SCARRING IN TAMARILLO FRUIT *(SOLANUM BETACEUM)*

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ABSTRACT

Fruit scarring in tamarillo (*Solanum betaceum*) is a cosmetic disorder causing extensive revenue losses to the New Zealand tamarillo growers. This study aimed to establish the cause of scarring. Three possible causes were tested experimentally: (1) fungal infection (2) insect damage and (3) physical injury. Inoculation with spore suspensions of *Botrytis cinerea* (~10^5 spores/ml) at fruit-set indicated no association between scarring and infection by this fungus. Among seven herbivorous invertebrates recorded on tamarillo, greenhouse thrips were the most likely incitants of scarring. Applications of thrips to developing fruit in fine-weave terylene bags (~120 thrips/bag) resulted in corky lesions. However, these were more superficial than the typical scarring of tamarillo. Damaging the epidermis by scratching or removing patches of cells on young fruit produced the characteristic corky scars. This suggests that any type of epidermal damage (e.g. wind-rub, hail or feeding insect) early in fruit development may cause scarring.

Keywords: tamarillo, tree tomato, fruit scarring, epidermis, *Botrytis cinerea* Pers., greenhouse thrips, *Heliothrips haemorrhoidalis* Bouché, physical injury.

INTRODUCTION

The tamarillo or tree tomato (*Solanum betaceum* Cav.) is a small subtropical tree originating from South America. Several cultivars with red or yellow skins are grown commercially in New Zealand, e.g. Red Beau, Ted's Red, Bold Gold and Kaitaia Yellow. Tamarillo are sensitive to frost and are therefore mainly grown in the Bay of Plenty, Northland and Auckland regions. Approximately 740 tonnes of tamarillo are produced in New Zealand annually, with an export value of $NZ700,000 (FreshFacts 2007). Major production constraints for the industry include tamarillo mosaic virus, storage rots and fruit scarring.

Scarring in tamarillo is a cosmetic disorder that reduces the marketability of the fruit. It is estimated that 10-20% of the fruit are affected by the disorder, resulting in significant revenue losses. The scars become visible as small dark marks on the skin of young fruit when they are approximately 3 cm long, and develop into corky lesions as the fruit expand.

A variety of factors may cause fruit scarring. In persimmon (*Diospyros kak*i L.), scars on the fruit skin are often a result of infection by the fungus *Botrytis cinerea* Pers. incurred at an early stage of fruit development (Rheinländer et al. 2008). Corky lesions, similar in appearance to scarring of tamarillo, have been reported in tomato fruit and aubergine following outbreaks of mites (*Polyphagotarsonemus latus* Blank) (Cross & Bassett 1982). Several species of thrips (Order Thysanoptera) cause scarring in a wide variety of fruit, including citrus (Froud et al. 2001), avocado (Yee et al. 2001) and stonefruit (Teulon & Penman 1996). Corky lesions may also arise from physical injury, such as wind-rub, which is easily confused with damage caused by pests (Phillips et al. 2007).

The aim of this study was to identify the cause of scarring in tamarillo. Three potential causes were investigated: (1) fungal infection, (2) insect damage and (3) physical injury. Each of these was tested experimentally.

METHODS

Study sites

The trial on fungal infection was conducted in two orchards, one in Auckland and one in the Bay of Plenty, in blocks of the cultivar 'Sweet 10'. Both orchards were surrounded by shelterbelts (mostly *Cupressus macrocarpa* Hartw. ex Gordon and *Pinus* sp.). The trials on insect damage and physical injury were undertaken in the Auckland orchard only.

Fungal infection

To examine whether the scarring in tamarillo is associated with infection by *B. cinerea*, as it is in persimmon, inoculation trials were undertaken in the two orchards. A spore suspension (~10^5 spores/ml) was made from cultures isolated from a tamarillo postharvest rot grown on potato dextrose agar. The suspension was applied at fruit set in March 2005 using a hand-held spray bottle to 120 fruit trusses distributed among 20 trees (5-10 trusses/tree) along two rows in each orchard. In a third row, 120 control trusses were sprayed with water. Weather conditions were overcast on both spray occasions. The incidence of scarring was recorded at fruit maturity in July 2005. Tamarillo typically shed a substantial amount of fruitlets (75-90% of the fruit on individual trusses, P.A. Rheinländer, unpubl. data) and many of the inoculated fruitlets abscised before reaching fruit maturity. The resulting number of fruit assessed for scarring was 416 and 306 in the Auckland and Bay of Plenty orchard, respectively. Differences in the proportion of fruit with scarring on each truss between inoculated and control fruit in the two orchards were tested using two-way ANOVA on arc-sine transformed data.

Insect damage

To find a likely mite or insect candidate that could be responsible for the fruit scarring, a monitoring programme was conducted to record pests associated with tamarillo. Leaves, flowers and fruit were sampled at monthly intervals (100-250 plant parts on each monitoring occasion) from August 2005 to January 2006. In the laboratory, the samples were inspected under the stereomicroscope and the number of different mites and insects on the various plant parts was recorded.

Although observed in low numbers, greenhouse thrips seemed the most likely candidate to cause fruit scarring amongst the insects recorded on tamarillo. They were therefore used for an inclusion trial. Adult greenhouse thrips were placed in fine-weave terylene bags (~120 thrips/bag), which were tied onto trusses of developing fruit (1.0-4.0 cm in length) in February 2006. The greenhouse thrips used for the experiment had been reared on lemons. This was assumed to have no effect on the trial because there have been no reports of strains of greenhouse thrips with host plant preferences. To each of ten trees, three bags with greenhouse thrips and an empty 'control' bag were tied onto individual trusses. Three trusses per tree without bags functioned as additional controls. The bags were removed after 3 weeks and the fruit were left on the trees until maturity, at which time they were inspected for scarring in July 2006. Differences in the proportion of fruit with scarring on each truss among treatments were tested using single factor ANOVA following arc-sine transformation.

Physical injury

Young tamarillo fruit are extremely tender and prone to injury. A trial was conducted in February 2006 to test whether wounding the epidermal layer during early fruit development would result in the scarring of tamarillo. Fruit were injured in two ways: (1) by lightly scratching the epidermal layer using a soft toothbrush and (2) by removing a patch of epidermal cells using an emery board. Each treatment was applied to 60 trusses of developing fruit (1.0-4.0 cm in length). Fruit not subjected to any injury functioned as controls. In total, the trial included 180 trusses of fruit (60 trusses/treatment). The incidence and the type of scarring resulting from wounding the skin with a toothbrush and an emery board were compared with those of untreated controls at fruit maturity in

May 2006. The difference in the incidence of scarring between treatments was tested using single factor ANOVA on arc-sine transformed data.

RESULTS AND DISCUSSION

Fungal infection

The scarring in tamarillo fruit did not appear to be associated with infection by the fungus *B. cinerea*. No significant difference in the incidence of scarring (P=0.53) was found in either orchard between the fruit that had been inoculated with the fungus and the untreated controls. In the Auckland orchard, the mean % fruit on each truss that contained scars was 23.8% ± 2.9% SE and 24.8% ± 5.2% SE for the inoculated and untreated control fruit, respectively. In the orchard in Bay of Plenty, the mean % scarring was 13.3% ± 5.2% SE for the inoculated fruit and 16.0% ± 5.2% SE for the controls.

In persimmon, the petals typically adhere to the fruitlets after they have withered. *Botrytis cinerea* first infects the petals and thereafter the underlying fruit tissue (Rheinländer et al. 2008). A similar infection strategy is known for *Sclerotinia sclerotiorum* (Lib.) de Bary, which can result in scarring in kiwifruit (Hoyte 2000). The petals in tamarillo may remain attached to the fruitlets but do not generally adhere to the epidermis. In an associated survey of the natural fungal flora of tamarillo petals (P.A. Rheinländer, unpubl. data), *B. cinerea* was isolated with a frequency of 1% and 9% in petals sampled from the two orchards in Auckland and in the Bay of Plenty, respectively. The low incidence of the fungus suggests that it is unlikely to be the cause of fruit scarring in tamarillo.

Insect damage

During the 6-month monitoring of pest associations, seven herbivorous invertebrate species were recorded on tamarillo foliage and fruit (Table 1). Only aphids (mainly *Myzus persicae*) and whiteflies (*Trialeurodes vaporariorum*) occurred in large numbers (>100 on each sampling occasion). Aphids were abundant on leaves, flowers and fruitlets, whereas whiteflies were abundant on leaves only. Both insects pierce the plant tissue and feed on the phloem, producing honeydew on which sooty mould grows. Their feeding does not generally result in fruit scarring.

The remaining species were encountered in low numbers (<10 individuals on each sampling occasion), usually on the leaves. The tetranychid mite (*Panonychus ulmi*) was encountered once in October in low numbers (<10). It feeds on plant material by puncturing the plant cell and sucking out the cell contents. This injury generally causes a stippling which results in hundreds of lighter coloured spots on leaves or fruit, rather than in corky scarring damage (Jeppson et al. 1975).

Among the recorded species of thrips, the greenhouse thrips (*Heliothrips haemorrhoidalis*) was the most common, although observed only in low numbers (<10). It was recorded on four out of six sampling occasions, whereas the other species of thrips were encountered once or twice. Greenhouse thrips are serious pests worldwide, causing feeding injury (generally a superficial scarring) to a wide range of fruit and vegetable crops (Scott Brown & Simmonds 2006). These were considered the most likely insect candidate to cause fruit scarring of tamarillo and were consequently used for the inclusion trial.

In the pest inclusion trial, grazing by greenhouse thrips on young tamarillo fruit resulted in scarring. The incidence of scarring was significantly (P<0.001) higher in fruit that had been subjected to thrips feeding than in the fruit in empty bags and the unbagged controls. On average, 98.8% ± 1.2% SE of the fruit in bags with thrips developed scarring (Fig. 1a). No significant difference was observed in the incidence of scarring between fruit in bags without thrips (32% ± 18% SE) and the unbagged controls (17% ± 10% SE).

The injury caused by thrips developed into a more superficial and less corky scarring than that typically observed on tamarillo fruit (Fig. 2c). The high numbers of thrips enclosed with fruit caused damage that covered extensive areas of the individual fruit, and these large scars appeared to inhibit fruit expansion. Typically, the scarring occurred at the upper part of the fruit around the sepals or on the sides where the fruit had been touching adjacent fruit, which were the areas where most thrips were found.

TABLE 1: Abundance of invertebrate herbivores recorded in association with various plant parts of tamarillo monitored at monthly intervals from August 2005 to January 2006 in an orchard in Auckland. The abundance of the different insects and mites is indicated by H = high, >100 individuals; M = moderate, 10-100 individuals; L = low, <10 individuals, – = not present.

Insects and mites	Leaves and buds	Flowers and buds	Fruitlets
Green peach aphid (*Myzus persicae* Sulzer)	H	H	M
Whitefly (*Trialeurodes vaporariorum* West.)	H	–	–
Greenhouse thrips (*Heliothrips haemorrhoidalis* Bouché)	L	–	–
New Zealand flower thrips (*Thrips obscuratus* Crawford)	L	L	–
Onion thrips (*Thrips tabaci* Lindeman)	L	–	–
Longtailed mealybug (*Pseudococcus longispinus* Targioni-Tozzetti)	L	–	–
Tetranychid mite (*Panonychus ulmi* Koch)	L	–	–

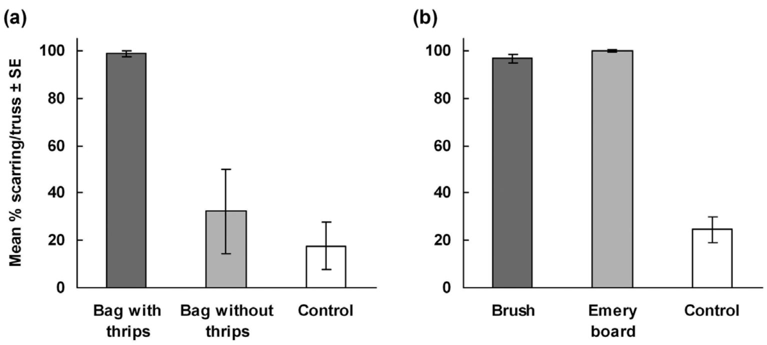

FIGURE 1: Mean incidence of scarring in tamarillo fruit that had been (a) placed in bags with greenhouse thrips (*Heliothrips haemorrhoidalis* Bouché) during fruit development, in empty bags or in unbagged control fruit, and (b) injured by a toothbrush or an emery board while the fruit were at an early stage of development, or in untreated control fruit. Values are mean % fruit containing scars on each truss ± standard error (SE) for 7-16 trusses per treatment in (a) and 60 trusses per treatment in (b). There were 1-6 fruit on each truss.

Physical injury

The wounding of the fruit skin always resulted in a scar (almost 100% incidence for both toothbrush and emery board), whereas the mean incidence of scarring in the control fruit was 24% ± 6% SE ($P<0.001$; Fig. 1b). The latter was within the same range as the values obtained for the controls in the inclusion trial (Fig. 1a). It was observed that the severity of the injury at maturity tended to be greatest on fruit that had been wounded when very small (< 2 cm in length).

The scarring resulting from physical injury (Figs 2d&e) was very similar to that typically observed in tamarillo fruit in the field (Figs 2a&b). Scratching the epidermal layer with a toothbrush consistently resulted in a brown, patchy and crazed corky scar, while using an emery board always resulted in a dark brown scab surrounded by a lighter coloured circular ring of split tissue. Physical injury such as wind-rub has been reported to cause corky scarring in other fruit, such as avocado (Phillips et al. 2007) and citrus (Grafton-Cardwell et al. 2003). In many cases, physical injury can be difficult to distinguish from damage caused by pests (Smith & Pena 2002).

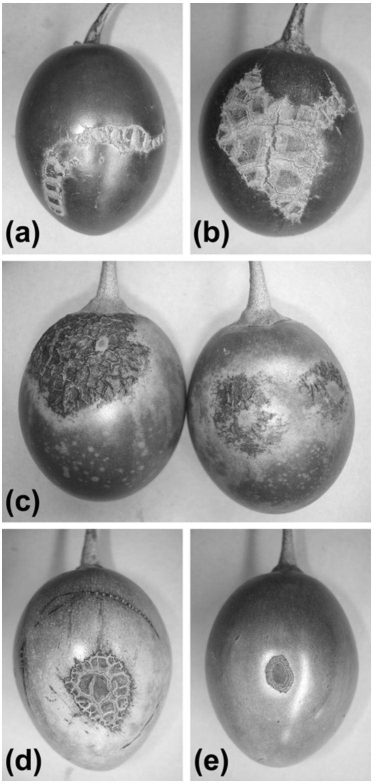

FIGURE 2: (a) and (b) Typical scarring on tamarillo fruit. (c) Scarring resulting from feeding by greenhouse thrips (*Heliothrips haemorrhoidalis* Bouché) incurred at an early stage of fruit development. (d) Corky lesions caused by injuring the epidermis with a toothbrush while the fruit was young. (e) Scarring resulting from removing a patch of epidermis with an emery board during fruit development.

CONCLUSIONS

This study suggests that although greenhouse thrips can cause fruit damage in tamarillo orchards, they are probably not the cause of the typical tamarillo scarring that was the subject of this investigation. The lesions resulting from their grazing were less corky than those typically observed in tamarillo. In addition, greenhouse thrips were only encountered in low numbers in the study site. The possibility that other mites or insects also cause scarring to tamarillo was not investigated. Wounding fruitlets by scratching or removing a patch of epidermis resulted in the characteristic scarring, which suggests that any type of physical epidermal damage incurred early in fruit development may result in scarring.

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