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SYMPTOMS OF AND VARIETY REACTION TO GREEN PITTING, A NON-PATHOLOGICAL DISORDER OF RED BELL PEPPERS IN QUEENSLAND

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SUMMARY

Symptoms of green pitting and their severity and association with high calcium (Ca) levels in Queensland grown red bell pepper (*Capsicum annuum* var. *grossum*) fruit are described. Eleven cultivars covering the expected range of severity of green pitting were field-planted on the Granite Belt, southern Queensland. Pits per fruit varied from nil in several cultivars to 22 in Yolo Wonder. Sixteen and 26% of fruit of major commercial cultivars Green Giant and Yolo Wonder, respectively, were graded unmarketable with more than six to eight pits per fruit. No major correlations existed between incidence of pitting and measured fruit traits. Number of pits per fruit decreased markedly on the third or fourth weekly harvest. Some implications for sweet pepper breeding are discussed.

I. INTRODUCTION

Green pitting of red bell peppers (*Capsicum annuum* L. var. *grossum* Sendt.) has caused undetermined losses to Queensland growers by rendering severely affected fruit unmarketable (figure 1). While the fresh vegetable market does tolerate a low to moderate incidence of pitted fruit, up to 25% cull of otherwise marketable fruit has been estimated in certain commercial plantings. A similar disorder was described as pitting in European, glasshouse-grown, bell peppers (van Uffelen 1975; Stolk and Maaswinkel 1977), and as 'black spot' in field grown crops in Texas, U.S.A. (Villalon 1975).

Repeated attempts by research and extension plant pathologists of the Queensland Department of Primary Industries to isolate causal organisms were unsuccessful, and damage caused by insect pests has never been associated with the disorder. High fruit Ca levels were associated with pitting (van Uffelen 1973). No corrective practices are known in Queensland.

Relative differences in susceptibility to pitting are known among major red bell pepper cultivars in Queensland, and observed in preliminary assessment of new cultivars. This paper describes symptoms and severity of pitting in Queensland-grown red bell peppers, the association with Ca, results of comparative cultivar assessment where expression of pitting was severe, and association of pitting with other measured fruit traits.

II. DESCRIPTION

Symptoms

Green pitting has been observed on red bell peppers from all producing districts in coastal Queensland and the Granite Belt. Differences in severity of symptoms on fruit from various districts are related in part to the susceptibility of cultivars predominant in different districts. Yolo Wonder and Green Giant are more susceptible than Yolo Y and Californian Wonder. No clear environmental differences have been identified in susceptibility to green pitting in the different districts.

Pits become apparent with colour change at maturity. They are round to irregular in shape, approximately 2 to 6 mm in diameter, pale to dark green, and generally sunken (figure 1). They extend through the thick pericarp to be clearly visible from the locular space. In severe cases, several closely-spaced pits appear to coalesce to form a blotch. As fruit senescence commences, pits become more chlorotic and more diffuse in margin. When the disorder is severe, all fruit of a susceptible cultivar are blemished with a few to more than 30 pits per fruit.

Symptoms closely fit the pitting described by van Uffelen (1973) and are similar to black spot (Villalon 1975), except that lesion pericarp tissue in Queensland fruit is not dry and black.

Calcium association

Van Uffelen (1973) reported pitting was associated with high fruit Ca concentration. Nutritional analyses of bell pepper fruit from the Granite Belt district showed high Ca levels in pitted fruit (Carroll, personal communication).

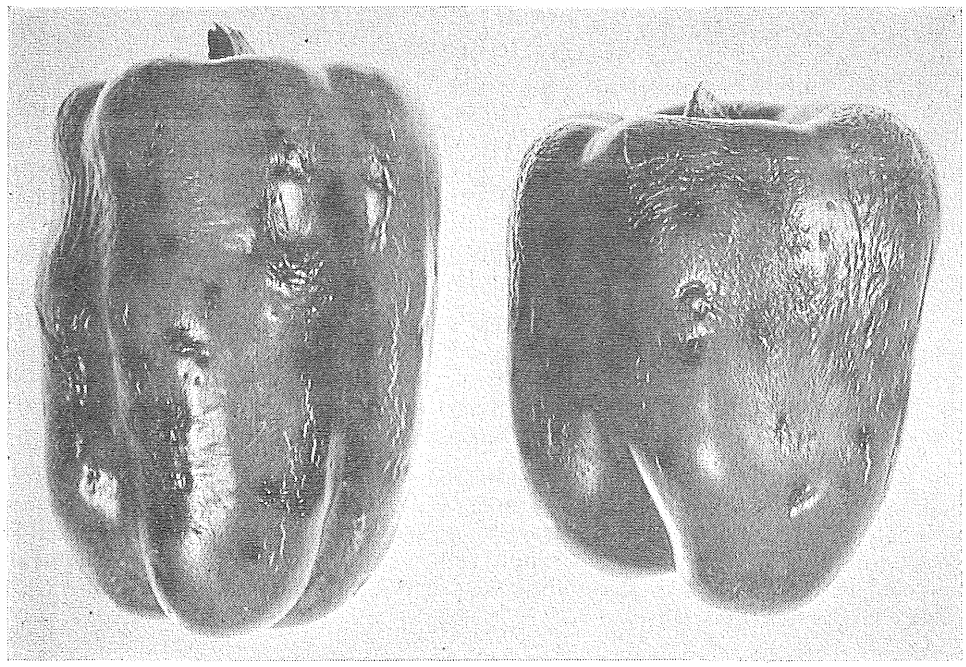

Figure 1. Bell peppers showing severe pitting.

TABLE 1

RAINFALL AND TEMPERATURE DATA FOR STANTHORPE FROM 14 DECEMBER 1976 TO APRIL 1977

Month	Rainfall (mm)		Wet days (No.)		Temperature °C	
	Received	Normal	Received	Normal	Mean daily	Normal
14–31 Dec. 1976 ..	37	..	2	..	20·3	..
Jan. 1977	74	97	6	10	20·4	20·9
Feb. 1977	109	85	9	9	20·3	20·8
Mar. 1977	133	67	13	9	18·6	19·0
Apr. 1977	77	41	9	6	15·6	15·7

In addition, pitted tissue contained higher Ca levels than non-pitted tissue from the same fruit (Carroll, personal communication). Glasshouse nutritional studies of cv. Californian Wonder confirmed that low Ca levels in the potting medium resulted in fewer pits (Carroll 1979).

While substantial cultivar differences in susceptibility were confirmed in a preliminary planting (unpublished data), no previous studies of cultivar differences in susceptibility are known to have been reported in Queensland. The present study at Stanthorpe on the Granite Belt of southern Queensland was made using cultivars expected to cover the range of symptom expression.

III. MATERIALS AND METHODS

The 11 cultivars field planted were—

Sheba	Yolo Y *	Midway
Early Bountiful	Allbig	Green Giant
Super Set	Jade	Yolo Wonder
Californian Wonder	Miss Belle	

A four-replicate randomized block design comprising 12 single-row plots, each containing 20 plants, was used, with intra and inter-row spacings of 1·3 m and 0·3 m respectively. The site was on a southerly slope of gentle and uniform gradient with replicates placed in sequence down the slope. Dolomite (2·2 t ha^{-1}) was incorporated in the infertile acid podsolic soil 2 weeks before transplanting, and 0·6 t ha^{-1} of a 5:7:4 N:P:K mixture (12·5% Ca analysis) was banded along planting rows. No further Ca was applied during the trial. Seedling transplanting occurred on 14 December 1976. Frequent irrigation, and routine pesticide and fungicide sprays were applied. Weed control was maintained.

Below-average rainfall was received during December 1976 and January 1977, while above-average rainfall occurred during February-April 1977 (table 1). Rainfall exceeded total evaporation losses from a nearby class A pan during March 1977. Temperatures during the trial period deviated little from the long-term means.

*Samples of Yolo Y from two Australian seed merchants were used.

TABLE 2

MEAN VALUES FOR TOTAL WEIGHT AND NUMBER OF FRUIT, % FRUIT BADLY PITTED AND % MARKETABLE FRUIT PER PLOT, AND NUMBER OF GREEN PITS AND WEIGHT PER FRUIT FOR 11 SWEET PEPPER CULTIVARS

Cultivar	Mean no. fruit per plot	Mean wt. fruit (kg) per plot	% Fruit badly pitted		% Marketable fruit		Mean no. pits per fruit	Mean wt. per fruit (g)
			Trans-formed*	Actual	Trans-formed*	Actual		
Sheba	293·6	31·34	0·000	0·0	1·456	98·7	0·0	108
Early Bountiful	246·4	28·26	0·000	0·0	1·226	88·6	0·0	115
Super Set	229·0	37·10	0·000	0·0	1·198	86·7	0·0	162
Yolo Y (b)	200·5	34·88	0·189	3·5	1·290	92·3	5·1	174
Californian Wonder	174·0	34·13	0·000	0·0	1·254	90·3	0·0	199
Allbig	186·8	29·12	0·253	6·3	1·149	93·3	7·0	154
Yolo Y (a)†	154·0	29·60	0·232	5·3	1·225	88·5	11·9	194
Jade	194·5	34·95	0·475	21·0	0·982	69·1	18·8	180
Miss Belle	156·3	30·08	0·172	2·9	1·140	82·6	4·6	198
Midway	190·8	31·84	0·391	14·5	0·921	63·4	20·2	167
Green Giant	145·8	31·09	0·410	15·9	0·998	70·6	14·3	213
Yolo Wonder	167·0	34·39	0·535	26·0	0·907	62·1	21·7	208
General mean	193·6	32·35	0·226	8·6	1·142	80·8	8·9	171
Necessary difference for significance 5%	45·5	Ns‡	0·133		0·113		5·9	28
Necessary difference for significance 1%	61·3		0·179		0·152		7·9	37

* Arc-sin transformation used for analysis.

† The same cultivar from two seed companies.

‡ Ns—not significantly different at $P < 0{\cdot}05$.

Weekly harvests were made from 16 March to 27 April 1977. The total fruit number and weight, and number of sunburnt, severely pitted, and marketable fruit were recorded per plot and percentage of each calculated. Fruit with fewer than six to eight pits each were considered marketable. The average weight per fruit was calculated. A random sample of 10 fruit per plot was selected in the four harvests to 6 April 1977, the number of pits counted and averaged. Sampling was discontinued beyond 6 April 1977.

At the single largest harvest of each plot, the following fruit parameters were recorded and averaged on a random sample of 10 fruit for calculation of correlation coefficients with incidence of pitting: fruit length, diameter, number of locules, and the mean of two measurements of pericarp thickness per transverse section of each fruit.

IV. RESULTS

Mean number of pits per fruit varied significantly from 0·0 in cultivars Sheba, Early Bountiful, Super Set, and Californian Wonder to 21·7 in Yolo Wonder (table 2). Several fruit of cultivar Californian Wonder exhibited pitting, but these fruit did not occur in random samples used to obtain this data. Among other major commercial cultivars, Green Giant showed severe pitting, and Yolo Y strains, which differed significantly, exhibited moderate levels of pitting.

Large significant differences occurred between cultivars for the percentage of severely pitted fruit. Culling removed 26 and 15·9% of fruit of cultivars Yolo Wonder and Green Giant respectively. Yolo Y strains with 3·5% and 5·3% cull did not differ significantly.

The mean number of pits per fruit was highest at the earlier harvests (table 3). On cultivars Midway and Allbig, numbers of pits per fruit increased substantially from harvests of 23 March to 30 March 1977. All cultivars showed a major reduction in numbers of pits from harvests of 30 March to 6 April 1977. Sampling was discontinued beyond 6 April 1977 because of low incidence of pitting.

TABLE 3

MEAN NUMBER OF GREEN PITS PER FRUIT AT EACH OF FIRST FOUR HARVESTS ON 11 RED PEPPER CULTIVARS

Cultivar	Harvest Date			
	16 March 1977	23 March 1977	30 March 1977	6 April 1977
Yolo Wonder	†	24·0	20·9	11·3
Green Giant	20·0	19·5	10·3	7·8
Yolo Y (a)*	†	12·2	15·3	6·4
Yolo Y (b)*	†	6·5	6·1	3·1
Midway	12·2	12·8	32·8	8·0
Miss Belle	†	2·1	6·8	5·1
Allbig	†	6·4	14·2	4·1
Jade	†	22·3	16·7	8·4
Californian Wonder	†	0·0	0·0	0·0
Sheba	0·0	0·0	0·0	0·0
Early Bountiful	0·0	0·0	0·0	0·0
Superset	0·0	0·0	0·0	0·0
Mean		8·8	10·3	4·5

* The same cultivar from two seed suppliers.

† First fruit mature on 23 March 1977.

Mean number of pits per fruit declined significantly ($P < 0{\cdot}05$), and total number and weight of fruit per plot increased significantly ($P < 0{\cdot}05$) with successive replicates laid out down the sloping site. However, correlation coefficients between mean number of pits per fruit and total number and weight of fruit per plot were low ($\tau = 0{\cdot}41$* *$P < 0{\cdot}05$, and $\tau = 0{\cdot}02$ respectively).

Correlation coefficients were low between both the mean number of pits per fruit and percentage of severely pitted fruit, and fruit length, diameter, locule number, pericarp thickness and percent sunburnt fruit. Sunburn frequently occurred before ripening and accounted for 8 to 14% of fruit harvested.

Despite large significant differences between cultivars for mean number of fruit per plot, mean fruit weight per plot did not differ significantly. Among commercial cultivars, Green Giant produced fewest fruit.

Significant differences between cultivars occurred for the percentage of marketable fruit with Yolo Wonder showing among the lowest percentages.

Cultivars differed significantly for mean weight per fruit, with commercial cultivars Green Giant, Yolo Wonder, Californian Wonder and Yolo Y (a) producing among the heaviest fruit, and Sheba and Early Bountiful the lightest. Mean number of pits per fruit and weight per fruit were positively correlated ($\tau = 0{\cdot}48$ * $P < 0{\cdot}05$).

V. DISCUSSION

The results confirm that up to 25% of red bell pepper fruit may be culled when pitting is severe. Severe pitting on major cultivars Yolo Wonder and Green Giant was evident. Had all fruit showing one or more pits been culled (van Eijsinga 1973), a substantially higher percentage of loss would have been recorded, with cultivars Yolo Wonder, Green Giant, Midway and Jade yielding few marketable fruit.

An examination of meteorological data from the trial site revealed no clear underlying environmental factor conducive to the expression of pitting. Above-average rainfall during fruit enlargement and maturation may have contributed to increased root growth and Ca uptake, large fruit size and absence of blossom-end rot in these fruit.

Van Eijsinga (1973) reported large red bell pepper fruit were probably more prone to pitting than small fruit. In comparison, Carroll (1979) reported that 38% of small predominantly parthenocarpic fruit of cultivar Californian Wonder were pitted following high lime application. The low positive correlation between mean number of pits per fruit and mean fruit weight was due primarily to the inclusion in the trial of cultivars Sheba and Early Bountiful with many small fruit free of pitting, and Green Giant and Yolo Wonder with fewer, large fruit and severe pitting. No trend was evident on other cultivars.

The large differences in susceptibility to pitting between cultivars indicated that resistance is hereditary in red bell peppers. However, no inheritance studies have been reported and no major correlations between incidence of pitting and other measured fruit traits were found in this study. The possible correlation between fruit size and pitting requires investigation. Queensland red bell pepper growers generally prefer cultivars with large fruit.

Cultivars Californian Wonder and Yolo Y remain of importance to the Granite Belt and humid coastal areas of Queensland respectively. Continuing evaluation of new red bell pepper cultivars has not identified those with a combination of all desired attributes and resistance to pitting. Sweet pepper disease resistance breeding in Queensland is proceeding (Hibberd *et al* 1979) using amongst others Yolo Y as a parent. Derived progeny will require evaluation for resistance to pitting. An evaluation of an early autumn harvest at Stanthorpe on the Granite Belt appears to be an appropriate site.

Pitting is associated with high fruit Ca levels in red bell peppers (van Uffelen 1973, Carroll 1979), while low fruit Ca levels are known to result in blossom-end rot (Barke and Menary 1971). The intermediate state between Ca sufficiency and when pitting occurs on susceptible cultivars has not been established. Evaluation of the role of K in modifying plant Ca uptake (van Eijsinga 1973) is being undertaken (Carroll, personal communication). Cultivars resistant to pitting are desirable.

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