....	Kanred × Hard Federation Sel.	24.0	57.2
285191	.....	Kanred × Hard Federation Sel.	38.0	57.2
285192	.....	Kanred × Hard Federation Sel.	38.0	57.2
285591	.....	Kanred × Hard Federation Sel.	27.1	21.8
289391	.....	Kanred × Hard Federation Sel.	60.0	57.2
254634	.....	Kanred × Hard Federation Sel.	40.0	57.2
285309	.....	Kanred × Hard Federation Sel.	56.0	57.2
285312	.....	Kanred × Hard Federation Sel.	38.0	57.2
2644	.....	Kanred × Marquis	62.0	57.2
2645	.....	Kanred × Marquis	56.0	57.2
255321	.....	Kanred × Marquis	56.0	57.2
255522	.....	Kanred × Marquis	62.0	57.2
264071	.....	Kanred × Marquis	52.0	57.2
2647	.....	Marquis × Kanred	56.0	57.2
457	.....	P. 1066 × Marquis	54.0	57.2
264308	.....	Tenmarq Sel.	54.0	57.2
285565	.....	Tenmarq Sel.	68.0	57.2
285705	.....	Tenmarq Sel.	68.0	57.2
285785	.....	Tenmarq Sel.	74.0	57.2
285884	.....	Tenmarq Sel.	44.0	57.2
285952	.....	Tenmarq Sel.	66.0	57.2
286015	.....	Tenmarq Sel.	62.0	57.2
2653	.....	Prelude × Kanred	54.0	57.2
....	8259	Prelude × Kanred	54.0	57.2
263749	.....	Prelude × Kanred	46.0	57.2
263755	.....	Prelude × Kanred	68.0	57.2
263826	.....	Prelude × Kanred	58.0	57.2
289368	.....	Prelude × Kanred	42.0	57.2
264138	.....	Kanred × Prelude	80.0	57.2
254147	.....	P. 1068 × Prelude	75.0	67.0
292984	.....	Kanred × Nebraska No. 28	56.0	57.2
28RN265	.....	Kawvale Sel.	.0	57.2
28RN272	.....	Kawvale Sel.	.0	57.2
285219	.....	Kawvale Sel.	.0	57.2
286117	.....	Kawvale Sel.	.0	57.2
2539	6938	Kharkof	66.7	50.2
2591	.....	Kharkof	68.0	57.2
2659	6686	Kharkof (Hays No. 2)	66.0	57.2
2472	5549	Kharkof Sel. (Montana No. 36)	86.0	50.2
2250	6700	Karmont	53.3	50.2
296740	.....	Krimka Sel.	52.0	57.2
2502	.....	Lawrence	26.6	50.2
....	4823	Leap	35.7	50.2
2614	.....	Lincalel	62.0	57.2
....	3275	Lofthouse	40.0	50.2
491	8896	Lutescens	48.0	57.2
5775	.....	Mammoth Red	6.6	50.2
....	3641	Marquis	50.0	31.4
2555	4636	Martin Amber	33.3	50.2
2578	3358	Mealy	30.0	50.2
....	.....	Mediterranean No. 31	.0	21.2
8215-4	.....	Mediterranean Sel. Tex	26.0	57.2

TABLE IV.—CONCLUDED.

Kansas or Sel. No.	C. I. No.	VARIETY OR STRAIN.	Per cent of plants infested.	
			Variety named.	Kanred in same test.
3015-56	.....	Mediterranean Sel. Tex	40.0	57.2
3015-105-4	.....	Mediterranean Sel. Tex	70.0	57.2
8116-12	.....	Mediterranean Sel. Tex	18.0	57.2
5933-8	.....	Mediterranean Sel. Tex	46.0	57.2
488	.....	Michigan Wonder	10.0	67.0
500	.....	Michigan Wonder	.0	57.2
2542	6690	Minard	62.0	50.2
2450	5149	Minhardi	26.7	50.2
469	8034	Minhardi × Minturki	75.0	67.0
2606	8215	Minhardi × Minturki	65.0	67.0
54	.....	Miracle	2.0	31.4
2536	6935	Newturk	75.0	67.0
2559	6301	Oakley	.0	50.2
307	5580	Odessa	19.0	31.4
2381	.....	Bartgrosskorniger	73.3	50.2
....	5342	Penn. Blue Stem	33.3	50.2
2590	5948	Penquite	13.3	50.2
....	6796	Pesterboden	60.0	50.2
....	8266	Pesterboden	70.0	57.2
....	5538	Peterson	26.6	50.2
333	.....	Poole Sel.	13.3	50.2
....	5654	Portage	20.0	50.2
....	3365	Pride of Genesee	6.6	50.2
2558	5380	Prosperity	.0	50.2
42	1915	Purplestraw	53.3	50.2
819	.....	Red May	20.0	50.2
....	.....	Red May	13.3	50.2
....	4509	Red Russian	66.6	50.2
833	1532	Red Russian	66.6	50.2
2101	6213	Red Winter	60.0	31.4
....	6390	Resaca	33.3	50.2
2556	5734	Rice	50.0	50.2
2543	6703	Ridit	73.3	50.2
258	5693	Rochester	66.6	50.2
....	5735	Rudy	6.6	50.2
2571	5920	Ruppert Giant	20.0	50.2
....	5921	Rural New Yorker No. 6	6.6	50.2
2582	6263	Rustproof	33.3	50.2
392	7364	Regal	70.0	67.0
432	6247	Sevier	46.6	50.2
460	5666	Sibley	46.6	50.2
....	6009	Sol	46.6	50.2
(b) 2-25	.....	Spelt × Turkey	13.3	50.2
....	.....	Squarehead	46.6	50.2
471	4298	Squarehead Master	60.0	50.2
....	5739	Stacey Premium	6.6	50.2
493	8862	Stepniatchka	70.0	57.2
296797	.....	Szeks Sel.	74.0	57.2
....	5657	Trumbull	31.1	50.2
1664	.....	Turkey	66.7	50.2
2105	.....	Turkey	41.0	31.4
2532	7005	Turkey Sel.	73.3	50.2
461	8219	Turkey Sel. (Ilred.) Ill. No. 10-110	86.7	50.2
354	.....	Turkey × Florence	13.3	50.2
357	.....	Turkey × Florence	53.3	50.2
346	.....	Turkey × Florence	45.0	67.0
....	6445	Walker	60.0	50.2
2066	.....	Winter Durum	33.3	50.2
391	6677	Winter Preston	33.3	50.2
....	3546	Winter King	2.0	57.2
318	6683	Wisconsin Pedigree No. 2	80.0	50.2
2560	3549	Wyandotte Red	20.0	50.2
70	.....	Valley	30.0	31.4
....	5923	Valley	20.0	50.2
2550	5948	Velvet Chaff	26.6	50.2

(a) The year in which the test was made may be ascertained from the following data concerning the per cent of Kanred plants infested: Fall 1922, 31.4 per cent; fall 1924, 50.2 per cent; spring, 1925, 28.5 per cent; fall 1925, 21.2 per cent; fall 1927, 67 per cent; fall 1929, fly nursery, 57.2 per cent; fall 1929, agronomy nursery, 21.8 per cent.

(b) Crosses and selections made by Dr. C. E. Leighty, Division of Cereal Crops and Diseases, U. S. Dept. of Agriculture, and reported under his Arlington Farm Nursery number.

In Table V data are given for eleven important varieties which have been tested at various times in the greenhouse or the muslin inclosure. In these experiments the number of plants was limited but the infestation was usually made very heavy in an attempt to break down the resistance of the resistant varieties. It will be noted that the rank of the varieties is approximately the same as in the field tests. Thus Turkey, Kanred, and Tenmarq have a high infestation in the greenhouse tests, as in the field. Fulhard, Kawvale, Illini Chief Sel. 223415, and Dawson Golden Chaff have a low infestation. Red Winter, Blackhull, and Superhard have a somewhat higher relative infestation in these greenhouse tests than in the field. The infestation of these varieties varies with the severity of infestation in the particular test.

Early in the investigation it became evident that varieties, selections, and hybrid lines, whether homozygous or heterozygous for agronomic characters, may be mixed populations so far as type of reaction to Hessian fly is concerned. Illini Chief and Fulcaster have been the varieties so far studied most intensively in this respect. Table VI and VII give the field data and Table VIII the greenhouse data for a number of selections of these two varieties. The Illini Chief selections were made specifically for a study of their fly reaction. The Fulcaster selections were made from Fulcaster, Kansas No. 55, by Mr. C. O. Johnston, of the Division of Cereal Crops and Diseases, United States Department of Agriculture, for studies of resistance to leaf rust, *Puccinia triticina* Eriks., Selection R. N. 6-226 has been named Fulhard and is carried under that name in Tables II, III, and V. In all tables pedigree strains have been listed separately.

In order to provide a convenient means of evaluating the data the average infestation of each variety is compared with the average of Kanred in the same tests. This method must be used with some caution since the relative infestation in some cases varied with the year and severity of infestation. Strictly speaking, only those tests conducted in the same season are comparable. In interpreting the data, no serious errors will be made if this fact is considered.

On the basis of the data given in Table III, and for purposes of discussion, strains of wheat may be grouped roughly into three classes with regard to reaction to Hessian fly. Such a classification of some of the more important or better-known varieties is given in Table IX, X, and XI. The presence of zero infestations in Table IX is not at present to be taken as evidence of immunity. In most cases those varieties with no infestation require more thorough testing.

TABLE V.—PER CENT OF INFESTATION IN VARIETY TESTS IN GREENHOUSE AND MUSLIN COVERED INCLOSURE.

Kansas No.	Variety or Strain.	Greenhouse, 1921.		Inclosure, 1921.	Greenhouse, 1926-'27.				Greenhouse, 1928-'29.			
		First test.	Second test.		First test.		Second test.		First test.		Second test.	
					Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.
570	Turkey	42.1	83.3	72.5	.....	.....	.....	.....	.....	.....	.....	.....
2401	Kanred	26.3	55.3	63.7	70.0	23.8	100.0	33.3	44.0	22.0	90.8	50.6
2637	Tenmarq	.....	.....	.....	.....	.....	70.0	25.0	70.6	32.0	98.0	47.0
343	Blackhull	.....	.....	.....	.....	.....	70.0	15.9	44.0	24.0	87.7	36.5
470	Superhard	.....	.....	.....	.....	.....	60.0	17.3	25.0	11.3	.....	.....
2132	Red Winter	16.6	33.3	25.2	50.0	8.1	60.0	18.1	63.0	27.7	.....	.....
2594	Fulhard	.....	.....	.....	.....	.....	.....	.....	.....	.....	13.0	3.1
2593	Kawvale	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.4	7.3
....	Illini Chief Sel. 223415	.....	.....	.....	.0	.0	.0	.0	4.5	1.4	27.0	8.0
2564	Dawson Golden Chaff	.....	.....	.....	.....	.....	.....	.....	2.0	.9	.....	.....
....	Marquis	.....	.....	.....	.....	.....	90.0	35.5	.....	.....	.....	.....

TABLE VI.—INFESTATION OF ILLINI CHIEF SELECTIONS BY HESSIAN FLY—PER CENT OF PLANTS AND TILLERS INFESTED.

Sel. No.	Fall, 1922, plants.	Fall, 1924, plants.	Spring, 1925, plants.	Fall, 1925, plants.	Fall, 1927.		Fall, 1929.		Average per cent of plants infested.	
					Plants.	Tillers.	Plants.	Tillers.	Sel. named.	Kanred in same tests.
1932S7	.....	.....	.....	.....	0.0	0.0	1.0	0.9	0.5	62.1
223414	7.0	0.0	0.0	0.0	23.0	9.4	.....	.....	6.4	39.7
223415	.0	.0	.0	.....	3.5	1.4	5.2	2.6	1.4	42.6
223418	17.0	6.6	.....	8.0	45.0	17.0	.....	.....	19.1	42.4
223420	2.0	13.3	.....	4.0	.0	.0	4.0	1.7	4.6	45.4
223421	.....	.....	.....	.....	15.0	4.3	14.0	8.4	14.5	62.1
223431	.0	.0	.0	.0	5.0	2.6	.0	.0	.8	42.6
223441	36.0	13.3	.0	8.0	70.0	38.0	.....	.....	28.5	39.7
223443	9.0	6.6	.....	.0	10.0	3.4	4.0	1.9	4.6	45.4

TABLE VII.—INFESTATION OF FULCASTER SELECTIONS BY HESSIAN FLY—PER CENT OF PLANTS AND TILLERS INFESTED.

NUMBER.	Fall, 1924.		Spring, 1925.		Fall, 1925.		Fall, 1927, F. N.		Fall, 1929, F. N.		Fall, 1929, A. N.		Average per cent of plants infested.	
	Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.	Sel. named.	Kanred in same tests.
Ks. 317 C. I. 6471	8.3	2.5	11.0	3.0	.0	.0	40.0	20.6	14.0	8.55	.....	.....	14.6	44.8
Ks. 2552 C. I. 3407	7.0	1.5	.0	.0	.0	.0	.....	.....	.....	.....	.....	.....	2.3	33.3
C. I. 4862	26.6	8.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	26.6	50.2
Ks. 426	.....	.....	.....	.....	.....	.....	.0	.0	.....	.....	.....	.....	.0	67.0
Ks. 2622	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	38.0	17.8	38.0	21.8
RN 2-225	.0	.0	.0	.0	.0	.0	10.0	2.8	4.0	1.5	.....	.....	2.8	44.8
RN 6-226 (Fulhard)	.0	.0	.0	.0	.0	.0	10.0	3.7	2.0	1.2	.....	.....	2.4	44.8
RN 7-211	.0	.0	.0	.0	.0	.0	45.0	14.7	.....	.....	.....	.....	11.2	41.7
RN 10-228	.0	.0	.0	.0	.0	.0	20.0	6.2	.....	.....	.....	.....	5.0	41.7
RN 13-231	.0	.0	.0	.0	.0	.0	10.0	4.3	4.0	1.62	.....	.....	2.8	44.8
RN 16-232	.0	.0	.0	.0	.0	.0	5.0	1.6	2.0	1.14	.....	.....	1.4	44.8
RN 19-233	6.6	1.2	13.0	4.4	.0	.0	35.0	7.8	.....	.....	.....	.....	13.6	41.7
RN 21-234	40.0	5.8	40.0	10.9	12.0	2.5	.....	.....	.....	.....	.....	.....	30.7	33.3
RN 28-236	.....	.....	.....	.....	.....	.....	5.0	.8	.0	.0	.....	.....	2.5	62.1
RN 30-237	26.6	7.9	9.0	3.2	.0	.0	.....	.....	.....	.....	.....	.....	11.9	33.3
RN 35-239	13.3	1.8	.0	.0	4.0	.9	.....	.....	.....	.....	.....	.....	5.7	33.3

The partial resistance of the varieties in Table X may be due to factors for resistance different from those in the varieties listed in Table IX. Those varieties with medium infestation may be heterogeneous mixtures so far as resistance to fly is concerned. This certainly is true of some varieties, as has been pointed out above.

Most of the varieties named in Table XI are more susceptible to fly than Kanred. Although the significance of this difference is of doubtful value from a resistance standpoint, it should be pointed out that in choosing Kanred as a standard for comparison with resistant varieties, other and more susceptible varieties might have been chosen.

TABLE VIII.—PER CENT OF INFESTATION IN GREENHOUSE TESTS OF SELECTIONS OF ILLINI CHIEF AND FULCASTER.

Sel. No.	1926-'27.				1927-'28.			
	First test.		Second test.		First test.		Second test.	
	Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.
Illini Chief Selections								
193287	20.0	3.3	10	3.6	.....	.....	44.0	10.6
223414	30.0	6.3	40	10.4	15.0	4.5	.....	.....
223415 Check	.0	.0	.0	.0	4.5	1.4	27.0	8.0
223418	.....	.....	.....	.....	21.3	6.9	.....	.....
223419	.....	.....	.....	.....	16.7	4.5	.....	.....
223421	30.0	3.0	20	5.8	14.0	4.4	.....	.....
223431	.0	.0	.0	.0	.0	.0	6.0	2.4
223441	60.0	13.8	60	20.0	32.0	15.0	.....	.....
223443	.....	.....	.....	.....	2.3	.7	.....	.....
Fulcaster Selections								
Ks. 317	.....	.....	.....	.....	24.0	10.9	.....	.....
RN 2-225	.....	.....	.....	.....	22.0	6.7	.....	.....
RN 7-211	.....	.....	.....	.....	34.0	12.1	.....	.....
RN 10-228	.....	.....	.....	.....	14.6	7.5	.....	.....
RN 13-231	.....	.....	.....	.....	38.6	18.6	.....	.....
RN 16-232	.....	.....	.....	.....	28.6	12.0	.....	.....
Kanred checks	70.0	23.8	100	33.3	44.0	22.0	90.8	50.6

TABLE IX.—AVERAGE PER CENT OF PLANTS INFESTED IN PRINCIPAL VARIETIES HIGHLY RESISTANT TO HESSIAN FLY FROM KANSAS HARD-WHEAT BELT. (*a*)

(Summarized from Table III.)

VARIETY.	Variety named.	Kanred in same tests.
Beechwood	3.0	50.7
Dawson Golden Chaff	1.8	44.8
Fulhard	.8	48.7
Honor	.8	44.8
Illini Chief Sel. No. 223415 (see also other selections)	1.7	44.8
Kawvale	1.9	40.9
Malakof	.0	62.1
Michigan Wonder (several selections)	.0	41.7
Purkof	2.5	62.1
Red Rock	.0	44.8
Russian	2.4	44.8
Schonacher	.0	33.3
Shepherd	1.8	44.8
Stoner (Miracle)	2.2	33.3

(*a*) See, also, certain selections of American Bronze, Early Red Clawson, Forward, Fulcaster, Fultz, Hedge Prolific, Mammoth Red, Mealy, Mediterranean, Odessa, Red Cross, and Reed Winter.

The data given emphasize the fact that there is a very marked difference in the susceptibility of wheat varieties and selections to fly from the hard-wheat belt of Kansas. There is a relatively close agreement between tests for any given variety in different years and under different intensities of infestation. Similar agreement also is shown between these data and those previously published dealing with the same varieties and infested by the same kind of Hessian fly. About the same relative infestation rank is maintained under greenhouse conditions where there is severe infestation, as in the field.

Comparatively little information is available concerning the harvest infestation due to the fact that for several years the infestation in the nurseries at that time has been low. In 1925 Beechwood, Ohio No. 9920, and Palmer showed an increased infestation beyond that recorded in the fall. An increase in the case of some varieties raises the possibility of a decrease in the case of others. Such changes would not be expected to appear in the data given, owing to the light infestation.

An important fact not heretofore emphasized is shown especially in Tables VI, VII, and VIII, as well as by certain varieties in the two larger tables, III and IV. A variety may be homogeneous for the usual agronomic characters, but decidedly heterogeneous for

resistance to the Hessian fly. Some of the selections of Illini Chief and Fulcaster are almost or quite as susceptible as Kanred, while others are very resistant. Strains of other varieties originating from various sources frequently show a variation in susceptibility to fly, although they are morphologically not distinquishable from each other. Among such varieties and strains may be mentioned Currell, Fultz, Mammoth Red, Mediterranean, Red Winter, Valley, etc. Data for these varieties are given in Tables III and IV. Within closely related groups of varieties a similar variability in fly reaction is evident. Among the members of the Blackhull group, Superhard and Darlington have a somewhat different fly record in the same tests. Early Kanred and certain selections of Kanred appear to be more susceptible than the original Kanred.

DESCRIPTIONS OF IMPORTANT VARIETIES

It does not seem necessary to describe many of the varieties of special interest with respect to reaction of Hessian fly and listed in Tables IX, X, and XI, since Clark, Martin, and Ball *(2)* have published descriptions of most of them. Clark *et al. (3)* have recently published maps and detailed information on the distri-

TABLE X.—AVERAGE PER CENT OF PLANTS INFESTED IN VARIETIES WITH MEDIUM INFESTATION BY HESSIAN FLY FROM THE KANSAS HARD-WHEAT BELT. (*a*)

(Summarized from Table III.)

VARIETY.	Variety named.	Kanred in same tests.
Blackhull	18.8	39.7
Superhard	17.0	62.1
Early Blackhull	17.2	57.2
Buffum No. 17	12.3	33.3
Gluten	7.2	44.8
Gipsy	3.0	44.8
Harvest Queen	18.5	42.6
Imperial Amber	5.4	44.8
Nigger	7.2	44.8
Nittany	4.0	44.8
Ohio No. 9920	9.4	41.7
Poole	7.0	41.7
Red Winter (Kan. No. 2132)	14.4	42.6
Silver Sheaf	11.8	58.1
Treadwell	9.4	45.2
Turkish Amber	5.5	62.1
Wheedling	4.1	41.7

(*a*) See, also, selections of Early Oakley, Gladden, Portage, Theiss, Valley, etc.

bution of the classes and varieties of wheat in the United States, which publication shows the distribution of many of the varieties discussed in this bulletin.

Varieties with Light Fly Infestation

Some of the more important characters of the varieties highly resistant to Hessian fly are shown in Table XII.

Fulhard, a selection from Fulcaster made at the Kansas station, produces dark hard grain of excellent quality, and is the only hard wheat in the list of varieties (Table IX) with light Hessian fly infestation. Fulhard has been tested for yield and other characters in replicated rod rows in the agronomy nursery at Manhattan during the five-year period, 1926 to 1930. The average yield of Fulhard in comparison with standard varieties of hard red winter wheat is given in the following tabulation:

	Bus. per acre.
Tenmarq	40.6
Fulhard	37.4
Superhard	36.8
Blackhull	35.6
Kanred	32.4
Turkey	28.3

TABLE XI.—AVERAGE PER CENT OF PLANTS INFESTED IN VARIETIES HEAVILY INFESTED BY HESSIAN FLY FROM THE KANSAS HARD-WHEAT BELT. (*a*)

(Summarized from Table III.)

VARIETY.	Variety named.	Kanred in same tests.
Altara	37.7	37.8
Burbank	43.0	62.1
Hussar	63.2	41.7
Improved Turkey	54.7	33.3
Iobred	39.1	44.8
Kanred (*b*)	39.7	.....
Kharkof	56.6	34.2
Minturki	47.4	41.7
Nebraska No. 6	45.5	32.8
Nebraska No. 60	53.0	32.8
Nebraska No. 28	34.4	39.7
Oro	60.0	62.1
Prelude × Kanred (Kan. No. 2628)	53.8	48.7
Sherman	59.5	41.7
Tenmark	40.0	39.5
Turkey	65.8	42.6
Zimmerman	30.5	41.7

(*a*) See, also, Bacska, Hard Winter Defiance, Kanred × Hard Federation, and Menno.
(*b*) Average infestation for all field tests of Kanred.

TABLE XII.—DESCRIPTION OF WINTER WHEAT VARIETIES HIGHLY RESISTANT TO HESSIAN FLY FROM THE HARD-WHEAT BELT.

VARIETY.	Straw.	Heads.	Glumes.	Grain.		Origin.	Adaptation.	Remarks.
	Purple or white.	Awnless or bearded.	Brown or white.	Red or white.	Hard or soft.			
Beechwood	P	A	B	R	S	Mixture of 3 varieties, 1898	Ohio and eastern United States	Synonym for Poole and Red May, not much grown.
Dawson	W	A	Lt. B	W	S	Sel. from Seneca, 1881	N. Y., Mich., and Ohio	Ranks next to Gold Coin in importance among white wheats in eastern U. S.
Fulcaster	P	B	W	R	S	Hybrid, Fultz × Lancaster, 1886	Southeastern Kan. and eastern U. S.	Leading variety of soft red winter wheat.
Fulhard	P	B	W	R	H	Sel. from Fulcaster, 1919	Not distributed to farmers	Produces dark hard grain; early.
Fultz	P	A	W	R	S	Sel. from Lancaster, 1862	Eastern U. S.	Second in acreage of soft red winter wheat.
Honor	W	A	Lt. B	W	S	Sel. from Dawson	N. Y.	Closely resembles Dawson; more winter hardy, stiffer straw, higher yield.
Illini Chief Sel	W	B	W	R	S	Sel. from Illini Chief, 1920	Not distributed to farmers	
Kawvale	P	B	W	R	Semi	Sel. from Indiana Swamp, 1919	Southeastern Kan.	Highly resistant to leaf rust, winterhardy, semihard grain.
Malakof	P	B	W	R	S	Sel., 1913		Resistant to leaf rust.
Mediterranean	P	B	B	R	S	Introduction from Europe	Northeastern Tex. and eastern U. S.	One of oldest varieties in U. S.
Michigan Wonder	P	A	B	R	S	Sel. Mo. Agr. Expt. Sta	Mo. and Mich.	Synonym for Red May.
Purkof	W	A	W	R	Semi	Hybrid, Mich. Amber × Malakof, 1912	Ind.	Winterhardy, susceptible to scab.
Red Rock	P	B	B	R	S	Sel. from Plymouth Rock, 1907	Mich., Ill., Ind., and Ohio	Very good for bread flour. Resembles Mediterranean.
Russian	W	B	B	R	Semi	Va. Agr. Expt. Sta., 1917	Eastern U. S.	Resembles Diehl-Mediterranean.
Schonacher	W	A	B	W	Semi	Cornell, 1917		Harder than Dawson, little grown.
Shepherd	P	A	B	R	S	Sel. from Tenn. Fultz	Ill.	Immune to flag smut and rosette disease.
Stoner (Miracle)	P	B	W	R	S	Sel., 1906	Eastern U. S.	A strain of Fulcaster.

TABLE XIII.—DESCRIPTION OF WINTER WHEAT VARIETIES WITH MEDIUM INFESTATION OF HESSIAN FLY FROM THE HARD-WHEAT BELT.

VARIETY.	Straw.	Heads.	Glumes.	Grain.		Origin.	Adaptation.	Remarks.
	Purple or white.	Awnless or bearded.	Brown or white.	Red or white.	Hard or soft.			
Blackhull	W	B	W	R	H	Sel. from Turkey, 1912	Kan. and Okla	High yield, high test weight, low winter-hardiness, inferior quality.
Early Blackhull	W	B	W	R	H	Sel. from Blackhull, 1920	Kan. and Okla	Similar to Blackhull except much earlier.
Superhard	W	B	W	R	H	Sel. from Blackhull, 1920	Kan. and Okla	Similar to Blackhull except dark hard grain.
Buffum No. 17	W	A	W	R	S	Sel. from Turkey, 1912	Wyo	Very winterhardy; late.
Gluten	W	B	W	R	S	Calif. Agr. Expt. Sta., 1902	Not grown commercially	———
Gipsy	W	B	W	R	S	Unknown, grown in Mo., 1877	Eastern U. S	———
Harvest Queen	W	A	W	R	S	Sel., De Soto, Kan., 1895	Ohio and eastern Kan	Stiff straw, winterhardy.
Hedge Prolific	P	A	B	R	S	Grown at Ind. Agr. Expt. Sta., 1884		Synonym for Poole.
Imperial Amber	W	B	B	R	S	Sel., 1913	Eastern U. S	Resistant to flag smut.
Mammoth Red	P	B	W	R	S	Okla., 1904	Eastern U. S	Closely resembles Fulcaster.
Nigger	P	B	W	R	S	Ohio, 1884	Eastern U. S	———
Nittany	P	B	W	R	S	Sel. from Fulcaster, 1909	Penn	Later and taller than Fulcaster.
Ohio No. 9920		A	B	R	Semi	Sel. from Poole, 1909	Ohio	Good milling wheat, flour very white, soft.
Poole	P	A	B	R	S	Ohio, 1884	Eastern U. S	A standard variety.
Portage	P	A	B	R	S	Sel. from Poole	Ohio, N. Y., and Penn	Similar to Poole, stiffer straw; higher yield and quality.

TABLE XIII—CONCLUDED.

VARIETY.	Straw.	Heads.	Glumes.	Grain.		Origin.	Adaptation.	Remarks.
	Purple or white.	Awnless or bearded.	Brown or white.	Red or white.	Hard or soft.			
Red winter	W	B	W	R	H	Sel. from Iowa Turkey, 1900	Not distributed to farmers	One of the few fly-resistant hard wheats.
Silver Sheaf	W	B	W	R	S	Composite cross, 1903	N. Y., S. Car., and eastern U. S.	Little grown.
Treadwell	W	B	W	W	S	Hybrid, 1868	Mich. and eastern U. S.	Little grown.
Turkish Amber	P	B	W	R	S			Synonym for Fulcaster.
Valley	W	B	W	R	S	Ohio, 1884	Ill., Ind., and Ohio	Resembles Gipsy.
Wheedling	P	A	B	R	S	Ind., 1890	Ind	Resembles China.

The Illini Chief selection here listed is one of the pedigree lines isolated at the Kansas Agricultural Experiment Station from the variety, Illini Chief, and differs from it in being bearded.

Kawvale, a pedigree selection from Indiana Swamp made at the Kansas station, has an unusual combination of desirable characters, viz, high yield, greater winterhardiness than the varieties Fulcaster and Currell now grown in southeastern Kansas, high degree of resistance to red leaf rust, and marked resistance to Hessian fly. This variety has been registered *(4)* by the American Society of

FIG. 3.—Flaxseed and larvæ maturing from eggs laid by the same female on plants of Kanred (right) and Blackhull (left), grown in the same pot. Seven adults emerged from flaxseed on Blackhull and eight from Kanred.

Agronomy and the United States Bureau of Plant Industry, and the first increase field was planted in southeastern Kansas in the fall of 1930. At the annual meeting of the Kansas Crop Improvement Association, held at Manhattan, February 5, 1931, Kawvale was approved for certification as a standard variety for eastern Kansas.

The average yields of Kawvale and Fulcaster are as follows:

	Fulcaster.	Kawvale.
Agronomy Nursery, Manhattan, 1922 to 1930	31.9	39.7
Agronomy Farm, Manhattan, 1926 to 1930	38.9	39.5
Southeastern Kansas Experiment Fields, 1927 to 1930	17.6	19.6
Coöperative variety tests on farms, 1928 to 1930	22.1	24.0
Average	27.6	30.7

Varieties with Medium Fly Infestation

Descriptions of the winter wheat varieties having medium Hessian fly infestation are given in Table XIII.

No more detailed description seems necessary for most of these varieties, but a few of special interest are discussed briefly in the following paragraphs.

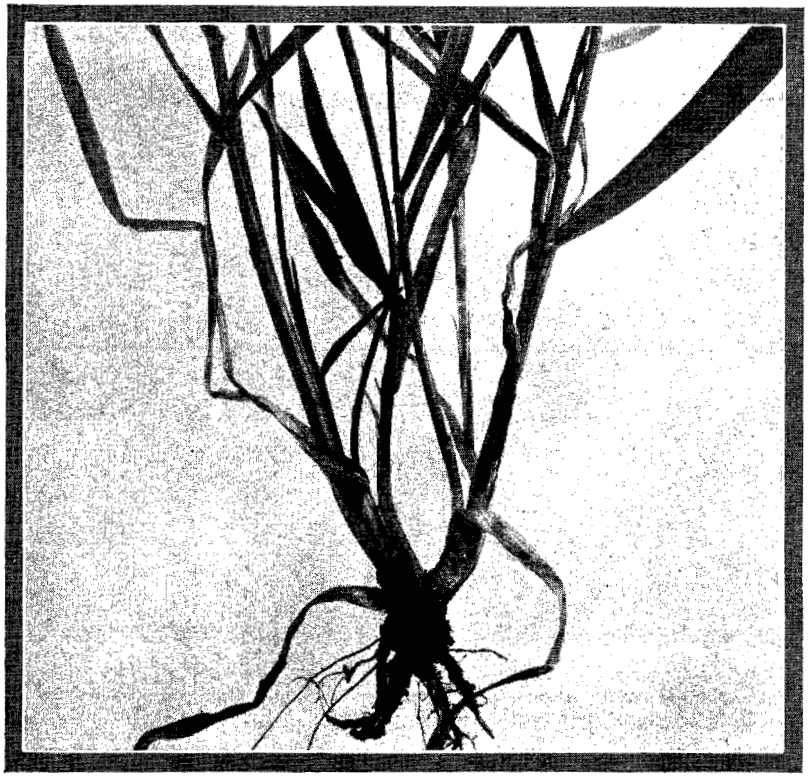

FIG. 4.—A plant of Blackhull wheat on which flaxseed developed without apparent injury to the tiller. Another tiller of the same plant of Blackhull and plants of Kanred on which the same female oviposited, showed typical injury.

Blackhull, Superhard, and Early Blackhull. These three strains of Blackhull are all moderately resistant or tolerant to Hessian fly, or at least have much lower average infestation than Kanred and Turkey. For several years Kansas farmers and county agricultural agents have observed that Blackhull wheat was less severely injured by fly than Turkey and Kanred. Experimental results in the fly nursery, in the greenhouse, and in the field agree with these observations. As will be pointed out later the larvæ of the Hessian

fly do not always develop normally on Blackhull (figs. 3 and 4) and may or may not injure the stems of Blackhull to the same extent as those of Turkey and Kanred.

Blackhull furnishes some evidence as to the possible performance of a resistant or semiresistant wheat under farm conditions. Some of the plats in a coöperative wheat variety test in Harvey county are shown in figure 5. The variety on the right is Superhard Blackhull the one on the left is Tenmarq. A fall infestation occurred at the right time to kill many of the plants, leaving a visible

FIG. 5.—Coöperative wheat variety test in Harvey county, Kansas, April, 1928. Estimated fly damage to Tenmarq (left) 95 per cent; to Superhard Blackhull (right) 25 per cent.

demonstration of the difference between the two wheats. This test occurred in the area where Blackhull has been planted for the longest period of time. In the center of its area of cultivation this variety appears to retain about the same relative position, in respect to fly infestation, that it holds in the nursery and greenhouse tests. In the same test, Turkey and Kanred showed about the same fly injury as Tenmarq.

A number of observations have been made of fields of Blackhull and adjoining or near-by fields of Turkey or Kanred. When planted at approximately the same time, the relative infestations were similar to those found in the experimental work. Adjoining fields of Blackhull and Turkey observed near Hays, on December 9, 1930, furnish a typical example of the behavior of these two varieties. Both fields were planted about September 15. One

field had been planted to Blackhull wheat for about five years and had received somewhat better care than the Turkey field. Both contained some volunteer wheat plants. A sample of 100 plants taken about 50 feet from the fence separating the two fields showed that 20 per cent of the Blackhull plants were infested. Twenty larvæ and 16 flaxseed were removed from the plants. Sixty per cent of the plants of Turkey were infested. A total of 85 larvæ and 134 flaxseed were removed from the Turkey plants. Observations of this kind concerning a variety that is by no means the best available from the standpoint of fly resistance strengthen the opinion held by the writers that resistance may prove an important aid in the control of the Hessian fly. Blackhull is not recommended as a fly-resistant variety to be used in a fly-control program, though compared with Turkey, Kanred, and Tenmarq, it does seem to have an advantage in this respect. It appears to be a semiresistant or tolerant variety.

Blackhull and Superhard are widely grown in Kansas and Oklahoma, and on the average produce higher yields than Turkey and Kanred, except in northwestern Kansas, where winterkilling or winter injury is often a factor of importance. Blackhull and Superhard usually have a higher test weight than Kanred and Turkey grown under the same conditions. The grain of Superhard is typically dark, hard, and of fine appearance, but has the same defects in gluten quality as Blackhull and Early Blackhull. For a more detailed discussion of Blackhull wheat in Kansas, see the bulletin by Salmon, Swanson, and Laude *(20)*.

Harvest Queen is the variety of soft red winter wheat most widely grown in northeastern Kansas. It is one of the most winterhardy varieties of soft wheat and has very strong straw. It is much less susceptible to fly from the hard-wheat belt than Kanred, the per cents of infestation being 18.5 and 42.6, respectively. Harvest Queen is more susceptible than some selections of Fulcaster and Kawvale, varieties which are also well adapted to eastern Kansas conditions.

Red Winter is the only hard wheat, aside from Fulhard and the Blackhull group, in the lists of varieties with low or medium infestation. This is a pedigree selection from a hard red winter wheat of the Turkey type. It is much more resistant to Hessian fly than Kanred, the per cents of infestation being 14.4 and 42.6, respectively. This strain has not shown enough promise as to other characters to be increased or considered for distribution to farmers, though so far as known it is about equal to Turkey in yield and quality.

Varieties with Heavy Fly Infestation

Some of the varieties with heavy fly infestation are described in Table XIV. Nearly all of these varieties are hard or semihard wheats. Such widely grown types as Turkey, Kharkof, and Kanred need no further comment. Burbank Super or Jones Winter

TABLE XIV.—DESCRIPTION OF WINTER WHEAT VARIETIES WITH HEAVY INFESTATIONS OF HESSIAN FLY FROM THE HARD-WHEAT BELT.

VARIETY.	Straw.	Heads.	Glumes.	Grain.		Origin.	Adaptation.	Remarks.
	Purple or white.	Awnless or bearded.	Brown or white.	Red or white.	Hard or soft.			
Altara	W	B	W	R	H	Sel. from Alberta Red, 1906	Not distributed to farmers	Produces dark hard grain, very little yellow berry.
Burbank Super	W	A	W (Pub.)	R	S	Burbank, 1917	Eastern U. S. and Pacific Northwest	Same as Jones Winter Fife, 1889.
Hussar	W	B	W	R	Semi	Ill., 1906	Not grown on farms	Resistant to bunt.
Improved Turkey	W	B	W	R	H	Sel. from Iowa Red Winter	Not distributed to farmers	Susceptible to leaf rust.
Iobred		B	B	R	H	Sel. from Banat, 1915	Iowa	Very short kernels, shatters easily.
Kanred	W	B	W	R	H	Ped. Sel. of Crimean, 1906	Kan., Okla., Tex., and Nebr	Weak straw, resistant to some forms of rust.
Kharkof	W	B	W	R	H	Introduction, 1900	Hard red winter wheat area	Slightly hardier than Turkey.
Minturki	W	B	W	R	Semi	Cross, Turkey × Odessa, 1902	Southern Minn., and northern Iowa	Very winterhardy, resistent to bunt.
Nebraska No. 6	W	B	W	R	H	Sel. from Turkey, 1907	Nebr	Higher yielding than Turkey.
Nebraska No. 60	W	B	W	R	H	Sel. from Turkey, 1907	Nebr	Higher yielding than Turkey.
Nebraska No. 28	W	B	W	R	Semi	Cross, Big Frame × Turkey, 1902		Not grown on farms, very early.
Oro	W	B	W	R	H	Sel. from Turkey, 1921	Eastern Oreg	Resistant to bunt, very good quality.
Prelude × Kanred, Kan. 2628	W	B	W	R	H	Cross, Prelude × Kanred, 1920	Not distributed to farmers	Good quality, very early.
Sherman	W	B	W	R	Semi	Sel. from Crimean, 1915		Resistant to bunt.
Tenmarq	W	B	W	R	H	Cross, P. 1066 (Crimean) × Marquis, 1916	South central Kan	Excellent quality, high yield, susceptible to scab, not very hardy.
Turkey	W	B	W	R	H	Introduction, 1873	Hard red winter wheat area	The standard variety of hard red winter wheat.
Zimmerman	W	A	W	R	S	Sel., Maryland, 1837	Formerly grown in eastern Kan	Not so winterhardy as Fulcaster, early.

Fife and Zimmerman are the only soft red winter wheats in this list. It is interesting to note that Hussar, Sherman, and Oro, three varieties resistant to bunt, are all very susceptible to fly.

Iobred, a variety selected and distributed by the Iowa Agricultural Experiment Station and now grown on a good many farms in northeastern Kansas, is only slightly less susceptible to fly than Kanred.

Minturki, a winterhardy semihard wheat bred and distributed by the Minnesota Agricultural Experiment Station, has a little higher average fly infestation than Kanred. This variety is a selection from the cross Turkey X Odessa. Turkey is susceptible to fly, Odessa is resistant. Minturki evidently has inherited the susceptibility to fly of the Turkey parent.

Nebraska No. 6 and Nebraska No. 60, two pedigree selections of Turkey make at the Nebraska station, appear to be more susceptible to fly than Kanred.

Nebraska No. 28, a very early variety of semihard wheat from the cross Big Frame (fly resistant) X Turkey (susceptible), has a slightly lower average fly infestation than Kanred, but would be classed as susceptible.

Prelude X Kanred, Kansas No. 2628, a very early strain bred at the Kansas station, is also susceptible to fly, but is promising in other respects, viz., high yield, earliness, good quality, and more cold resistant than most early varieties.

Tenmarq is as susceptible to fly as Kanred, on the average, and in some tests has been more heavily infested than Kanred. In one of the coöperative wheat variety tests (fig. 5) Tenmarq was almost completely killed by fly, while Superhard was much less severely injured. Tenmarq is less winterhardy than Turkey and Kanred, but is as hardy as Blackhull. It is very susceptible to scab. Tenmarq is one to three days earlier than Kanred, has stiffer straw, and has some of the excellent milling and baking qualities of Marquis, its spring-wheat parent. With respect to yield and most other characters it is a promising variety, and will probably be distributed by the Kansas station to farmers in south central Kansas where tests indicate it is well adapted.

RELATION BETWEEN FLY RESISTANCE AND OTHER CHARACTERS

During the course of the experiments on fly resistance in wheat, the writers have been impressed with the fact that nearly all of the varieties showing marked resistance are soft wheats. This relation is clearly evident in Tables IX and XI. Thus Fulhard is the only variety of hard wheat with a very low average fly infestation, and it is a selection from Fulcaster, an old and widely grown variety of soft wheat.

Conversely, among the seventeen varieties with heavy infestation of fly listed in Table XI, there are only two soft wheats, Burbank and Zimmerman.

Even in the group of varieties with medium fly infestation, Red Winter is the only variety of hard wheat, aside from the Blackhull group. Although Blackhull is classed as a hard red winter wheat on the market, it is not a typical hard wheat of the Turkey group, either in plant or kernel characters. The kernels of Blackhull wheat have a thick bran coat and do not usually have the dark red color and luster characteristic of Turkey. In some of its plant characters Blackhull resembles the soft wheats. Blackhull is less winterhardy than Turkey, Kharkof, and Kanred.

The apparent relation between reaction to Hessian fly and texture of grain may be more or less incidental and is probably not a direct or close physiological correlation. If it is due to genetic linkage, the linkage is not complete or even very close, for it has not been difficult to obtain segregates from crosses of hard, fly-susceptible varieties with soft, fly-resistant types, that combine hard texture of grain and fly resistance.

Until more detailed studies of this relationship have been made it is probably not worth while to do more than to suggest two possible partial explanations:

1. The soft wheats and the Hessian fly have had a long association in the eastern United States, and natural selection may have been operating since the latter half of the eighteenth century, when the Hessian fly is supposed to have been introduced from Europe, in such a way as to result in the survival of a good many resistant varieties. According to McColloch *(14)* the Hessian fly was first reported in Kansas in 1871, when it was found infesting wheat in a few of the eastern counties. This date coincides very closely with the introduction of hard Turkey wheat in Kansas in 1873. Thus the Hessian fly and the hard winter wheats have been associated in this country for only about fifty-seven years, while fly and the soft wheats have been living together for about 150 years.

2. The number of distinct varieties of soft winter wheat included in these trials has been much greater than the number of distinct types of hard red winter wheat. A similar ratio exists between the number of distinct varieties of soft and hard wheats grown on farms in the United States. The larger number of varieties of soft wheat is probably due, in part at least, to the fact that the soft wheats have been subjected to natural and artificial selection, including variety testing and plant breeding, for almost 100 years longer than have the hard winter wheats. It seems logical to expect that the number of resistant varieties of soft and hard wheats would be at least roughly proportional to the total number of strains of each group tested, and this proved to be the case.

There seem to be more fly-resistant varieties with purple straw than with white, but this apparent relation, like that between fly resistance and texture of kernels, may be incidental or due to the fact that purple-strawed varieties are found mostly in the soft-

wheat group. It is of interest to note that Fulhard and Kawvale, fly-resistant varieties having hard and semihard kernels, have purple straw.

With the exception of the two characters, grain texture and color of stem, discussed in the preceding paragraphs, fly resistance does not seem to be associated with any other commonly observed characters of the wheat plant, such as time of maturity, awn type, glume, or kernel color. It seems likely that if any true physiological correlations exist, they will be found only by careful biochemical and physiological studies of the host plant in relation to the parasite.

Future experiments should include a much larger number of bread wheats and should also include at least representative types of other species. Even though most of these other species have lower chromosome numbers than *Triticum vulgare,* if fly-resistant types can be found in them, they may prove of considerable value in crossing.

INHERITANCE OF RESISTANCE IN CROSSES OF RESISTANT BY SUSCEPTIBLE VARIETIES

Studies are in progress regarding the inheritance of fly resistance, and data have been obtained which are of considerable interest. Tables XV and XVI give the field data and Table XVII gives the data from the greenhouse regarding a number of crosses involving resistant and susceptible parents. The crosses involving Illini Chief as a resistant parent were made to study the reaction to Hessian fly. Those involving Fulcaster were made by Mr. C. O. Johnston in connection with leaf-rust studies, and were made available to the writers for the Hessian fly trials.

All the selections involved in these tables represent F_5 or later generations. Some of the strains are reselections from hybrid lines found to be segregating for fly resistance or other characters. Among the crosses involving Illini Chief, there are some hybrids which are as susceptible as the susceptible parent and others which are about as resistant as Illini Chief. Selection No. 244382, of this cross, was reselected on an agronomic basis and the two selections also show decided differences in fly resistance. Selection No. 244382-1 is very resistant while selection No. 244382-2 is only modesately so. The same conditions appear in Nos. 244404, 244406, and others. The greenhouse data also show that some hybrid selections from resistant and susceptible crosses are about as resistant as the resistant parent, others are as susceptible as the susceptible parent, still others are intermediate.

The most important fact brought out by these data is that resistance is an inherited character which may be combined with other desirable ones and that fly resistance is not closely linked with any observed agronomic character such as awn type and kernel texture.

Hybrids involving Fulcaster (Table XVI) show a wide variation in resistance. The Fulcaster crosses were subjected to the two tests having the heaviest infestation. One of the best of these lines,

No. 20-2-13-311, is a cross involving the selection of Fulcaster now known as Fulhard.

A large number of the fly-resistant hybrids, especially the Illini Chief X Kanred crosses, have been tested for yield, stiffness of straw, and other agronomic characters in the agronomy nursery, and a few of the more promising ones have been advanced to plat tests at the agronomy farm. None of these crosses have been found promising enough to increase for distribution to farmers. More recent crosses involving such improved sorts as Fulhard, Kawvale, and Tenmarq are now being tested in the agronomy nursery.

TABLE XV.—PER CENT OF PLANTS INFESTED BY HESSIAN FLY IN CROSSES INVOLVING ILLINI CHIEF AS A RESISTANT PARENT.

Sel. No.	Fall, 1922.	Fall, 1924.	Spring, 1925.	Fall, 1925.	Fall, 1927.	Fall, 1929.	Average per cent of plants infested.	
							Variety named.	Kanred in same tests.
Illini Chief × Kanred								
242247	0						0.0	31.4
242248	0	7	0	8			3.7	32.8
242249	0	26			20	18	16.0	51.4
242251	30	67	20	20			34.2	32.8
242252	10	13	0	8	35	8	12.3	42.6
242253	10	33				26	23.0	46.2
242254					70		70.0	67.0
242255	30	66	0	16			28.0	32.8
244337-2		0	0	0	0	10	2.0	44.8
244337-4		0	0	0	5		1.2	41.7
244337-3		0	6	12			6.0	33.3
244341-3		0	20	0	15		8.7	41.7
244341-5		7	0	0	15		5.5	41.7
244342-1		0	0	0			.0	33.3
244377-2		0	7	0			2.3	33.3
244377-3		7	0	0			2.3	33.3
244377-4		0	0	32	25		14.2	41.7
244377-5		13	0	4	35		13.0	41.7
244377-6		8	0	4	20		8.0	41.7
244380-1		0	7	0	0	8	3.0	44.8
244380-3		0		4	20		8.0	46.1
244381-1		0	0	0	3	14	3.4	44.8
244381-2		0	7	0	3	12	4.4	44.8
244381-3		7	0	0	0	8	3.0	44.8
244381-7		0	0	4	10		3.5	41.7
244382-1		0	0	0	0	10	2.0	44.8
244382-2		20	20	0	10		12.5	41.7
244385-3		0	0	0	15		3.7	41.7
244385-6		7	0	0	30		9.2	41.7
244408-6		20	20	0	45		21.2	41.7
285005						6	6.0	57.2
285015						6	6.0	57.2
285016						14	14.0	57.2
285018						10	10.0	57.2

TABLE XV—CONCLUDED.

Sel. No.	Fall, 1922.	Fall, 1924.	Spring, 1925.	Fall, 1925.	Fall, 1927.	Fall, 1929.	Average per cent of plants infested.	
							Variety named.	Kanred in same tests.
Kanred × Illini Chief								
244386-4		.0	0	0	10	8	3.6	44.8
244396-1		.0	0	0	5	.....	1.2	41.7
244398-6		.....	.....	.....	.....	2	2.0	57.2
244398-10		20.0	0	0	5	.....	6.2	41.7
244402-2		7.0	0	4	10	.....	5.2	41.7
244402-4		.0	0	4	15	.....	4.7	41.7
244404-4		.0	0	0	45	38	16.6	44.8
244404-5		.0	0	0	10	.....	2.5	41.7
244404-8		.0	0	0	40	28	13.6	44.8
244406-2		6.6	0	0	23	.....	7.4	41.7
244406-4		.0	0	0	30	.....	7.5	41.7
244406-7		.0	0	0	30	.....	7.5	41.7
244406-9		13.3	0	0	40	.....	13.3	41.7
244406-11		13.3	0	4	30	.....	11.8	41.7
244406-13		13.3	0	0	30	.....	10.8	41.7
285023		.....	.....	.....	.....	10	10.0	57.2
285030		.....	.....	.....	.....	0	.0	57.2
285034		.....	.....	.....	.....	20	20.0	57.2
285044		.....	.....	.....	.....	8	8.0	57.2
285045		.....	.....	.....	.....	44	44.0	57.2
285055		.....	.....	.....	.....	44	44.0	57.2
Crimean (P. 1068) × Illini Chief								
244120-5		.0	0	5	20	.....	6.2	41.7
244411-7		.0	0	0	5	4	1.8	44.8
244413-3		.0	0	4	40	.....	11.0	41.7
244413-4		.0	0	0	15	.....	3.7	41.7
244413-5		.0	0	0	3	14	3.4	44.8
244414-8		.0	4	0	20	.....	6.0	41.7
244414-11		.0	0	4	10	.....	3.5	41.7
244414-12		.0	0	0	3	8	2.2	44.8
285090		.....	.....	.....	.....	26	26.0	57.2
Illini Chief × Altara								
244410-1		6.6	0	12	30	.....	12.1	41.7
244410-3		20.0	0	0	25	.....	11.2	41.7
244410-9		13.3	.....	4	40	.....	14.3	41.7
282258		.....	.....	.....	.....	10	10.0	57.2
282259		.....	.....	.....	.....	28	28.0	57.2
282278		.....	.....	.....	.....	10	10.0	57.2
282279		.....	.....	.....	.....	4	4.0	57.2
282281 (143)		.....	.....	.....	.....	24	24.0	57.2
282281 (155)		.....	.....	.....	.....	12	12.0	57.2
282285		.....	.....	.....	.....	6	6.0	57.2
Harvest Queen × Illini Chief								
244419-5		.0	0	12.0	15	.....	6.7	41.7
244419-15		.0	0	21.2	15	.....	9.0	41.7
Illini Chief × Marquis								
242195	4	.0	0	8.0	18	16	7.6	42.6
242212	0	13.0	.....	.....	3	4	5.0	51.4
242213	10	7.0	0	4.0	0	4	5.0	42.6
242214	10	7.0	0	.0	0	0	3.4	42.6
242215	30	.0	0	.0	.....	.....	7.5	32.8
242216	0	13.0	0	.....	43	.....	14.0	49.5
242217	0	7.0	7	4.0	13	.....	6.2	39.6
242218	20	6.0	0	.....	.....	.....	8.7	36.7
242222	0	46.0	.....	.....	18	.....	21.3	49.5
242234	10	33.0	.....	.....	30	31	26.0	51.4
242252	.....	.....	.....	.....	20	12	16.0	62.1

TABLE XVI.—PER CENT OF PLANTS AND TILLERS INFESTED BY HESSIAN FLY IN CROSSES INVOLVING FULCASTER AS A RESISTANT PARENT.

Sel. No.	Fall, 1927.		Fall, 1929.		Average per cent of plants infested.	
	Plants.	Tillers.	Plants.	Tillers.	Variety named.	Kanred in same tests.
Kanred × Fulcaster						
30-1-15-399	10	3.3	.....	.....	10.0	67.0
30-1-3-394	20	15.7	22	11.8	21.0	62.1
26-1-2-354	40	14.3	.....	.....	40.0	67.0
26-626-393	70	27.4	.....	.....	70.0	67.0
22-1-20-340	75	50.0	78	40.7	76.5	62.1
33-3-449-623	.....	.....	14	3.9	14.0	57.2
26-4-3-368	.....	.....	66	34.1	66.0	57.2
22-1-24-343	.....	.....	52	25.2	52.0	57.2
26-4-3-368-1	.....	.....	74	36.9	74.0	57.2
30-1-21-400-1	.....	.....	58	29.0	58.0	57.2
274384	.....	.....	26	13.6	26.0	57.2
263549	.....	.....	26	13.2	26.0	57.2
266305	.....	.....	34	14.9	34.0	57.2
266317	.....	.....	62	34.4	62.0	57.2
266348	.....	.....	60	31.8	60.0	57.2
274377	.....	.....	12	8.1	12.0	57.2
Kanred × Fulhard						
20-2-13-311	25	13.2	12	3.9	18.5	62.1
Marquis × Fulcaster						
292878	.....	.....	16	8.7	16.0	57.2
292882	.....	.....	16	9.7	16.0	57.2

GREENHOUSE TESTS OF F_1 PLANTS

A few tests have been made of the infestation of F_1 plants resulting from crosses between the resistant Illini Chief Sel. No. 223415 and susceptible Tenmarq, and between Illini Chief and Kanred. The number of plants available for these tests has been limited, but the results indicate that the first-generation hybrids tested are almost as heavily infested as the susceptible parent. The intensity of the infestation was not great enough to determine whether the dominance of susceptibility over resistance was complete or partial. Some tests of F_1 hybrids between equally susceptible parents have shown that there is no effect which may be attributed merely to the hybridity of the plant, that is, to hybrid vigor.

KINDS OF RESISTANCE

The various inherited characterietics of the wheat plant which may affect the damage done by the Hessian fly have been studied as opportunity permitted. The data presented above deal principally with the ability of a given larva to commence feeding, to grow, and to cause damage to the host plant. It has been shown that there is a decided difference in the number of flies which are

able to develop on the several varieties. With some of these it approaches an "all or none" phenomenon, especially with pure strains of fly. Illini Chief, Kawvale, Fulhard, etc., can be described as highly resistant varieties. They are, in fact, almost immune. A larva from the hard-wheat belt fly usually fails to develop normally on these varieties. If development is started it is usually completed. It has been shown above that this kind of resistance is inherited. The evidence available points to the probability that this type of resistance is primarily physiological. The infestation

TABLE XVII.—PER CENT OF PLANTS AND TILLERS INFESTED IN GREEN-HOUSE TESTS OF CROSSES INVOLVING ILLINI CHIEF AS THE RESISTANT PARENT.

Sel. No.	1926-'27.				1927-'28.			
	First test.		Second test.		First test.		Second test.	
	Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.	Plants.	Tillers.
Illini Chief × Marquis								
242212	30.0	5.3	20.0	3.7				
242213							46.0	11.2
242214	30.0	6.3	40.0	10.4			52.0	15.7
242216	30.0	7.1	60.0	16.1	45.0	18.7		
242217	10.0	1.2	20.0	4.8				
264148	50.0	13.7	60.0	22.8				
264147	40.0	7.2	80.0	18.3				
264146	40.0	10.1	60.0	18.0				
242222	70.0	21.8	70.0	11.9				
242234	50.0	12.0	90.0	20.9	38.6	24.0		
Illini Chief × Kanred								
242241	70.0	15.6	80.0	29.8				
242242	50.0	9.9	80.0	42.5				
242243	60.0	15.8	50.0	13.8				
242244	60.0	12.4	70.0	19.6				
242245	70.0	24.1	60.0	29.5				
242247	40.0	12.5	70.0	25.0				
242249	50.0	5.4	20.0	9.4	14.3	6.5		
242252	60.0	14.9	40.0	13.3	8.5	2.8		
242253	70.0	17.5	30.0	10.8				
242254	60.0	11.5	40.0	10.3				
244404	30.0	6.9	50.0	8.8				
244337-2							28.5	10.8
244337-4							34.0	10.0
244380-1							38.0	17.5
244381-1							13.8	2.9
244381-3							46.9	11.9
244382-1							32.6	10.4
244385-3							77.5	26.5
Kanred × Illini Chief								
244386-4							38.2	10.3
244396-1							43.0	11.6
244398-10							54.2	17.2
244402-4							55.8	14.5
244404-5							67.3	18.1
244404-8							61.2	27.6
Kanred Checks								
	70.0	23.8	100	33.3	44.0	22.0	90.8	50.6

rank of Illini Chief and Kawvale is very similar with respect to fly from the hard-wheat belt, but the two differ in infestation by soft-wheat belt fly. This is taken as evidence that more than one genetic factor is involved in the fly resistance of these varieties.

In contrast to this, some of the varieties, notably those of the Blackhull group, show a kind of partial resistance or tolerance to the fly. This is brought out clearly in figures 3, 4, and 6. In one case 33 flaxseed developed on a single tiller of Blackhull wheat without apparent injury to the tiller. In another case 34 flaxseed

FIG. 6.—Culms of Blackhull wheat showing variation in size of flaxseed and in their location with respect to the nodes. The normal position and size of flaxseed as found on most varieties are as shown at the right.

and larva developed on a single tiller, apparently without injuring it.. All the flaxseed and larvæ were abnormally small and poorly developed and the flaxseed had a very light brown color. In both cases normal flaxseed and the usual injury appeared on Kanred from eggs laid by the same female on plants grown in the same pot. This type of development, involving smaller numbers of larva per tiller, is not infrequent in the greenhouse studies and may also be observed in the field. In the latter case implantation of the small flaxseed occurs high up on the internode and not, as usual, just above the node. A range of variation in this regard is shown in figure 6. In some of the experiments eggs laid by a single female give both large and small flaxseed and differential injury on a single Blackhull plant. It seems evident that this matter does not involve

a genetic difference in the fly, but perhaps may be connected with the part of the plant on which the eggs are laid *(17) (18)*. This reaction of Blackhull has been found to occur with fly from both the hard- and the soft-wheat belt.

Observation of the varieties infested under greenhouse conditions has shown that there is some variation in the rate at which fly develop on the different varieties. To date very little quantitative evidence has been gathered. The difference is probably a matter of food value or food availability and may be related to the tolerance described above. To prove definitely the existence of this type of resistance would require careful life-history work on favorable wheat varieties with pedigreed strains of fly. Resistance of this kind is of technical interest and may be of practical importance in the field.

The ability of a plant to produce new tillers after an infestation is believed to be an important characteristic, which if possessed by a variety with moderate resistance may render it very valuable under conditions of severe infestation. It has already been shown that certain varieties have a high plant infestation and a relatively low tiller infestation, due to heavy stooling. This is a factor which is greatly influenced by climatic and edaphic conditions. However, it probably has a genetic basis.

In the earlier literature on resistance of wheat to the attack of the Hessian fly much stress is laid on the relationship to stiffness of straw. Salmon *(21)* has made available some numerical measurements of the stiffness of straw in several of the common varieties. Strength of straw is correlated with ability to withstand wind and rain, that is, with lodging under field conditions. No information is available concerning the correlation of strength of straw with fly damage, because of lack of heavy spring infestation at Manhattan in recent years. Another character which should be carefully studied is the ability of a stiff-strawed variety to mature plump grain in spite of the fly. Certain hybrids have been secured in the study of fly resistance which have very stiff straw. For instance, Illini Chief X Marquis Sel. No. 242212 has a remarkably stiff straw combined with a rather high degree of resistance to the fly of the hard-wheat belt. Thus steps have been taken to combine two important qualities concerned in resistance in a single strain of wheat.

BIOLOGICAL STRAINS OF HESSIAN FLY

The data given in the preceding sections of this bulletin deal only with Hessian fly from the hard-wheat belt of Kansas. Painter *(17)* has shown that the infestation when fly from other localities were used with the same varieties of wheat, is very different. Some additional data which have since accumulated are given in the following paragraphs.

The presence of biological strains of Hessian fly was suspected and the study inaugurated for several reasons. In the first place

the literature contains conflicting information regarding the infestation of different varieties of wheat and other small grains in different localities. Secondly, farmers and entomologists in Kansas have noticed that varieties of soft wheat, known to be susceptible in eastern states, were relatively resistant in central and western Kansas. In the third place, an explanation was sought for the occasional one or two infested plants in the Illini Chief selections which were unusually resistant. The late Prof. J. W. McColloch had called attention to some of these facts in various project reports to the director of the Kansas Agricultural Experiment Station.

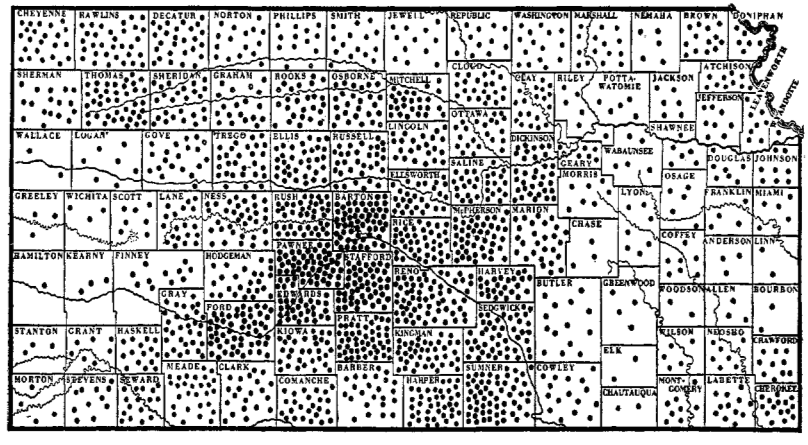

FIG. 7.—Map showing the average annual wheat acreage in Kansas, 1921 to 1930. Note the two distinct wheat-growing regions, soft wheat in the eastern counties and hard wheat in central and western Kansas. (Each dot represents 5,000 acres.)

In Kansas there are two chief wheat-growing regions—an eastern soft-winter-wheat belt and a central and western hard-winter-wheat belt, separated by a rolling or even rugged pasture region known as the "Flint Hills" or Bluestem Pasture region, within which wheat is grown but sparingly and then only in the narrow valleys. The distribution of wheat in Kansas is shown in figure 7. Some hard red winter wheat is grown on the uplands of eastern Kansas and some soft red winter wheat in the valleys of central Kansas.

UNIFORM FLY NURSERIES IN THE FIELD

In the fall of 1928 a number of uniform fly nurseries were planted at selected localities in the state. Each consisted of 36 varieties, strains, and hybrids planted in 16-foot rows, duplicated. The seed for each variety was identical throughout the set of tests, and in many cases represented recent pedigree selections. Only the nursery at Columbus, Kan., had sufficient infestation to warrant both fall and spring counts. Some infested cooperative variety test plats

in western Kansas gave additional information. In the fall of 1929 seven uniform fly nurseries were planted and five were infested.

The one at Columbus was very heavily infested. The infestation in these tests expressed as a per cent of the number of tillers infested is given in Table XVIII. The figures as given are averages for 50 plants of each variety, except at Columbus in the fall and spring of 1929, when 75 and 20 plants, respectively, were examined, and in Reno county, when 100 were examined. The data are arranged in order of the average per cent of tillers infested by fly in the Kansas hard-wheat belt; that is, from Riley (Manhattan), Lincoln, Rice, and Reno counties.

It will be seen that there is little variation in the relative ranks of the different varieties in the various localities in the hard-wheat region. These results also coincide very well with those which have been secured over a series of years at Manhattan as shown in Tables III and IV. On the other hand, the results at Columbus, in southeastern Kansas, are very different. This is well illustrated by the data for Illini Chief Sel. No. 223415 and Dawson, obtained from the fall count in 1925. This difference holds true in the other tests in the soft-wheat belt, regardless of difference in infestation intensity.

The fact that the degree of infestation depends upon the particular population of fly is brought out still more clearly in Tables XIX and XX, which give a summary of much of the available data concerning the infestation of Illini Chief Sel. No. 223415 and Kanred. Table XIX gives this data for fly from the hard-winter-wheat belt and Table XX for fly from the soft-winter-wheat belt of southeastern Kansas (Columbus).

It will be seen that in most of the tests with fly from the hard-wheat belt Illini Chief has been highly resistant, whereas Kanred has been very susceptible, regardless of what criterion is used as a measure of infestation. This, however, is not true for fly from southeastern Kansas. In fact the infestation averages a little greater for the Illini Chief than for Kanred. Moreover, the data appear sufficient to indicate that the difference is not due to a heavier infestation in the soft-wheat belt. Comparable though more limited data show a similar difference in reaction to fly from the hard and soft wheat areas for Dawson and certain other varieties of soft wheat.

TABLE XVIII.—EXPERIMENTAL DATA FROM UNIFORM FLY NURSERY TESTS IN 1928-'29 INDICATING THE PRESENCE OF BIOLOGICAL STRAINS OF HESSIAN FLY.

(Arranged in order of the average per cent tillers infested in the hard-wheat belt.)

Kan. or Sel. No.	VARIETY.	Riley county, Manhattan.	Lincoln county.	Rice county.	Reno county.	Average for hard wheat belt.	Cherokee county (a).		
							Fall, 1928.	Fall, 1929.	Spring, 1929.
2593	Kawvale	0.0	0.0	0.0	0.5	0.1	4.8	18.3	6.7
500	Michigan Wonder	.0	.0	.0	1.3	.3	.....	46.0	.....
242214	Illini Chief × Marquis	.0	1.4	.0	3.7	1.3	1.3	23.0	.....
223415	Illini Chief Sel	3.7	.5	.0	1.1	1.4	12.6	48.9	34.9
2564	Dawson	1.3	2.6	1.2	1.6	1.7	16.8	49.8	38.5
2594	Fulhard	2.1	.0	.0	4.7	1.7	1.6	25.2	7.2
470	Superhard	3.6	1.9	.8	2.3	2.2	1.2	25.2	3.8
483	Early Blackhull	2.8	1.4	2.2	4.7	2.8	1.7	17.5	1.3
501	Currell	8.4	.7	.9	1.6	2.9	.....	42.3	.....
2132	Red Winter	5.7	2.9	.0	5.7	3.6	1.1	15.4	19.1
317	Fulcaster	8.5	2.9	.8	7.9	5.0	4.1	25.0	25.3
19	Harvest Queen	8.8	2.5	2.5	6.6	5.1	10.3	43.8	48.1
343	Blackhull	9.4	4.8	3.6	7.0	6.2	3.6	23.9	5.1
505	E. G. Clark No. 40	9.6	3.9	5.1	14.5	8.3	.....	40.9	.....
2637	Tenmarq Sel	17.8	7.6	7.9	8.7	10.8	.....	38.6	.....
2628	Prelude × Kanred	23.3	5.5	3.7	10.8	10.8	17.2	39.4	.....
2401	Kanred	16.2	7.9	10.3	10.1	11.1	13.3	32.0	51.9
495	Oro	22.3	4.7	8.9	9.9	11.5	18.3	44.0	59.0
492	Ukrainka	17.2	11.8	3.2	16.8	12.3	.....	40.4	.....
2652	Prelude × Kanred	22.6	8.9	2.9	15.0	12.3	.....	42.0	.....
242234	Illini Chief × Marquis	18.0	10.5	9.9	11.3	12.4	.....	47.5	.....
490	Kooperatorka	32.7	8.2	6.4	5.4	13.2	.....	24.7	.....
254634	Kanred × Hard Federation	17.1	10.2	10.3	15.8	13.4	.....	43.2	.....
439	Tenmarq	27.9	8.5	10.6	9.1	13.8	10.2	50.5	52.0
2642	Kanred × Marquis	22.4	6.3	16.5	16.9	15.5	.....	41.9	.....
Number of plants examined		50	50	50	100	.....	50	75	20
Maximum per cent plants infested on heaviest row		64	36	36	50	.....	64	92	100
Maximum fly per 50 plants for any one variety		79	31	27	73	.....	124	561	415

(a) Columbus—Southeastern Kansas.

TABLE XIX.—INFESTATION OF ILLINI CHIEF SEL. NO. 223415 AND KANRED BY FLY FROM THE HARD-WINTER-WHEAT BELT.

(Arranged in order of per cent of Kanred tillers infested.)

Experiment No. and year. (a)	Illini Chief Sel.			Kanred.		
	Per cent infested.		Total number of fly. (b)	Per cent infested.		Total number of fly. (b)
	Plants.	Tillers.		Plants.	Tillers.	
1 1929	0.0	0.0	0	50.0	20.9	42
2 1929	4.6	1.5	2	44.0	22.0	73
3 1927	.0	.0	0	70.0	23.8	44
4 1930	4.8	1.4	2	43.5	24.5	39
5 1930	.0	.0	0	68.0	31.0	56
6 1929	5.2	2.6	3	57.2	32.0	62
7 1927	.0	.0	0	100.0	33.3	20
8 1927	3.3	1.4	13	67.0	35.3	511
9 1930	6.0	1.8	3	62.4	40.6	122
10 1929	18.3	9.7	45	75.0	44.0	246
11 1929	3.4	3.0	19	54.8	48.9	324
12 1929	27.0	7.9	53	90.8	50.6	419
13 1929	11.1	7.7	6	100.0	64.0	120
14 1928	58.0	52.2	56	100.0	96.0	306
Total			202			2,384
Av. per cent infested	10.1	6.4		70.1	40.5	

(a) All these experiments were carried on in the greenhouse except Nos. 6 and 8, which were in the fly nursery at Manhattan in the fall.
(b) Data in these columns are comparable horizontally but not vertically.

TABLE XX.—INFESTATION OF ILLINI CHIEF SEL. NO. 223415 AND KANRED BY FLY FROM THE SOFT-WINTER-WHEAT BELT.

(Arranged in order of per cent of Kanred tillers infested.)

Experiment No. and year. (a)	Illini Chief Sel.			Kanred.		
	Per cent infested.		Total number of fly. (b)	Per cent infested.		Total number of fly. (b)
	Plants.	Tillers.		Plants.	Tillers.	
1 1928 (fall)	44.0	12.6	79	47.3	13.3	63
2 1929 (fall)	81.4	48.9	706	76.0	32.0	372
3 1929	80.0	62.0	87	70.0	36.8	28
4 1929 (spring)	73.4	34.9	52	80.0	51.9	129
5 1929	100.0	100.0	102	60.0	60.0	34
6 1930	92.0	62.1	405	96.4	77.6	694
Total			1,431			1,320
Av. per cent infested	78.4	53.4		71.6	45.3	

(a) Experiments Nos. 3, 5 and 6 were carried on in the greenhouse at Manhattan; Nos. 1, 2, and 4 in the fly nursery at Columbus, Kan.
(b) Data in these columns are comparable horizontally but not vertically.

UNIFORM GREENHOUSE TESTS

Fly from the soft-wheat belt and from the hard-wheat belt were brought into the greenhouse at Manhattan, and the plants were infested by these strains separately but in adjacent cages with as nearly uniform conditions as possible and at as nearly the same time as the emergence of fly permitted. Flaxseed from Carpenter, Ohio, and Indianapolis, Ind., were used in a similar manner to infest plants of the same varieties. The data from these tests are given in Table XXI. The results in the greenhouse tests of fly from different localities in Kansas closely parallel the field data in spite of the obvious differences in tillering of the plants and the intensity of infestation.

During the winter of 1929-'30 another test was conducted with similar results, as shown in Table XXII. In this test approximately 1,000 flaxseed from each locality were used. In this, as in some of the other tests, the fly from the soft-wheat belt appear to develop better under greenhouse conditions than do the fly from the hard-wheat belt. While this may account for the heavier infestation by the fly from eastern Kansas, it does not account for the differential infestation abilities.

TABLE XXI.—INFESTATION OF WHEAT BY BIOLOGICAL STRAINS OF FLY IN GREENHOUSE TESTS, 1928-'29.

VARIETY. (a)	Per cent of tillers infested by fly from—					
	Lincoln county (hard-wheat belt).	Cherokee county (soft-wheat belt).		Carpenter, Ohio.		Indianapolis, Ind.
		First test.	Second test.	First test.	Second test.	
Illini Chief Sel. No. 223415	0.0	100.0	62.0	75.6	12.0	46.6
Rye	.0	18.0	21.1	12.5	4.3	5.5
Kawvale	.0	72.7	25.9	4.7	.0	17.7
Emmer	.0	90.0	43.8	.0	20.0	10.0
Honor	2.4	80.0	59.0	47.3	13.3	32.1
Spelt	2.9	60.0	27.8	20.0	.0	5.7
Red Winter	4.8	54.5	62.5	4.3	.0	13.0
Durum	5.0	22.0	20.0	15.3	.0	.0
Blackhull	14.8	70.0	45.0	22.2	6.2	30.1
Kanred	20.9	60.0	36.8	43.0	.0	43.3
Total number of fly (all varieties)	102	521	459	489	21	255
Av. number of tillers per plant	3.6	1.0	3.9	.....	1.7	4.0

(a) Ten plants of each variety.

TABLE XXII.—INFESTATION OF WHEAT BY BIOLOGICAL STRAINS OF FLY IN GREENHOUSE TESTS, 1929-'30.

(Arranged in order of per cent of tillers infested by fly from Manhattan, Kan.)

VARIETY. (a)	Per cent of tillers infested by fly from—		
	Riley county (Manhattan).	Reno county.	Cherokee county (S. E. Kan.).
Ill. Chief Sel. No. 223415	1.8	1.44	62.1
Kawvale	4.8	1.43	55.1
Velvet Node (Kan. 503)	18.1	3.34	51.6
Blackhull	20.2	9.46	35.0
Prohibition (Kan. 502)	23.4	6.71	52.5
Kanred	40.6	24.5	77.5
Kooperatorka	48.6	22.2	88.0
Tenmarq	51.6	36.4	77.5
Early Blackhull	59.0	22.5	72.6
Max. per cent plants infested in any variety	90	62.5	100
Max. number of fly on 45 plants (approx.)	310	100.0	694

(a) An average of 45 plants of each variety.

SOIL TESTS

Soil is conceivably one of the important factors concerned in differences in the composition of plants and thus might influence the difference in infestation of varieties in the two localities under consideration. In southeastern Kansas, especially, the soil is frequently deficient in lime. In order to test soil as a factor in the resistance of wheat to Hessian fly the following kinds of soil were used. They are intended to represent a wide range of natural and artificially treated soils:

No. I. . . . Derby soil (a heavy red clay, high in silica) from near the insectary at Manhattan.

No. II. . . Dune sand, Laurel fine sand from the south end of Hunter's Island, Kansas river, near Manhattan.

No. III. . . The following soils, low in silica, from southeastern Kansas:
Series A. Gerald soil (planted with Kanred and Illini Chief).
Series B. Cherokee soil (planted with Tenmarq and Kawvale).

No. IV. . . Soil used in No. I plus 50 grams cow manure per 4-inch pot *(i.e.,* at rate of about 4½ tons per acre).

No. V. . . Soil used in No. I plus 1 gram $CaH_4(PO_4)_2$ and 4 grams $CaCO_3$ per 4-inch pot.

Except in the case of No. III, ten pots of each kind of soil were planted with Kanred, Illini Chief Sel. No. 223415, Tenmarq, and Kawvale, an average of about two plants per pot. Due to insufficient soil, only five pots of each of soil No. III were planted,

as shown above. When fully tillered the plants were infested with Hessian fly from the hard-wheat belt.

The experiment was repeated, using the same pots, soil, varieties, and conditions, except that the plants were infested in the three- or four-leaf stage, thus removing largely the effect due to differential tillering, on the various soils. The results of both experiments are almost identical. Table XXIII gives the data for the second test as an example of the results. There is no evidence of an interchange of position between resistant and susceptible varieties as was the case in the comparison between infestations by fly from the hard- and the soft-wheat belt. The data from both tests are summarized in Tables XXIV and XXV.

TABLE XXIII.—RELATION OF VARIETY AND KIND OF SOIL TO INFESTATION BY FLY FROM THE HARD-WHEAT BELT.

Soil No.	Variety of Wheat.	Tillers.			Number of flax-seed.	Number of larvæ.	Total number of fly.
		Total number.	Number infested.	Per cent of infestation.			
I.....	Illini Chief Sel	65	0	0.00	0	0	0
	Kawvale	72	0	.00	0	0	0
	Kanred	54	29	51.90	54	3	57
	Tenmarq	65	34	52.40	59	15	74
	Total	256	63	.....	113	18	131
	Average	.....	.....	24.60	.....	.....	.....
II.....	Illini Chief Sel	82	4	4.90	5	2	7
	Kawvale	61	1	1.64	0	1	1
	Kanred	76	40	52.70	51	17	68
	Tenmarq	70	46	65.80	87	42	129
	Total	289	91	.....	143	62	205
	Average	.....	.....	31.50	.....	.....	.....
III....	Illini Chief Sel	37	0	0.00	0	0	0
	Kawvale	31	1	3.23	2	0	2
	Kanred	34	15	44.10	22	4	26
	Tenmarq	43	17	39.50	31	1	32
	Total	145	33	.....	55	5	60
	Average	.....	.....	22.80	.....	.....	.....
IV....	Illini Chief Sel	77	4	5.20	4	3	7
	Kawvale	94	1	1.06	0	1	1
	Kanred	106	56	52.80	72	27	99
	Tenmarq	87	37	42.60	40	11	51
	Total	364	98	.....	116	42	158
	Average	.....	.....	26.90	.....	.....	.....
V.....	Illini Chief Sel	64	2	3.13	1	4	5
	Kawvale	95	3	3.16	3	1	4
	Kanred	88	35	39.80	57	17	74
	Tenmarq	61	31	50.90	40	11	51
	Total	308	71	.....	101	33	134
	Average	.....	.....	22.10	.....	.....	.....

TABLE XXIV.—AVERAGE INFESTATIONS OF WHEAT VARIETIES FOR ALL SOILS USED IN THE GREENHOUSE EXPERIMENTS.

	Kawvale.		Illini Chief Sel.		Kanred.		Tenmarq.	
	Per cent of tillers infested.	Total number of fly.	Per cent of tillers infested.	Total number of fly.	Per cent of tillers infested.	Total number of fly.	Per cent of tillers infested.	Total number of fly.
First test.....	7.2	36	9.7	45	44.0	246	60.4	391
Second test.....	1.7	8	3.08	19	48.9	324	50.6	337
Av.....	4.4	22	6.39	32	46.4	285	55.5	364

TABLE XXV.—RANK OF SOILS ACCORDING TO PER CENT OF TILLERS INFESTED.

SOIL NO.	Kawvale.		Illini Chief Sel.		Kanred.		Tenmarq.		Av.	Av. rank.
	1st test.	2d test.	1st test.	2d test.	1st test.	2d test.	1st test.	2d test.		
I.....	3	1	3	1	4	4	3	4	2.9	3
II.....	4	3	4	4	1	5	4	5	3.8	5
III.....	5	5	1	2	3	2	2	1	2.6	2
IV.....	2	2	5	5	2	3	5	2	3.2	4
V.....	1	4	2	3	5	1	1	3	2.5	1

The average per cent of tillers infested for the varieties may be compared with the individual cases given in the preceding tables. In studying the rank of the soils, that from the soft-wheat belt gives a zero infestation on Illini Chief selection, but the highest infestation of any soil for Kawvale. This is exactly the reverse of what happens when these two varieties are infested with fly in the soft-wheat belt. For all the varieties in both experiments there is no very marked agreement in the effect of soil type on infestation, although the rank of the five soils is the same in both tests. These data show no very pronounced effect of soil on Hessian fly infestation.

SELECTIVE BREEDING OF STRAINS OF HESSIAN FLY

In infestations by fly from the hard-wheat belt a few flaxseed mature on Illini Chief. The presence of these may have been due to ecological conditions or to an impurity; that is, heterozygous condition in inherited factors influencing resistance in either host plant or insect. Experience with infestations under diverse conditions has established the improbability of the action of ecological conditions. Repeated futile attempts to purify completely the pop-

ulations of Illini Chief selection with respect to the factors for fly resistance, led to the study of possible biological strains of fly by selective breeding methods. In these tests single pairs or single mated females were each caged on pots containing plants of Kanred and Illini Chief Sel. No. 223415. (Fig. 1.) When fly from the hard-wheat belt were used most of these experiments resulted in infestation of Kanred alone, although as many or more eggs were deposited on plants of Illini Chief. An occasional fly would infest both Kanred and Illini Chief about equally. These two strains of fly retained their respective infestation abilities through three generations.

In approaching the same problem from another angle an attempt was made to build up an infestation on Illini Chief by a kind of continuous mass selection. In several experiments it was found that the few flaxseed which developed on Illini Chief from infestations of central Kansas fly always gave about equal infestations on Kanred and Illini Chief selection, when the varieties were infested by these selected flaxseed. On the other hand, fly which developed on Kanred have always given a heavy infestation on Kanred and a very small infestation or no infestation on Illini Chief, in succeeding generations.

POSSIBLE MODE OF ORIGIN OF BIOLOGICAL STRAINS

A brief discussion of the possible origin of the biological strains of Hessian fly in the populations of the hard- and soft-wheat areas of Kansas seems in order, even though there is no certain evidence on their exact mode of origin. There are at least three possible explanations, which are outlined below.

1. Separate Introduction to Kansas.—McColloch *(14)* has given a history of the Hessian fly and has described its migration in Kansas. During the first ten years—1871 to 1881—it was confined to what is now the soft-wheat belt, perhaps by the same ecological factors that now limit the distribution of the fly population there. By 1891, or perhaps even five or six years earlier, the fly had spread to near the western edge of the wheat region as it then existed. This sudden jump may have been natural spread, or it may have been a separate introduction. Areas exist in New York *(19)* where the reaction of the fly to Dawson Golden Chaff wheat is similar to the reaction of this variety to fly from the hard-wheat belt of Kansas and different from the reaction of Dawson to fly from the soft-wheat belt of Kansas. At about this time (1873) Russian immigrants settling in central Kansas brought in Turkey wheat. With it they may have brought in *Ægilops cylindrica* Host, a Eurasian wheat-field weed *(7),* and perhaps also a new stock of Hessian fly. Thus the fly of the hard-wheat belt might have come from the eastern United States or from Europe. In this case its immediate origin in Kansas would represent a separate introduction from the origin of the population of fly in the soft-wheat belt.

2. Ecological Conditions. — It is entirely possible that other characters which render the hard-wheat-belt strain of fly more adapted to the drier conditions of central and western Kansas may be linked with the ability to infest wheats of the Turkey type. The relationship to infestation on native grasses may play a part in this adaptation.[1]

3. Genetic Considerations. — The genetic constitution of the biological strains of fly is not well known. In studying crosses between a strain infesting both Kanred and Illini Chief and one infesting Kanred alone, the former appeared to be dominant. The mortality is high, making this point difficult to determine. It is entirely possible that the former strain may be heterozygous. Strains may exist that have not been demonstrated and which will infest Illini Chief alone. In such a case the two populations of fly could be produced by segregation, accompanied by natural spread, coupled with natural selection in favor of the adapted hosts. Such an occurrence may explain the origin of biological strains of fly.

SUMMARY OF EVIDENCE ON BIOLOGICAL STRAINS

The proof for the presence of biological strains of Hessian fly is based on the following facts or lines of evidence:

1. Observations on Kansas farms indicate that in the hard-wheat belt the soft wheats are less injured by fly than the hard wheats. In the soft-wheat belt frequently the reverse is true.
2. There is a lack of agreement in the literature in regard to the fly infestation of some varieties in different localities.
3. Identical varieties or strains give very different infestation data in the soft-wheat belt from that which they give the hard-wheat belt of Kansas.
4. The relative rank of a variety is changed very little under the wide range of infestation intensities studied. In studying a resistant and a susceptible variety in a series of infestations of different intensities, as the latter approaches 100 per cent plant or tiller infestation, each additional increment of fly adds to the per cent of infestation of the resistant variety without material change in these data for the susceptible variety. Under these conditions the difference between the varieties shows in the total fly present on each variety and these data show the usual differences.
5. When brought into the greenhouse to infest wheat, under uniform conditions, fly from the several localities retained their characteristic infestation abilities.
6. The ability of the fly from the hard-wheat belt to infest varieties in a differential manner is not materially affected by a wide range of natural and artificial soil conditions.
7. It is possible to select, individually or in mass, from the nor-

1. Since this manuscript was prepared, W. B. Noble has published a paper on "Two wild grasses as hosts of the Hessian fly, *Phytophaga destructor*." Jour. Agr. Research 42: 589-592. 1931.

mal fly population of the hard-wheat belt, a group of individuals which have a different infestation ability from the original or natural population of fly.

8. The relationships with pure lines of wheat and the individual breeding experiments with the fly indicate that these biological or physiological strains are genetically distinct. The evidence available also indicates that the population of fly in any one locality consists of a mixture of two or more strains which differ in their ability to infest the several varieties of wheat.

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