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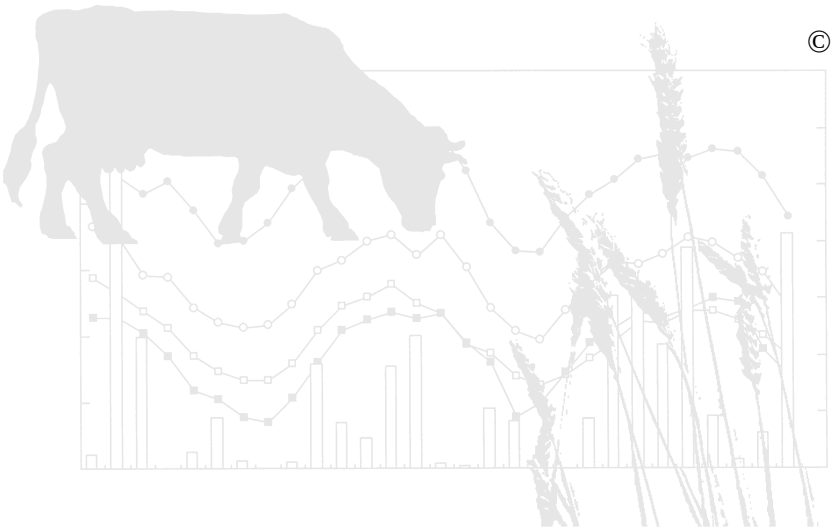

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Production locality affects mango fruit quality

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Summary. Differences in mango (cv. Kensington Pride) fruit quality under commercial and research conditions have been frequently noted. To assess the potential for production conditions to influence fruit quality, 'Kensington Pride' mango fruit were obtained from 2 adjacent sites on an orchard on shallow nodular yellow podsolic soil in tropical North Queensland, 1 block of trees growing on soil with river gravel (site 1) and another without gravel (site 2). Fruit were also obtained from trees on a gleyed podsolic soil (site 3) in subtropical south-east Queensland. Fruit were harvested weekly for 4 weeks, with quality determined after ripening at 22ºC and after storage at 10ºC for 4 weeks. Eating quality and percentage dry matter increased, while days to eating soft decreased with later harvests. Fruit from site 3 (cooler growing conditions, rain during the harvest period) had acceptable eating quality at a lower dry matter than fruit from sites 1 and 2. The percentage of green colour on the skin (GS) at ripe was higher at harvest 2 in fruit from sites 1 and 2, but was lower at harvest 4 in fruit from all sites. Disease severity in fruit ripened without storage was higher in site 3 fruit, while body rots (caused mainly by *Colletotrichum* spp.) increased (site 3 only) and stem end rots (caused mainly by *Dothiorella* spp.) decreased with later harvests. Fruit firmness and GS decreased during storage at 10ºC, but fruit from site 3 were generally softer, with higher GS, than those from the other sites. Chilling injury was also higher in fruit from site 3.

Additional keywords: *Mangifera indica*, ripening, colour, storage, quality, preharvest/postharvest interaction.

Introduction

Many production factors, such as production locality, soil type, climate, cultivar, nutrition and irrigation have an important impact on temperate fruit quality and storage performance (Ferguson 1980; Beverly *et al*. 1993), and similar influences are being reported in subtropical and tropical fruit (Monselise and Goren 1987; Hofman 1996).

The Australian mango industry is placing increasing emphasis on quality. Factors such as disease, appearance (colour, blemishes), internal disorders and differences in ripening rate between fruit from the same and different localities are commercially important. Some postharvest practices have been developed to reduce variability and improve predictability of fruit quality (e.g. ethylene treatment to synchronise ripening), but it is equally important to understand and manipulate the factors influencing quality at harvest. Several aspects of mango quality have been shown to be influenced by production practices, such as high soil nitrogen being associated with more green skin at ripe (Oosthuyse 1993), and soil type affecting internal disorders (Young and Miner 1961; Burdon *et al*. 1991).

This study was conducted to assess the potential for production factors to influence mango fruit quality. Fruit from trees growing on 2 different soil types on the same property, and from a property in another production district, were ripened without and after storage, with fruit quality assessed during storage and ripening.

Materials and methods

Fruit

Mango fruit (*Mangifera indica* cv. Kensington Pride) were obtained from 3 sites. A commercial orchard near Mareeba (tropical North Queensland; lat. 19.34º, long. 147.25º) on a shallow nodular yellow podsolic (or lithosol) soil provided 2 adjacent sites; site 1 with gravel causing poor water and nutrient retention, and site 2 without the gravel. The third site (site 3) was on a commercial orchard near Nambour (subtropical south-east Queensland; lat. 26.36º, long. 145.25º) on a gleyed podsolic soil (or yellow ferrosol). Fruit were sampled from 5 trees from each of sites 1 and 2, and 10 trees from site 3. All trees were 6–8 years of age and received good (sites 1 and 2) and average (site 3) management based on standard commercial practices. Panicles on the north side

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of the tree and at mid canopy height were tagged at the same stage of flowering to minimise the effects of flowering date on maturity at harvest. Rainfall and temperature data were obtained from nearby weather stations.

Harvesting started at the earliest commercial maturity (14 December 1993 from sites 1 and 2, and 17 January 1994 from site 3). Six fruit per tree for sites 1 and 2, and 4 fruit per tree for site 3, were harvested at weekly intervals for 4 weeks. Fruit were harvested during early morning, and transported to the laboratory within 1 day of harvest (by air from sites 1 and 2, and by road from site 3). On arrival, all fruit were de-sapped, weighed and dipped in prochloraz (0.05% v/v Sportak) for 30 s. Three fruit from each tree (2 for site 3) were ripened at 22ºC by placing the fruit from each site in individual 30 L plastic barrels (15 fruit per barrel for sites 1 and 2, and 20 for site 3) and ventilating with ethylene-free air (passed through a Purafil filter) at 2000 mL/min and 93% relative humidity. Fruit were assessed at eating soft for quality. The remaining 3 fruit per tree (2 for site 3) were placed in standard cartons and held at 10ºC under normal atmospheres for 4 weeks and ripened at 22ºC for a further 10 days. Fruit quality was assessed during storage and ripening.

Fruit quality

Fruit firmness was measured by gentle hand pressure using a scale: 6, hard; 3, eating soft; 1, over-soft. These corresponded to firmness readings of 45, 6 and 1 N, respectively, as measured on an Instron Universal Testing Machine model 1122, fitted with an 8 mm hemispherical probe (probe penetration 2 mm) interfaced with a computer. Days to eating soft (DTES) was measured as the days from harvest to reach a firmness rating of 3. Skin colour was visually assessed as the percentage of green area on the skin (GS), ignoring the red colour where this occurred. Flesh colour at eating soft was rated using a Yolk Colour Fan (Roche Pharmaceutical Co.) with a scale from 1 (very pale yellow) to 8 (typical mango flesh colour) to 14 (very orange), corresponding to CIELAB L^* of 82.0, 75.1, 65.9, a^* of 2.3, 21.6, 38.7, and b^* of 48.2, 77.4, 68.9, respectively, as measured by a Hunter Labscan 6000 Spectrocolourmeter fitted with 25-mm orifice, D65 illuminant and a 10º observer. Lenticel spotting severity was assessed on a scale: 0, none; 25, a few small spots; 50, moderate number of small spots or a few large spots; 75, large number of small spots or moderate number of large spots; 100, large number of large spots. Chilling injury (CI) was rated as the percentage of the fruit surface area affected, based on the symptoms described by Snowdon (1990).

Disease severity was measured at eating soft, or after storage and ripening. Fruit body rots (caused mainly by *Colletotrichum* spp.) on the side of the fruit, and stem end rots (caused mainly by *Dothiorella* spp.) at the stem end of the fruit, were rated as the percentage of the fruit surface area affected.

The percentage dry matter (DM) was determined by drying a combined subsample of flesh from each fruit from each tree (replication) to constant weight in a vacuum oven at 70ºC.

Statistical analyses

Analysis of variance was used to test for differences between sites and harvests, and their interaction. The effect of sites was tested against the variability between trees within sites, while the harvest effect and site by harvest interaction were tested against the interaction between harvests and trees within sites. The variability of fruit within harvests within trees was also calculated. For DM and eating quality, fruit from each harvest for each tree were bulked so that no estimate of fruit-to-fruit variability could be made.

An angular transformation was applied to individual fruit data before analysis of variance for GS, and severity of stem end rots, body rots, lenticel spotting and CI.

As the interaction between sites and harvests was often significant ($P<0.05$) the site by harvest means are presented. Pairwise comparisons between these means were made using the protected least significant difference test.

Stem end rots and body rots were not present in fruit ripened without storage at sites 1 and 2 for harvests 2, 3 and 4, so site 3 means for these harvests were compared with the constant zero using a 1-tailed Student's *t*-test, with the variance estimated by the pooled variance between trees within the 4 harvests at site 3.

Simple linear regressions were fitted separately for the 3 sites. The data were combined and parallel lines fitted in cases where the slopes of the fitted lines were not significantly different ($P>0.05$). If the intercepts were also not significantly different ($P>0.05$) then data were pooled and a single regression equation fitted.

All statistical testing was carried out at $P = 0.05$ except where otherwise indicated.

Results

Maximum and minimum air temperatures were higher near sites 1 and 2 than near site 3 (Table 1). Rainfall was lower near sites 1 and 2 during most of the fruit growth period (Fig. 1). During the harvest period, rainfall near sites 1 and 2 ranged from 0 to 25 mm/week, and near site 3, from 51 to 115 mm/week.

No storage

The DM increased with date of harvest in fruit from all 3 sites (Fig. 2). Fruit from sites 1 and 2 had similar DM, while those from site 3 had lower DM for all harvests except harvest 2. Eating quality also increased with later harvests. Fruit from site 3 had higher eating quality than those from site 1 at harvests 1 and 4, but was not significantly different at other harvests, nor from

Table 1. Average maximum and minimum temperatures (°C) near sites 1 and 2 (North Queensland) and near site 3 (south-east Queensland) during the period of 'Kensington Pride' mango fruit growth and harvest (October 1993–February 1994)

Date	Sites 1 and 2		Site 3	
	Max. temp.	Min. temp.	Max. temp.	Min. temp.
October 1993	31	17	27	13
November 1993	31	19	28	16
December 1993	31	20	28	17
January 1994	34	22	30	21
February 1994	—	—	28	20

site 2 fruit. The DTES decreased with later harvests in fruit from all sites. Fruit from site 3 at harvests 2 and 3 ripened more quickly than those from site 1. Fruit from all sites showed significant increases with harvest date in flesh colour at eating soft, but the pattern was not consistent with harvest. Flesh colour in fruit from site 1 was consistently less yellow (lower colour rating) than those from other sites.

Fruit with higher DM had higher eating quality (P<0.01, Fig. 3), with no difference in the relationship between sites 1 and 2. However, fruit from site 3 had a higher intercept (higher eating quality at the same DM) than those from sites 1 and 2.

The DM was negatively correlated with DTES (Fig. 3; P<0.01 for sites 1 and 2, P<0.05 for site 3). Again, fruit from sites 1 and 2 had similar relationships. At the same DM, site 3 fruit ripened more quickly than those from sites 1 and 2, especially at lower DM.

The GS at harvest decreased at harvest 4, but less so in site 3 fruit where this attribute was higher than at sites

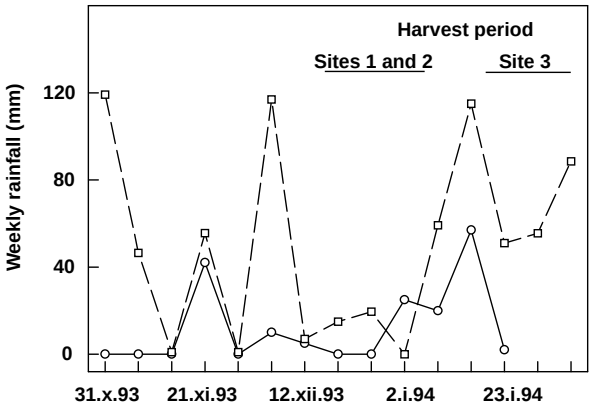

Figure 1. Rainfall (mm) received per week near sites 1 and 2 (○) (North Queensland) and near site 3 (□) (south-east Queensland) during the period of 'Kensington Pride' mango fruit growth and harvest (October 1993–February 1994).

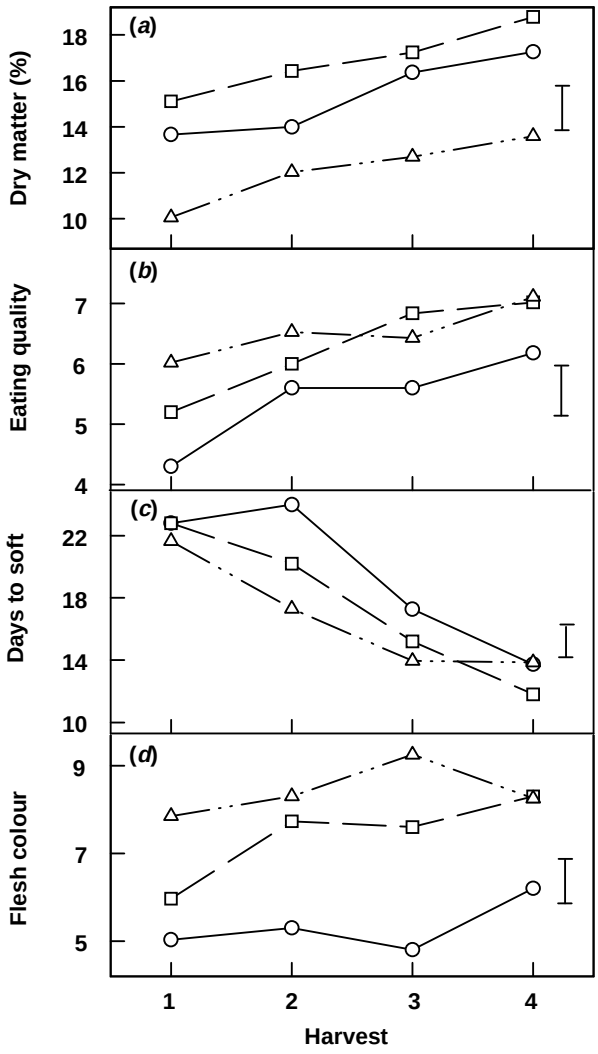

Figure 2. The effect of harvest time (weekly intervals) and production site [sites 1 (○) and 2 (□) in North Queensland, site 3 (△) in south-east Queensland] on (*a*) the percentage dry matter at harvest, (*b*) eating quality (1–9) at eating soft, (*c*) days from harvest to eating soft at 22°C, and (*d*) the flesh colour (0–14, based on yellow colour) at eating soft, of 'Kensington Pride' mangoes. Vertical bars represent the average l.s.d. (P = 0.05) for comparison of site by harvest means.

1 and 2 (Fig. 4). At eating soft, the GS increased at harvest 2 in site 1 and 2 fruit, but decreased with later harvests. In site 3 fruit, the GS was lower at harvest 4 than at the other harvests.

There were significant (P<0.01) negative correlations between DM and GS at eating soft (angular transformed) for all sites (R^2 = 0.19), and significant (P<0.01) positive correlations between DTES and GS at eating soft for site 1 (R^2 = 0.22) and site 3 (R^2 = 0.19). There were also significant (P<0.01) positive correlations between

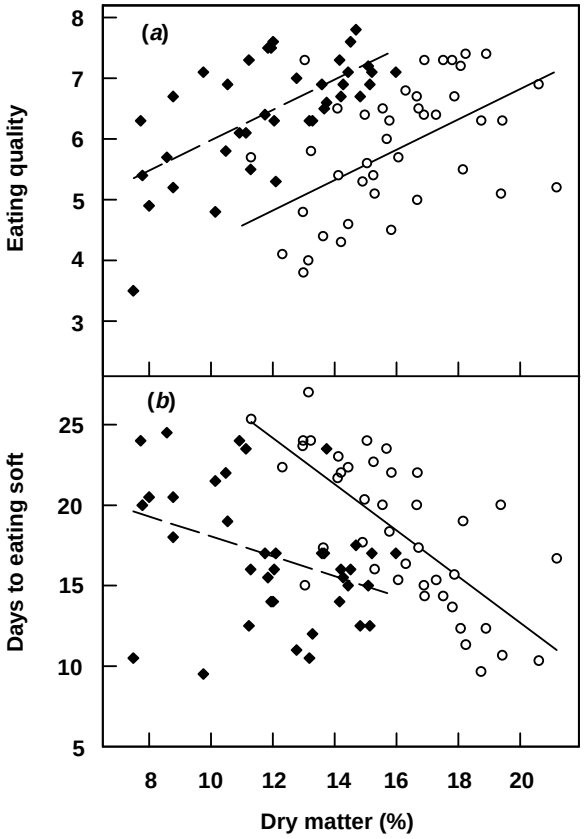

Figure 3. The relationship between percentage dry matter at harvest and (*a*) eating quality (1–9) and (*b*) days from harvest to eating soft, for 'Kensington Pride' mango fruit harvested from production sites 1 and 2 (○), and site 3 (◆). Regressions for fruit from sites 1 and 2 were not significantly different and are represented by the same regression line (solid line). For the eating quality regression, site 3 is represented by a parallel (dashed) line. The slope of the regression lines is 0.250 and the intercepts are 1.82 (sites 1 and 2), and 3.48 (site 3) (R^2 = 0.36, P<0.01). For the days to eating soft regression the equation for sites 1 and 2 is days to eating soft = –1.55 (% DM) + 43.4 (R^2 = 0.59, P<0.01), and for site 3, days to eating soft = –0.62 (% DM) + 24.3 (R^2 = 0.14, P<0.05).

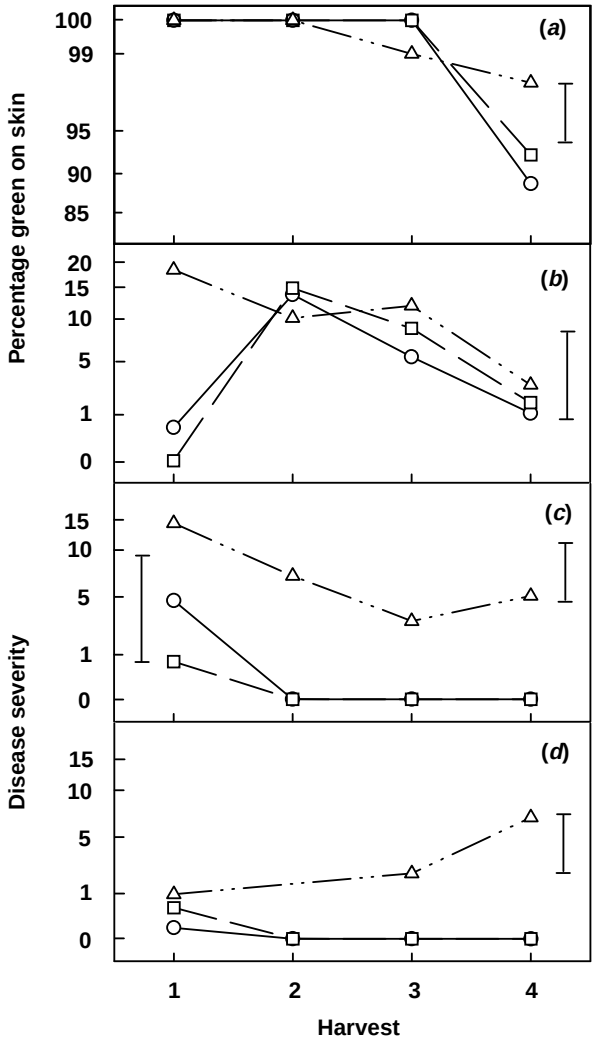

Figure 4. The effect of harvest time (weekly intervals) and production site [sites 1 (○) and 2 (□) in North Queensland, site 3 (△) in south-east Queensland] on the percentage of the skin with green colour at (*a*) harvest and (*b*) eating soft, and the severity (percentage of fruit surface area affected) of (*c*) stem end rots and (*d*) body rots at eating soft, of 'Kensington Pride' mangoes ripened at 22ºC. Data are angular transformed. Vertical bars represent the average l.s.d. (P = 0.05) for comparison between means. For percentage green on skin at harvest, the l.s.d. is for comparison between sites at harvest 4 only. For disease severity, the bar on the left is for comparison between sites for harvest 1 (no significant differences for body rots), and on the right, for comparisons between harvests for site 3.

firmness and GS of fruit at the time when the first fruit for that site and harvest had reached eating soft, for site 1 (R^2 = 0.35) and sites 2 and 3 pooled (R^2 = 0.08). These correlations indicated that fruit ripening more quickly had less GS at eating soft.

The severity of stem end rots decreased with harvest. In harvest 1, site 3 fruit had more stem end rots than site 2 fruit (Fig. 4). No stem end rots were recorded for site 1 and 2 fruit in harvests 2, 3 and 4, whereas in site 3, stem end rots severity was greater than 0 in those harvests. There was low body rots severity on fruit from all sites at harvest 1, but no body rots were recorded for subsequent harvests from sites 1 and 2. For site 3 fruit, body rots severity was greater than 0 in harvests 3 and 4.

Storage

Fruit from all sites and harvests softened during storage at 10ºC, and softening was accelerated when placed at 22ºC (Fig. 5). After 10 days at 22ºC, fruit were at or slightly softer than eating soft.

At harvest, most fruit had a firmness rating of 6. However, after 3 weeks of storage, firmness of site 3

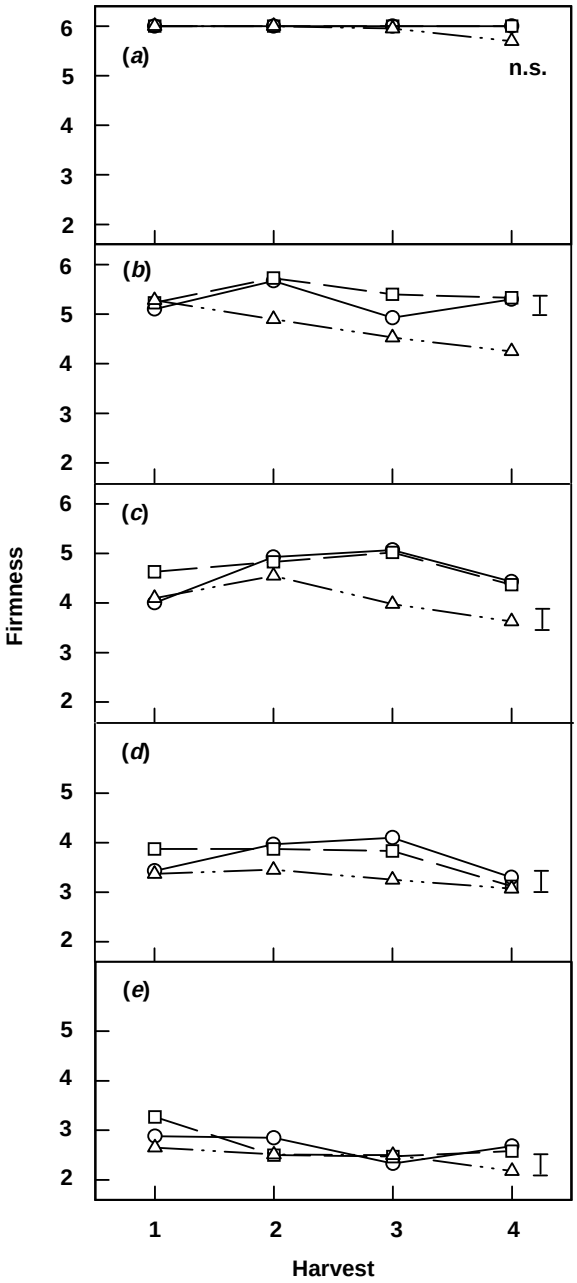

Figure 5. The effect of harvest time (weekly intervals) and production site [sites 1 (○) and 2 (□) in North Queensland, site 3 (△) in south-east Queensland] on fruit firmness (6, firm; 3, soft) (*a*) at harvest and following storage at 10ºC for (*b*) 3 and (*c*) 4 weeks, then after ripening at 22ºC for (*d*) 5 and (*e*) 10 days, of 'Kensington Pride' mangoes. Vertical bars represent the average l.s.d. (P = 0.05) for comparison of means.

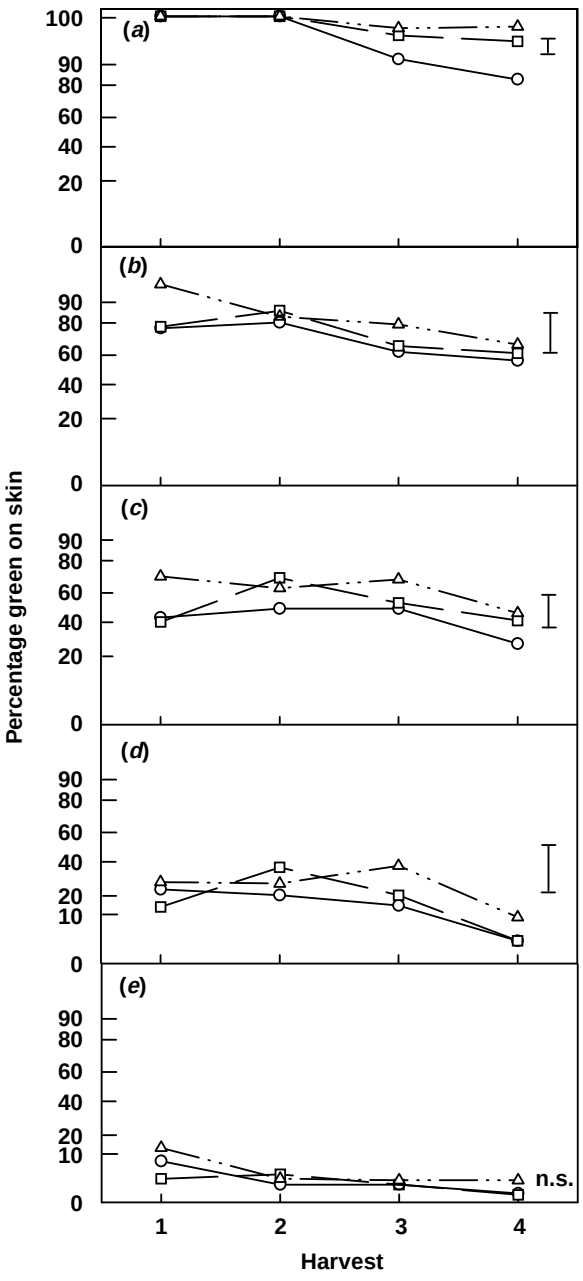

Figure 6. The effect of harvest time (weekly intervals) and production site [sites 1 (○) and 2 (□) in North Queensland, site 3 (△) in south-east Queensland] on the percentage of the fruit skin with green colour at (*a*) harvest and following storage at 10ºC for (*b*) 3 and (*c*) 4 weeks, then after ripening at 22ºC for (*d*) 5 and (*e*) 10 days, of 'Kensington Pride' mangoes. Data are angular transformed. Vertical bars represent the average l.s.d. (P = 0.05) for comparison of means.

fruit decreased with harvest, and was lower than site 1 and 2 fruit at harvests 2, 3 and 4. After 4 weeks of storage at 10ºC, firmness decreased from harvest 3 to 4 in site 1 and 2 fruit and from harvest 2 to 4 in site 3 fruit. Also, site 3 fruit from harvests 3 and 4 were softer than those from sites 1 and 2.

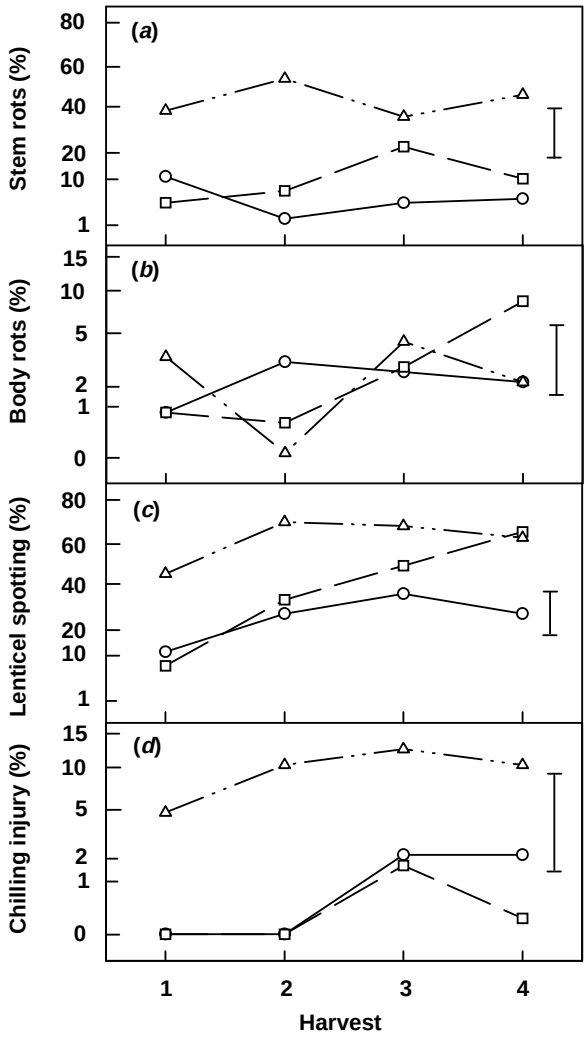

Figure 7. The effect of harvest time (weekly intervals) and production site [sites 1 (○) and 2 (□) in North Queensland, site 3 (△) in south-east Queensland] on the severity (percentage of the fruit surface area affected) of (*a*) stem end rots and (*b*) body rots, (*c*) severity of lenticel spotting (0, nil; 100, severe), and (*d*) chilling injury (percentage of the fruit surface area affected) following storage at 10ºC for 4 weeks, and then at 22ºC for 10 days, of 'Kensington Pride' mangoes. Data are angular transformed. Vertical bars represent the average l.s.d. ($P = 0.05$) for comparison of means.

After 5 days at 22ºC, firmness was lower at harvest 4 in site 1 and 2 fruit than from harvests 2 and 3, but there was no effect of harvest on site 3 fruit (Fig. 5). Site 3 fruit from harvest 3 were softer than those from sites 1 and 2 at harvest 3. After 10 days at 22ºC, fruit from site 3 were softer than site 2 fruit at harvest 1, and softer than site 1 fruit at harvest 4.

Fruit from all sites and harvests also showed reductions in the GS during storage at 10ºC (Fig. 6). Site 1 fruit from later harvests showed reductions in the GS at harvest, and these fruit were less green than those from sites 2 and 3. At 3 weeks, 4 weeks and 4 weeks + 5 days at 22ºC, the GS of harvest 4 fruit was generally less than those from earlier harvests, but after 10 days at 22ºC, there was no harvest effect. After 3 and 4 weeks at 10ºC, fruit from site 3 had more GS than those from the other sites at harvest 1 only.

Stem end rots severity after storage for 4 weeks at 10ºC and 10 days at 22ºC was higher in fruit from site 3 at harvests 1, 2 and 4, than in fruit from sites 1 and 2 (Fig. 7). Body rots were less severe and inconsistent across sites and harvests. The severity of lenticel spotting was generally lower at harvest 1 than at other harvests for all sites, and was greater in site 3 fruit with harvests 1, 2 and 3.

Chilling injury severity in site 3 fruit was higher than site 1 and 2 fruit at harvests 1 and 2, and higher than site 2 fruit at harvest 4.

Discussion

The characteristics of the production site and cultural practices can influence many aspects of fruit quality (Hofman 1996). The current investigation demonstrated the potential for these factors to influence mango fruit quality. While the study was not intended to identify the major factors determining quality, it has indicated that soil type can be a factor, since fruit from sites 1 and 2 were subjected to similar cultural and environmental influences, yet had differing quality. Climate probably had a large influence also because of the larger differences in quality between fruit from site 3 and those from the other 2 sites, than between fruit from sites 1 and 2.

Similar effects of harvest date on DM have been noted by Gangwar and Tripathi (1973) and Saeed *et al.* (1975) in mango. Its relationship to eating quality has also been noted by Peacock *et al.* (1985), and this provided the basis for its use as a minimum maturity standard (14% DM in Australia). Peacock *et al.* (1985) also noted that production location affected the intercepts of the linear relationship between DM and eating quality. However, of the 5 production sites they evaluated, their sites near our sites 1 and 2, and near site 3, had the same linear relationship, which is contrary to the current results. In the current investigation, rain during the harvest period for site 3 may have reduced DM to a greater extent than eating quality, thereby resulting in a lower intercept. These results illustrate the caution required in using DM alone as a maturity standard. Other criteria such as weather (temperature and rainfall) also need to be considered. Similar considerations are required when reduced irrigation is used to increase fruit DM to more quickly attain the minimum maturity standard (Diczbalis *et al.* 1995).

The reduction in DTES with harvest has also been noted in mango by Peacock *et al.* (1986) and Medlicott *et al.* (1988). These results, and the effect of maturity on CI noted in this study, suggest that fruit of lower maturity should be used for long-term storage. The effect of production site on CI suggests that careful consideration of production area and/or climate is required to maximise storage potential. Similar considerations may also be necessary for other postharvest treatments. For example, Jacobi and Wong (1992) noted that mango fruit from certain production areas were more susceptible to injury from high humidity hot air treatment than those from other areas. Climate just before harvest may be particularly important because of the potential negative effects of rain at harvest on quality (Wainwright and Burbage 1989; Mead and Winston 1991).

Green skin colour on ripe 'Kensington Pride' fruit is becoming an increasing commercial problem in Australia (S. N. Ledger pers. comm.), so the early development of good skin colour before significant fruit softening would be a distinct advantage. Postharvest factors, especially ripening temperatures outside the range of about 18–22ºC, can result in more green colour on the skin at eating soft (McLauchlan and Wells 1994; O'Hare 1995). However, production conditions can also influence the relationship between skin colour and softening as indicated in the present study. For example, high soil nitrogen applications (Oosthuyse 1993; McKenzie 1994) have been associated with increased green mango fruit skin colour at ripe. Also, Medlicott *et al.* (1988), and the results of the current study, indicate that more mature fruit have less green skin at ripe. Further research is in progress in this area.

In conclusion, this study has indicated the potential for production conditions (soil, cultural and/or climatic) to influence mango fruit quality. Further studies are required to identify those production factors having the greatest effect on quality, so that both quality and yield can be better controlled to meet market requirements.

Acknowledgments

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