Powdery mildew resistance genes in Northwest European winter barley varieties

Meldugresistensgener i nordvesteuropæiske vinterbygsorter

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Summary

Of the 69 winter barley varieties tested 22 had no powdery mildew resistance genes effective against any of the 15 pathogen cultures applied. Forty-seven varieties had from one and up to four powdery mildew resistance genes derived from one or more of nine different sources of resistance. Thirty-six varieties had one or both resistance genes from 'Ragusa' *(Ml–(41/145)* and *Ml–h);* nine varieties had the two closely linked resistance genes from *Hordeum spontaneum* line 204 *(Ml–a6* and *Ml-a(Sp2));* four had resistance from 'Wong' *(Ml–(Wo));* two had one or both genes *Ml-g* and *Ml-(CP)* probably from 'Weihenstephan CP'; two had gene *Ml-a4* from unknown sources; one had gene *Ml-a7* from 'Rogers'; one had gene *Ml-a(Ar)* from 'Emir'; and two had not-identified genes. Several varieties had additional, unidentified resistance, usually producing a moderately susceptible reaction. Most of the resistances are of limited practical value due to prevalence of the corresponding virulences in the Northwest European pathogen population, and due to their presence in spring barley varieties. The only exception may be the 'Wong' resistance that may be long lasting due to the relatively high infection type.

A new powdery mildew resistance gene tentatively designated *Ml-a(Sp2)* was disclosed in the derivatives of *H. spontaneum* line H 204; it is closely linked in coupling to gene *Ml-a6,* and confers a 2-3n infection type.

Key words: Powdery mildew, resistance, genes, winter barley, barley varieties.

Resumé

Kimplanter af 69 vinterbygsorter og nogle byglinier med kendte meldugsresistensgener blev afprøvet med 15 udvalgte isolater af bygmeldug. På grundlag af afprøvningens resultater og oplysninger om sorternes afstamning er det udledt, hvilke resistensgener den enkelte bygsort har. De 69 sorter er anført alfabetisk med angivelser af deres ejer/forædler, deres afstamning og deres meldugresistens.

22 sorter har ingen påviselige resistensgener, og 47 har ét, to, tre eller fire resistensgener, der stammer fra følgende 9 kilder. Resistensgenerne *Ml-(41/145)* og *Ml-h* fra 'Ragusa' er enkeltvis eller begge til stede i 36 sorter. *Ml-a6* og et nyt, hertil nært koblet gen betegnet *Ml-a(Sp2)* fra *Hordeum spontaneum* linie 204 findes i 9 sorter. Resistens – kaldet *Ml-(Wo)* – fra 'Wong' findes i 4 sorter. *Ml-g* og

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i ét tilfælde *Ml-(CP)*, begge fra 'Weihenstephan CP', er i 2 sorter. *Ml-a4* fra en ukendt kilde er i 2 sorter, *Ml-a7* fra 'Rogers' er i 1 sort, og *Ml-a(Ar)* fra 'Emir' er i 1 sort. Desuden har 2 sorter resistens fra to ukendte kilder. Dertil kommer, at i alt 7 sorter har ekstra resistens fra ukendte kilder.

Alle de resistensgener, der er til stede i de 69 vinterbygsorter, har nok begrænset værdi for nutidens vinterbygdyrkning, da sorter med disse gener angribes mere eller mindre af meldug i Nordvesteuropa. Det må tilskrives, at de fleste af disse resistensgener har været til stede i vinter- eller vårbygsorter med stor udbredelse i mange år, således at meldugpopulationen har haft mulighed for at ophobe de korresponderende virulensgener. En undtagelse herfra er tilsyneladende resistensen fra 'Wong' og muligvis en af de ukendte resistenser ('Capri'), som begge er effektive over for de anvendte meldugisolater. Disse to resistenser betinger dog en forholdsvis høj infektionstype og kan derfor muligvis overvintre levende meldug.

Nøgleord: Bygmeldug, resistens, gener, vinterbyg, bygsorter.

Introduction

Spring barley (*Hordeum vulgare* L.) varieties with major genes for resistance to the powdery mildew fungus (*Erysiphe graminis* DC. ex Mérat *f.sp. hordei* Marchal) have been widely grown in Denmark since the middle sixties. Growing of winter barley was banned from 1968 to 1978 to protect the large area of about 1.5 mil. ha spring barley from powdery mildew overwintering on the winter barley crop. The appearance of more effective fungicides and increased yield of winter barley has changed the situation. Abolition of the ban in 1979 has increased the interest for possible powdery mildew resistance genes in winter barley.

Previously, powdery mildew resistance genes in 106 Northwest European spring barley varities were identified by *Torp, Jensen* and *Jørgensen* (1978). The aim of the present investigation was to identify the powdery mildew resistance genes in Northwest European winter barley varieties, predominantly those that may be grown in Denmark.

Material and Methods

A total of 69 winter barley varieties and lines were analyzed for powdery mildew resistance spectra. Most of them were selected due to their occurrence on the national list in Germany (FRG), The Netherlands, Sweden, and U.K., in 1977–1979 (Beschreibende Sortenliste 1977–1980, Beschrijvende Rassenlist voor Landbouwgewassen 1977, Beskrivande Sortlista 1978, and Description of Cereal Varieties 1977), respectively. These lists comprise a total of 48 different winter barley varieties. Thirty-six of these were tested together with 12 new varieties and lines from the official trials in Denmark in 1979, and from the European Brewery Convention trials in 1979 (*J. Rasmussen* and *J. Larsen*, pers. comm.). Furthermore, 21 old varieties appearing in the pedigrees of several of the actual varieties were also tested.

As reference material the powdery mildew resistance donors given in the pedigrees of the 69 varieties were chosen, along with some varieties and lines with known genes for powdery mildew resistance. In addition, we included five barley varieties with known genes for powdery mildew resistance that have been used in the breeding of spring barley. These 15 entries are listed in Table 1.

Seed samples of the barley varieties and lines were from the collection at Risø or were kindly supplied by *E. Bollerup*, The Pajbjerg Foundation, Denmark; *J. Larsen*, Carlsberg, Denmark; *Aa. Munk*, Sejet, Denmark; *H. Hänsel*, Probstdorfer, Austria; the collection in Gatersleben, Germany (GDR); and the USDA Small Grains Collection, Beltsville, U.S.A.

Fifteen cultures of the powdery mildew fungus, i.e. clones of the fungus propagated from single conidia or colonies, were used. They were selected according to the results of prior testing, in order to obtain virulence/avirulence genes in such combinations that the maximum number of the expected resistance genes could be differentiated.

Table 1. Barley varieties or lines with known genes for powdery mildew resistance
Bygsorter eller linier med kendte meldugresistensgener

Resistance *Resistens*	Variety or line *Sort eller linie*	Gene(s) *Gen(er)*	Ref.*
Ragusa b	Ragusa b	Ml-(41/145)+Ml-h	14
Weihenstephan 41/145	Weihenstephan 41/145	Ml-(41/145)	14
Weihenstephan 37/136	Weihenstephan 37/136	Ml-h	15
Weihenstephan CP	Weihenst. CP 127422	Ml-g+Ml-(CP)	13
Goldfoil	Goldfoil CI 928	Ml-g	5
Wong	Wong CI 6728	Ml-(Wo)**	22
HOR 1063	HOR 1063	Ml-a4***	14
Rogers	Rogers CI 9174	Ml-a7+Ml-?	15
Arabische	Emir	Ml-a(Ar)***	13
H. spontaneum 204	Voldagsen 8141/44	Ml-a6+Ml-a(Sp2)***	7
H. laevigatum	Bomi	Ml-(La)	13
Monte Cristo	Mona	Ml-a9+Ml-a4***	13
Lyallpur	Nordal	Ml-a7+Ml-a4***	13
Rupee	Rupal	Ml-a(Rul)***	13
Algerian	Tyra	Ml-a	13

* The numbers refer to those in the list of references. (Tallene henviser til tallene i litteraturlisten).
** Designation of the 'Wong' resistance in this study. (Betegnelse for 'Wong' resistensen i denne publikation).
*** Genes *Ml-a4, Ml-a(Ar), Ml-a(Rul)*, and *Ml-a(Sp2)* are proposed to be designated *Ml-k, Ml-a12, Ml-a13*, and *Ml-a14*, respectively in *H. Giese, J. Helms Jørgensen, H. P. Jensen*, and *J. Jensen:* Linkage relationships of powdery mildew resistance genes on barley chromosome 5. – Hereditas (in press). (Generne *Ml-a4, Ml-a(Ar), Ml-a(Rul)* og *Ml-a(Sp2)* er foreslået betegnet hhv. *Ml-k, Ml-a12, Ml-a13* og *Ml-a14* iflg. ovennævnte reference).

Five of the cultures, A6(290), Em A30(1488), C15(1416), JEH 22 (140675-18-e4-e1), and 63.1, are described in our earlier publication on spring barley *(Torp et al.,* 1978). The following seven cultures were received from the collectors: Culture Dj B10 collected in the Netherlands by *A. Balkema-Boomstra* (pers. comm.), and MK 24-76 in Sweden by *J. Meyer* (pers. comm.). Cultures JEH28 (130675-60-e5), JEH29 (M 22), and JEH36 (M 31-10) were from Denmark *(J. E. Hermansen,* pers. comm.). JEH29 is a spontaneous *Ml-g* virulent mutant of JEH28 *(Hermansen,* 1980). Cultures TY4 (VDH154/72), TY5 (VLP 2.2240) were collected in Denmark by *C. Holm Nielsen* (pers. comm.). Finally, the cultures R 71/1, R 63 and R 153 were collected in 1971, 1978, and 1979, respectively at Risø.

The disease tests of the winter barleys were carried out by inoculating the first-leaf stage seedlings and scoring them after about 10 days according to the 0–4 scale as described previously *(Torp et al.,* 1978). The test with Em A30 was conducted twice as a number of important conclusions are based on the reaction to this culture.

The analysis of the tests was carried out according to the gene-for-gene hypothesis previously shown to be valid for the pathogen/host system of powdery mildew/barley *(Moseman,* 1966). The genotype of each variety was inferred by holding together the infection types, and resistance spectra obtained in the present investigation, and the available information about the donors, and the origin of the varieties.

Results

Resistance spectra

The seedling tests revealed a total of 17 different resistance spectra within the winter barley varieties. These are listed in Table 2, which also shows the normal, low infection types and the genes or likely genes responsible for the different reactions. The majority of the spectra are differentiated by significant variations in the pattern of resistant and susceptible reactions to the 15 pa-

Table 2. The 17 resistance spectra, the known resistance genes, the infection types, and the patterns of reaction to the 15 mildew cultures
De 17 resistensspektre, de kendte resistensgener, infektionstyperne og reaktionen over for de 15 meldugisolater

Spectrum number *Spektrum nummer*	Spectrum designation *Spektrum betegnelse*	Resistance conditioned by gene(s) *Resistens betinget af gen(er)*	Normal infection type(s) when resistant *Normal(e) infektionstype(r) ved resistens*	Reaction to culture* *Reaktion over for isolat* A6	EmA30	C15	DjB10	JEH22	JEH28	JEH29	JEH36	MK24-76	R71/1	R63	R153	TY4	TY5	63.1
1	Ragusa b	Ml-(41/145)	0 = R_1	R_1	R_1	S	R_2	R_2	S	S	S	S	S	S	S	R_2	S	S
		+ Ml-h	1–2cn = R_2															
2	Weihenst. 41/145	Ml-(41/145)	0 = R	R	R	S	S	S	S	S	S	S	S	S	S	S	S	S
3	Weihenst. 37/136	Ml-h	1–2cn = R	R	S	S	R	R	S	S	S	S	S	S	S	R	S	S
4	Weihenstephan CP	Ml-g	0 = R_1	R_1	R_1	S	S	S	R_1	S	S	S	R_1	R_1	S	R_2	R_1	S
		+ Ml-(CP)	1cn = R_2															
5	Goldfoil	Ml-g	0 = R	R	R	S	S	S	R	S	S	S	R	R	S	S	R	S
6	Wong	Ml-(Wo)	3c = R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
7	HOR 1063	Ml-a4**	1cN = R	R	R	R	R	R	S	S	S	S	R	R	R	R	R	R
8	Rogers	Ml-a7	0–1n = R_1	R_1	R_1	R_1	R_1	R_1	S	S	S	R_1	R_1	S	R_1	R_2	R_2	S
		+ Ml-?	1–2cN = R_2															
9	Arabische	Ml-a(Ar)**	0 = R	R	S	R	R	R	R	R	S	R	S	R	R	S	R	R
10	*H. spontaneum*	Ml-a6	0 = R_1	R_1	R_2	R_1	R_1	S	S	S	S	R_1	R_1	R_2	R_2	R_1	S	R_1
		+Ml-a(Sp2)**	2–3n = R_2															
11	Ragusa b + *H. spontaneum*	Ml-(41/145)	0 = R_1	R_1	R_1	R_1	R_1	R_2	S	S	S	R_1	R_1	R_3	R_3	R_1	S	R_1
		+ Ml-h	1–2cn = R_2															
		+ Ml-a6	0 = R_1															
		+ Ml-a(Sp2)**	2–3n = R_3															
12	Weihenst. 41/145 + *H. spontaneum*	Ml-(41/145)	0 = R_1	R_1	R_1	R_1	R_1	S	S	S	S	R_1	R_1	R_2	R_2	R_1	S	R_1
		+ Ml-a6	0 = R_1															
		+ Ml-a(Sp2)**	2–3n = R_2															

Table 2. (continued)

Spectrum number *Spektrum nummer*	Spectrum designation *Spektrum betegnelse*	Resistance conditioned by gene(s) *Resistens betinget af gen(er)*	Normal infection type(s) when resistant *Normal(e) infektionstype(r) ved resistens*	Reaction to culture* *Reaktion over for isolat*															
				A6	EmA30	C15	DjB10	JEH22	JEH28	JEH29	JEH36	MK24-76	R71/1	R63	R153	TY4	TY5	63.1
13	Weihenst. 37/136 + *H. spontaneum*	Ml-h + Ml-a6 + Ml-a(Sp2)**	1–2cn = R_2 0 = R_1 2–3n = R_3	R_1	R_3	R_1	R_1	R_2	S	S	S	R_1	R_1	R_3	R_3	R_1	S	R_1
14	Weihenst. 41/145 + Wong	Ml-(41/145) + Ml-(Wo)	0 = R_1 3c = R_2	R_1	R_1	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2
15	Herta	Ml-?	1–2Cn = R	S	S	S	S	S	S	S	S	S	S	S	S	R	S	S
16	Banteng	Ml-? Ml-?	1–2cn = R_1 2–3c = R_2	R_2	S	S	R_1	R_1	R_2	R_2	S	S	S	S	R_2	R_1	R_2	R_2
17		None		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

*R = resistant, S = susceptible. The R_1, R_2 and R_3's are only valid within each spectrum. *(R = resistent, S = modtagelig. R_1, R_2 og R_3'erne gælder kun inden for hvert enkelt spektrum).*

) se footnote * in Table 1. *(se fodnote *** i tabel 1).*

thogen cultures. The spectra within three groups, however, are closely related, i.e. numbers 1, 2, and 3; numbers 4 and 5; numbers 10, 11, 12, and 13.

Spectra numbers 1-10 are conferred by resistance from one donor each. Spectra numbers 11-14 are conferred by resistance from two donors each, while spectra numbers 15 and 16 are not-identifiable. Furthermore, some varieties ('Birgit', 'Capri', 'Dunja', 'Dura', 'Ola', 'Fenella', and 'Tapir') show unidentified, additional resistance. Spectrum number 17 represents varieties susceptible to all the 15 applied pathogen cultures.

The 17 spectra are noted below; the barley varieties and the donors or lines with known genes within each spectrum, and the resistance genes involved are described.

Spectrum number 1 (Ragusa b) comprises 'Ragusa b', and the nine varieties: 'Ago', 'Ambio', 'Astrix', 'Birgit' that has some unidentified infection type 3-4c resistance in addition, 'Hauters Wintergerste', 'Katja', 'Marilyn', 'Mädru', and 'Perga'.

The resistance in the winter barley line 'Ragusa b' was discovered in 1930 by *Honeker* (cf. *Wolfe & Schwarzbach,* 1978a) and has been used extensively in breeding winter barley varieties in Germany. 'Ragusa b' possesses two dominant, independently inherited genes, *Ml-(41/145)* and *Ml-h,* conditioning infection types 0 and 1-2cn, respectively; the genes are present singly in the two lines 'Weihenstephan 41/145' and 'Weihenstephan 37/136' *(Nover,* 1957, *Nover & Lehman,* 1968, *Wiberg,* 1974a). The gene in 'Weihenstephan 37/136' is supposed to be identical to gene *Ml-h (Moseman et al.,* 1965, *Nover et al.,* 1968, *Wolfe,* 1972).

Spectrum number 2 (Weihenstephan 41/145) comprises the 14 varieties: 'Dea', 'Dunja', 'Dura', 'Espe', 'Firlbecks Vierzeilige', 'Gerbel', 'Hydra', 'Igri', 'Malta', 'Peragis 12 Melior', 'Senta', 'Sonja', 'Tapir', and 'Tilli' in addition to the line 'Weihenstephan 41/145'. Three of the varieties, 'Dunja', 'Dura', and 'Tapir', have some unidentified infection type 3-4c resistance in addition. This may be the »field resistance« suggested to be present in 'Dura' *(E. Schwarzbach,* pers. comm.).

The resistance is conditioned by a single dominant gene, *Ml-(41/145).* This gene is weakly linked to the *Ml-a* locus on chromosome 5, but independent of the *Ml-(HOR 1063)* gene *(Wiberg,* 1974a, b), which is identical to gene *Ml-a4.*

Spectrum number 3 (Weihenstephan 37/136) comprises the line 'Weihenstephan 37/136' and the varieties: 'Bollo', 'Regia', and 'Testa'. The resistance to mildew is conditioned by a single dominant gene, independent of *Ml-g, Ml-a, Ml-k,* and *Ml-p,* and is considered to be gene *Ml-h,* the same as in 'Hanna' (cf. above and *Wiberg,* 1974b).

Spectrum number 4 (Weihenstephan CP) comprises only 'Capri' in addition to 'Weihenstephan CP 127422', which has two resistance genes *Ml-g* and *Ml-(CP)* located on chromosome 4 conditioning infection types 0 and 1cn, respectively, *(Torp et al.,* 1978). 'Capri' has in addition a third, unidentified resistance, *Ml-?,* of 2-3cn infection type. 'Capri' was not susceptible to any of the 15 cultures applied.

Spectrum number 5 (Goldfoil) comprises only line 'RPB 26-73D' in addition to 'Goldfoil' CI 928, which carry *Ml-g (Moseman,* 1966). This spectrum differs from spectrum number 4 only in the high reaction to culture TY4 indicating that gene *Ml-(CP)* is not present. 'Fenella' has in addition resistance of 3n infection type, *Ml-?,* to some cultures virulent on 'Goldfoil'.

Spectrum number 6 (Wong) comprises the varieties 'Hudson' and 'Ogra' besides 'Wong' CI 6728. 'Wong' is a hybrid made in China between 'Orel' and an unnamed variety and is reported highly resistant to powdery mildew (22). 'Wong' has infection type 3c with a reduced number of colonies with all cultures; in the present investigation this resistance is designated *Ml-(Wo).* Varieties with 'Wong' resistance are difficult to separate from susceptible ones in seedling tests.

Spectrum number 7 (HOR 1063) comprises two barleys, 'Ackermanns Tschermack' and line 'R. 201112' in addition to 'HOR 1063', which carry *Ml-a4 (Wiberg,* 1974a), that is apparently identical to *Ml-k* (cf. *Torp et al.,* 1978,), and conditioning infection type 1cN.

Spectrum number 8 (Rogers) comprises 'Ola', and the donor 'Rogers' CI 9174. 'Rogers' is selected from Composite Cross III (22); it has a single dominant gene at or near the *Ml-a* locus conferring resistance to all cultures except those with the *Ml-a7* virulence gene *(Wiberg,* 1974b). In the present investigation the resistance spectrum of 'Rogers' corresponds to that of *Ml-a7* in 'Nordal' (cf. *Torp et al.,* 1978). The two infection types, 0-1n and 1-2cN, respectively, indicate, however, that a second gene, *Ml-?*, may be present. This in turn is not *Ml-a4* due to the susceptibility to culture 63.1; it may, however, be the same as the second gene in Long Glumes (cf. *Torp et al.,* 1978).

Spectrum number 9 (Arabische) comprises 'Maris Trojan' and the ancestor 'Emir'. The resistance of infection type 0 or 0-1n is conditioned by a single semidominant gene, *Ml-a(Ar),* at the *Ml-a* locus *(H. Giese,* pers. comm.).

Spectrum number 10 (H. spontaneum) comprises only 'Barbo' and 'Voldagsen 8141/44', the latter having gene *Ml-a6* with infection type 0 *(Moseman et al.,* 1965). In the present study 'Barbo' and 'Voldagsen 8141/44' have, however, a 2-3n reaction to cultures Em A30, R 63 and R 153 indicating the presence of a second gene in addition to gene *Ml-a6*. As this gene is closely linked in the coupling phase to gene *Ml-a6 (H. Giese,* pers. comm.), and as it is the second gene derived from *Hordeum spontaneum* line H 204 we provisionally designate this new gene *Ml-a(Sp2)*.

Spectrum number 11 (Ragusa b and *H. spontaneum)* comprises 'P. 526', 'Vogelsanger Früh', 'Vogelsanger Gold', and 'Hasso'. This spectrum combines spectra 1 and 10 conditioned by genes *Ml-(41/145), Ml-h, Ml-a6,* and *Ml-a(Sp2)*.

Spectrum number 12 (Weihenstephan 41/145 and *H. spontaneum)* comprises 'Mammut', 'Palatia' and the line 'V.LP 2.4960'. This spectrum combines spectra 2 and 10 conditioned by genes *Ml-(41/145), Ml-a6,* and *Ml-a(Sp2)*.

Spectrum number 13 (Weihenstephan 37/136 and *H. spontaneum)* comprises only 'Kiruna'. This spectrum combines spectra 3 and 10 conditioned by genes *Ml-h, Ml-a6,* and *Ml-a(Sp2)*.

Spectrum number 14 (Weihenstephan 41/145 and Wong) comprises 'Doris' and 'Hexa'. This spectrum combines spectra 3 and 6 conditioned by *Ml-h* and *Ml-(Wo)*.

Spectrum number 15 (Herta) comprises 'Fimbul II' which reacts with infection type 1-2Cn to culture TY 4 in the present study. The present and supplementary tests of 'Fimbul II' and of the spring barley variety 'Herta' (cf. *Torp et al.,* 1978) suggest that 'Fimbul II' and 'Herta' carry the same unidentified gene *Ml-?*.

Spectrum number 16 (Banteng) comprises 'Banteng' with infection types 1-2cn and 2-3c, which indicate that two genes are involved. The donor and genes are, however, not identified.

Spectrum number 17 comprises 22 varieties susceptible to all 15 cultures: 'Atlantis', 'Breustedts Atlas', 'Breustedts Schladener I', 'Carstens zweiz. Wintergerste', 'Escourgeon Grignon', 'Friedrichwerter Berg', 'Glatta', 'Hatif Grignon', 'Herfordia', 'Hoppel', 'Jumbo', 'Leon', 'Majo', 'Manon', 'Maris Otter', 'Mirra', 'Pella', 'Pioner', 'Tavern', 'Tschermacks zweiz.', 'Urania', and 'Vinesco'.

The resistance conferred by genes *Ml-a9* in 'Mona', *Ml-a(Ru1)* in 'Rupal', and *Ml-a* in 'Tyra' (cf. Table 1) were not found in the winter barleys tested. Gene *Ml-(La)* in 'Bomi', that is widely distributed in Danish spring barleys and confers a 2-3cn infection type, could not be distinguished with certainty from the 2-3cn resistance present in the winter barley variety 'Capri'.

Barley varieties

The 69 winter barley varieties are listed below in alphabetical order according to their names or designations, followed by the CI or HOR numbers (accession number in the USDA Small Grains Collection in Beltsville, Maryland, U.S.A., or in the collection in Gatersleben (GDR), respectively) when known. Then the names of the owners/breeders of the varieties are given when known. The reaction of the varieties to powdery mildew refers solely to the results obtained in the present study. The origin is given next, followed by a reference or a number referring to the list of

references. The genotype is that inferred by the present authors based on the present results.

'Ackermanns Tschermacks', HOR 2041, J. Ackermann & Co., Irlbach, FRG.*
Reaction: Spectrum 7 (HOR 1063). Infection type 1cN.
Origin: Unknown.
Genotype: Gene *Ml-a4*.

'Ago', F. von Lochow-Petkus, GmbH, Bergen, FRG.
Reaction: Spectrum 1 (Ragusa b). Infection types 0 and 1-2cn.
Origin: From '3412' *(J. Rasmussen,* pers. comm.).
Genotype: Genes *Ml-(41/145)* and *Ml-h*. The information about the origin is insufficient to verify the presence of the genes determined by the spectrum.

'Ambio', F. von Lochow-Petkus, GmbH, Bergen, FRG.
Reaction: Spectrum 1 (Ragusa b). Infection types 0 and 1-2cn.
Origin: ('3941' × 'Perga') × 'Melior' *(J. Rasmussen,* pers. comm.).
Genotype: Genes *Ml-(41/145)* and *Ml-h* from 'Perga'.

'Astrix', Florimond Desprez, Cappelle par Templeuve, France.
Reaction: Spectrum 1 (Ragusa b). Infection types 0 and 1-2cn.
Origin: '256711' × ('Ares' × 'Hatif Grignon') (23).
Genotype: Genes *Ml-(41/145)* and *Ml-h*. The information about the resistance in the ancestors is insufficient to verify the presence of the genes determined by the spectrum.

'Atlantis', HOR 3242, Otto Breustedt GmbH, Schladen, FRG.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: ('Friedrichswerther' × 'Chiro Chiko') × 'Breustedt 6129' (24b).
Genotype: No resistance genes apparent.

'Banteng', R. J. Mansholt, Westpolder, and G. Gertsema, Groningen, Netherlands.
Reaction: Spectrum 16 (Banteng). Infection types 1-2cn and 2-3 c.
Origin: (('Platen 2349' × 'Vinesco') × 'Dea') × 'Jumbo' (26).
Genotype: The two infection types suggest the presence of two genes. They may be derived only from 'Platen 2349', because the other ancestors are either susceptible or 'Dea' with gene *Ml-(41/145)*. Only the 2-3c reaction of 'Banteng' to culture A6 exclude that *Ml-h* could be responsible for the 1-2cn reaction obtained with three other isolates. The lack of *Ml-h* is, however, supported in tests with other cultures at Tystofte Experimental Station *(C. Holm Nielsen,* pers. comm.).

'Barbo', F. von Lochow-Petkus, GmbH, Bergen, FRG.
Reaction: Spectrum 10 *(H. spontaneum)*. Infection types 0 and 2-3n.
Origin: ('3941' × 'Perga') × 'Melior' *(J. Rasmussen,* pers. comm.).
Genotype: Genes *Ml-a6* and *Ml-a(Sp2)*. 'Barbo' may have *Ml-a6* and *Ml-a(Sp2)* from the ancestor '3941'; genes *Ml-(41/145)* and *Ml-h* in the ancestor 'Perga' have not been transferred.

'Birgit', W. von Borries-Eckendorf, Leopoldshöhe, FRG.
Reaction: Spectrum 1 (Ragusa b). Infection types 0, 1-2cn, and 3-4c.
Origin: ('Herfordia' × 'H. 204') × '702/52' × 'Wssh 382/49', *(J. Rasmussen,* pers. comm.).
Genotype: Genes *Ml-(41/145)* and *Ml-h*. The information about the resistance in the pedigree is insufficient to verify the presence of the genes determined by the spectrum. 'Birgit' has some unidentified infection type 3-4c resistance; it has, however, not genes *Ml-a6* and *Ml-a(Sp2)* from line 'H. 204' in the pedigree.

* In the description of the varieties, the Federal Republic of Germany, the German Democratic Republic, and the United Kingdom are denoted by FRG, GDR, and UK, respectively.

'Bollo', F. von Lochow-Petkus, GmbH, Bergen, FRG.
Reaction: Spectrum 3 (Weihenstephan 37/136). Infection type 1-2cn.
Origin: ('3941' × 'Atlas') × 'Hauters' *(J. Rasmussen,* pers. comm.).
Genotype: Gene *Ml-h* derived from 'Hauters'; gene *Ml-(41/145)* has not been transferred.

'Breustedts Atlas', Otto Breustedt GmbH, Schladen, FRG.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Breustedts Stam' × 'Schladener I' (24b).
Genotype: No resistance genes apparent.

'Breustedts Schladener I', HOR 2269, Otto Breustedt GmbH, Schladen, FRG.
Reaction: Spectrum 15. Susceptible to all 15 cultures.
Origin: 'Friedrichwerther Berg' × ('Eckendorfer' × 'Schwarze'). *(E. Rehse,* pers. comm.).
Genotype: No resistance genes apparent.

'Capri', Rijksstation voor Plantenveredeling, Gembloux, Belgium.
Reaction: Spectrum 4 (Weihenstephan CP). Infection types 0, 1cn and 2-3cn.
Origin: 'Manon' × 'Mädru' (25).
Genotype: Genes *Ml-g, Ml-(CP),* and *Ml-?*. The resistance genes in 'Capri' are not in accordance with the parents, which are 'Manon', susceptible, and 'Mädru' with *Ml-(41/145)* and *Ml-h*. 'Capri' has an unidentified infection type 2-3cn resistance which cannot be distinguished from that of *Ml-(La)* in 'Bomi'; it was not susceptible to any of the 15 cultures.

'Carstens zweizeilige Wintergerste', HOR 2, Toni Heidenreich, Bad Swartau, FRG.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Wintergerste' × 'Sommergerste' (24b).
Genotype: No resistance genes apparent.

'Dea', HOR 3255, W. Engelen, Büchling, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: (('Ragusa' × 'Peragis 12') × 'Heilsfranken' × 'Friedrichwerther Berg' × 'Tschermacks zweiz.') × (('Ragusa' × 'Mahndorfer') 'Bolivia' × 'Ragusa') (24b).
Genotype: Gene *Ml-(41/145)* derived from 'Ragusa'; *Ml-h* in 'Ragusa' has not been transferred.

'Dido' see 'Tavern'.

'Doris', W. von Borries-Eckendorf, Leopoldshöhe, FRG.
Reaction: Spectrum 14 (Weihenstephan 41/145 and Wong). Infection types 0 and 3c.
Origin: ('Eck.' × 'Mahndorfer' × 'Wong') × 'Mädru' *(J. Rasmussen,* pers. comm.).
Genotype: Gene *Ml-(41/145)* and *Ml-(Wo)* from 'Mädru' and 'Wong', respectively. Gene *Ml-h* in 'Mädru' has not been transferred.

'Dunja', W. Engelen, Büchling, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection types 0 and 3-4c.
Origin: 'Firlbecks vierz.' × 'Ungar. R 52' (24b).
Genotype: Gene *Ml-(41/145)* derived from 'Firlbecks vierz.'; 'Dunja' has unidentified 3-4c infection type resistance.

'Dura', Q. Streng and E. Eder, Aspachhof, Post Uffenheim, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection types 0 and 3-4c.
Origin: 'Ragusa' × 'Peragis' × 'Doria' (24b).
Genotype: Gene *Ml-(41/145)* derived from 'Ragusa'; *Ml-h* in 'Ragusa' has not been transferred. 'Dura' has unidentified 3-4c infection type resistance. This may be the »field resistance« suggested to be present in 'Dura' *(E. Schwarzbach,* pers. comm.).

'Escourgeon Grignon', HOR 2624, Grignon, France.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: Unknown.
Genotype: No resistance genes apparent.

'Espe', Bezirk Mittelfranken, Triesdorf, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: 'Triesdorf 4731' × 'Dina' × 'Mädru' (25).
Genotype: Gene *Ml-(41/145)* derived from 'Mädru', but *Ml-h* has not been transferred.

'Fenella', Rothwell Plant Breeders Ltd., Lincoln, U.K.
Reaction: Spectrum 5 (Goldfoil). Infection types 0 and 3n.
Origin: 'Desprez 55146' × 'Inra 10.66' *(N. H. Chamberlain,* pers. comm.).
Genotype: Genes *Ml-g* and *Ml-?*. The information about the resistance of the parents is insufficient to verify the presence of *Ml-g*. In addition to *Ml-g* 'Fenella' has unidentified resistance of infection type 3n, *Ml-?*.

'Fimbul II', W. Weibull AB., Landskrona, Sweden.
Reaction: Spectrum 15 ('Herta'). Susceptible to all cultures except TY4, which gives an infection type 1-2Cn, as it also gives with the spring barley variety 'Herta'.
Origin: Selection from 'Fimbul I' ('Tjekoslovakiskt' × 'Gull') (21).
Genotype: The data suggest that 'Fimbul II' may have an unidentified gene present in some spring barley varieties (cf. *Torp et al.,* 1978).

'Firlbecks vierzeilige', HOR 3218, Firlbeck KG, Atting-Rimkam, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: 'Mahndorfer' × 'Victoria' × 'Ragusa' × 'Friedrichwerther Berg' (24a).
Genotype: Gene *Ml-(41/145)* derived from 'Ragusa', but *Ml-h* has not been transferred.

'Friedrichwerther Berg', HOR 2272.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: Unknown.
Genotype: No resistance genes apparent.

'Gerbel', Florimond Desprez, Cappelle par Templeuve, France.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: ('Ager' × 'Jumbo') × 'FDE 244-95' (23).
Genotype: Gene *Ml-(41/145)* may be derived from 'Ager' or 'FDE 244-95'.

'Glatta', W. von Borries-Eckendorf, Leopoldshöhe, FRG.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: ((Friedrichwerther' × '835/36') × 'M IV') × 'Friedrichwerther 865/36' (24b).
Genotype: No resistance genes apparent.

'Hasso', F. von Lochow-Petkus, GmbH, Bergen, FRG.
Reaction: Spectrum 11 (Ragusa b and *H. spontaneum).* Infection types 0, 1-2cn, and 2-3n.
Origin: 'Dura' × '12563' *(J. Rasmussen,* pers. comm.).
Genotype: Genes *Ml-(41/145), Ml-h, Ml-a6* and *Ml-a(Sp2). Ml-(41/145)* derived from 'Dura'. The information about the resistance of the other parent is insuffient to verify the presence of the other genes as determined by the spectrum.

'Hatif Grignon', CI 10417, Grignon, France.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: Selection from landrace (12).
Genotype: No resistance genes apparent.

'Hauters Wintergerste', HOR 2349, H. Schmidt, Landau-Queichheim, FRG.
Reaction: Spectrum 1 (Ragusa b). Infection types 0 and 1-2cn.
Origin: (('Ragusa' × 'Peragis 12') × 'Heilsfranken' × 'Friedrichwerther Berg' × 'Tschermack zweiz.') × (('Ragusa' × 'Mahndorfer') × ('Bolivia' × 'Ragusa')) (24b).
Genotype: Ml-(41/145) and *Ml-h* derived from 'Ragusa'.

'Herfordia', HOR 3248, Gebrüder Dippe, Saatzucht GmbH, Herford, FRG.

Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Peragis Stamm' × 'Schladener' (24b).
Genotype: No resistance genes apparent.

'Hexa', R. J. Mansholt, Westpolder, and G. Gertsema, Groningen, Netherlands.
Reaction: Spectrum 14 (Weihenstephan 41/145 and Wong). Infection types 0 and 3c.
Origin: 'Vulcan' × 'Jumbo' (25).
Genotype: Gene *Ml-(41/145)* and *Ml-(Wo)* may both be derived from 'Vulcan' for which we lack information.

'Hoppel', ('Hop') Blondeau, Bersée, France.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: ('Hybrid 456' × 'Feebar') × 'Hatif Grignon' (23).
Genotype: No resistance genes apparent.

'Hudson', HOR 3264, Cornell Agricultural Experiment Station, Ithaca, U.S.A.
Reaction: Spectrum 6 (Wong). Infection type 3c and a reduced number of colonies.
Origin: 'Michigan Winter' × 'Wong' (22).
Genotype: Ml-(Wo) derived from 'Wong'.

'Hydra', B. Müller, Büchbrunn, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: 'Malta' × 'Hauters 4r' × 'Carsten' × 'Astrid' × 'Carlsberg II' (25).
Genotype: Gene *Ml-(41/145)* derived from 'Hauters 4r', but not *Ml-h*.

'Igri', J. Ackermann & Co., Irlbach, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: ('820' × '1427') × 'Ingrid' (23).
Genotype: Gene *Ml-(41/145)* may be derived from '820' or '1427'.

'Jumbo', HOR 3168, R. J. Mansholt, Westpolder, and G. Gertsema, Groningen, Netherlands.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Vindicat' × 'Breustedt 75/29' *(J. Rasmussen,* pers. comm.).
Genotype: No resistance genes apparent.

'Katja', W. Engelen, Büchling, FRG.
Reaction: Spectrum 1 (Ragusa b). Infection types 0 and 1-2cn.
Origin: 'Dea' × 'Herfordia' × 'Sentaline' × 'Hauters 4r' (25).
Genotype: Genes *Ml-(41/145)* and *Ml-h* derived from 'Hauters 4r' and/or 'Dea'.

'Kiruna', O. Streng and E. Eder, Aspachhof, Post Uffenheim, FRG.
Reaction: Spectrum 13 (Weihenstephan 37/136 and *H. spontaneum).* Infection types 0, 1-2cn and 2-3n.
Origin: 'St. Streng' × 'Dura' × 'V. Gold' *(J. Rasmussen,* pers. comm.).
Genotype: Genes *Ml-h, Ml-a6* and *Ml-a(Sp2)* derived from 'V. Gold'; *Ml-(41/145)* present both in 'Dura' and 'V. Gold' has not been transferred.

'Leon', R. J. Mansholt, Westpolder, and G. Gertsema, Groningen, Netherlands.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Herfordia' × 'Dea' *(J. Rasmussen,* pers. comm.).
Genotype: No resistance gene has been transferred from 'Dea'.

'Majo', Toni Heidenreich, Bad Swartau, FRG.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Dea' × 'Hauters' *(J. Rasmussen,* pers. comm.).
Genotype: No resistance genes has been transferred from the parents.

'Malta', J. Ackermann & Co., Irlbach, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: (('Carstens zweiz.' × 'Area') × 'Dea') × 'Herfordia' (23).
Genotype: Gene *Ml-(41/145)* derived from 'Dea'.

'Mammut', W. von Borries-Eckendorf, Leopoldshöhe, FRG.
Reaction: Spectrum 12 (Weihenstephan 41/145 and *H. spontaneum)*. Infection types 0 and 2-3n.
Origin: 'V. Gold' × ('Mädru' × 'Weissenhause st. 382/49) *(J. Rasmussen,* pers. comm.).
Genotype: Genes *Ml-(41/145), Ml-a6* and *Ml-a(Sp2)* derived from 'V. Gold' and/or 'Mädru', gene *Ml-h* has not been transferred.

'Manon', Rijksstation voor Plantenveredeling, Gembloux, Belgium.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Bordia' × 'Gembloux 165' (12).
Genotype: No resistance genes apparent.

'Marilyn', Pflanzenzucht Oberlimpurg, Dr. Franck, Schwäbisch Hall, FRG.
Reaction: Spectrum 1 (Ragusa b). Infection types 0 and 1-2cn.
Origin: Unknown.
Genotype: Genes *Ml-(41/145)* and *Ml-h.*

'Maris Otter', National Seed Development Organization Ltd., Cambridge, U.K.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Proctor' × 'Pioneer' (23).
Genotype: No resistance genes apparent.

'Maris Trojan', National Seed Development Organization Ltd., Cambridge, U.K.
Reaction: Spectrum 9 (Arabische). Infection type 0.
Origin: ('Emir' × 'M. Concord'[2]) × ('C 205' × 'M. Otter'[3]) × 'Carstens Wintergerste' × ('France 7' × ('M. Concord' × 'M. Puma')) (23).
Genotype: Gene *Ml-a(Ar)* derived from 'Emir'. Genes *Ml-a6* and *Ml-a(Sp2)* in 'M. Concord' are not transferred.

'Mirra', W. von Borries-Eckendorf, Leopoldshöhe, FRG.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'G. 109' × 'Herfordia' (23).
Genotype: No resistance genes apparent.

'Mädru', HOR 3244, W. von Borries-Eckendorf, Leopoldshöhe, FRG.
Reaction: Spectrum 1 (Ragusa b). Infection types 0 and 1-2cn.
Origin: 'Mahndorf.' × 'Ragusa' × 'Bolivia' × 'Nacktgerste' (24b).
Genotype: Genes *Ml-(41/145)* and *Ml-h* derived from 'Ragusa'.

'Ogra', HOR 3307, F. von Lochow-Petkus, GmbH, Bergen, FRG.
Reaction: Spectrum 6 (Wong). Infection type 3c and a reduced number of colonies.
Origin: ('Domina' × 'Melchior') × 'Wong' × 'Atlas' *(J. Rasmussen,* pers. comm.).
Genotype: Ml-(Wo) derived from 'Wong'.

'Ola', Sveriges Utsädesförening, Svalöv, Sweden.
Reaction: Spectrum 8 (Rogers). Infection types 0-1n and 1-2cN.
Origin: 'Svalöf 08009' bc × 'Rogers' (25).
Genotype: Gene *Ml-a7* and *Ml-?* derived from 'Rogers'.

'Palatia',
Reaction: Spectrum 12 (Weihenstephan 41/145 and *H. spontaneum)*. Infection types 0 and 2-3n.
Origin: Unknown.
Genotype: Genes *Ml-(41/145), Ml-a6* and *Ml-a(Sp2).*

'Pella', HOR 3057, BV Landbouwbureau, Wiersum, Netherlands.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'LBW 335' × 'Urania' (26).
Genotype: No resistance genes apparent.

'Peragis 12 Melior', HOR 3063, Heine Peragis, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0 and 1-2cn. The seed sample tested was heterogenous.

Origin: 'Peragis Stamm' × 'Weihenst. Mehltaures'. (24b).
Genotype: Part of the tested sample carried gene *Ml-(41/145)* which may be derived from 'Weihenst. Mehltaures'; another part may carry *Ml-h*.

'Perga', Heine Peragis, FRG.
Reaction: Spectrum 1 (Ragusa b). Infection types 0 and 1-2cn.
Origin: ('Ragusa' × 'Mahnd. Victoria' × 'Bolivia' × 'Ragusa') × 'Mahnd. Victoria' × 'Ragusa' × 'Nackgerste' (24b).
Genotype: *Ml-(41/145)* and *Ml-h* derived from 'Ragusa'.

'Pioneer', HOR 2914, National Seed Development Organization Ltd., Cambridge, U.K.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Tschermacks zweiz.' × 'Spratt Archer' (23).
Genotype: No resistance genes apparent.

'P. 526', Probstdorfer Saatzucht, GmbH, Vienna, Austria.
Reaction: Spectrum 11 (Ragusa b and *H. spontaneum*). Infection types 0, 1-2cn and 2-3n.
Origin: (('Vinesco' × 'Urania') × 'Hauters') × 'V. Gold' *(H. Hänsel,* pers. comm.).
Genotype: Genes *Ml-(41/145),, Ml-h, Ml-a6,* and *Ml-a(Sp2)* derived from 'V. Gold' and/or 'Hauters'.

'Regia', Firlbeck KG, Atting-Rimkam, FRG.
Reaction: Spectrum 3 (Weihenstephan 37/136). Infection type 1-2cn.
Origin: 'Hauters' × 'Dina' (26).
Genotype: Gene *Ml-h* derived from 'Hauters' from which *Ml-(41/145)* has not been transferred.

'Robusta' see 'Testa'.

'RPB 26-73D' see 'Fenella'.

'R. 201112', Risø, Roskilde, Denmark.
Reaction: Spectrum 7 (HOR 1063). Infection type 1cN.
Origin: Selection from 'Breustedts Atlas' *(J. H. Jørgensen,* unpubl.).
Genotype: Gene *Ml-a4* probably derived from an outcross in 'Breustedts Atlas'.

'Senta', HOR 3247, W. Engelen, Büchling, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: 'Firlbecks vierz.' × 'Dea' (24b).
Genotype: Gene *Ml-(41/145)* derived from either 'Firlbecks vierz.' or 'Dea'.

'Sonja', W. Engelen, Büchling, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: 'Tria' × 'Malta' (23).
Genotype: Gene *Ml-(41/145)* derived from 'Malta'.

'Tapir', R. J. Mansholt, Westpolder, and G. Gertsema, Groningen, Netherlands.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection types 0 and 3-4c.
Origin: 'DSGW 169' × 'Pella' *(J. Rasmussen,* pers. comm.).
Genotype: Gene *Ml-(41/145)* and infection type 3-4c resistance. The information about the resistance of the parents is insufficient to verify the gene determined by the spectrum.

'Tavern' ('Dido'), Pflanzenzucht Oberlimpurg, Dr. Franck, Schwäbisch Hall, FRG.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: ('Tria' × 'Senta') × 'St. 820' *(J. Rasmussen,* pers. comm.).
Genotype: No resistance gene has been transferred from 'Senta'.

'Testa' ('Robusta'), Probstdorfer Saatzucht, GmbH, Vienna, Austria.
Reaction: Spectrum 3 (Weihenstephan 37/136). Infection type 1-2cn. Test of three different seed samples shows that some of the plants have infection type 0 with culture EmA30, which is virulent on *Ml-h* indicating that the variety is contaminated with another resistance.

Origin: ('Vinesco' × 'Urania') × 'Hauters' *(J. Rasmussen,* pers. comm.).
Genotype: Gene *Ml-h* derived from 'Hauters'; in addition a part of the variety may have gene *Ml-(41/145).*

'Tilli', Otto Breustedt GmbH, Schladen, FRG.
Reaction: Spectrum 2 (Weihenstephan 41/145). Infection type 0.
Origin: 'Herfordia Wi.' × 'Firlbecks Wi.' *(J. Rasmussen,* pers. comm.).
Genotype: Gene *Ml-(41/145)* probably derived from 'Firlbecks Wi.'.

'Tschermacks zweizeilige Wintergerste', HOR 1667, Probstdorfer Saatzucht GmbH, Vienna, Austria.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: (('Kirches Wintergerste' × 'Kirches 2-zeilige') × ('4-zeilige Wintergerste' × 'Heines Riesenwintergerste') (1).
Genotype: No resistance genes apparent.

'Urania',
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Vindicat' × 'Escourgeon 185/79' *(E. Rehse,* pers. comm.).
Genotype: No resistance genes apparent.

'Vinesco', Fond Bevordering Veredeling Landbouwgewassen, Netherlands.
Reaction: Spectrum 17. Susceptible to all 15 cultures.
Origin: 'Vindicat' × 'Escourgeon 185/79' *(J. Rasmussen,* pers. comm.).
Genotype: No resistance genes apparent.

'Vogelsanger Früh', Max-Planck-Institut, Köln, FRG.
Reaction: Spectrum 11 (Ragusa b and *H. spontaneum).* Infection types 0, 1-2cn and 2-3n.
Origin: Selection from 'Vogelsanger Gold' *(V. Haahr,* pers. comm.).
Genotype: Genes *Ml-(41/145), Ml-h, Ml-a6* and *Ml-a(Sp2)* derived from 'Vogelsanger Gold'.

'Vogelsanger Gold', Max-Planck-Institut, Köln, FRG.
Reaction: Spectrum 11 (Ragusa b and *H. spontaneum).* Infection types 0, 1-2cn and 2-3n.
Origin: ('Isaria' × *'Hordeum spont. nigr.')* × 'Wintergerste'[5] (24b).
Genotype: Genes *Ml-(41/145), Ml-h, Ml-a6* and *Ml-a(Sp2)* the two last derived from *'Hordeum spontaneum nigrum'* and *Ml-(41/145)* and *Ml-h* probably derived from 'Wintergerste'.

'v. LP 2.2240' see 'Hasso'.

'v. LP 2.4960', F. von Lochow-Petkus, GmbH, Bergen, FRG.
Reaction: Spectrum 12 (Weihenstephan 41/145 and *H. spontaneum).* Infection types 0 and 2-3n.
Origin: ('Dunja' × 'Barbo') × 'V. Gold' *(J. Rasmussen,* pers. comm.).
Genotype: Genes *Ml-(41/145), Ml-a6* and *Ml-a(Sp2)* derived from 'V. Gold' and/or 'Dunja' and 'Barbo'. Gene *Ml-h* has, however, not been transferred.

Discussion

Of the 69 winter barleys tested, 47 showed resistance. The resistance genes are derived from at least nine different sources or donors, and revealed – due to donor gene combinations – 17 different resistance spectra including the fully susceptible. The resistance to be expected from the origin of each variety were consistent with the genotypes deduced from the resistance spectra for 17 barleys: 'Ambio', 'Hauters Wintergerste', 'Katja', 'Mädru', and 'Perga' carrying *Ml-(41/145)* and *Ml-h;* 'Dunja', 'Malta', 'Peragis 12 Melior', 'Senta', 'Sonja', and 'Tilli' carrying *Ml-(41/145);* 'Hudson' and 'Ogra' carrying *Ml-(Wo);* 'Ola' carrying *Ml-a7* and *Ml-?;* 'P. 526', 'Vogelsanger Früh' and 'Vogelsanger Gold' carrying *Ml-(41/145), Ml-h, Ml-a6,* and *Ml-a(Sp2).*

As several of the donors carry more than one resistance gene, the resistance of their derivatives may differ. Seventeen barleys were without one or two genes present in their donors: 'Banteng', 'Bollo', 'Kiruna', 'Regia', and 'Testa' where gene *Ml-(41/145)* is absent; 'Dea', 'Doris',

'Dura', 'Espe', 'Firlbecks vierz.', 'Hydra', 'Mammut', and 'v. LP 2.4960' where gene *Ml-h* is absent; 'Barbo' and 'Capri' with *Ml-(41/145)* and *Ml-h* absent; 'Birgit' and 'Maris Trojan' with *Ml-a6* and *Ml-a(Sp2)* absent.

Insufficient information was available on the parents and their possible resistance for the following 15 barleys: 'Ago', 'Astrix', 'Birgit', and 'Marilyn' carrying *Ml-(41/145)* and *Ml-h;* 'Gerbel', 'Igri', and 'Tapir' carrying *Ml-(41/145);* 'Fenella' carrying *Ml-g* and *Ml-?;* 'Ackermanns Tschermack' carrying *Ml-a4;* 'Barbo' carrying *Ml-a6* and *Ml-a(Sp2);* 'Hasso' carrying *Ml-(41/145), Ml-h, Ml-a6,* and *Ml-a(Sp2);* 'Palatia' carrying *Ml-(41/145), Ml-a6,* and *Ml-(Sp2);* 'Hexa' carrying *Ml-(41/145)* and *Ml-(Wo);* and 'Banteng' and 'Fimbul II' carrying not-identified genes.

Two barleys have one or two resistance genes more than indicated by the pedigree. The resistance spectrum of 'Capri' suggests the presence of *Ml-g, Ml-(CP),* and *Ml-?;* as the two first genes are known to be absent in the parents, the parentage stated is less probable. Line 'R. 201112' having gene *Ml-a4* was selected in the susceptible variety 'Breustedts Atlas' *(J. Helms Jørgensen,* unpubl. data).

The following seven barleys have additional, unidentified resistance: 'Birgit', 'Capri', 'Dunja', 'Dura', 'Ola', 'Fenella', and 'Tapir'. For 'Birgit', 'Dunja', 'Dura', and 'Tapir' it is of infection type 3-4c that is difficult to distinguish from the susceptible type, for 'Capri' it is 2-3cn with all cultures applied, and for 'Fenella' it is infection type 3n with some cultures. Finally, 'Ola' has type 1-2c with one of the cultures applied in addition to that conferred by gene *Ml-a7.*

Among the 23 barleys apparently without resistance genes 'Leon' and 'Tavern' could be expected to have gene *Ml-(41/145),* and 'Majo' to have *Ml-(41/145)* and *Ml-h* from their ancestors.

The genotypes determined for 'Astrix', *Ml-(41/145)* and *Ml-h,* for 'Igri', 'Malta', and 'Sonja', *Ml-(41/145),* and susceptibility in 'Hoppel' and 'Maris Otter' are in agreement with *Wolfe* (1977). The gene *Ml-(41/145)* present in 'Gerbel' and 'Senta' according to their spectra are, however, not in accordance with the findings of *Ml-(41/145)* and *Ml-h* by *Wolfe* (1977). The presence of one or both of the 'Ragusa' genes in 'Dunja', 'Dura', 'Hauters Wintergerste', 'Mädru', and 'Senta' agrees with the findings of *Nover* and *Lehmann* (1968).

A comparison of the present results with the German (FRG) list of varieties for 1980 (ref. 20 d), which gives symbols for the powdery mildew resistance »factors« present in the winter barley varieties, discloses disagreements in 19 out of the 25 varieties that are common in the list and the present study. Eight varieties with the symbol »keine« (Resistenzfaktoren) have – according to the present study – gene *Ml-(41/145)* and one variety has genes *Ml-(41/145)* and *Ml-h;* one variety with the symbol »u1« and one with »–« have *Ml-(41/145);* three varieties with the symbol »Ha« (Resistenzfaktor identisch mit dem von 'Hauters') (apparently gene *Ml-h)* have the two genes *Ml-(41/145)* and *Ml-h;* one variety with »Wo« has gene *Ml-(41/145)* in addition to *Ml-(Wo);* and four varieties with »Sp« have either *Ml-h* or *Ml-(41/145)* and *Ml-h* in addition to the two linked *'H. spontaneum'* resistance genes, *Ml-a6* and *Ml-a(Sp2).* Thus, the disagreement is only on the two 'Ragusa' genes, of which the one, *Ml-(41/145),* is apparently disregarded in the German list of varieties, and the other, *Ml-h,* is not detected when present together with the *'H. spontaneum'* resistance.

The resistance present in most of the winter barley varieties are different from that present in most of the spring barley varieties *(Torp et al.,* 1978). This agrees with a strategy for utilizing genes for powdery mildew resistance, namely, that resistance genes should not be in common for the two barley types. The first resistance, from 'Ragusa', *Ml-(41/145)* and *Ml-h,* only known from winter barleys, is present fully or partly in 36 of the 47 winter barley varieties with resistance. The second resistance, from 'Wong', *Ml-(Wo),* present in four varieties is recently introduced; the infection type is moderately susceptible with all cultures applies; it is possible that the selection pressure favouring 'Wong' virulence in the mildew population may only be moderate, and conse-

quently, that this resistance may be long lasting. Due to the relatively high infection type varieties with the 'Wong' resistance may act as overwintering host for the powdery mildew. The third resistance, from *H. spontaneum, Ml-a6* and *Ml-a(Sp2),* which is present in nine winter barley varieties has never been distributed in spring barley varieties in Denmark (cf. *Jørgensen & Torp,* 1978). The fourth resistance, present in 'Banteng', have two intermediate infection types. The last five resistance genes, *Ml-g, Ml-a7, Ml-a(Ar), Ml-a4,* and *Ml-?,* represented only by 'Capri' and 'Fenella', by 'Ola', by 'Maris Trojan', by the old variety 'Ackermanns Tschermack' and line 'R. 201112', and by 'Fimbul II', respectively, are apparently present also in spring barleys.

The finding of a new powdery mildew resistance gene, tentatively designated *Ml-a(Sp2),* in derivatives of *H. spontaneum* line H 204, and closely linked to gene *Ml-a6 (H. Giese,* pers. comm.), is an additional case of spontaneous »pyramidizing« of powdery mildew resistance genes in barley. It appears that most if not all of the outstanding sources of powdery mildew resistance owe their broad spectrum of resistance to the presence of two or more, often closely linked, resistance genes (cf. e.g., *Moseman & Jørgensen,* 1973, *Wiberg,* 1974b).

Unfortunately, most of the powdery mildew resistance genes present in the winter barley varieties are of limited practical value due to the prevalence of the corresponding virulence genes in the pathogen population in Northwest Europe (cf. e.g., *Jørgensen & Torp,* 1978, *Wolfe & Schwarzbach,* 1978a, b). The 'Ragusa' resistance *(Ml-(41/145)* and/or *Ml-h)* became widely distributed in winter barley varieties in Germany (FRG) in the 1950's with a consequent upsurge of the virulent C races. Spring barley varieties with 'Weihenstephan CP' resistance *(Ml-g* and *Ml-(CP))* increased in popularity after World War II, so that, by 1960, these varieties were considered susceptible. The *'H. spontaneum'* resistance *(Ml-a6* and *Ml-a(Sp2))* was released commercially in spring barley in the early 1960's, and the corresponding virulence increased rapidly in the mid and late 1960's. The 'Arabische' resistance *(Ml-a(Ar))* became widespread in Denmark (variety 'Emir') and the U.K. (variety 'Sultan') about 1970, and they were considered susceptible after a few years. In Denmark these varieties were replaced by varieties with 'Lyallpur' resistance *(Ml-a7* and *Ml-a4),* which in turn became susceptible by about 1975.

More recent data from Denmark support these trends. Scores for powdery mildew attack on winter barley varieties in field trials in 1978 and 1979 *(Rasmussen,* 1979) show that varieties with resistance genes from 'Ragusa', *'H. spontaneum',* and 'Wong', singly or combined, only somewhat retard the powdery mildew attack; they had scores from 3.3 to 5.5 (on scale 0-10) when 'Mirra' without any known resistance genes had a score of 5.2. Furthermore, determinations of the virulence frequencies in the pathogen population at Risø in 1977 and 1978 (*Jørgensen,* 1978, *L. Munk,* pers. comm.) have shown relatively high frequencies of the virulences corresponding to all the resistances present in the winter barley varieties described here with three exceptions. The two exceptions are the 'Wong' and the 'Capri' virulences that were not observed, and the third exception is the 'Arabische' virulence; it has declined to a level of around 10 per cent, probably due to the disappearance from the Danish market between 1972 and 1975 (cf. *Jørgensen & Torp,* 1978) of varieties with this resistance, and the absence of this resistance to a great extent in Germany (FRG) (cf. *Wolfe & Schwarzbach,* 1978b).

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