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Genetic Immunity to Apple Mildew Incited by *Podosphaera leucotricha*[1]

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Abstract. **A source of immunity to apple mildew, *Podosphaera leucotricha* (Ell.&Ev.) Salm., derived from a *Malus* species, when crossed with susceptible cultivars, conferred immunity to 50% of its progeny in greenhouse and field tests. Reciprocal crosses indicated a nuclear gene. A greenhouse method for large-scale screening is described.**

Few genetic sources of high resistance or immunity to apple mildew are known. For greatest breeding efficiency, the character should be sexually transmitted, and should be dominant, simply inherited, and stable. Even those cultivars usually considered highly resistant may, under weather conditions highly favorable to the organism, show undesirable susceptibility (8, 10). Immunity thought to be under single gene control was reported by Knight and Alston (4), but later their hypothesis was revised to account for 2 different genes plus modifiers (2, 5, 11).

Progeny data indicate that the resistance observed in cultivars of the dessert apple is under polygenic control (1, 8, 9). The value of this resistance for breeding purposes is diminished by the several years of field screening often necessary to determine the degree of resistance as well as its stablility under varying weather conditions (6, 7, 8). Simply inherited and stable immunity, reliably identifiable at an early plant age in large populations would materially advance progress in breeding for mildew resistance.

In the fall of 1972, greenhouse tests for mildew resistance identified a single plant grown from open-pollinated seed of 'Starking Delicious' as highly resistant. This plant was propagated and tests were continued over the following 2 years in both the greenhouse and the field. On the basis of its complete freedom from mildew infection throughout the series of tests, it was judged to be immune. The distinct foliar lobes, fruit diameter of only 3 cm, and astringent flavor indicated its pollen parent was a *Malus* species.

Propagated trees of this mildew-immune selection (MIS) first bloomed in 1975. MIS was crossed with 'Pricilla' as seed parent, and reciprocally with 'Jonathan'. 'Pricilla' was selected due to its relatively low susceptibility to apple mildew and for its genetic immunity to apple scab incited by *Venturia inaequalis* (Cke.) Wint. 'Jonathan' was chosen for its known high susceptibility to apple mildew and its strong tendency to transmit this character to its progeny. Techniques for pollen collection and controlled crossing were described earlier (3).

Seeds from controlled pollinations were extracted in late Sept., dried for 72 hr, and either stratified at 2 to 3° C or held dry in poly bags at ca–17°. For spring screening tests, seeds were stratified 90 days or more in a mixture of 3 horticultural–grade vermiculite: 2 ground peat, (by vol) and were germinated in this mixture. After germination and production of 1 or 2 true leaves, the seedlings were transplanted to sterilized soil in plant bands. Seeds for fall tests were held frozen until at least 90 days before the desired time of germination, then stratified in poly bags of moist finely ground peat at ca 6 to 7°. The seeds were washed from the peat and planted in plant bands of sterilized soil.

Inoculum for spring greenhouse screening was obtained from heavily-infected 2 or 3 yr old apple seedlings dug the preceding fall, held over winter at 2 to 3° C, and replanted in pots of soil in the greenhouse. New foliage became infected as it was produced, providing abundant spores. For fall greenhouse tests, infected shoots were excised from plants in the field, and held in vessels of water close to and about 0.5 m above the young seedlings being tested. The inoculum sources were shaken lightly at least once daily to release spores. After sporulating infections became visible on susceptible seedlings, the entire test planting was fanned twice daily to spread inoculum to all plants. Spores were also transferred by brush from heavily sporulating infections to plants not showing infection.

In early June, 1976, all seedlings still alive from the spring test were transplanted outdoors close to heavily mildew-infected apple seedlings.

In both spring and fall greenhouse tests, sporulating infections were visible on susceptible foliage within 6 to 7 days after inoculation. Infection spread rapidly over the entire test plantings, result-

Fig. 1. Mildew immune (left) and susceptible (right) siblings from 'Jonathan' × a mildew immune seedlings, spring greenhouse test of 1976.

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Table 1. Segregation of mildew immune:susceptible apple seedlings from controlled crosses in greenhouse tests of spring and fall, 1976.

Progeny	Immune No.	Immune %	Susceptible No.	Susceptible %	X^2 (1:1)	P
Pricilla x MIS[z] (spring test)	42	50.6	41	49.4	0.012	>0.9
Pricilla x MIS (fall test)	82	50.3	81	49.7	0.006	>0.9
Jonathan x MIS (spring test)	43	54.4	36	45.6	0.620	>0.3
MIS x 'Jonathan' (spring test)	27	52.9	24	47.1	0.882	>0.3

[z]MIS = mildew-immune selection.

Table 2. Field incidence of apple mildew infection, June to Oct., 1976, on seedlings which showed immune or susceptible reactions in previous greenhouse test.

Progeny	Greenhouse immune (no.)	Field infected (no.)	Greenhouse susceptible (no.)	Field infected (no.)
Pricilla x MIS[z]	42	0	30[y]	30
Jonathan x MIS	43	0	27[y]	26
MIS x Jonathan	27	0	17[y]	17

[z]MIS = mildew-immune selection.

[y]Fewer susceptible seedlings were field tested than shown in Table 1 due to the death of some plants by destruction of foliage in the greenhouse test.

ing in heavily sporulating infections on both foliage and shoots. Infection on susceptible plants was so heavy that degrees of susceptibility could not be clearly discerned. Some plants in each progeny died as a result of severe infection. The plants tested were thus classified as either immune or susceptible. Those plants in the immune class remained entirely free of any infection throughout the test (Fig. 1). This reaction was identical to that of the MIS parent.

In each progeny, segregation of immune: susceptible plants resulted in 1:1 ratios (Table 1). Chi-Square analyses indicated no significant differences from 1:1 segregation.

The outdoor test under heavy infection pressure during the 1976 growing season resulted in almost no change in the ratios observed in the spring greenhouse test (Table 2). Those seedlings that had been immune in the greenhouse remained entirely free of infection, and with a single exception all of those that had been susceptible in the greenhouse developed further infections in the field. Although the infections on susceptible individuals may have provided additional inoculum, the agreement between the greenhouse test and the field test was of a high order.

The data indicate recovery of a major dominant genetic factor from MIS conferring immunity to *P. leucotricha* in both the greenhouse and the field. Segregation data from reciprocal crosses with 'Jonathan' indicate that a nuclear, rather than a cytoplasmic, factor is involved.

The genetic system reported here appears to be different from that reported by Knight and Alston (4). No clear ratios of immune:susceptible could be discerned from crosses of their immune sources with the susceptible 'Idared' (unpublished data). Neither of the *Malus* species or forms reported to confer immunity (4) existed either nearby or in the vicinity.

The obligate parasitic nature of the pathogen precluded testing against physiologic races other than those existing locally. Widespread testing of immune segregates in other geographic areas is therefore desirable. Nevertheless, the high order of agreement between greenhouse and field tests indicate that with this or a similar genetic system large scale greenhouse screening of young seedlings can reliably be conducted. The combination of this genetic system with the simple screening test should materially aid incorporation of apple mildew immunity into new forms of the cultivated apple.

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A Scarfskin-like Disorder of Apples[1]

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For about 20 years we have noticed a disorder on fruits of apple (*Malus domestica* Borkh.) in our orchards that appears near harvest as red color develops. This disorder usually starts on the upper (stem end) inside cheek as a finely stippled whitish area ranging from a trace to the whole fruit being covered and produces a milky appearance with greatly reduced red color. In severe outbreaks the cuticle becomes slightly roughened but usually the surface is smooth. The disorder has become a serious economic concern especially in 'Rome Beauty' grown in sandy soils. The disorder lowers the grade because affected fruit (>15% of surface covered) is classified by the U.S. Federal-State Inspection Service as a "smooth russet" defect.

This disorder resembles "scarf-skin" described by Beach in 1905 (1) "as a dull or clouded appearance to a red skin as in 'Sweet Winesap' or 'Black Gilliflower' ". It also resembles the characteristic whitish-grey areas found in 'Stayman Winesap'. In 1959 Dayton (2) reported that these light areas in 'Stay-

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