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Macadamia nut size and maturity influenced by lime and nitrogen applications

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Abstract. A long-term study of the effects of lime and nitrogen on a young macadamia orchard included acidifying sulfate of ammonia treatments to separate pH and Ca effects of lime applications. Lime, *per se*, had no influence on yield, quality, or trunk girth growth. Annual nitrogen applications (with or without neutralising applications of lime), however, consistently depressed the size of nuts and kernels and the percentage of first grade kernels, but had no effect on yield or other quality characteristics. More nuts developed with N treatments but failed to fill effectively.

Additional keywords: Macadamia integrifolia, kernel.

Introduction

Lime applications had no effect on macadamia seedling growth at soil pH 4–5.5 (1 : 5 in water) but tended to depress growth at higher soil pH (Aitken *et al.* 1990). Yield from mature trees also tended to decline at higher levels of pH, although this was not significant (Stephenson *et al.* 1996). Lime-induced chlorosis of macadamias, associated with iron deficiency, has been well documented in Hawaii (Fox *et al.* 1986) and has been observed in orchards with high soil pH in Australia (R. L. Aitken, pers. comm.). Baigent and O'Brien (1987) did not record yield responses to either lime or dolomite applications over a relatively narrow pH range up to pH 5.4. It is concluded that macadamias are relatively tolerant of soil acidity. This short communication reports on a long-term study designed to show the effects of both lime and acidifying sulfate of ammonia applications to young macadamia trees on tree growth and yield, and quality of nuts. Initial results covering the first year's production of nuts were reported by Stephenson *et al.* (1996).

Materials and methods

A field trial was established in an unirrigated orchard of young (*c.* 1 year old), non-bearing, Kau (HAES 344) macadamia (*Macadamia integrifolia* Maiden and Betch) trees at Cootharaba, Queensland, as described by Stephenson *et al.* (1996). The pH_W (1 : 5 in water) of this coarse-textured soil was 5.1 at 0–5 cm, declining to 4.6 at 20–30 cm. Treatments consisted of 4 rates of agricultural lime (0, 200, 400, and 800 g $CaCO_3/m^2$) together with an N treatment (240 g $(NH_4)_2SO_4/m^2$), and N plus lime (240 g $(NH_4)_2SO_4/m^2$ + 360 g $CaCO_3/m^2$). Lime applied in the latter treatment was designed to counter the acidifying effects of the N fertiliser and was applied approximately 1 month after application of the N (in November–December) to minimise volatilisation of N. Treatments were applied to 5 m by 5 m single tree plots, centered on the tree and replicated 4 times. To achieve uniform distribution of fertiliser, each plot was subdivided into 1 m by 1 m subplots and appropriate amounts of the fertiliser uniformly were applied through a sieve. Lime treatments were applied only once in October 1988 and the N and N plus lime treatments were applied in October–November from 1988 to 1998, coinciding with nut set–early nut development.

Normal commercial management of trees was carried out, but no ameliorants or N fertilisers were applied. Data were collected annually for tree growth (assessed by trunk girth measurements), nut-in-shell (NIS) and kernel yield, and kernel quality: kernel recovery (KR, kernel weight/NIS × 100) and percentage first grade kernel (G1K, >72% oil, SG = 1, floats in tap water).

The data were analysed using linear mixed models including treatment terms to test for the effect of liming and N treatments and additional terms to account for extra random variation due to years, replicates, the individual trees, and the interaction of these factors. Generalised least squares was used for the fixed effects and best linear unbiased prediction (Robinson 1991) for the random effects. The REML method of variance component estimation (Patterson and Thompson 1971) was used and the Wald statistic was used to assess the significance of fixed effects. All analyses were carried out using the `samm` mixed modelling facility (Butler *et al.* 2001) in SPLUS.

Results

Neither lime nor N treatments influenced yield of NIS, kernel yield, trunk girth growth, or KR during the first

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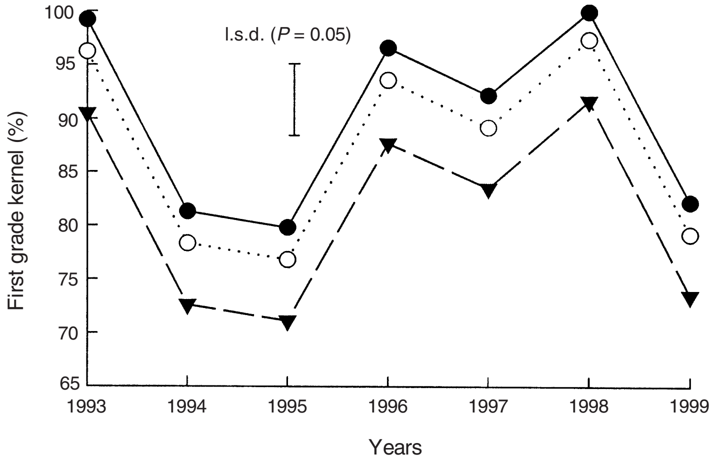

Fig. 1. Seasonal mean percentage first grade kernel from trees receiving various lime applications (○), nitrogen fertiliser (▼), or untreated controls (●).

6 years of production. Yield of control trees ranged from 1.3 kg NIS/tree in 1993 to 15 kg/tree in 1998 and 13.4 kg/tree in 1999. Average kernel recoveries were 28.9, 28.2, 27.3, 30.9, 25.8, 33.5, and 31.5% in 1993 to 1999, respectively. Mean trunk girth increased from 2.5 to 50 cm over the 9 years of the trial. Figure 1 shows that G1K was consistently depressed by *c.* 8–10% by N treatments. The average G1K from lime treatments was not significantly lower than that of control trees. Mean nut and kernel weights were reduced by *c.* 8–12% with N treatments, but lime treatments had no effect (Figs 2 and 3). Reduction in mean nut size did not apply generally (Fig. 4), but was reflected in a smaller percentage of nuts in the larger category (>24 mm) and a higher percentage in the smaller category (19–24 mm).

Discussion

The lack of a yield response to liming this coarse-textured acidic soil is consistent with the results of previous studies with both bearing (Baigent and O'Brien 1987) and non-bearing trees (Aitken *et al.* 1990). Although Stephenson *et al.* (1996) reported a tendency for yield to be depressed at soil pH >5.5, this was not so in this study (Aitken *et al.* 1996) in which surface soil pH during the first year was increased from 5.1 to 6.1, 6.6, 7.1, and 6.1 by 200 g, 400 g, 800 g lime, and 360 g lime + N, respectively, and dropped to 4.4 with N. Soil pH_w, however, declined progressively to year 5 by *c.* 0.8 for each of the lime treatments. These results support the conclusion that macadamias are tolerant of soil acidity (Stephenson *et al.* 1996).

The depression of G1K with the relatively high rates of N used in this study (1.26 kg N/tree) was more marked and consistent than reported previously (Stephenson and Gallagher 1989*b*; Stephenson *et al.* 2000). Nevertheless, higher applications of N tended to cause a reduction in G1K in all studies. For example, trees that received 690 g N/tree had lower G1K than 'control' trees receiving only 230 g N/

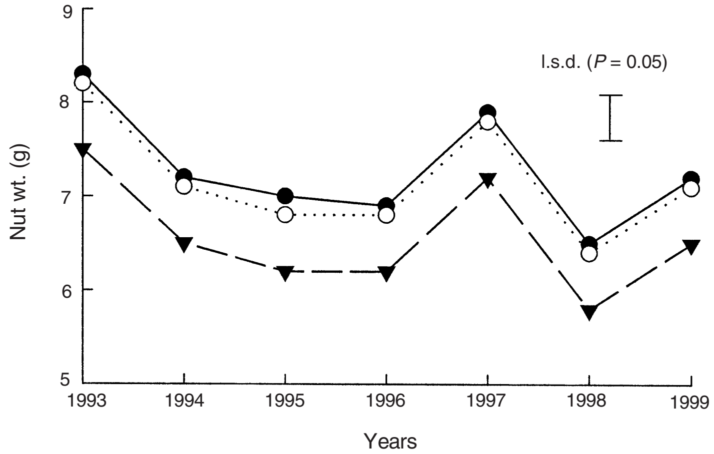

Fig. 2. Seasonal mean nut weight from trees receiving various lime applications (○), nitrogen fertiliser (▼), or untreated controls (●).

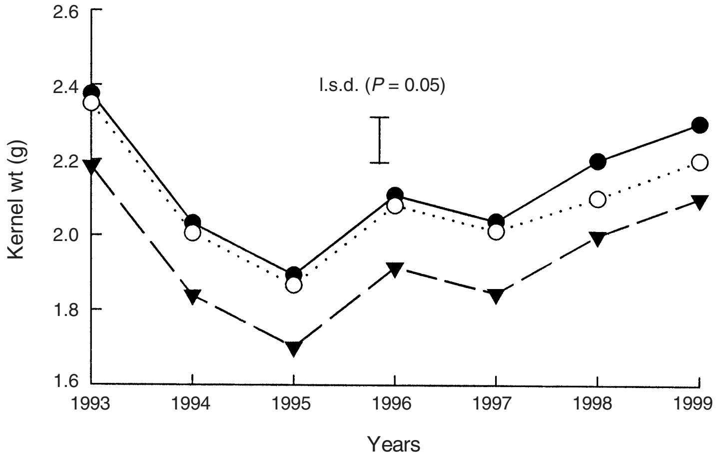

Fig. 3. Seasonal mean kernel weight from trees receiving various lime applications (○), nitrogen fertiliser (▼), or untreated controls (●).

tree per year (Stephenson *et al.* 1989*b*). Monthly split applications, however, resulted in higher G1K than single applications in April, presumably due to more effective utilisation and less leeching. The single application of 1.26 kg N/tree applied annually in October–November in the current study would have enhanced nut growth and oil accumulation when the demand for N and assimilates was high (Stephenson *et al.* 1997).

The fluctuation of G1K levels is partly explained by rainfall during the latter stages of oil accumulation (Stephenson *et al.* 2000); low rainfall in March, April, or May appears to be associated with high G1K. Rainfall was low over this period in 1993, high in 1994, low in 1995, 1996, and 1998, and high in 1997 and 1999. High rainfall at this time may induce a supplementary peak of vegetative flushing (Stephenson and Gallagher 1989*a*) which, in turn, may adversely affect G1K (Stephenson *et al.* 2000), perhaps by competition for assimilates at this high-demand stage. Other seasonal factors undoubtedly influence G1K. In years in which G1K was low, yield and kernel recovery also tended to be low.

The smaller nuts and kernels from trees fertilised with N appear to be the result of trees setting more nuts but being unable to fill them normally, since total yield was similar for all treatments. Fig. 4 shows that high N reduced the percentage of large (>24 mm) nuts by more than 10%, and increased intermediate sized nuts (19–24 mm) by about 10% and small reject nuts only marginally. Stephenson *et al.* (1989*b*) reported a similar response to N applied to HAES 660, a variety that commonly produced a substantial proportion of small, unmarketable nuts. Since HAES 344

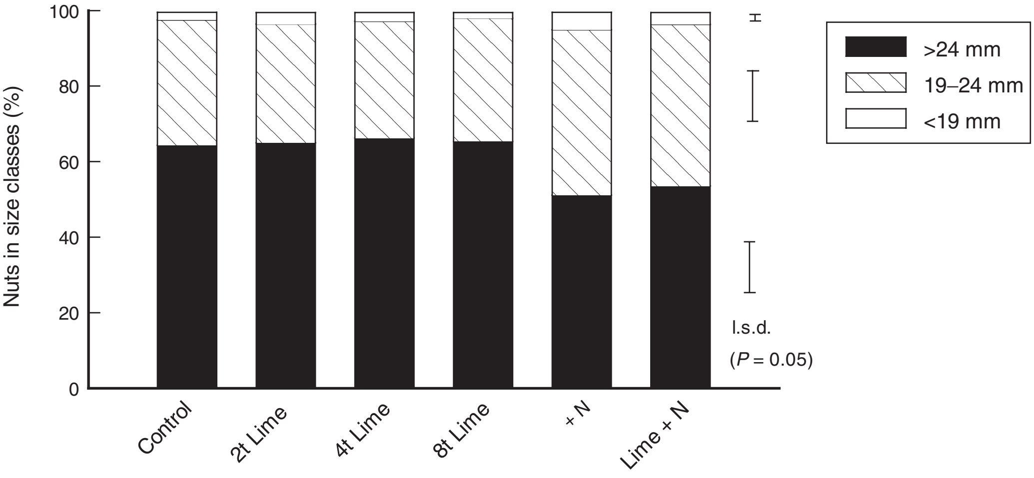

Fig. 4. Percentage of nuts in <19 mm, 19–24 mm, and >24 mm size classes from various lime and nitrogen treatments.

trees normally produce nuts of relatively uniform size, this response to high N applied in a single dose could apply generally across other varieties. Smaller rates of N applied in multiple split applications are less likely to cause a reduction in nut and kernel size but are likely to result in higher G1K (Stephenson *et al.* 1989*b*).

Although smaller kernels may be desirable for some commercial markets such as chocolate-coated macadamias, manipulation of kernel size with N is unlikely to be a useful management tool to target such markets, particularly when high N tends to depress yield of commercial kernel (Stephenson *et al.* 1989*b*, 1997).

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References

Aitken RL, Stephenson RA, Gallagher EC (1990) Effect of lime application to strongly acidic soils on the growth of macadamia seedlings. *Australian Journal of Experimental Agriculture* **30**, 421–426.

Aitken RL, Stephenson RA, Moody PW, Gallagher EC (1996) Amelioration of coarse-textured acidic soils used for macadamia production. II. Effects of surface applied lime on subsoil properties. *Australian Journal of Agricultural Research* **47**, 109–119.

Baigent DR, O'Brien K (1987) Effects of lime/dolomite application on macadamia productivity. In 'Proceedings of the Second Australian Macadamia Research Workshop'. (Eds T Trochoulias, I Skinner) pp. 117–124. (Australian Macadamia Society: Hawthorne, Qld)

Butler DG, Cullis BR, Gilmour AR, Gogel BJ (2001) 'Spatial analysis mixed models with S-PLUS.' (Queensland Department of Primary Industries)

Fox RL, M^{c}Call WW, Hue NV (1986) Macadamia nutrition studies with special reference to chlorosis induced by lime, phosphate, manganese and aluminium. In 'Proceedings of the 26th Annual Meeting of the Hawaii Macadamia Nut Association.' pp. 87–105. (Hawaii Macadamia Nut Association, Hawaii)

Patterson HD, Thompson R (1971) Recovery of inter-block information when block sizes are unequal. *Biometrika* **58**, 545–554.

Robinson GK (1991) That BLUP is a good thing: the estimation of random effects. *Statistical Science* **6**, 15–51.

Stephenson RA, Aitken RL, Gallagher EC, Moody PW (1996) Amelioration of coarse textured acidic soils used for macadamia production. I. Tree growth, yield and leaf nutrient composition. *Australian Journal of Agricultural Research* **47**, 97–107.

Stephenson RA, Gallagher EC (1989*a*) Timing of nitrogen application to macadamias. 1. Tree nitrogen status and vegetative growth. *Australian Journal of Experimental Agriculture* **29**, 569–574.

Stephenson RA, Gallagher EC (1989*b*) Timing of nitrogen application to macadamias. 3. Reproductive growth, yield and quality. *Australian Journal of Experimental Agriculture* **29**, 581–585.

Stephenson RA, Gallagher EC, Doogan VJ (1997) Leaf nitrogen as a guide for fertilising macadamia. *Australian Journal of Experimental Agriculture* **37**, 599–604.

Stephenson RA, Gallagher EC, Doogan VJ, Mayer DG (2000) Nitrogen and environmental factors influencing macadamia quality. *Australian Journal of Experimental Agriculture* **40**, 1145–1150.

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