# Field susceptibility of Japanese-type plums to *Xanthomonas campestris* pv. *pruni*

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**Summary.** Fifty-five cultivars and 9 breeding selections of Japanese-type plum (*Prunus salicina* and hybrids) were evaluated from 1985 to 1988 for their susceptibility in the field to *Xanthomonas campestris* pv. *pruni* in a cultivar screening trial at the Granite Belt Horticultural Research Station (GBHRS), Applethorpe, Queensland. Laroda, Friar and Beauty were the most susceptible cultivars and showed severe leaf shothole, summer twig cankers and twig death. October Purple, Eldorado, Santa Rosa and Blackamber were also susceptible, displaying leaf shothole and twig cankers in the worst years. The locally established cultivars Doris, Queensland Red Ace, Shiro and Santa Rosa have been considered our most susceptible cultivars but were not as susceptible as many of the recent Californian introductions. Californian cultivars were more susceptible to bacterial spot than the selections from the GBHRS plum breeding program. The incidence of bacterial spot was higher in the years of high summer rainfall. Seventeen genotypes including 5 GBHRS selections did not display symptoms of bacterial spot. Wilson (*P. salicina* x *P. cerasifera*) is considered a good source of bacterial spot resistance for use in breeding.

## Introduction

Bacterial spot (*Xanthomonas campestris* pv. *pruni*) is a serious disease of stonefruit in the Granite Belt region of Queensland (Moffett 1973) and in other summer rainfall areas worldwide (Anderson 1956). The Granite Belt is in south-eastern Queensland at the subtropical latitude of 28°S, but the altitude of 800–940 m above sea level ensures a temperate climate. The average annual rainfall is 762 mm, 59% of which falls in the spring–summer period from September to February (Ward 1952). The high summer rainfall with driving winds from locally heavy thunderstorms and heavy dews (Anderson 1956), sandy soils (Matthee and Daines 1968) and frequent occurrence of hail in this region facilitate disease outbreaks. The source of spring inoculum is bacteria surviving over winter in twig cankers and from infected leaf scars from autumn leaf fall (Moffett 1973). Highly susceptible cultivars are unsuitable for commercial production (Heaton 1983).

The Granite Belt Horticultural Research Station (GBHRS) plum breeding program aims to produce high quality plums which are adapted to the local summer rainfall environment (Topp 1983). Information on bacterial spot susceptibility of plums is important for use in selecting parental lines for this program. Susceptibility ratings are also required to evaluate new commercial introductions prior to their recommendation to orchardists. This report describes the field susceptibility of Japanese-type plum (*Prunus salicina* and hybrids) cultivars and GBHRS plum breeding selections rated over a 4-year period at the GBHRS, Applethorpe, Queensland.

## Materials and methods

### *Trees*

A total of 64 genotypes including 9 GBHRS breeding selections were rated during 1985–88 at the GBHRS. They were grown on Nemaguard peach seedling rootstock with trickle irrigation at spacings of 3 by 4 m, with a herbicide strip along the tree row and sod between the rows. The trees received standard commercial pest and disease control sprays (Geyle *et al.* 1985) including copper hydroxide or copper oxychloride sprays at budswell in spring and at leaf fall in autumn. The trees were part of an ongoing stonefruit cultivar evaluation trial during which outbreaks of bacterial spot have occurred regularly. Tree age varied from 3 to 10 years, with new cultivars being added to the trial as they became available. Each cultivar was represented by 2–4 trees which were planted in adjacent clonal groups. Cultivars were arranged randomly in the trial with respect to susceptibility to bacterial spot (i.e. cultivars were planted at random as they were introduced over successive years).

*Measurement of bacterial spot*

Bacterial leaf spot symptoms appear as small, circular to angular, water soaked spots which separate from the leaf tissue with age to leaving a shothole lesion. The twig cankers are greasy, tan-colored, elongated, sunken areas which develop on current season's growth and which girdle the limb in severe cases. The cankers become rough and raised as the branch grows and in advanced stages the branches wilt and dieback. Twig cankers and twig death were considered a greater problem than leaf shotholing for commercial control of the disease because of their potential as overwintering sources of inoculum (Moffett 1973). Cankers were included in our rating scale as the most severe level of bacterial spot on the vegetative plant parts. Bacterial spot on fruit was not rated because of its low incidence.

**Table 1. Susceptibility of plum cultivars and selections to bacterial spot at Applethorpe, Queensland over four years of testing (1985–88)**

Bacterial spot ratings: 0, no disease; 1, 1–5% infected leaves; 2, 6–25% infected leaves; 3, 26–50% infected leaves; 4, >50% infected leaves and/or twig cankers; 5, as for rating 4 plus twig death

Origin code: ALA, Auburn University, Alabama; AUS, Australian cultivar not released from a specific breeding program; CAL-A, Agricultural Experiment Station, Davis, California; CAL-B, Mr Luther Burbank, Sebastopol, California; CAL-U, United States Department of Agriculture, Fresno, California; CLE, Clemson University, South Carolina; GB, Granite Belt Horticultural Research Station, Applethorpe, Qld, Australia; MISO, Missouri State Fruit Experimental Station; NZ, New Zealand cultivar not released from a specific breeding program; SA, Fruit and Fruit Technology Research Institute, Stellenbosch, South Africa; USA, United States of America cultivar not released from a specific breeding program

Means followed by common letter are not significantly different at $P$=0.05

| Clone name | Origin | Bacterial spot rating: Worst year (1987)[A] | Bacterial spot rating: Average (1985–88) | Clone name | Origin | Bacterial spot rating: Worst year (1987)[A] | Bacterial spot rating: Average (1985–88) |
|---|---|---|---|---|---|---|---|
| Au Producer | ALA | 0.0 | 0.0 lm | Kelsey | USA | 1.0 | 0.8 ghijkl |
| Barton's Pride | AUS | 0.0 | 0.0 m | Laroda | CAL–A | 5.0 | 4.6 a |
| Beauty | CAL-B | 4.5 | 3.6 ab | Late Santa Rosa | AUS | 1.5 | 1.1 fghij |
| Black Santa Rosa | AUS | 1.5 | 0.4 ghijklm | Mariposa | USA | 0.0 | 0.0 m |
| Blackamber | CAL-U | 1.7 | 2.3 bcdef | Methley | SA | 1.5 | 1.1 fghij |
| Bruce | USA | 0.0 | 0.0 m | Narrabeen | AUS | 1.0 | 0.3 ijklmn |
| Burbank | CAL-B | 0.0 | 0.3 ijklmn | Nubiana | CAL-A | 1.5 | 1.5 defghi |
| Burmosa | CAL-A | 1.0 | 0.4 hijklm | October Purple | unknown | 4.0 | 3.0 bc |
| Cadwells | AUS | 1.0 | 1.5 cdefghijklm | Ozark Premier | MISO | 0.5 | 0.3 ijklmn |
| Casselman | USA | 0.5 | 0.3 hijklm | Plumcot NSW | AUS | 1.5 | 1.3 efghij |
| Chalco | unknown | 2.0 | 1.5 defghi | Purple | ALA | 0.5 | 0.1 jklm |
| Davis | AUS | 0.0 | 0.0 m | Purple King | NZ | 1.5 | 0.5 ghijklm |
| Donsworth | AUS | 0.0 | 0.1 jklm | Queen Rosa | CAL-U | 1.5 | 1.0 fghijk |
| Doris | CAL-B | 1.5 | 1.4 defghij | Queensland Red Ace | AUS | 3.0 | 1.4 defghij |
| Duffs Early Jewel[B] | NZ | 0.5 | 0.0 jklm | Redheart | CAL-A | 1.0 | 0.3 ijklmn |
| Early Jewel | AUS | 0.0 | 0.0 m | Redgold[B] | SA | 0.5 | 0.0 jklm |
| Eldorado | USA | 3.5 | 2.7 bcde | Reubennel[B] | SA | 0.5 | 0.0 jklm |
| Elephant Heart Sport | AUS | 1.8 | 1.6 defgh | Ruby Blood | AUS | 0.0 | 0.0 m |
| Formosa | CAL-B | 3.0 | 1.5 defghi | Salad | AUS | 0.0 | 0.0 m |
| Friar | CAL-U | 5.0 | 3.8 ab | Santa Rosa | CAL-B | 3.0 | 2.6 bcd |
| Frontier | CAL-U | 0.0 | 0.6 ghijklm | Satsuma | CAL-B | 1.0 | 0.8 ghijkl |
| GB1–48 | GB | 0.0 | 0.0 jklm | Satsuma Type | AUS | 1.5 | 1.3 efghij |
| GB1–86 | GB | 0.0 | 0.0 lm | Shiro | CAL-B | 3.5 | 1.8 cdefg |
| GB1–98 | GB | 0.0 | 0.4 ghijklm | Simka | USA | 0.5 | 0.1 jklm |
| GB2–46 | GB | 1.0 | 0.3 ijklmn | Skuse Seedling | AUS | 0.0 | 0.0 m |
| GB3–91 | GB | 1.5 | 0.4 hijklm | Stirling | AUS | 3.5 | 1.6 defgh |
| GB3–195 | GB | 0.0 | 0.0 klm | Toka | USA | 0.0 | 0.2 ijklmn |
| GB11–40 | GB | 0.0 | 0.0 lm | Wade | CLE | 0.5 | 0.5 ghijklm |
| GB12–21 | GB | 0.0 | 0.0 lm | Wickson | AUS | 0.0 | 0.0 jklm |
| GBN1T6 | GB | 0.0 | 0.0 lm | Wilson | AUS | 0.0 | 0.0 m |
| George Wilson | NZ | 0.5 | 1.4 defghij | Wilson Type | AUS | 0.0 | 0.0 m |
| Harry Pickstone | SA | 0.0 | 0.0 m | Wilson Early | NZ | 1.0 | 0.3 ijklm |

[A]Worst year data are not adjusted for year effects.

[B]Cultivars with bacterial spot symptoms in the worst year (1987) but a zero average rating when adjusted for year effects by least squares analysis.

Bacterial spot symptoms were rated in March of each year on a 0–5 scale as follows: 0, no lesions on foliage; 1, 1–5% of leaves with lesions; 2, 6–25% of leaves with lesions; 3, 26–50% of leaves with lesions; 4, >50% of leaves with lesions and/or twig cankers; 5, as for rating 4 plus twig death.

*Statistical analysis*

The data were non-orthogonal containing 32 missing values out of a total of 256. Least squares analysis was used to calculate year effects and the raw data were adjusted accordingly to obtain the mean response of each genotype over years. Observations within genotypes within years were always from adjacent trees. Hence, the data for each year were regarded as a set of single (averaged) values from each genotype which was present in that year.

## Results

Susceptibility of the genotypes to bacterial spot in the worst year (1987) and for the 4-year the average are shown in Table 1. Forty-two of the 64 genotypes were rated susceptible. Laroda, Friar and Beauty were the most susceptible (mean ratings of 3.6 to 4.6). October Purple, Eldorado, Santa Rosa and Blackamber were also severely affected with mean susceptibility ratings of 2.3 to 3.0 but with twig cankers observed on the most severely affected trees. Seventeen genotypes, including 5 of the 9 GBHRS breeding selections, displayed no symptoms of bacterial spot. Low levels of bacterial spot (mean rating <1) were observed in 42 genotypes. In this group were all the GBHRS selections; Harry Pickstone, Redgold and Reubennel from South Africa; Au Producer and Purple from Alabama; and 10 chance seedlings originating in Australia.

The cultivars Duffs Early Jewel, Redgold and Reubennel were free of bacterial spot except in the worst year, 1987, when a trace was detected. The least squares analysis in adjusting for year effects causes these cultivars to have a zero rating over the 4-year average.

The mean rating for bacterial spot susceptibility in 1987 and 1988 for the genotypes, based on their place of origin, are shown in Table 2. Cultivars from the 3 Califorian sources when grouped together (15 cultivars) were significantly ($P<0.05$) more susceptible than the GBHRS selections (9 genotypes) and an 'all other' plum group (7 cultivars).

The years of highest summer rainfall, 1987 and 1988, had significantly ($P<0.05$) greater mean bacterial spot ratings than 1985 and 1986. The September–March rainfall (mm) and the mean (± s.e.) bacterial spot ratings were 366 mm and 0.7 (± 0.2) for 1985; 458 mm and 0.6 (± 0.2) for 1986; 683 mm and 1.5 (± 0.1) for 1987; and 537 mm and 1.4 (± 0.1) for 1988.

**Table 2. Mean (± s.e.) rating for bacterial spot susceptibility during 1987–88 (two worst years) based on place of origin**

See Table 1 for explanation of susceptibility rating and origin codes

| Origin | No. of cultivars | Mean 1987–88 rating |
|---|---|---|
| CAL-U | 4 | 2.5 ± 0.7 |
| CAL-A | 4 | 2.2 ± 0.7 |
| CAL-B | 7 | 1.7 ± 0.4 |
| MISO | 1 | 0.3 ± 1.3 |
| CLE | 1 | 0.3 ± 1.3 |
| GB | 9 | 0.3 ± 0.4 |
| SA | 3 | 0.2 ± 0.8 |
| ALA | 2 | 0.1 ± 0.9 |

## Discussion

The high summer rainfall and frequent occurrence of hail on the Granite Belt means that plum varieties which are highly susceptible to bacterial spot are unsuitable for cultivation at this location. Hail damage provides ideal conditions for spread of bacterial spot as it is usually associated with summer thunderstorms. The wound provides an entry site, and the warm, wet conditions are ideal for disease development. Hail damage occurred twice during this study and causes severe damage 4–5 times annually in the district (A. D. Geyle, pers. comm.). In rating the GBHRS breeding progeny for bacterial spot, we consider seedlings in which hail damage has occurred and the wound healed cleanly to be among the most resistant. Many of the Californian plums were susceptible under these conditions. The locally established plum cultivars Doris, Queensland Red Ace, Shiro and Santa Rosa, which have been considered our most susceptible cultivars (Heaton 1983), were not as susceptible as the recent Californian introductions.

Because of the early interspecific hybridization work of Luther Burbank, there are many species in modern Japanese-type plums (Jones 1928). Although there are many species involved, the modern Californian cultivars are based on a fairly narrow germplasm pool, with most of the United States Department of Agriculture, Fresno and Agricultural Experiment Station, Davis plums that were tested having Gaviota, Eldorado and/or Santa Rosa in their parentage. Gaviota has been reported as susceptible and as transmitting susceptibility to its progeny (Hurter and van Tonder 1980). Eldorado is also susceptible and 100% of its progeny were susceptible (Hurter and van Tonder 1975). Santa Rosa and Eldorado are descendants of *P. simonii*, and Popenoe (1959) suggested that susceptibility to stem canker derived from this source. It seems likely that the narrow germplasm pool of the Californian plums coupled with the absence of selection for resistance to bacterial spot has resulted in susceptibility. The most tolerant cultivars from California, Redheart, Wickson, Burbank and Satsuma do not have Gaviota, Eldorado or Santa Rosa in their ancestry.

Our varietal ratings generally agree with other work on plums (Hurter *et al.* 1971; Keil and Fogle 1974; Norton and Rymal 1978; Simeone 1982), but there are discrepancies. For example, Satsuma plum has been reported as resistant by Hurter *et al.* (1971) and rated 0.8 in the present study, but was classed as susceptible (61–100% leaves infected) by Keil and Fogle (1974). Another example is Ozark Premier which is rated 5 (0–5 scale) by Simeone (1982) and 4 (1–5 scale) by Keil and Fogle (1974) but 1 (0–5 scale) by Norton and Rymal (1978) and 0.3 in the present study. Possible explanations for these differences are: (i) different rating scales measure different levels of the 1 symptom or different symptoms; (ii) genotype x environment (bacterial strain) interaction can alter the ranking of cultivars (du Plessis 1988); or (iii) inoculum may be unevenly spread through the trial areas. Rapid and even spread of the disease in our study was facilitated by the high planting density, favorable climatic conditions, random distribution of susceptible cultivars, and the large number of genotypes carrying the inoculum (66% of genotypes had some bacterial spot).

The GBHRS breeding selections showed high levels of resistance to bacterial spot under conditions of commercial orchard pest and disease control. Wilson is a parent of most of these selections although Early Jewel and Early Gem have also been used as parental stock. GBHRS selections with this type of ancestry have a distinctly small, crinkled, glossy leaf associated with the *P. salicina* x *P. cerasifera* in Wilson. Trees with this leaf type seldom show the angular and greasy leaf hole or defoliation due to bacterial spot. Other Australian chance seedlings such as Bartons Pride and Davis which have the same leaf type and presumably similar ancestry were also free from bacterial spot.

Wilson, which orginated as a chance seedling in New South Wales in the early 1920s (Allen 1920), is considered to be synonymous with Eclipse from South Africa (Hurter *et al.* 1971). Eclipse was used in the breeding of bacterial spot resistant plums in South Africa (Hurter and van Tonder 1980). None of their 1423 progeny were selected for further evaluation because of poor fruit size. We have also noted the small fruit size of Wilson progeny, but continue to use advanced selections with Wilson parentage to obtain bacterial spot resistance. Our observations at the GBHRS suggest that Wilson is also synonymous with Wilson's Early from New Zealand. Wilson's Early was grown adjacent to the very susceptible cultivars Friar and Laroda and maintained its resistance under this extreme pressure. This augurs well for its use as a parent in resistance breeding.

The inheritance of resistance to bacterial spot has not been clearly defined. Sherman and Lyrene (1981) concluded that leaf spot resistance in peach is controlled by a few major, dominant genes. Norton (1967) noted that resistance to limb cankers in plum appeared to be the result of 1 major, recessive gene with possible modifying factors. Layne (1966) reported that resistance to leaf spot and resistance to fruit spot in apricot may be inherited separately. Further studies in Japanese-type plums are in progress to determine the relationship between the 3 phases of bacterial spot (on leaves, twigs and fruit) and their mode of inheritance.

Orchardists are growing some susceptible cultivars such as Friar and Queensland Red Ace on the Granite Belt and these cultivars require costly management strategies to avoid damage from bacterial spot. Hail netting prevents limb damage and summer copper sprays are applied when leaf spot symptoms are excessive, but this has resulted in premature defoliation and fruit russetting. Orchardists employ these practices because they lack high quality, resistant cultivars. We are studying the wide variation in susceptibility to bacterial spot to identify resistant genotypes for cultivar recommendations and for breeding plums with resistance to bacterial spot.

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