

The isolation of a further new race of *Erysiphe graminis* DC. f.sp. *hordei* Marchal and the genetical basis of the resistance of 'Lyallpur 3645'

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Abstract

Besides the race "Amsel-C₂", a new race of barley mildew (*Erysiphe graminis* DC. f.sp. *hordei* Marchal) has been isolated from a still resistant variety 'L 94'. This race has provisionally been denoted "Lyallpur 3645-C₁₇". It is able to overcome the resistance of 'Lyallpur 3645'.

It appears most likely that the barley variety 'Lyallpur 3645' has two closely linked genes for resistance, one for hypersensitivity and the other for an intermediate type of reaction. The first is present in the variety 'Amsel' and both in 'Heine 4808'.

The reactions indicate that race "Lyallpur 3645-C₁₇" has only one gene for virulence in addition to the ones present in race "Amsel-C₂".

A survey is given of the seedling reaction of some 60 previously very or moderately resistant varieties, after infection with the two new races.

Introduction

The varieties 'Amsel', 'Arabische' and 'L 94', the last one originating from Ethiopia, are included in the European Barley Disease Nursery, and have been tested at several sites in Europe for a number of years.

'Amsel' is a mildew resistant German variety, derived from 'Lyallpur 3645'. 'Arabische' and 'L 94' are known to show some mildew pustules under field conditions, but only rarely so, and are thus considered resistant. During the summer of 1968 some pustules of barley mildew, *Erysiphe graminis* D.C. f.sp. *hordei* Marchal, were found on all three varieties at our trial field.

We were anxious to know whether these pustules were formed either fortuitously by one of the races already known or by a new race, and in the latter event, what would be the reaction to it of varieties related to 'Amsel'.

Materials and methods

Spores from the pustules mentioned were used to infect detached leaves of the susceptible variety 'Haisa', floating on a 50 ppm aqueous benzimidazole solution, as described by Wolfe (1965). In this way cultures were maintained until the autumn.

By then of each culture ten subcultures were made by multiplying individual pustules, using the same technique. When sporulation occurred the subcultures were

multiplied on seedlings of 'Haisa', and tested several times under greenhouse conditions on seedlings of the set of varieties used for differentiating races of barley mildew as described by Nover et al. (1968). In addition the varieties from which the isolates were originally made were included, and also some varieties related to 'Amsel', viz. 'Lyallpur 3645', 'Heine 4808' (which like 'Amsel', is derived from 'Lyallpur 3645') a new breeder's-line derived from 'Heine 4808' and two other 'Lyallpur'-varieties.

Reaction readings were made 10 days after inoculation according to the following scale of types:

- 0 no symptoms visible
- I necrotic hypersensitivity reaction
- II necrotic flecks with some mycelium, no sporulation
- III sporulation on necrobiotic or heavy chlorotic tissue
- IV sporulation on green or light chlorotic tissue.

Results and discussion

The isolate from 'Arabische' as well as all ten subcultures reacted as race C₁₀. 'Arabische' did not show a susceptible type of attack when reinfected with the isolate.

The culture from 'Amsel' appears to be exactly similar to the one which in the meantime has been described by Nover (1968) and provisionally denoted by her as race "Amsel-C₂". On the set of differentials it reacts like race C₂, showing susceptibility (type IV) on the three Weihenstephaner-lines CP 127422, 37/136 and 41/145, and on the variety Hor 1657.

The curious fact that 'Lyallpur 3645', which is the source of resistance of 'Amsel', appeared moderately resistant in our trials, has already been mentioned by Nover.

A new race

The third isolate, from L94, has been multiplied and used for some months in other trials concerned with the study of mildew resistance. Plants of both the F₁ {(Menelik × Heine 4808) × Haisa} and the F₁ {(Menelik × Heine 4808) × Heine 4808} appeared susceptible with a type IV-reaction. This suggests that something peculiar has happened, since 'Heine 4808' has hitherto reacted to all known races as a resistant variety, the resistance being dominant. Moreover the same plant material has also been tested with race C₅, to which race it was resistant.

The isolate from L94 and the subcultures were tested on the set of differentials and in addition on the varieties 'Amsel', 'Heine 4808' and the 'Lyallpur'-numbers 3645, 3647 and 4595. Furthermore an advanced breeder's-line was included, the mildew resistance of which was derived from 'Heine 4808'. In Table 1 a survey is given of the results.

Based on the pattern of reactions of the ten differentials the cultures would have to be determined as race C₁₇, giving a type IV-reaction with the three Weihenstephaner-lines, 'Anatolien Hor 1063' and 'Indien Hor 1657'. But, in addition, the varieties 'Amsel', 'Heine 4808', the new breeder's-line, and the donor source of resistance of these varieties 'Lyallpur 3645', and 'Lyallpur 4595' appeared fully susceptible. It is remarkable that the new race attacks 'Amsel', 'Heine 4808' and the breeder's-line,

Table 1. Reaction of the differential set and some additional varieties when infected with races C₂, Amsel C₂, C₁₇ and the new race of *Erysiphe graminis* f. sp. *hordei*.

Differential variety	Race			
	C ₂	Amsel C ₂	C ₁₇	X
1. Weihest. CP 127422	IV	IV	IV	IV
2. Weihest. 37/136	IV	IV	IV	IV
3. Weihest. 41/145	IV	IV	IV	IV
4. H. spontaneum H. 204	r	r	r	r
5. Gatersleben Mut. 511	r	r	r	r
6. Gatersleben Mut. 501	r	r	r	r
7. Hor 1063	r	(II-)III	IV	IV
8. Hor 1657	IV	IV	IV	IV
9. Hor 1036	r	r	r	r
10. Algerian	r	r	r	r
Amsel	r	IV	r	IV
Heine 4808	r	II	r	IV
Breeder's-line	r	II	r	IV
Lyallpur-3645	r	(II-)III	r	IV
Lyallpur-3647	r	II	r	II
Lyallpur-4595	r	III	r	IV

Tabel 1. De reactie van het differentiërende sortiment en enkele andere rassen na infecties met de fysio's C₂, Amsel-C₂, C₁₇ en het nieuwe fysio van *Erysiphe graminis* f. sp. *hordei*.

while with race "Amsel-C₂" only 'Amsel' reacts as type IV, the others being still resistant. As is described by Nover (1968), 'Lyallpur 3645' reacts to "Amsel-C₂" with chlorotic to necrotic flecks around the infection site. This is in agreement with our finding of type II-III, i.e. some sporulation upon necrotic tissue. 'Heine 4808' reacts as type II, i.e. necrotic spots without sporulation.

Based on the pattern of attack given in Table 1 it is proposed to denote the new race as "Lyallpur 3645-C₁₇", on the analogy of Nover's notation of "Amsel C₂", at least until there is international agreement to include 'Amsel' and/or 'Lyallpur 3645' (or 'Heine 4808') in the series of differential varieties.

The resistance of 'Lyallpur 3645'

It may be deduced from the results that the resistance of 'Lyallpur 3645' is most probably based on two genes, each of which gives resistance, though one gives the hypersensitivity type reaction and the other an intermediate type. The variety 'Amsel' presumably has received only the first gene, while, from their types of attack, 'Heine 4808' and the breeder's line have inherited both.

It is to be supposed that both genes are closely linked, because Lau (1962) and Karimi (1965) and Scholtz and Nover (1967) concluded that one dominant gene was involved in 'Lyallpur 3645', judging from the results of tests with the races known until then. The situation which arises now after finding two new races is comparable with that reported by Wiberg (1968). It appeared from his tests that the resistance of a series of varieties, which was formerly believed to be based on one dominant gene, is in reality

due to a close linkage of two genes, one of them giving a hypersensitivity type reaction, the other an intermediate type.

It is reasonable to suppose that the gene for resistance in 'Amsel' is present in 'Lyallpur 3645' together with the gene (or gene complex) which confers resistance in the differential variety HOR 1063. This is indicated by the comparable reactions of both 'Hor 1063' and 'Lyallpur 3645' after infection with race "Amsel-C₂", while 'Hor 1063' on the other hand showed in many of our previous trials with other existing races an intermediate type of reaction. If this hypothesis were true it would be sufficient to use the notation "Amsel-C₁₇" and then only 'Amsel' would have to be added as a differential variety.

After infection with both "Amsel-C₂" and "Lyallpur 3645-C₁₇" the variety 'Lyallpur 4595' reacts in exactly the same manner as 'Lyallpur 3645' and therefore presumably contains the same combination of genes for resistance. 'Lyallpur 3647' on the other hand is still resistant to the new races.

It is well known that growing a resistant variety very often sooner or later leads to the finding of one or more races able to overcome this resistance. Recently this has been the case with the variety 'Impala', which was widely spread in The Netherlands and other countries. A group of races, among which were C₄, C₅ and C₁₀, then became predominant. These races are able to overcome the resistance based on the ml_{a6} gene, which is present in 'Impala' in combination with ml_g. As has been shown by Wolfe (1965, 1968) the race spectrum shifts in accordance with the spectrum of commercial varieties.

The finding of both new races in The Netherlands once more indicates the existence within a mildew population of as yet undetermined races. The existing spectrum of commercial varieties does not demand their presence, especially not in the case of "Lyallpur 3645-C₁₇". The variety 'Amsel' is grown in N.W. Germany but not so in The Netherlands, nor other varieties in which possibly the same resistance has been incorporated. According to the research of Hermansen (1968) it would be possible for "Amsel-C₂" to have been brought to us by wind from N.W. Germany. But this seems unlikely in the case of "Lyallpur 3645-C₁₇", since, as far as is known, no commercially grown variety exists the resistance of which is of the type of Lyallpur 3645 or Heine 4808. The results here presented clearly indicate that such a race becomes predominant only when it is selectively favoured by the range of existing varieties. Yet in the breeding material which has been released by the Foundation for Agricultural Plant Breeding the variety 'Heine 4808' has been used many times as a source of mildew resistance. Thus the finding of a new race able to overcome this resistance may be of considerable significance.

Finally a survey is given of the reaction of a series of varieties, hitherto fully or almost fully resistant, after infection with the new race "Lyallpur 3645-C₁₇".

Susceptible (type IV):

'Dans Irisaka', 'Multan-Glabron', 'Cleroff', 'Long Glumes', 'Abessinian 3', 'Chevron', 'Ab. 6208/48', 'Lyallpur P' and 'Wong'.

The first three varieties show some resistant reaction (type III) when infected with "Amsel-C₂". This is comparable with the reaction of Lyallpur 3645. 'Wong' has not been tested with "Amsel-C₂".

Moderately resistant or moderately susceptible (type III):

'Abessinian 12', 'Ab. 14', 'Ab. 23', 'Ab. 1116/47', 'Ab. 1139', 'H. laevigatum L 56', 'Minerva', 'L 99', 'Nigrate', 'EP 74', 'Spiti', 'Arlington Awnless', 'J 20' (II), 'Mian Wali' (II) and 'Zweizeilige BBA 822' (II).

These varieties reacted similar after infection with "Amsel-C₂", except the last three which reacted as indicated between brackets.

Resistant (no sporulation, types 0, I and II):

'Ab. 2', 'Ab. 6', 'Ab. 16', 'Ab. 1102', 'Ab. 1128', 'L 92', 'L 94', 'L 96', 'L 97', 'L 98', 'L 100', 'Ep 71', 'EP 73', 'Arabische', 'Emir', 'Sultan', 'Engledow India', 'Jerusalem II', 'Menelik', 'Lyallpur B.S.', 'Ricardo', 'Rupée', 'Hor 1457', 'Grannenlose zweizeilige', 'Black Russian', 'CI 8503', 'Nigrisubnudum', 'I 25', 'Nudimelanocroton' and 'MC 20'.

All varieties except 'EP 73' after infection with "Amsel-C₂" react with a similar type of resistance. EP 73 shows a type III reaction.

No varieties have been found susceptible to "Amsel-C₂" but moderately or fully resistant to "Lyallpur 3645-C₁₇". This again indicates that "Lyallpur 3645-C₁₇" probably has one gene for virulence in addition to "Amsel-C₂".

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Samenvatting

De isolatie van een nieuw fyso van gerstemeeldauw Erysiphe graminis DC. f.sp. hordei Marchal verduidelijkt de genetische basis van de resistentie van de lijn 'Lyallpur 3645'

Twee fyso's van gerstemeeldauw, *Erysiphe graminis* DC. f.sp. *hordei* Marchal zijn gevonden, waarvan één niet eerder is beschreven. Dit laatste fyso wordt voorlopig aangeduid als "Lyallpur 3645-C₁₇", het andere is het zgn. "Amsel-C₂"-fyso.

Met behulp van beide fyso's is duidelijk geworden dat de lijn 'Lyallpur-3645' twee nauw gekoppelde resistentiegenen bezit; een gen voor een overgevoeligheidsreactie en een ander gen voor een intermediaire reactie.

In het ras 'Amsel' is alleen het overgevoeligheidsgen aanwezig, in 'Heine 4808', evenals 'Amsel' afkomstig van kruisingen met 'Lyallpur 3645', zijn beide genen aanwezig.

Het fyso "Lyallpur-3645-C₁₇" lijkt daarom één gen voor virulentie meer te hebben dan "Amsel-C₂".

Tenslotte is een overzicht gegeven van de kiemplantreactie na infectie met beide fyso's van ongeveer 60 gerstrassen die eerder zeer goed of matig resistent waren.

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