

'Dulong QHI' and 'Redlands Trailblazer', PRSV-W-, ZYMV-, and WMV-resistant Winter Squash Cultivars

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Winter squash or pumpkin [*Cucurbita maxima* Duchesne ex Lam.] is an important culinary vegetable in Australia. Zucchini yellow mosaic virus (ZYMV), the watermelon strain of papaya ringspot virus (PRSV-W), and to a lesser extent watermelon mosaic virus type 2 (WMV) often cause substantial losses in this crop (Greber et al., 1987; Herrington et al., 1989). No cultural practice satisfactorily controls these diseases in commercial crops in Queensland. 'Redlands Trailblazer' and 'Dulong QHI' are gray-skinned, trailing types of winter squash with high levels of resistance to ZYMV, PRSV-W, and WMV. While 'Redlands Trailblazer' was initially developed to provide commercial growers with a virus-resistant winter squash, it did not gain commercial acceptance because it suffered from occasional skin cracking and water-soaked flesh when grown in Queensland. Recently, 'Redlands Trailblazer' has demonstrated the advantage of its virus resistance for use in organic vegetable production where severe and regular ZYMV infections limit the use of other cultivars. 'Dulong QHI' also has high

levels of resistance to ZYMV, PRSV-W, and WMV. It was developed to provide local growers a commercial, multiple virus-resistant winter squash.

Origin

Both 'Redlands Trailblazer' and 'Dulong QHI' originated from a cross between *C. maxima* and *Cucurbita ecuadorensis* Cutler and Whitaker. *Cucurbita maxima* cultivars Queensland Blue and Jarrahdale are variable gray-skinned, firm and orange-fleshed, tan seed-colored, vine types of winter squash susceptible to PRSV-W, ZYMV, and WMV (Herrington et al., 1988a). *Cucurbita maxima* 'Jarrahdale' is the most commonly grown gray-skinned cultivar in Australia. *Cucurbita ecuadorensis* is a wild species from Ecuador (Cutler and Whitaker, 1969) with resistance to PRSV-W, ZYMV, and WMV (Provvidenti et al., 1978, 1984) but with numerous undesirable characteristics, including hard rind and bitter flesh (Cutler and Whitaker, 1969; Metcalf et al., 1982). The initial cross of *C. maxima* 'Queensland Blue (Selected Strain)' with *C. ecuadorensis* was followed by three backcrosses to *C. maxima* 'Queensland Blue' (Selected, Large, and Wallworks Strains, consecutively), two generations of self-pollination, and two generations of open-pollination. A selected plant was then crossed to 'Jarrahdale' (Yates Seed Co.) and to 'W19' (a selection of parentage similar to the preceding). The resultant progeny were intercrossed. The pedigrees of 'Redlands Trailblazer' and 'Dulong QHI' are shared to this point.

For 'Redlands Trailblazer', a selected F₁ plant was self-pollinated and progeny were selected for PRSV-W and ZYMV resistance for a further five generations, then open-pollinated

in isolation for two generations. Resistance to PRSV-W, ZYMV, and WMV was confirmed in samples from the open-pollinated populations.

For 'Dulong QHI', development was more complex but best described as mass selection. Selected F₂ plants were intercrossed, followed by one generation of self-pollination. The resulting F₂ plant was crossed to 'Jarrahdale' (New World Strain) and the subsequent populations mass-selected under open-pollination for six generations (giving population A). A similar population (population B) was produced by one generation of open-pollination following a cross between 'Jarrahdale' (SPS strain) and the third generation of the open-pollination series leading to population A. Populations A and B were randomly mixed and open-pollinated, followed by two generations of self-pollination, then three generations of open-pollination. Most generations were selected for resistance to PRSV-W, ZYMV, and WMV.

Isolates of virus were maintained in *C. maxima* 'Queensland Blue' for PRSV-W, *C. maxima* 'Jarrahdale' for ZYMV, and *Cucurbita pepo* L. 'Regal Black' for WMV. The PRSV-W isolate 505 is the "severe" isolate referred to in Herrington et al. (1989). The ZYMV isolate 293 is the isolate ZYMV-B referred to in Greber et al. (1988). The WMV isolate 369 was originally isolated from unspecified cucurbits in Queensland and confirmed by serology and particle morphology as WMV (Persley, unpublished data).

When selecting for resistance, fully expanded, carborundum-dusted cotyledons of test and control plants were manually inoculated, on each of two consecutive days, with infective tissue ground (1:10–1:20) in 0.1 M phosphate buffer (Herrington et al., 1988b). Either the plants under selection or another sample from the test population were inoculated and evaluated. Disease severity on plants at the 4–5 expanded leaf stage was scored 14–16 d after cotyledonary inoculation as the estimated percentage of leaf area that was chlorotic on the youngest expanded leaf (Herrington et al., 1989). Those plants or families with mildest symptoms were selected. Plants in the final evaluations of resistance in Nov. 1993 and 1999 were similarly inoculated and scored. Using the consecutive day inoculation strategy, all inoculated susceptible control plants of *C. maxima* 'Jarrahdale' or 'Queensland Blue' and, where used, the F₁ (*C. maxima* 'Jarrahdale' × *C. ecuadorensis*), which has a resistance level intermediate between *C. maxima* 'Jarrahdale' and *C. ecuadorensis*, became infected.

The comparative trials were conducted in a glasshouse using standard cultural and evaluation techniques (Herrington et al., 1989). There were between seven and 24 plants of each line distributed over seven or eight pots in each trial. Preliminary analyses of disease severity for the different lines indicated large differences among means. These differences were accompanied by large differences in variability that were not effectively stabilized by the angular transformation. Following further

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statistical examination, the data were appropriately analyzed using plant as the experimental unit. Pairs of lines were compared for severity of a particular disease using two-tailed *t* tests assuming unequal variances.

Description

C. maxima 'Dulong QHI' is an open-pollinated, moderately vigorous, moderately branched, vine-type winter squash that is highly resistant to ZYMV, PRSV-W, and WMV, with medium green, reniform leaves showing no silvering. Sepals on female flowers tend to be petalous. The medium-sized (3.2 kg, 120 × 226 mm), slightly to moderately ribbed, flattened fruit with light to medium gray skin, matures midseason. 'Dulong QHI' fruit have thick (50 mm), well-textured, good-flavored orange flesh, and tan or brownish seeds. One hundred seeds weigh 17.4 g. 'Dulong QHI' is highly resistant to ZYMV, PRSV-W, and WMV following mechanical inoculation of the cotyledons (Table 1). Some systemic movement of virus occurs as seen in isolated chlorotic spots, but mosaic symptoms do not develop.

'Redlands Trailblazer' is an open-pollinated, moderately vigorous, moderately branched, vine-type winter squash that is highly resistant to ZYMV, PRSV-W, and WMV, with medium green, reniform leaves showing no silvering. Leaf blades become moderately incised after about the 20th node but not earlier. A female flower is produced in about every fifth node commencing at the 12th node and the first opens ≈45 days after sowing. The medium-sized (3 kg, 160 × 225 mm), slightly ribbed, flattened globe-shaped fruit with medium gray somewhat dull skin, matures midseason. The rind of 'Redlands Trailblazer' is not hard but in some environments the surface has cracked to varying degrees. 'Redlands Trailblazer' fruit have a small (16 mm) crown, moderately thick (36 mm), orange flesh, and white seeds. One hundred seeds weigh 16 g.

The reaction of 'Redlands Trailblazer' and 'Dulong QHI' to manual inoculation (Herrington et al., 1989) with ZYMV or PRSV-

Table 1. Reactions of winter squash genotypes to artificial inoculation with PRSV-W, ZYMV, and WMV.

Cultivar	Disease severity ^{a, y}					
	ZYMV		PRSV-W		WMV	
	1993	1999	1993	1999	1993	1999
Dulong QHI	---	2.2 a (0.80)	---	0.1 a (0.05)	---	0.2 b (0.06)
Redlands Trailblazer	0.2 a (0.06)	0.4 a (0.13)	0.1 a (0.08)	0.1 a (0.01)	0.2 a (0.04)	0.04 a (0.02)
F ₁ (Jarrahdale × Redlands Trailblazer)	22 b (3.83)	---	11 b (1.6)	---	9 b (1.34)	---
Jarrahdale	89 c (1.78)	95 b (1.01)	58 c (3.76)	87 b (3.51)	72 c (4.41)	84 c (1.66)

^aDisease severity is the percentage leaf area chlorotic 14–16 d after cotyledonary inoculations.

^yMean separation within columns by individual comparisons using two tailed *t* tests, at *P* = 0.05, assuming unequal variances. Parentheses enclose the standard error of the mean. Number of plants assessed varied from 13 to 24 in 1993 and 7 to 16 in 1999.

W usually includes necrotic lesions on the inoculated cotyledons. 'Redlands Trailblazer' and 'Dulong QHI' have maintained high levels of resistance in the fields subjected to high levels of natural disease pressure. With 'Redlands Trailblazer' in hybrid combination with susceptible genotypes the resistance is reduced but still relatively high (Table 1), while that of 'Dulong QHI' is not yet assessed. Our observations suggest, however, that with plants of 'Redlands Trailblazer' crossed with a susceptible pink- or orange-skinned genotype, their resistance is sufficiently reduced to allow, upon infection, substantial areas of the fruit rind to become green, as in the susceptible orange-skinned genotype.

Availability

'Dulong QHI' and 'Redlands Trailblazer' seed is available for research and test purposes but trial and commercialization agreements may be required. Please address all requests for seed to: Contracts and Compliance, Department of Primary Industries, Floor 6, Primary Industries Building, 80 Ann St., Brisbane, Queensland, 4001 Australia.

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