Studies on the Disease Resistance in Barley I. Varietal Differences in Resistance to Powdery Mildew, ERYSIPHE GRAMINIS D. C. f. HORDEI Marchal.

By

Y. Nishikado, R. Takahashi and U. Hiura

Introduction

Through improvements in disease control measures and practices, it is seldom that a barley crop is lost to any extent by the powdery mildew. The mildew attack is favored by climatic conditions, such as those prevailed throughout western Japan during the warm winter of 1949, which proved that the spraying of fungicides alone will not satisfactorily check the epidemic. A resistnat variety is, therefore, most desired under such conditions, and will always be of necessity for and beneficial to the barley growers, even if other effective control methods are found.

For breeding a resistant variety, physiological races of the barley mildew, *Erysiphe graminis* D. C. f. *hordei* MARCHAL must be considered because its specialization has been demonstrated. For the tests described below, the mildew which is commonly present in Okayama prefecture and regarded as a mixture of several races was used.

Barley covered 807 varieties, collected by R. TAKAHAHSI from various regions of the world. The Japanese varieties were of local or native origin which included those recommended by the respective prefectural authorities. Experiments were chiefly carried out by U. HIURA.

The writers wish to acknowledge the Ministry of Education for defraying a part of the expenses of this study. They are also obliged to Mr. T. NAKAYAMA for the preparation of the English text of this paper.

Methods

Seedling plant method was used for determining the resistance to the powdery mildew, in spite of generally accepted fact that matured barley plants suffer most from the mildew during about the time of heading. Tests with grown plants especially under field conditions not only involve more labor and time but usually accompany loss in precision of the experiment and a danger of possible scattering of cultured conidia over the neighboring fields. The symptoms in the seedling stage are more distinct than the matured. HONECKER (2) states that, gernerally, seedlings under diffused light at 15 - 20°C. in the laboratory become more susceptible. HIRATA (1), with more

than 220 Japanese varieties, found that resistance in the seedling stage is maintained throughout the life of the plant. The use of seedling, therefore, appears to be more desirable for this type of experiment.

Each variety of seedlings was cultured by sowing 4 or 5 selected seeds in an earthen pot 8 cm. in diameter, filled with the soil of the Institute. The pots were set in greenhouse concrete benches, and 20 cc. of 0.5% solution of ammonium sulphate was supplied to each of the pots when the plumule emerged.

Inoculations were made over the seedlings by shaking heavily mildewed plants in such a way that the first two blades will be uniformly covered with the conidia. The inoculum was originally gathered from an infected Kobinkatagi barley, one the highly susceptible local varieties, in 1948. It had been propagated since by continuous inoculations on the seedlings of the same variety. No water was applied upon the leaves of the plants after inoculation, as sufficient moisture was maintained for infection by setting the pots on the moistened soil and covering with glass cases that fitted over the benches. This kept the moisture in the compartment for two weeks, the entire period from the inoculation to the final recording of the results.

According to HONECKER (2), the infection of the mildew is affected to a lesser extent by such environmental conditions as the momentary changes of temperature, light and humidity than the rusts. Continuous high temperatures above 30° C. or low temperatures below 10° C., intense direct sunlight or defficient light inhibiting assimilation in the plant do affect the infection. In order to prevent seedlings from exposures to the sun and high temperatures, the roof of the greenhouse was covered with bamboo blinds on bright days. In spite of this, the temperature in the greenhouse became too high after middle of April. Subsequent inoculations were, therefore, conducted in glass infection chambers covered at the top with galvanized iron sheets. In this method the pots were not set on the moistened soil, but instead, the leaves were watered with a sprinkler on the fourth or fifth day after inoculation. A comparison, using 40 varieties of varying susceptibility, showed no noticiable decline in the infection by this change.

Experiment was repeated at least twice during the period of February 19 to May 11, 1949. The temperatures fluctuated between 10 and 20° C. and never at any time reached above 25° C.. In the earlier part of the season, however, the temperature fell as low as 3° C..

Classification of infection types

The growth of mildew became visible at about 7 days after inoculation, but the distinction of the reaction types was more apparent after 10 to 14 days. Six classes of reaction were distingiushed referring to the results of MAINS and DIETZ (4) and also of HONECKER (3). In this classification the resistant group was subdivided to show clearly the gradiation of resistance, while susceptible group, which was also inclusive of some more distinguishable classes, was denoted together as type 4.

I. Neither mycelium nor sporulation develops.

Type i. Highly resistant (immune). Plant is perfectly sound macroscopically.

Type o. Resistant. No mycelium but minute chlorotic or necrotic spots visible macroscopically. The infection is evident.

II. Mycelium over the leaf surface in thin layer, accompanied by some sporulation.

Type 1. Moderately resistant. Slight developments of mycelium and sporulation. Development of distinct chlorotic or necrotic spots.

Type 2. Slightly resistant. Moderate development of mycelium, with a slight conidia formation. Chlorotic or necrotic areas of various modifications.

Type 3. Moderately susceptible. Moderate developments of mycelium and sporulation. Slight chlorotic or necrotic spots may or may not develop.

III. Active development of mycelium with abundant conidia formation.

Type 4. Susceptible. Abundant mycelium and conidia formation. Outline of pustule distinct. Infection areas do not show discoloration at first, but later developing into chlorosis. Leaves wither from the tip.

The above reaction types were recorded on individual seedlings, taking into consideration the formation of pustules since their occurrence was peculiar to the variety to some extent.

Results and discussion

Results of inoculations are tabulated indicating the greenhouse and the shaded chamber experiments in Appendix 1 and 2. The table shows a close consistency under the two conditions. It also shows a very small difference in the disease reaction, with regards to the extremes of resistance and susceptibility. A considerable number of varie-

Table 1. Geographical distribution of the reaction types of barley varieties to powdery mildew.

Growing region	Resistant i-0	Intermediate 1-3	Susceptible 4	Number of varieties tested
	%	%	%	
Northern Japan	47	22	31	36
Hokuriku district	16	10	74	38
Central and Southern parts of Japan	6	8	86	226
Japanese indigenous varieties and bred strains of Kōnosu Exp. Station	5	8	87	191
Northern Korea	0	71	29	14
Southern Korea	0	9	91	56
Manchuria	24	45	31	42
North China	0	0	100	11
Central China	0	2	98	92
Russia	18	53	29	29
Europe and America	39	39	22	49
Southeasthern Asia	33	45	22	9
Wild barleys	33	40	27	15
Total %	11	15	74	807

ties belonged to the intermediate classes, showing a fluctuating range of 2 and 3. Several varieties were recognized as mixed forms; Iwate-ōmugi No. 1 and No. 3. contained types i-o and 4, with no intermediate types. Some varieties like Awa-mugi (a Japanese local variety), Zairai-shu (a Korean local variety), one strain from central China, Vankhuri, Lennees, Australian Chevalier, and Russian No. 80 showed a variation extending into four classes.

Table 1 summarizes the frequency distribution of varieties into three groups of reaction to the mildew, namely, types i-o, 1-3 and 4, at different geographical regions of the world.

Barley from regions of central and southern parts of Japan, southern Korea, and North and central China, and Japanese indigenous varieties, and bred strains from Kōnosu Experiment Station were characterized by high frequencies in the susceptible class. In Hokuriku district of Japan, inclusive of Akita, Yamagata, Niigata and Fukushima prefectures, 16 percent of the varieties were resistant. Northern Korea, Manchuria, Russia and southeastern Asia consisted mainly of intermediate and resistant varieties. Europe, America, Saghalein, and northern Japan which includes Miyagi, Iwate, Aomori, and Hokkaidō showed the highest frequency of 47-39 percent resistant class.

Wild barleys were mostly intermediate in reaction. Viewing from these groupings, barley of northern Japan, northern Korea and Manchuria are apparently different from those of central and southern Japan, southern Korea, and China proper. The geographical distribution of resistant varieties in eastern Asia coincides with TAKAHASHI's (6, 7) recognition of a distinct phylogenetic difference in barley as represented by the short-haired rachilla and the hairless leaf sheath types of the same region. It is of interest that there exists a group of resistant varieties as represented by Kairyō-bōzu-mugi elsewhere in Ehime prefecture. Where is the origin of these resistant varieties of northeastern Asia? TAKAHASHI (6, 7) found that the proportion of hulled barley varieties having short-haired rachillas or hairless leaf sheath is great in Europe, northern parts of Japan, north Korea, and Manchuria, while it is the opposite in southeastern Asia. He also ascertained that a majority of the varieties of northern Japan and Manchuria have historical and geographical interrelation with northern Europe. He suspected that the hulled varieties with these characters in northeastern Asia may be of north European origin. That is, these characters of hulled barley of eastern Asia may be regarded as European origin. The 2-row barley is distinct from east Asiatic varieties; while the naked barley, of east Asiatic origin.

A search for the origin of Japanese resistant varieties was, therefore, based upon the above asumption and approached by studying the rachilla type, presence or absence of hairs in the leaf sheath, ear type, and hulled or nakedness of the grain. These data are shown in table 2.

Table 2 shows that most of the resistant varieties, excluding Chevalier, Golden Melon, Mensury and a few others which are undoubtedly known to be of foreign origin, have at least one of the four characters or are known to be hybrids of foreign varieties. This, although, does not means that the resistance is genetically linked with these characters, it is a fact that almost all of the Japanese varieties, excepting

Table 2. Relation of the four characters of the Japanese resistant varieties to powdery mildew.

Resistant varieties in Japan	Rachilla hair	Leaf sheath hair	Ear form	Adherence of lemma	Remarks
Hokudai No. 1	long	no	2-rowed	hulled	Chevalier × Golden Melon
Hokudai No. 4	do	do	do	do	do
Hokudai No. 9	mixed	do	do	do	do
Date No. 2	long	with	4-rowed	do	
Kachidoki	mixed	no	do	do	Sanseki × Honaga
Moravia	long	do	2-rowed	do	introduced from Czecho
Murasaki-hadaka	do	with	4-rowed	naked	Hosogara No. 2 × Kome-hadaka
Miyagi No. 123	short	no	6-rowed	hulled	Spontaneum × Koshimaki
Shidabun No. 1	long	do	4-rowed	do	
Miyako C	short	do	do	do	
Yuki-shirazu A	long	mixed	do	do	
Yuki-shirazu C	short	do	do	do	
Sanjaku-honaga C	do	no	do	do	
Sangatsu	long	with	do	do	
Hoso-mugi C	short	no	do	do	
Nakaizumi-zairai	long	with	6-rowed	do	
Mukade-mugi	do	do	do	do	
Hoso-mugi No. 3	mixed	mixed	4-rowed	do	
Aizu-hadaka No. 3	long	no	6-rowed	naked	Rikuu No. 1 × Mensury (Iwate)
Aizu No. 6	do	with	do	hulled	Kenyoshi × Iwate-ōmugi
Hoso-mugi	mixed	no	4-rowed	do	
Hakata No. 2	long	do	2-rowed	do	Australian Chevalier × Golden Melon
Kairyō-bōzu-mugi	do	do	6-rowed	naked	wa. 35, 61 × Bōzu-mugi
Dajōkan	do	with	4-rowed	hulled	
Hosogara No. 1	do	do	do	do	
Kenyoshi No. 3	do	no	do	do	
Nihonsan	short	do	do	do	
Hosogara No. 2 C	do	with	do	do	
Kōnosu No. 30	long	no	2-rowed	naked	Golden Melon Strain ?

the few listed above, were recognized highly susceptible or intermediate to the mildew.

A majority of the varieties from northern Korea were intermediate, but none were highly resistant. Highly resistant varieties from Manchuria are regarded as those having been introduced from Russia, Therefore, the present tests showed that local barley varieties of east Asiatic origin, including Japan, Korea, Manchuria, and China, have no or little resistance to powdery mildew, and that varieties possessing high resistance may have been originated from Europe, or are the breeds of other foreign varieties. Only four Japanese naked varieties, Murasaki-hadaka, Aizu-

hadaka No. 3, Kairyō-bōzu-mugi, and Kōnosu No. 30 were resistant. These four varieties, however, are hybrids from resistant hulled varieties. It appears, therefore, that since there are no resistnat naked varieties, it may be that resistance is not found on eastern Asiatic varieties.

In spite of having no direct hereditary association of resistance with short-haired rachilla and hairless leaf sheath, their geographical distributions coincide closely with one another.. The reasons are as follows: the characters of long and short haired rachilla and haired and hairless leaf sheath are detected in resistant varieties. In original, resistance as well as short haired rachilla is scarcely and the condition that high frequency of hairless leaf sheath is rare in east Asiatic varieties. Since these three characters originated from foreign varieties, it signifies that the distribution of these characters in eastern Asia implies the growing regions of European and American or Russian varieties. TAKAHASHI's above recognition on the geographical distribution of short-haired rachilla and hairless leaf sheath apply only to hulled barley. to which the resistance is entirely restricted to.

ROEMER and others (5) have stated that there are no winter barley resistant to mildew, and this may be true inasmuch as regionally, the resistant varieties are found in spring varieties. We have found some winter varieties resistant, which indicates that resistance is not always associated with the summer habit. This subject will be discussed in detail after further investigation.

If venture to say, in concluding, about foreseeing of breeding resistant varieties, it may be mentioned that the resistant character can be introduced into susceptible eastern Asiatic varieties suitable for central and southern Japan.

Summary

1. By using the seedling plant method in greenhouse, 807 barley varieties from various parts of the world were tested for the reaction to the powdery mildew prevalent in Okayama prefecture.

2. Among varieties from south Kantō regions of Japan, southern Korea and China, the resistance was scarce. Majority of intermediate varieties were from northern Korea, Manchuria, Russia, and southeastern Asia: while most resistant varieties were from the northern Tōhoku regions of Japan, Europe and America. Wild barleys were not necessarily resistant, the percentage of resistant varieties being similar to those varieties from southeastern Asia.

3. Presumably, most resistant varieties of northern Tōhoku, northern Korea, and Manchuria originated and were introduced from Europe, America, and Russia. Therefore, varieties of eastern Asia were fouud hardly resistant to the powdery mildew, at least to that wide spread in Okayama district.

4. Resistant varieties were very rare in naked barley. There were, however, some that were resistant, which is due to crossing with resistant hulled varieties. It is possible, from above results, to breed new naked mildew resistant varieties adaptable to various localities of Japan.

Literature cited

1. HIRATA, K. Nōgyō oyobi Engei, 22:3: 127-8, 1947.
2. HONECKER, L. Zeitschr. f. Züchtg., A, 19: 577 - 602, 1934.
3. _____ Phytopath. Zeit., 10: 197 - 222, 1937.
4. MAINS, E. B. and S. M. Dietz. Phytopath. 20: 229 - 239, 1930.
5. ROEMER, Th., W. H. FUCHS and K. ISENBECK. Die Züchtung resistenter Rassen der Kulturpflanzen, pp. 214 - 27, Berlin, 1938.
6. TAKAHASHI, R. Nōgakukenkyū, 37: 4: 132-6, 1947.
7. _____, J. Yamamoto and Y. Itano. Nōgakukenkyū, 38: 1: 5-10, 1948.

Appendix 1. Reactions of barley varieties to powdery mildew, *Erysiphe graminis* D. C. f. *hordei*.

Varieties tested	Typical type	Range of reactions
Japanese Varieties		
Saghalien		
Hokudai No. 1	i	i
Zairai-shu (Saghalien)	3	3—4
Sumire-mochi	3	3—4
Marumi No. 1 (Saghalien)	4	3—4
Hokkaido		
Hokudai No. 4	0	i—0
Hokudai No. 9	0	i—0
Chevalier (winter barley)	0	i—1
Sapporo-rokkaku	4	3—4
Chevalier (2-rowed)	i	i
Chevalier (Hokkaido)	0	i—0
Date No. 2	i	i
Hokusei (winter barley)	1	0—1
Wase-rokkaku	4	3—4
Kachidoki	0	0—1
Moravia	i	i—0
Murasaki-hadaka	0	0—1
Hokuto-hadaka	3	3—4
Pref. Aomori		
Hosogara No. 2	3	2—4
Pref. Iwate		
Mensury No. 2	0	0—1
Iwate-ōmugi No. 1	0—4	0—4
Iwate-ōmugi No. 3	i—4	i—4
Pref. Miyagi		
Miyagi No. 123	i	i—0
Golden Melon (Miyagi)	1	i—2
Shidabun No. 1	i	i
Miyako C	0	i—0
Yuki-shirazu A	0	i—0
Yuki-shirazu C	i	i—0
Sanjaku-honaga C	0	i—0
Pref. Akita		
Ōu No. 3	4	3—4
Sangatsu	i	i—0
Senpoku	4	3—4
Pref. Gunma		
Golden Melon (Gunma)	0	i—0
Haramachi	4	3—4
Hōnen	4	3—4
Pref. Saitama		
Golden melon Saitama No. 1	0	i—1
Pref. Chiba		
Hozoroi	4	3—4
Pref. Kanagawa		
Chikurin	4	3—4
Pref. Yamanashi		
Dai-rokkaku	4	3—4
Pref. Nagano		
Hoso-mugi	0	0—1
Pref. Gifu		
Shiro-ōmugi	4	3—4
Yane No. 44	3	2—4
Pref. Shizuoka		
Shiro-chinko	4	3—4
Pref. Mie		
Golden Melon (Mie)	0	i—0
Ōsaka No. 6	4	3—4
Shirodō No. 6	4	3—4
Pref. Kyōto		
Wase Golden Melon	i	i—0
Bōzu-ōmugi No.1	4	3—4
Pref. Hyōgo		
Golden Melon (Hyōgo)	0	i—1

Varieties tested	Typical type	Range of reactions
Pref. Nara		
Yamato-hadaka	4	3—4
Pref. Wakayama		
Shiro-chinko	4	3—4
Kodama No. 13	3	2—4
Pref. Tottori		
Aizu-strain No. 22	3	3—4
Pref. Shimane		
Hayakiso No. 3	4	3—4
Pref. Okayama		
Wase-bōzu	3	2—3
Fushiguro	4	3—4
Okayama-hadaka No. 1	4	3—4
Kii-mugi	3	3—4
Pref. Hiroshima		
Kōbai No. 10	4	3—4
Shiro-chinko	4	3—4
Pref. Yamaguchi		
Hakata No. 2	i	i—0
Ohori-hadaka	4	3—4
Pref. Tokushima		
Chinko No. 1	4	3—4
Chinko No. 83	3	2—4
Pref. Kagawa		
Kobin No. 1	4	3—4
Shiro-chinko No. 1	4	3—4
Kagawa-hadaka No. 1	3	2—4
Pref. Ehime		
Yane-hadaka No. 2	4	3—4
Ehime-hadaka No. 1	3	3—4
Ehime-hadaka No. 2	2	1—2
Kairyō-bōzu-mugi	0	i—1
Kairyō-hadaka No. 2	2	1—3
Heiwa-hadaka	2	1—3
Pref. Kōchi		
Kitagawa-chōbō	4	3—4
Kōchi-wase-hadaka	4	3—4
Pref. Saga		
Hizahachi	3	3—4
Ukibashiro	4	3—4
Pref. Nagasaki		
Golden Melon	i	i—0
Ōgara	4	3—4
Pref. Kumamoto		
Nigōkumajima	3	3—4
Wase-hadaka	4	3—4
Pref. Ōita		
Kairyō-hadaka	4	3—4
Ōita-hizahachi	4	3—4
Pref. Miyazaki		
Hitokawa	3	2—4
Miyazaki-hadaka	3	3—4
Hayatori-hadaka	3	3—4
Pref. Kagoshima		
Golden Melon (Kagoshima)	0	i—0
Kairyō-hizahachi	4	3—4
Nigatsuko	3	2—3
Formosa		
Barley-type	4	2—4
Tainan	4	3—4
Tainan No. 1	4	2—3
Zairai No. 1	4	2—4
Shazan-shu	4	3—4
Indigenous Hulled Varieties		
Nakano-wase	4	3—4
Nochi	4	3—4
Hiroshima-zairai	3	3—4
Kumoi	4	3—4
Natsudaikon(Summer Barley)	4	3—4
Shirozasa	3	2—4
Sotokagi	4	3—4
Yabane	3	3—4
Dajōkan	0	i—0
Kyūgō	4	3—4
Katamen	4	3—4
Hosogara No. 1	0	0—1
Koike-rokkaku No. 2	3	3—4
Kesashiro	3	3—4
Sakaiwa-rokkaku No. 27	4	3—4
Kenyoshi No. 3	0	i—1
Higashiyama No.1	4	3—4
Hida	4	3—4
Gose-shikoku	4	3—4
Nihonsan	0	0—1
Hosogara No. 2, A	0	i—0
Mensury A No. 1 (Iwate)	1	0—2
Mensury A No. 2 (Iwate)	0	i—0
Mensury C (Iwate)	0	0—1

Varieties tested	Typical type	Range of reactions
A-type Chevalier (6-rowed)	i	i—0
A-type Sangatsu	3	2—3
Golden Melon (Ibaragi)	i	i—0
Indigenous Naked Varieties		
Murasakibo	4	3—4
Kitaki-hadaka	3	3—4
Chōshirō	4	3—4
Isejiro	4	3—4
Tashiro-bōzu	4	3—4
Hōzan	3	2—3
Ōuchi No. 1	4	3—4
Oshichi	3	1—3
Shiroseto	4	3—4
Mishimasen	4	3—4
Gun'eki	3	1—3
Awa-mugi	3	1—4
Hizen	4	3—4
Chōhaku	4	3—4
Miho-hadaka No. 10	4	3—4
Kyūshū No. 19	3	3—4
Yamaguchi-hadaka	4	3—4
Hiratsuki	4	3—4
Kuratate	4	3—4
Bred Strains		
Kōnosu No. 25	3	3—4
do No 30	0	i—0
Kinai No. 36	4	3—4
Yane-hadaka	4	3—4
Korean Varieties		
South Chölla		
Kawa-mugi	3	3
Hadaka-mugi	4	3—4
Teisen No. 5	4	3—4
North Chölla		
Zenshū-zairai	4	3—4
Keiroku	4	3—4
South Kyŏngsang		
Tōei-kawa-mugi	4	3—4
Hadaka-mugi	3	2—4
Shinkyō-kawa-mugi	4	3—4
Murasaki-hadaka	4	3—4
Waidō	4	3—4
Shinshū-hadaka	4	3—4
North Kyŏngsang		
Waikan-kawa-mugi	4	3—4
Zairai-shu	3	1—4
Kawa-mugi	2	1—3
Hōka-kawa-mugi	3	3—4
South Chungchŏng		
Tonbori	4	3—4
Uessarupori	4	3—4
North Chungchŏng		
Kawa-mugi	4	3—4
Sō-mugi No. 15	4	3—4
Kyonghwi		
Yōhei-rokkaku	4	3—4
Rokkaku-tama-mugi	4	3—4
Hwanghai		
Kawa-mugi	3	1—4
Konmonpori	2	1—3
Kangwŏn		
Neietsu-rokkaku	4	3—4
South Phyŏngan		
Zairai-kawa-mugi	3	2—4
Zairai	3	3—4
Zairai-shiro-hadaka	3	3—4
North Phyŏngan		
Murasaki-ōmugi	4	3—4
Teishū-zairai	3	2—4
South Hamkyong		
Inunoo	2	1—3
Hōzan-zairai	3	2—3
Anpen-zairai	4	3—4
North Hamkyong		
Kyōjō-rokkaku	3	2—4
Manchurian Varieties		
Vladivostok	2	1—2
Feng T'ien Pai	2	1—3
Harbin Railway Experiment Station Strain 13-8A	2	1—3
Harbin Railway Experiment Station Strain 16-7	2	1—3
Indigenous Variety No. 1	3	2—4
Indigenous Variety No. 2	3	2—4
Feng T'ien Hei	4	3—4
P'êng Chiannng Mu Ling	2	1—3
P'êng Chiang Chao Tung	4	3—4
San Chiang P'o Li	2	1—3
San Chiang Fu Chin	2	1—3

Varieties tested	Typical type	Range of reactions
Chien Tao Yen Chi	2	1—2
Chien Tao Lung Ching	2	1—3
Feng T'ien Hsin Min	4	3—4
Indigenous Variety No.3	4	3—4
Four-rowed Variety	4	3—4
San Ho	4	2—4
T'ung Chiang	3	2—4
Chia Mu Ssŭ	4	3—4
An Ta	4	2—4
Hu Lan	0	i—0
Harbin indigenous Variety	4	3—4
P'o Li	2	2—3
T'ao Nan	2	1—2
San Ch'a Ho	3	3—4
Tung Fêng	1	1—2
Vladivostok	1	0—2
No. 16 - 17	2	2
No. 35 - 1009	0	0
No. 4790 - 10	0	i—0
Ji 35 K - 36 - 964	0	i—0
O. A. C - 21	3	3—4
Hanna (Kung Chu Ling)	0	i—0
Golden Melon (Kung Chu Ling)	0	i—0
No. 22 - 1	0	0
No. 1703 - 1	i	i—0
No. 1881 - 3	0	i—0
No. 4887 - 3	i	i
Chinese Varieties and Others		
Northern China		
Lu T'ai	4	3—4
I Hsien	4	2—4
Li Ts'un No. 1	4	3—4
Chiao Hsien No. 3	4	3—4
Chiao Hsien No. 5	4	3—4
Chang Tien	4	3—4
Central China		
P'u K'ou No. 1	3	2—4
Wu Hu	4	3—4
Ku Tsê No. 1	4	3—4
Liu Ssŭ Chiao No. 1	4	2—4
Chiu Chiang	4	3—4
Jui Ch'ang No. 2	4	2—4
Mu Shih Chiang No. 1	4	3—4
Mu Shih Chiang No. 2	4	3—4
Ti T'ien Ch'iao No. 1	4	2—4
do No. 2	4	3—4
do No. 3	4	3—4
Pai Sha-Ta Yeh No. 1	3	1—4
Ta Yeh No. 2	4	3—4
do No. 5	4	3—4
do No. 12	4	3—4
Pao An Chên No. 1	4	3—4
do No. 3	4	2—4
do No. 4	4	3—4
Chin Niu Chên No. 3	4	2—4
Hsin An Tien No. 3	4	3—4
Chiao Chuang No. 3	4	3—4
do No. 6	4	3—4
Chêng Chou No. 1	4	3—4
Ch'ang Chou No. 1	4	3—4
Southeastern Asia		
E. P. 973 (type 2)	3	3—4
J. 20 (type 3)	0	i—0
J. 5 (type 3)	0	0—1
H. E. S. No. 1 (type 15)	1	0—1
H. E. S. No. 4 (type 12)	i	i—0
H. E. S. No. 39 (type 16)	4	3—4
A. 222 almora	2	0—2
Irakian Black	3	1—3
Europe and America		
Italian (barley)	2	1—3
French No. 1	4	2—4
Bethges & Ölze St. XIII	i	i—0
Hadostreng	i	i—0
Hanna × Kargyn	2	1—3
Weichenstephaner No. 1	i	i
do No. 2	i	i—0
Svanhals	0	i—0
German Golden	i	i—0
German No. 17	0	i—0
do No. 27	3	2—4
do No. 30	2	0—3
do No. 46	3	2—4
do No. 56	4	3—4
do No. 59	0	i—0
do No. 64	3	3—4
do No. 77	4	3—4
Hanna	2	i—3

Varieties tested	Typical type	Range of reactions	Varieties tested	Typical type	Range of reactions
Greinitzleben	4	2—4	Russian No. 35	2	1—3
Binder	i	i—0	do No. 36	i	i—0
Maja	i	i—0	do No. 42	4	3—4
Opal	i	i	do No. 43	0	i—1
Tammi	4	3—4	do No. 45	4	3—4
Olli	4	2—4	do No. 46	3	2—4
Vankhuri	2	i—3	do No. 60	3	3—4
Vaga	1	i—2	do No. 79	1	1—2
Lennes	3	1—4	do No. 80	3	1—4
Brome	1	i—1	Caucasus	0	i—0
Barbless	4	2—4	Russian No. 7	3	1—3
Sulton	i	i—0	do No. 39788	4	3—4
Chevalier	i	i—0	do No. 41118	0	i—0
Duckbill	3	1—3	do No. 5	4	3—4
Ebisu	0	i—0	do No. 17	4	3—4
Australian Chevalier	3	1—4	do No. 18	2	1—2
Chilian Chevalier	i	i	do No. 19	4	3—4
Manmuth	i	i—0	do No. 25	4	3—4
Trebi No. 4	i	i—0	do No. 54	3	2—4
do No. 1	0	i—0	do No. 81	1	0—1
Coast No. 2	0	i—0	do No. 73	3	3—4
Nudideficiens	4	3—4	**Wild Species and Varieties**		
Minn. No. 90-5	2	0—2	H. Spontaneum	3	3
Colsess No. 1, a	1	1—2	H. Spontaneum nigrum	i	i
do No. 1, b	1	1—2	H. Spont. 2558 (Persia)	1	0—1
Nigronudum	1	1—2	do. No. 3325 (Mesopotamia)	1	1
Coast No. 3	3	1—3	do No. 4140 (Afghanistan)	3	2—4
do No. 5	3	1—3	do No. 4142 (Afghanistan)	3	2—3
Brachytic	4	2—4	do No. 4164 (Afghanistan)	4	3—4
Russia			do No. 5060 (Caucasus)	1	1—2
Russian No. 1	2	1—3	do No. 5101 (Turkestan)	4	3—4
do No. 8	i	i—0	do No. 6586 (Afghanistan)	i	i—0
do No. 10	3	2—4	H. murinum (Oregon)	i	i
do No. 12	2	1—3	H. Gussoneanum(California)	0	i—1
do No. 14	3	2—4	H. pusillum (Kansaus)	0	i—1
do No. 20	3	2—4			

Remarks: The highly susceptible varieties among those tested in this investigation are excluded in this table, and shown in the following table.

Appendix 2. Names of the highly susceptible barley varieties to powdery mildew, tested in this investigation.*

Japanese Varieties

Hokkaidō: Wase-yonkaku, Taiki-ōmugi, Sangatusko No. 1, Marumi No. 16. *Miyagi*: Miyagi-rokkaku No. 23, Hozoroi, Miyako A, Hadaka-mugi. *Akita*: Rikuu No. 1, No. 2, Ōu No. 1, No. 2, No. 4, No. 5, No. 6, Gozen, Okachi, Iwatebizen No. 2, Australian, Eekendorfer. *Yamagata*: Hoso-mugi A, Hanbōzu. *Fukushima*: Zairai-rokkaku, Bizenwase No. 53, Miyagi-rokkaku No. 2, Sekitori No. 3, Ban-sekitori No. 1, Aizu No. 7, Shiro-hadaka No. 1, *Niigata*: Ōmugi-shin No. 1, Zenkōji, Rokkaku No. 1, Nagaoka. *Toyama*: Sekitori, Ugawa-ōmugi *Ishikawa*: Kahokugun-zairai, Nomigun-zairai, Bōzu-ōmugi, Ishikawa-chinko. *Fukui*: Honzō-rokkaku, Chikurin-ibaragi No. 3. *Ibaragi*: Hozoroi-ibaragi No. 1, Jōshū-shiro-hadaka. *Tochigi*: Bōzu No. 1, Sekitori No. 1, Toranoo No. 1. *Gunma*. Hakubaku No. 6, Bizen-wase No. 5, Shiro-yoshigara No. 22, Manriki, Sekitori-den No. 2. *Saitama*: Gose-yonkoku-Saki No. 1, Bizen-wase-saki No. 1, Toranoo-saki No. 1, Sekitori-saki No. 1. Kōbai-saki No. 1. *Chiba*: Santoku, Sekitori No. 2. *Tōkyō*. Kingyoku, Shikoku, Okayama. *Kanagawa*: Wase-mino, Kamakura, Ashigara-wase, Shiro-chinko. *Yamanashi*: Hanbōzu, Bizen-wase No. 36, Toranoo No. 7, Suishō-sekitori No. 30 *Nagano*: Dai-rokkaku, Hakubaku, Raiden, Bizen-wase, Toranoo, Sekitori, Baitori, Shinano No. 1. *Gifu*: Kyūshōbō No. 49, Tanikaze No. 105, Shirochinko. *Shizuoka*: Shizuoka-shiro-rokkaku No. 1, Kuro-mugiNo. 148, Iwata-santoku, Kinai-sekitori No. 2, Aka-shinriki, Kobinkatagi. *Aichi*: Shiroguma, Yokozuna, Sakigake, Tanikaze, Kobinkatagi, Ichi-wase, Shiro-ume, *Mie*: Mie-Chinko, Baitori No. 15, Taihaku, Kobinkatagi, Shiro-chinko No. 2. *Shiga*: Shigahozoroi No. 1, Shiga-chinko No. 9, Shiga-hachikoku No. 5, Shiga-wase-hadaka No. 6. *Kyōto*. Dai-rokkaku No. 1, Shiro-ōmugi No. 1, Hachikoku, Shin-shinriki No. 1, Shin-awaji, Aka-shinriki. *Nara*: Yonkoku-mugi, Hakumai No. 1, Nara-wase. *Wakayama*: Tankankodama. *Tottori*: Mizuho No. 2, Shiro-ōmugi, Kobinkatagi. *Shimane*: Hayakiso No. 2, Shimane-ōmugi No. 10, Han-hadaka No. 2, Makibata-ōmugi, Ichinen-mugi No. 2, Kobinkatagi No. 4. *Okayama*: Shindō, Zairai-tanbō, Aizu No. 22, Aizu No. 39, Sōshin No. 2, Shinkō No. 3, Yahazu, Kobinkatagi, Shirotō, Okayama-hadaka No. 1, Kohaku. *Hiroshima*: Baitori No. 11, Kobinkatagi, Shikkishirazu. *Yamaguchi*: Benkei No. 3. *Tokushima*: Tokushima-kagawa No. 5, Wase-hadaka, Shishikui-zairai. *Kagawa*: Kobinkatagi, Yane-hadaka No. 1, Wase-chinko. *Kōchi*: Beppu-zairai, Irino-zairai, Kitagawa-bōzu, Nahari-mubō, Ōishi No. 49. *Fukuoka*: Takeshita, Shinriki-mugi. *Saga*: Katano, Eijō-hadaka, Saga-hadaka, Oni-hadaka No. 1. *Nagasaki*: Mikuriya, Mishima-hadaka, Shimabara-hadaka, Ehime-hadaka No. 1, Nagasaki-wase-hadaka. *Kumamoto*: Hachikoku, Shimabara. *Ōita*: Oita-hadaka, Ōita-nejire, Wase-hadaka, Kobinkatagi. *Miyazaki*: Sagatairyū No. 2, Osaba No. 1, Sangatsu-hadaka No. 1, Nejire No. 2. *Kagoshima*: Kamaore No. 1, Hakubaku No. 8, Wase-hadaka, Kōbai No 1, Shiro-hada, Kagoshima-hadaka. *Formosa*: Indian Barley, Zairai No. 2, Pamir No. 3, Taihoku. *Indigenous Hulled Varieties*: Wase-ōmugi, Haya-ōmugi, Suwa, Haya-mugi, Saitama-nishiki, Yahagi, Shigahayakiso, Suishō-futsū, Fukuhara Rokujō, Hiroshima, Minokuro, Binbō-tasuke, Mie, Oni, Kintoki, Ryōbin, Tanikaze, Niho, Akakawa, Nagoya-bizen, Nagashiki, Yanagi-bo, Jakkūshū, Kinroku, Kinai-usukawa, Ī-ishi, Ao-mugi, Jūshū, Shiro-nishiki, Chikusa, Mitori, Okayama, Bō-ochi, Usumaki, Kagi, Kanazuchi, Komeirazu, Takayama-sangatsu No. 1, Ōeyama-rokkaku No. 1, Sanjaku, Kyōse-rokkaku No. 14, Kinukawa No. 22, Hanbō No. 8, Kairyō-hachikoku, Kairyō-ōmugi, Kuiamari, Kinukawa-gozen No. 22, Hosogara No. 2 A, Wasemugi, M-type Rokkaku-mugi Kyōto-ōmugi, Hitokawa, S-type Hanbō, M-type Haru-ōmugi, A-type Ōeyama-rokkaku. *Indigenous Naked Varieties*: Bijin Genpachi, Kome-hadaka, Mishima, Bōzu-hadaka, Shirodama A, Shirogorō, Ōiki, Mitsuishi, Shiro-miyuki, Akasaka, Hōnen, Tanba-shiro, Narumi-hadaka, Zairai-ao, Kinetoku, Shakkingire, Kokeroku, Tokuji, Totsugawa, Shirodama B, Kikin-shirazu, Wakamatsu, Shinonome, Ao-hadaka, Tamashima, Hashikura, Asahi-hadaka, Kunitomi, Kawaguchi-hadaka, Osome, Sōbē, Wase-shiro, Shinakashi Kairyō No. 1, Kairyō-suzumeyakko, Kairyō-nejireyakko, Kome-hadaka No. 1, Kome-

* The names of the barley varieties are arranged according to their home localities.

hadaka No. 13, Harima No. 3, Miho No. 22, Henro No. 108, Shiro-hadaka, Mogi-hadaka, Wase-hadaka, Bōzu-mochi, Kome-mugi-shu, Shiro-bōzu No. 83, Bōzu, Tarumi. Hōnen No. 6, A-type Rikuu, MihoNo. 3, Mishima No. 41, Kagekiyo. *Bred Strains*: Ōmugi No. 5, No. 15, No. 19, Kūnosu No. 1, No. 6, No. 10, No. 12, No. 14, No. 17, No. 19, No. 22, No. 50, No. 51, No. 53, No. 54, No. 55, No. 57, No. 58, No. 59, No. 60, No. 62, KinaiNo. 27, No. 35, Ikei No. 4, No 14, Muyūji, Kama-irazu, Yūhōshu, Kogane-mugi.

Korean Varieties

Southern Chölla: Kawa-mugi, Kumamoto, Hadaka-mugi, Chinandō-hadaka, Ao-mugi, Fuauwaisarupori. *Northern Chölla* Sō-mugi, Nangenchō No. 2, Ninjitsudō-hadaka, Chosuidō-hadaka, Saigen-zairai, Kinzan-zairai, Neietsu-aki-hadaka. *Southern Kyöngsong*, Shinshū-zairai, Kyoshō-zairai. *Northern Kyöngsang*: Sarupori, Kawamugi, Teisen No. 1, Geijitsu-montonpori, Zairai-hadaka, Zairai-rokkaku, Kōyō-zairai, Sarupori *Southern Chungchöng*: Chunbori, Chōbō, Kōjō-zairai. *Northern Chungchöng*: Sō-mugi, Hadaka-mugi, *Kyongkwi*: Hadaka-mugi, Ōmugi-zairai Ryujin-sō-mugi. *Hwanghai*: Zairai-shu, Zairai-shiro, *Kangwön*: Uruchingun-zairai, Kasengun-zairai,

Chinese Varieties and Others

Manchuria: Fu Chin, Man Kou, Mu Lan, Brio. *Northern China*: Hsin Hsien, Pei Ching, Ting Hsien, Shan Tung, Li Ts'un No. 2. *Central China*: Ta T'ung, Ti Chou, Ti Chou-Tuan Chia Ai No. 1, No. 2, No. 3, Ta Kung Kuan, Ta Kung Kuan-Shou Chia Ch'iao No. 1, No. 2, Tung Liu, Ku Tsê No. 2, No. 3, Liu Ssŭ Chiao No. 2, Ta Wang Miao No. 1, No. 2, Jui Ch'ang No. 1, Hsin Wu Ko No. 1, No. 3, Mu Shih Chiang No. 3, Yang Hsin No. 1, No. 2, No. 3, Pai Sha P'u No. 1, No. 2, Pai Sha-Ta Yeh No. 2, No. 3, No. 4, No. 5, Ta Yeh No. 1, No. 3, No. 4, No. 6, No 7, No. 8, No. 9, No. 10, No. 11, No. 13, No. 14, No. 15, Pao An chên No. 2, No. 5, Chin Niu Chên No. 1, No. 2, Hsin An TienNo. 1, No. 2, Chiao Chuang No. 1, No. 2, No, 4, No. 5, Hsi P'ing, Chêng Chou No. 2, No. 3, No. 4, No. 5, No. 6, No. 7, No. 8, Ch'ang Chou No. 2, Su Chou No. 1, No. 2, Shang Hai No. 1, No. 2, No. 3, No. 4, No. 5, No. 6, No. 7. *Others*: H. E. 3649, Cape, Russian No. 15, H. Spont. 4163 (Afghanistan), H. agriocrithon 6496.