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THE RELATIVE RESISTANCE OF WHEAT VARIETIES TO BUNT (*TILLETIA TRITICI*).

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I. Introduction.

In 1923 the attention of the present writer was called to the high percentages of bunt (*Tilletia tritici*) occurring in some of the pure line selections of Hen Gymro wheat which were under study by Mr. T. J. Jenkin at the Welsh Plant Breeding Station. The selections were made for the most part in 1920 and multiplied on the ear to row system, and in three years the majority of the lots were found to be badly bunt contaminated.[1] Since Hen Gymro is known to be a composite variety, including a series of types which differ by clearly marked morphological characters

[1] In subsequent years the disease was satisfactorily controlled by the application of copper carbonate dust (see 16).

(8), an experiment was started with the object of testing a number of pure line selections in the hope that some might be found to differ also in regard to bunt resistance. For comparison with Hen Gymro certain common British wheat varieties were included in the trials, together with several varieties from other countries which have been recorded as possessing exceptional resistance to bunt.

It is not necessary on this occasion to review in detail the work already published on varietal resistance of wheat to bunt, since this work was summarised by Humphrey and Woolman (7), and by Reed in 1924 (15).

The pioneer in this as in other aspects of wheat breeding was Farrer in Australia, and as the outcome of his work we have the relatively resistant varieties Genoa and Florence (2, 13).

In Germany the most extensive studies in this problem were made by Von Kirchner, who tested for bunt resistance during the period 1903-1916 360 varieties and selections of cultivated wheats. Considering the species as a whole, *T. durum*, *polonicum* and *monococcum* showed the highest resistance, but infection of one or more varieties of these species was obtained; while within each of the species *T. compactum*, *turgidum*, *spelta*, *dicoccum*, and *vulgare*, several varieties were found of marked susceptibility. Among varieties of *T. vulgare* Fürst Hatzfeld, Hohenheimer No. 77 and Beardless Odessa were exceptionally resistant, but none were found to be immune.

More recently in Germany a number of winter wheat varieties were tested for bunt resistance by Zade (20). Among fifty-six varieties only one, Heils Dickkopf, showed high and consistent resistance to bunt over a four seasons' trial. This variety, together with two others which showed a weaker resistance, were included in the experiments described below.

In 1918 the Australian resistant variety Florence was found to be highly resistant in some American trials (4), and at the same time certain selections of Turkey, a red Crimean wheat, remained almost free from infection under conditions which produced over 70 per cent. infection in susceptible varieties. A highly resistant and promising variety, Ridit, is the outcome of the cross Turkey x Florence, which was made at that time and studied by Gaines (4, 5).

An extensive search for bunt resistant varieties of wheat was made in America during the years 1918-20; nearly all the commercial varieties of wheat grown in the United States were tested at more than one station and numerous samples from Australia, India and South Africa were also included. Three

strains of White Odessa, nine selections from Turkey and the varieties Ridit, Florence and Banner Berkeley proved to be highly resistant to bunt (*Tilletia tritici*), while strains of Hussar and Martin, both varieties of common wheat, appeared to be actually immune (19). These varieties have remained free from infection in all subsequent trials in the United States and may be regarded as completely resistant to all collections of *Tilletia tritici* so far investigated in that country.

The genetics of bunt resistance have been studied by Gaines (5), Gaines and Singleton (6) and Briggs (1). Gaines, working with the highly resistant varieties Turkey and Florence, showed that in some wheat varieties bunt resistance is not a simple Mendelian unit character. If Mendelian, it is composed of multiple factors, and apparently different wheats possess different kinds of resistance (5). Briggs, using the completely resistant forms Martin and Hussar in crosses with highly susceptible varieties, found that resistance to bunt was completely dominant in Martin and almost completely dominant in Hussar. He concludes that the two varieties are apparently not exactly similar in their resistance to bunt, resistance in Hussar being due probably to more than one Mendelian factor (1).

From the genetical work already published one may conclude that it should not be difficult to use these immune varieties of wheat in breeding for bunt resistance.

II. Experimental Data and Discussion of Results.

The same method of testing any particular line selection or variety of wheat was used throughout the series of experiments described in the present paper. Samples of the grain to be tested were shaken with excess of bunt spores, the surface of the grain thus treated being appreciably darkened by large numbers of spores adhering to it. In the first experiment (harvest year 1924) the spores were taken from an English farm crop of Benefactor. In the subsequent years a spore collection was used which came originally from a Welsh crop of April Bearded wheat and was propagated at the station on Hen Gymro in 1925 and on various varieties in 1926.[2]

The grain thus contaminated was sown under field conditions in five-foot drills at the approximate rate of four grain per inch. Every grain sample under test was sown in duplicate, with the exception of those included in the March sowing, 1925 (Table II).

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[2] No significant difference was observed in the infection capacities of the two collections employed, but the experiments were not designed to test this point critically.

In 1924 and 1926 the plants from each row were pulled by hand at harvest and divided into three groups as follows :—

1. Plants bearing heads containing only healthy grain.
2. Plants bearing both healthy and bunted heads.
3. Plants bearing only heads with bunted grain. Partially infected heads were classified as " bunted."

The plants in each group were counted and recorded, and an estimation was also made of the number of healthy and bunted heads in each row. In 1925 the rows were cut at ground level and the percentage of disease was estimated only on the basis of bunted heads. It is evident from the tables that where estimations were made by both methods the figures show in most cases good agreement. Considerable divergence only occurred when the number of plants was unusually small, with the result that certain plants had space for excessive tillering. On the whole the figures given by estimating the percentage of bunted plants are slightly higher than those obtained when the heads alone are used as a basis for estimation. In 1926 (Table III) the greatest divergence between the two methods was 14 per cent. (April Bearded). Taking the average of the same fifty-six lots we have :—

Percentage bunted plants	...	...	73
Percentage bunted heads	...	...	72

In 1924 the corresponding figures for Hen Gymro selections were 69 per cent. and 65 per cent.

It will be convenient to consider the results under three headings :—

1. Pure line selections of Hen Gymro.
2. Foreign varieties selected for bunt resistance.
3. Common British varieties.

The results are summarised in Tables I, II and III.

1. *Pure line selections of Hen Gymro.*

In 1924 twenty-two pure line selections were tested for bunt resistance by the method outlined above, all the lots being sown on the same date, 6th February, 1924.

The range of infection throughout the experiment was 49-85 per cent. on an estimation of infected plants, 46-84 per cent. on an estimation of bunted heads (Table I). Although there was an apparent difference between the resistance of one line and another the results did not offer grounds for hoping that a highly bunt-resistant strain might be discovered by this method. It was decided, however, to repeat the trial in the following season with

the same lines and to include also eighteen other selections not previously tested. The grain was contaminated and sown on 4th November, 1924.

In the harvest year 1925 the infection was slightly lower than in the previous season. The average for all lines of Hen Gymro tested was 53 per cent.; the range among forty selections was 27-72 per cent., the estimation being made on the basis of bunted heads.

Considering lines tested in both seasons, the results do not show in all cases close agreement; certain lines which appeared to be relatively resistant in 1924 were found to be somewhat heavily infected in 1925. While a more extensive study might possibly reveal certain small but real differences in regard to bunt resistance between pure line selections of Hen Gymro wheat, it was not considered to be a useful subject for further investigation, since not a single selection in either season showed outstanding resistance. Such differences as appeared in the results were probably accidental departures from an average figure, which, under the conditions of the 1924-25 experiments, seems to lie between 50 per cent. and 70 per cent. This view is confirmed by the following result, obtained in 1926 when two lots were again tested, which showed respectively the highest and the lowest infection in a two year average in 1924-25 :—

Station No.	*Average 1924-25.*	*Percentage bunted heads 1926.*
150	33	80
378	76	81

In Table I the selections have been grouped according to ear characters, but it is evident that no correlation was found to exist between morphological features and resistance to bunt.

Since the method of pure line selection appears in the matter of bunt resistance to offer so little hope of success, breeding experiments have been started with the object of trying to introduce resistance by crossing selected lines of Hen Gymro with certain of the resistant varieties of *Triticum vulgare*, which will be discussed in the following section.

2. *Foreign varieties selected for bunt resistance.*

By the courtesy of Dr. Zade and Dr. Gaines, to whose work reference has already been made, samples were obtained in 1924 and 1925 of certain varieties of common wheat, which had been especially marked in their experiments for relatively high bunt resistance. These varieties have been tested three or four times

in the seasons 1924-26, together with certain British varieties which were included for comparison. The British varieties were not selected from any definite knowledge of their resistance or susceptibility to bunt. The data from four experiments are summarized in Table II.

TABLE I.

Showing the relative susceptibility to bunt of pure line selections of Hen Gymro wheat, 1924-25.

Ear Characters.	*Station No.*	1924 *per cent. bunted plants.*	1924 *per cent. bunted heads.*	1925 *per cent. bunted heads.*	*Average 2 years per cent. bunted heads*
Bearded, red, smooth glumes ..	194	58	55	53	54
,, ,, ..	195	75	76	48	62
,, ,, ..	196	70	56	43	50
,, ,, .	285	78	67	63	65
,, ,, ..	501	—	—	61	—
,, ,, ..	502	—	—	50	—
Bearded, red, rough glumes	206	66	55	66	61
,, ,, ...	209	73	68	43	56
Bearded, white, smooth glumes ..	215	75	72	43	58
,, ,, ..	219	64	61	65	63
,, ,, ..	292	49	46	49	48
	354	81	81	36	58
,, ,, ..	407	—	—	52	—
,, ,, ..	469	—	—	72	—
,, ,, ..	470	—	—	50	—
,, ,, ..	378*	82	84	67	76
Bearded, white, rough	357	77	78	48	63
Semi-bearded, red, smooth	513	—	—	57	—
,, ,, ,, ...	520	—	—	56	—
,, ,, rough	505	—	—	43	—
Beardless, red, smooth glumes ..	140	68	66	54	60
,, ,, ..	148	63	62	59	61
,, ,, ..	150	44	38	27	33
,, ,, ..	326	63	59	45	52
,, ,, ..	189	—	—	56	—
,, ,, ..	490	—	—	51	—
,, ,, ..	494	—	—	66	—
,, ,, ..	496	—	—	65	—
Beardless, red, rough glumes	157	76	62	59	61
Beardless, white, smooth glumes..	165	78	70	53	62
,, ,, ..	171	65	69	51	60
,, ,, ..	473	—	—	55	—
,, ,, ..	474	—	—	57	—
,, ,, ..	480	—	—	56	—
,, ,, ..	481	—	—	46	—
,, ,, ..	484	—	—	59	—
Beardless, white, rough glumes ..	178	75	82	41	62
,, ,, ..	274	60	46	65	56
,, ,, ..	277	85	73	37	55
,, ,, ..	522	—	—	61	—
Average	—	69	65	53	58

* Glumes pale red.

In 1924 the rows of wheat in this experiment were unfortunately attacked somewhat severely by wireworm, and the number of plants which survived until harvest was too small to admit of reliable conclusions in all cases. Moreover, two of the

samples, Ridit and Turkey (and possibly Hussar) were apparently not free from impurity. The results, nevertheless, are not without interest. Martin remained completely bunt-free under conditions which resulted in 82 per cent. of bunted plants in one line of Hen Gymro and 14-52 per cent. bunt in other common British wheat varieties.

In the following season two sowings were made. On the 4th November, 1924, the same varieties were sown again, the seed in this case being taken from the healthy plants of the 1924 experiment. Three samples from Germany were then included for the first time.

In this trial two lines of Hen Gymro gave 65 per cent. and 67 per cent. of bunted heads, Pommersche and Kirches (Germany) gave respectively 72 per cent. and 67 per cent., while eight varieties commonly grown in the British Isles gave 6 per cent.—35 per cent. Ridit, Florence and Turkey, with 3 per cent., 7 per cent. and 17 per cent. bunt, showed a certain degree of resistance, while Hussar and Martin were entirely bunt-free. Heils Dickkopf, with 20 per cent. bunt, was distinctly more resistant than the other German varieties, a result which agrees with that obtained by Dr. Zade in Germany.

In the same season a second sowing was made on 10th March, 1925, new samples of seed of the American varieties having been received for trial, together with White Odessa, which was then tested in Wales for the first time. In this experiment the highest figures for bunt were given by two spring varieties, Red Marvel and April Bearded, which were almost completely infected, producing respectively 87 per cent. and 92 per cent. of bunted heads. Pommersche and Kirsches were again relatively susceptible with 31 per cent. and 50 per cent., while Heils Dickkopf with 4 per cent. was highly resistant. Florence, with 41 per cent., was distinctly less resistant than in the previous November sowing. The British varieties, Benefactor, Little Joss, Cook's Wonder and Hen Gymro (219), showed surprisingly low bunt infections when compared with results obtained in 1926 from grain sown in November. White Odessa and Turkey showed high resistance. Ridit, Hussar and Martin gave only healthy plants.

In 1926 the same varieties were again studied for bunt resistance from sowings made on 10th November, 1925. In this trial strong infection was obtained with Kirsches, Pommersche and the British varieties, which showed a range of 56 per cent.—88 per cent. bunted plants. In comparison with these, Florence, Heils Dickkopf and Turkey (38 per cent., 18 per cent. and 12 per

cent.) were more resistant, White Odessa and Ridit (9 per cent. and 2 per cent.) were highly resistant, and Hussar and Martin completely resistant, again producing only healthy plants. These two varieties have, therefore, with the doubtful exception of Hussar in 1924, remained bunt-free in four trials extending over three seasons and conducted under conditions which did not fail to produce in certain other varieties very high percentages of disease. Ridit, Turkey and White Odessa have shown marked resistance in three trials (1925-26), and results with these varieties also agree very closely with those obtained in America. This, undoubtedly, is the result of first importance arising out of the present series of experiments, since it appears to indicate that varieties showing high resistance to bunt over a long period in America, and proving of value there in breeding experiments, behave in this same way to *Tilletia tritici* in this country and may possibly be used here also for the production of bunt-resistant varieties.

This result was not altogether anticipated in view of the increasing number of parasitic fungi which, on investigation, prove to be differentiated into several distinct biologic species, to which varieties of cultivated plants show varying degrees of resistance. Thus it was found recently that certain oat varieties resistant to *Ustilago laevis* in America were markedly susceptible to Welsh collections of the same fungus (14, 17). Fortunately for the plant breeder *Tilletia tritici* appears to be less variable in this respect, and up to the present time no well established biologic species of this fungus have been discovered.[3] Thus the variety Florence, which was bred in Australia for bunt resistance, has proved of value as a bunt-resistant variety in America. It appears now from the results of the above experiments that Martin and Hussar, which are immune to bunt in America, show the same reaction to the disease in this country and may conceivably be of value here in breeding work.

Interesting in the same connection is the behaviour in these trials of the three German varieties, Pommersche, Kirsches and Heils Dickkopf. The results agree in so far as Heils Dickkopf is concerned, since this variety in Wales and in Germany showed relatively high resistance. With the two varieties, Kirsches and Pommersche, rather higher results were obtained in Wales (1925-26) than were obtained in Germany by Dr. Zade (1920-23), but this discrepancy in results might be due to seasonal variation,

[3] Results indicating that biologic species of *Tilletia tritici* do exist have been obtained in America by Faris (3).

since Dr. Zade informs me by letter that higher figures for infection were obtained in 1924-25 than in the earlier series of experiments reported on in 1923 (20).

TABLE II.

Showing the relative susceptibility to bunt (*Tilletia tritici*) of certain wheat varieties from Germany, United States and Britain, 1924-26.

SOURCE OF SEED AND VARIETY.	*Station No.*	1924 *Feb. sown per cent. bunted plants.*	1924 *Feb. sown per cent. bunted heads.*	1925 *Nov. sown per cent. bunted heads.*	1925 *March sown per cent. bunted heads.*	1926 *Nov. sown per cent. bunted plants.*	1926 *Nov. sown per cent. bunted heads.*
GERMANY:							
Heils Dickkopf	589	—	—	20	4	18	15
Kirsches	590	—	—	67	50	84	80
Pommersche	591	—	—	72	31	62	58
U.S.A.:							
Florence	579	(35)	(10)	7	—	—	—
	612	—	—	—	41	38	20
White Odessa	607	—	—	—	7	9	4
Ridit	580	28*	32*	3	—	—	—
	610	—	—	—	0	2	1
Turkey	578	20*	30*	17	—	—	—
	611	—	—	—	4	12	11
Hussar	581	(8)	(4)	0	—	—	
	609	—	—	—	0	0	0
Martin	582	0	0	0	—	—	—
	608	—	—	—	0	0	0
BRITAIN:							
Yeoman	120	25	26	26	—	63	54
Victor	121	(20)	(35)	24	—	75	74
Benefactor	126	14	11	20	10	62	62
Squarehead's Master	123	—	—	6	—	78	73
Standard Red	128	(47)	(45)	22	—	80	78
Little Joss	127	52	54	35	13	56	47
Svalof Iron	561	46	37	19	—	69	71
Cooks Wonder	571	(30)	(15)	35	15	80	81
Hen Gymro	378	82	84	67	—	83	84
	219	64	61	65	15	65	67
Red Marvel	686	—	—	—	—	81	80
	19	—	—	—	87	—	—
April Bearded	606	—	—	—	92	—	—

* Samples 578 and 580 gave rise to a mixed population. Figures marked ( ) are based on only ten to twenty plants owing to a severe attack of wireworm in March. In the case of Hussar (581) only thirteen plants survived, of which one was bunted. It is, of course, possible that this plant was a rogue, since the variety remained immune in three subsequent trials, each of which involved a large number of plants.

8. *British wheat varieties.*

In 1924-25 certain of the British varieties included in the trials with foreign samples gave somewhat unexpectedly low percentages of infection. So far as the writer is aware no extensive trial has been made in this country to determine the relative bunt resistance of wheat varieties commonly grown in Britain, but it appears to be generally held that certain varieties such as Squarehead's Master, Little Joss and Benefactor are highly susceptible to bunt. In these trials Squarehead's Master produced in the first two seasons only a small number of

plants, but these were almost completely bunt-free.[4] Benefactor, Standard Red and Svalof Iron also gave low figures when compared with a variety such as Hen Gymro. The writer decided, therefore, to obtain a larger number of samples of British wheats and to test these for bunt resistance under conditions made as favourable as possible for infection. Fifty-six samples were obtained, contaminated with bunt spores, and sown on 10th November, 1925. A period of unusually cold weather followed the date of sowing and the germination was delayed for nearly six weeks. In most cases, however, a good stand was made and closely concordant results were obtained from the duplicate rows. The results are given in Table III, from which it will appear that the conditions were particularly favourable for infection by bunt. One sample (Fortuna) showed 91 per cent. of bunted plants, nineteen of the winter-sown wheats gave over 80 per cent. of bunt, and the lowest figure in the whole experiment was Little Joss (127) with 56 per cent.

The varieties have been grouped on the colour and morphology of grain and ear, but there is no indication in these data of a correlation between such characters and resistance to bunt. Taking the average of all white-grained and all red-grained varieties the same figure, viz., 75 per cent. of bunted plants, is obtained for the two groups. In America also, taking the average of a large number of samples, the soft red winter wheats and the white-grained winter wheats showed close agreement, having, respectively, 60.2 per cent. and 58.8 per cent. infection, while the hard red winter wheats proved to be relatively more resistant, with only 22.7 per cent. infection (19). The latter group included several selections of Turkey, which, as previously stated, is relatively a very resistant variety. Of British wheats tested in Wales, Yeoman is undoubtedly the hardest red wheat, and it is perhaps worthy of record that among eight samples included in the trial the bunt infection varied between 60 per cent.—67 per cent., a range of figures undoubtedly high, but one which falls below the average for the varieties taken as a whole. It should be understood that these varieties were sown on the same day and under the same conditions as the resistant American varieties

[4] This raises the question as to a possible selective action of environmental factors on a mixed population of bunted and healthy plants. Some evidence has been brought forward which indicates the relatively low rate of establishment of bunt-contaminated grain as compared with bunt-free grain (16, 18). Although exact data are not available, there is some evidence that in the 1926 experiment "winter killing" was less pronounced than in 1924-25 and the percentage of bunted plants was remarkably high in certain varieties which gave in the two previous years relatively few plants and low percentage of disease. Experiments to test this point further are in progress.

TABLE III.

Showing the relative susceptibility to bunt of wheat varieties supplied by firms in the British Isles, 1926.

*Name of variety supplied with sample.**	*Station No.*	*Percent. bunted plants.*	*Percent. bunted heads.*
A. WINTER SOWN.			
1. *Triticum vulgare* var. *albidum*†			
Dutch Million ...	1	57	54
Million III ...	708	74	65
Benefactress ...	675	66	68
White Standup ...	702	83	87
Standup White ...	691	84	79
Double Standup White ...	716	70	66
Old Brooker's White Standup	667	80	78
White Wonder ...	683	85	79
Wilhelmina ...	668	81	82
Wilhelmina ...	710	87	85
Victor ...	121	75	74
Victor ...	680	78	81
Average ...		77	75
2. *T. vulgare* var. *alborubrum*			
New Empire ...	694	73	72
3. *T. vulgare* var. *leucospermum*			
Benefactor ...	126	62	62
Average white grained varieties ...		75	74
4. *T. vulgare* var. *milturum*			
Little Joss ...	127	56	47
Little Joss ...	671	71	65
Little Joss ...	684	65	64
Little Joss ...	709	66	62
Standard Red ...	128	80	78
Standard Red ...	664	80	75
Standard Red ...	679	72	70
Standard Red ...	689	77	73
Squarehead Master ...	123	78	73
Squarehead Master ...	665	77	79
Squarehead Master ...	669	80	78
Squarehead Master ...	677	77	69
Squarehead Master ...	687	77	79
Squarehead Master ...	692	85	84
Squarehead Master ...	701	87	87
Squarehead Master ...	705	67	69
Red Chaff Squarehead ..	718	63	61
Red Standup ...	700	80	83
Average ...		74	72
5. *T. vulgare* var. *lutescens*			
Yeoman ...	120	63	54
Yeoman ...	681	67	65
Yeoman ...	695	66	71
Yeoman ...	717	60	57
Yeoman II ...	658	66	66
Yeoman II ...	688	63	58
Yeoman II ...	712	67	72
Yeoman King ...	708	64	68

TABLE III (Continued).

Showing the relative susceptibility to bunt of wheat varieties supplied by firms in the British Isles, 1926.

*Name of variety supplied with sample.**	*Station No.*	*Percent. bunted plants.*	*Percent. bunted heads.*
5. *T.vulgare* var. *lutescens* (con.)			
Iron ...	561	69	71
Iron ...	682	76	77
Iron III ...	663	74	77
Iron III ...	714	77	77
Harvester ...	693	79	76
Harvester ...	690	74	70
Foch ...	674	79	76
Crown ...	659	84	82
Rector ...	666	73	72
Rector ...	676	66	62
Chevalier ...	661	78	80
Chevalier ...	715	87	86
Browick ...	673	61	48
Stormproof ...	698	89	87
Croxten Champion ...	699	85	86
Iduna ...	711	60	58
Red Admiral ...	704	58	56.
John Bull ...	672	78	75
Fortuna ...	713	91	91
Twenty-one ...	707	78	76
Red Marvel‡ ...	686	81	80
Average ...		73	72
6. *T.vulgare* var. *ferrugineum*			
New Bearded ...	685	65	58
Average red grained varieties		75	71
7. *T.turgidum* var. *dinurum*			
Riveits ...	670	60	67
8. *T.turgidum* var. *iodurum.*			
Blue cone ...	706	63	65
9. *T.vulgare* mixed types			
Hen Gymro (pure line selections)	378	83	81
Hen Gymro (pure line selections)	219	65	67
Hen Gymro (pure line selections)	150	72	80
Hen Gymro (pure line selections)	484	78	83
B. Spring Sown.			
1. *T.vulgare* var. *lutescens*			
Red Marvel‡ ...	723	87	86
2. *T.vulgare* var. *ferrugineum*			
April Bearded ...	722	80	94
Average fifty-six lots ...		73	72

* The samples have been grouped on ear characters by the writer, but no attempt has been made to deal with the problem of synonyms. Obvious "rogues" (in all cases rare) were excluded from the results.

† The names of varieties are taken from "The Wheat Plant", by J. Percival.

‡ The glumes in Red Marvel are very pale red. This variety is classified as *milturum* by Percival.

dealt with in the previous section of this paper, two of which remained completely bunt-free. It is evident that in comparison with these the British wheat varieties tested in Wales in this experiment are one and all highly susceptible to bunt when grown under conditions favourable for infection.

III. Biological Observations.

In addition to the data furnished by these experiments, and already discussed, as to the varietal resistance of wheat to bunt, the results present certain features which are of interest from the point of view of the interaction of host and parasite.

1. *Partially diseased ears.*

When the resistance of varieties was estimated on the basis of percentage infected heads, ears which showed one or more bunted grain were classified as diseased. From the examination of some thousands of heads involved in the above experiment it became evident that in most varieties partially diseased ears were comparatively of infrequent occurrence, the infected heads bearing in nearly every case bunted grain only. In 1925 two varieties, Heils Dickkopf and Pommersche, seemed to be outstanding exceptions to this rule, and an estimation was made, therefore, of the percentage of healthy grain occurring in heads obviously invaded by the parasite. For comparison a few other varieties were examined in the same way and further data were obtained in 1926 (Table IV).

Three varieties only, Florence and the two named above, were outstanding in this respect, from 30 per cent.—45 per cent. of the grain produced by infected heads being apparently free from disease. Heils Dickkopf and Pommersche showed in addition an appreciable number (7 per cent.—20 per cent.) of grain clearly invaded by the fungus but not completely destroyed. In some cases the fungus spores were restricted to small tumour-like swellings on the upper part of the grain and the embryo was uninjured and capable of germination.[5]

The close agreement of the data obtained in the two seasons appears to suggest that incomplete invasion of the ear by the fungus is characteristic of the particular variety of wheat and is a further manifestation of relative resistance to the parasite.

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[5] The separation into "healthy", "partially bunted" and "completely bunted" grain was made by eye examination and is therefore only relative. A grain was classed as "partially bunted" when approximately half of the endosperm was hard and white. A germination of 76 per cent. was obtained when 50 "partially bunted" grain were sown on sand.

Florence and Heils Dickkopf, which showed the highest percentage of healthy grain among infected ears, are varieties which take a relatively high place when resistance is judged by the percentage of bunted plants or heads. Pommersche, on the other hand, produced in these experiments a high percentage of bunted plants and heads, but over 30 per cent. of the grain from infected heads was healthy. In all other susceptible varieties studied the proportion of healthy grain produced by infected ears was low—certainly not above 2 per cent. (Table IV). It is suggested that the phenomenon of partially diseased ears might possibly prove of interest in genetical studies of bunt resistance.

TABLE IV.

Showing the percentage of healthy, partially bunted and completely bunted grain in heads of wheat infected by *Tilletia tritici*.

VARIETY.	*Station No.*	*Year.*	*No. of heads examined.*	*Total No. of grain*	*Healthy grain per cent*	*Partially bunted grain per cent*	*Completely bunted grain per cent.*
Heils Dickkopf	589	1925	20	319	45.4	13.5	41.1
,, ,, ...	589	1926	30	356	43.5	18.8	37.7
Pommersche.....	591	1925	20	497	36.3	15.5	48.2
,, ...	591	1926	50	810	33.1	6.7	60.2
Florence	612	1926	25	399	39.6	1.0	59.4
Turkey	611	1926	6	122	6.6	0.0	93.4
Kirsches	590	1925	20	386	3.9	1.0	95.1
,, ...	590	1926	50	1530	.8	0.0	99.2
Rivetts	670	1926	20	1428	1.9	0.0	98.1
Penefactor	126	1925	20	847	.7	.1	99.2
.....	126	1926	25	1272	1.4	0.0	98.6
Little Joss	684	1926	30	886	.9	0.0	99.1
Dutch Million	1	1926	25	1081	.7	0.0	99.3
Yeoman	- -	1926	175	4077	.5	0.0	99.5
Wilhelmina	710	1926	30	770	.3	0.0	99.7
Standard Red	679	1926	30	897	.2	0.0	99.8
Hen Gymro	—	1925	50	—	0.0	0.0	100.0
,, ,, ...	150	1926	50	1373	0.0	0.0	100.0
Svalof Iron	663	1926	30	1210	0.0	0.0	100 0

2. The influence of Tilletia tritici on growth in height.

That the fungus exercised a retarding influence on growth in height was evident in all the varieties studied in this series of experiments, the bunted tillers being noticeably shorter in the stem than those bearing healthy heads. In 1925 measurements were made on fifty healthy and fifty bunted tillers from each of eleven Hen Gymro selections and five other varieties. The percentage differences in height in favour of the tillers bearing healthy heads are given by the following figures :—

Hen Gymro (average of eleven selections)				27 per cent.
(Range 20 per cent.—55 per cent.).				
Pommersche	...	...	...	28 per cent.
Heils Dickkopf	...	...	...	24 per cent.
Standard Red	...	...	...	18 per cent.
Yeoman ...	...	...	...	38 per cent.
Cook's Wonder	...	...	...	20 per cent.

The range of figures cannot be taken as indicating real differences between the behaviour of the one variety and another, since they are based on one set of measurements only, but it is of interest to note that the growth of the relatively resistant variety Heils Dickkopf was in this case retarded to the same extent as certain of the more susceptible varieties. Experiments dealing directly with the influence of *Tilletia tritici* on vegetative growth have been discussed in a separate paper (18).

IV. Summary.

1. Of forty pure line selections of Hen Gymro wheat studied for susceptibility to bunt none showed outstanding resistance. No correlation between morphological characters and relative susceptibility was indicated by the results.

2. Of sixty-five samples, including some thirty-two varieties of British wheats, tested in one season for bunt resistance all showed relatively high susceptibility (56 per cent.—91 per cent.).

3. Two varieties, Martin and Hussar, both immune to *Tilletia tritici* in America, appear to be completely resistant also to bunt in Wales. White Odessa, Ridit and Turkey, also varieties of *T. vulgare*, which have shown high bunt resistance in America, proved to be relatively resistant in these trials.

4. Heils Dickkopf, a variety which has shown resistance to bunt in Germany, was relatively resistant in Wales.

5. Three varieties, Florence, Heils Dickkopf and Pommersche, developed a considerable proportion (33 per cent.—45 per cent.) of healthy grain among the bunted grain of infected heads. In the majority of varieties studied the invasion of the infected ears was usually complete.

6. The experiments indicate the need for improving British wheat varieties as far as bunt resistance is concerned, and at the same time suggest the possibility of introducing resistance by crosses with the immune varieties Hussar and Martin.

7. The behaviour in Wales of certain foreign wheat varieties of known bunt resistance gives support to the view that *Tilletia tritici* is not a fungus with many highly specialised biologic species.

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A SURVEY OF THE INSECT PESTS OF MID AND WEST WALES.

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The following notes on the chief insect pests of cultivated crops in Mid and West Wales are the result of a survey of the area which has been carried out during the last four years. Since the tract of country surveyed comprises the following seven counties—Brecon, Cardigan, Carmarthen, Merioneth, Montgomery, Pembroke and Radnor,—with a total area of 4,859 square miles, a survey of four years' duration cannot claim to be exhaustive. It has, however, been carried out in detail sufficiently full to enable the making of a fairly complete record of the insect pests of the area.

A knowledge of the prevalent insect pests of the area is necessary before adequate steps can be taken to suppress them, and the chief reasons for the inclusion of this record in the *Welsh Journal of Agriculture* are, firstly, that no such record has previously been made, and secondly, it is hoped that farmers and others will help to make the record complete by communicating with the writer whenever they need advice on the suppression of insect pests. Such advice, which, needless to say, is free of charge, will be gladly given.

The figures comprising the following table are taken from *The Report on the Acreage under Crops*, Vol. LIX, Part I, issued