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Effects of temperature on premature nut drop in macadamia

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Summary

Five-year-old macadamia (*Macadamia integrifolia*, Maiden and Betche) trees were grown in controlled environment glasshouse bays for 10 weeks after nut set. High temperature (30 and 35°C compared with 20 and 25°C) induced a larger number of nuts to drop early. A subsequent 5°C increase from the two lower temperatures promoted further nut drop whereas when it was maintained at the higher temperatures or reduced from them to 25°C, there was little, if any, additional late drop. An intermediate rate of late nut drop was recorded after a 5°C increase from 30 to 35°C, presumably because at 30°C nut retention had already been adversely affected. It is suggested that 30°C might be critical in promoting unacceptable levels of nut drop. By avoiding extreme day temperatures, the proportion of the potential crop which is lost through premature nut drop may be reduced.

INTRODUCTION

In Australia, macadamia (*Macadamia integrifolia*, Maiden and Betche) trees usually flower profusely in spring and set a large number of nuts, many of which fall while immature (Williams 1980; Nissen and Stephenson 1980). This phenomenon has also been reported for macadamias in Hawaii (Urata 1954; Sakai and Nagao 1980) and is apparent in many tree fruit crops(Leopold 1964). The pattern of drop in Hawaii (Sakai and Nagao 1980) appears to be similar to that in Australia (Nissen and Stephenson 1983), with most nuts falling between 5 and 6 weeks after anthesis, coinciding with the commencement of endosperm development. Since fallen nuts at this stage have been successfully fertilised (Sedgley 1981), it should be possible for them to be retained and develop normally under suitable conditions, providing the tree has the capacity to support them.

Various growth regulators such as naphthalene acetic acid have been used to reduce the abscission of young macadamia fruitlets (Williams 1980; Stephenson 1980) but responses tended to be variable and were not necessarily reflected in higher nut yields (Stephenson *et al.* 1984). Other factors, therefore, must influence the drop of immature nuts, competition among individual nuts for food, water and mineral nutrients being likely (Childers 1975; Sedgley 1981). Jones and Cree (1965) found that yield of Washington navel oranges over a 38 year period was negatively correlated with high maximum temperature during the June fruit drop period. The usual local macadamia nut drop period also coincides with hot dry spring conditions.

This work was carried out to study the effects of temperature on retention of nuts.

MATERIALS AND METHODS

Two parts of the experiment were carried out sequentially in naturally lit controlled environment glasshouse bays. Five 5-year-old potted macadamia trees [1 to 2 each of cultivars Keauhou (cv. 246), Keaau (cv. 660) and Kau (cv. 344)] which had flowered and set nuts outdoors under ambient conditions were subjected to either 20, 25, 30 or 35°C days, 19 days after nut set. Average relative humidity (r.h.) was 80% (range 60 to 90), night temperature was 15°C and day length, 12 hours. Trees in each treatment had a similar number of nuts set at the beginning of the experiment.

Four weeks after the start of the experiment when many nuts on trees at high temperatures had fallen, trees with nuts remaining were re-randomised and allocated to different day temperature/r.h. regimes (3 trees, 1 of each cultivar, per treatment/pre-treatment combination). It was planned to compare nut drop from trees at 25°C with that at 35°C, at 80% and 40% r.h. The equipment, however, was unable to maintain the desired low humidity. Consequently, the regimes were restricted to 25°C/80%, 30°C/40% and 35°C/80% r.h. Night temperature was unchanged. This part of the experiment was designed to study changes in mean day temperature and relative humidity on nut retention during the latter part of early nut development prior to rapid increase in nut size.

Numbers of racemes and nuts, and nut size, were recorded initially and at 7 to 14 day intervals during both experiments. The condition and size of dropped nuts in each bay were noted weekly. Fallen nuts could not be identified with individual trees within glasshouse bays and thus statistical analysis of these data was not possible. Relative nut number remaining on trees after the second lot of treatments were imposed were subjected to linear regression analysis and slope differences were determined by test of homogeneity analysis.

RESULTS

Table 1 shows that high temperature (30 and 35°C vs 20 and 25°C) promoted greater abscission of macadamia racemes and nuts. Only 40% of the racemes which had been present on trees two weeks after nut set were retained five weeks later at 30°C, 10% at 35°C and 70% at or below 25°C. The number and percentage of nuts retained under each temperature regime were of similar relative order of magnitude.

Table 1. The effect of day temperature in controlled environments on retention of racemes and nuts on macadamia trees seven weeks after nut set

	Day temperature (°C)			
	20	25	30	35
Racemes retained per tree (%)*	70*a*†	70*a*	40*b*	10*c*
Nuts retained per tree (%)*	39*a*	29*a*	17*ab*	4*b*
Absolute nut no. retained/tree	44.1*a*	35.4*a*	7.5*ab*	1.1*b*

* Final no. (at seven weeks) ÷ original no. (at two weeks) x 100.

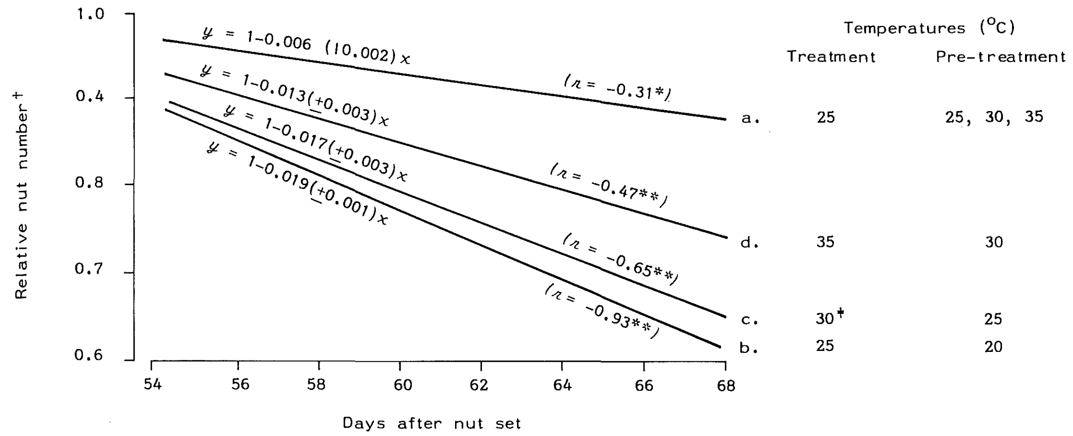
† Numbers followed by the same letter are not significantly different ($P<0.05$).

Dropped nuts were observed to be smaller at 20°C (30 mg) and 25°C (90 mg) compared with 190 mg at 30°C and 240 mg at 35°C. Splitting tended to be most prevalent in the larger nuts. These nuts contained developing endosperm tissue but undeveloped embryos.

After the initial nut drop period, temperatures maintained at, or reduced to 25°C, resulted in little, if any, additional nut drop (Figure 1). When temperatures were increased by 5°C to 25°C and 30°C, however, further nut drop occurred, the rate of drop being significantly greater ($P<0.01$) than when the temperature was maintained at, or reduced to, 25°C. The rate of drop was intermediate between and not significantly different from those of other treatments when temperature was increased from 30 to 35°C.

DISCUSSION

The amount of nut drop increased with increased temperature, although differences between 20° and 25°C, and between 30° and 35°C were not significant. Nut drop was, however, greater at the high temperatures (30 to 35°C) compared with 20 to 25°C, suggesting that 30°C may be the threshold in promoting greater than normal premature nut drop. This is consistent with the findings of Jones and Cree (1965) on premature drop of oranges.



†Final Nut number ÷ initial nut number at commencement of experiment.

‡The relative humidity for this treatment was 40%. In all other cases it was 80%.

Figure 1. The time course of the proportion of nuts present at the beginning of the second series of temperatures(corresponding with the end of the initial nut drop peak) which remained on the trees. Data were means from 10 to 60 racemes on each of 3 trees per treatment.

Trochoulias and Lahav (1983) reported adverse effects on growth of macadamia at temperatures of 30°C and above. During the experiments reported here, similar adverse effects were observed at high temperatures, particularly at 35°C. They included proliferation of multiple, spindly branches bearing small, malformed and chlorotic leaves. High temperature may have influenced nut drop directly through its influence on nut growth and development, or indirectly through adverse effects on tree growth and metabolism. Work is needed to clarify this.

Differences in levels of nut drop were apparent early, within 10 to 15 days of temperatures being imposed. Macadamias in south-east Queensland are frequently exposed to periodic heatwaves during early nut development. Developmental stages at which nuts are sensitive to abscission after high temperature exposure, therefore, need to be established.

Additional drop after the initial nut drop peak, in response to small (5°C) increases in temperature (Figure 1), demonstrate the sensitivity of young nuts, particularly to increases from 20 to 25°C and 25 to 30°C. A similar temperature increase from 30 to 35°C had a smaller adverse impact. It is likely that 30°C is critical for nut drop and an increase to 35°C has little further effect. In the field, sporadic peaks of nut drop occur outside the usual seasonal peak which is at 5 to 6 weeks after anthesis. These appear to be associated with sudden changes in weather patterns, particularly increased day temperature.

The larger dropped nuts at higher temperatures reflect on overall increase in nut growth. A larger proportion of these larger nuts had split, a condition which may be caused by a complex array of factors, including high temperature and rapid fruit growth (Teaotia and Singh 1970). It appears that nut growth was greater than the capacity of the tree to maintain and fill all nuts.

The presence of substantial nut drop at all temperatures supports the view that factors other than temperature may influence nut retention. Childers (1975) and Sedgley (1981) suggested that competition for food, water and nutrients is the primary cause of premature nut drop, whereas Leopold (1964) concluded that it was associated with endogenous auxin levels. Nevertheless, this study shows that temperature does influence the extent of premature nut drop and there may be scope for alleviating drop by protecting trees from high temperatures. Allan *et al.* (1982) employed a system of intermittent sprinkling to reduce heat stress in macadamia. Such measures, particularly at an early stage when endosperm is developing but prior to embryo growth, may significantly reduce the level of nut drop and result in higher yields.

Environmental factors other than temperature are likely to influence the extent of premature nut drop. Subsequent work (Stephenson and Gallagher, unpub. data 1986) shows that atmospheric and soil water stress effect nut drop. Because of the apparent sensitivity of macadamias, new plantations should be sited in areas with temperate climatic conditions. In existing areas irrigation should, if possible, be provided to alleviate stress induced by high temperatures. In the longer term, there may be scope for selecting cultivars better adapted to Australian conditions.

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