The way to do research is to attack the facts at the point of greatest astonishment.

Celia Green (1935 - )

British philosopher, psychologist and physicist

# Chapter 1

## GENERAL INTRODUCTION

Few fruit embody summer lusciousness more vividly than the tropical sensuality of a mango (*Mangifera indica* L. (Anacardiaceae)) fruit. After pineapples (45.2 %), it is the second most important tropical fruit crop (25.2 %) (Food and Agriculture Organisation, 2002; Saúco, 2004).

Considered indigenous to eastern Asia, Myanmar and North Eastern India, mangoes have been cultivated for at least the past 4000 years. Tree crop farmers in South Africa experimented with its cultivation since the turn of the 1900th century and in 1920 the first commercial production began in the vicinity of Tzaneen (S 23º49' E 30º20') (South African Mango Growers Association, 2004). Mango trees are evergreen, andromonoecious and capable of growing up to 250 years old, annually bearing abundantly flowering thyrses (Watson & Dallwitz, 1992; Judd *et al*., 2002). However, the plant culls the majority of its flowers, eventually bearing only a few fleshy drupes.

Variations in sensorial characteristics are cultivar dependant (Knight, 1997). As a globally popular commodity that also has cultural importance, a wide array of varieties in terms of colour, shape, smell and taste have been developed. The characteristic smells and tastes result from the organic acid, terpenoid and free sugar content of the fruit, varying from almost bland to distinctly turpentine, from sweet to acidic (Singh *et al*., 2004). Cultivar development and selection depends on these chemical profiles, along with other genetically determined traits such as fibrousness, colour and shape (Lavi *et al*., 1997).

Not all cultivars are suitable for cultivation in all production areas, since physical variables related to weather and geographic location affect fruit physiology, tree architecture and innate resistance to pathogens (Bompard, 1993; Human & Rheeder, 2004). Even if initially successful, commercial development of a cultivar includes consideration of other critical factors that may only become apparent after several seasons of cultivation, marketing and processing (López *et al*., 1995; Ponce de León *et al*., 2000). One of the reasons for this is that physiologically, commercially important cultivars have to deal with strenuous export conditions and extended export periods. Inland production areas are up to 2000 km away from Cape Town, the major export harbour, and fruit is transported in refrigerated units until eventual transfer to specialised shipping facilities. Turn around time can be up to 28 days before the product reaches the European port terminals, some 10 000 km away from Cape Town. During this period, the fruit must withstand desiccation and might be exposed to chilling injury. As an example, 'Heidi' was initially developed for the export market, but was unable to withstand prolonged cooling under commercial conditions. This only became evident after all other selection criteria were successfully addressed and commercial growers invested in the cultivar. Irregular bearing exacerbates the cultivar's problems. However, this is not the only example of cultivar failure (Finnemore, 2000). Many mango difficulties reflected by specific cultivars are related to horticultural and farming practices.

Apart from physical parameters that influence production within a geographical area, ethnic and cultural preferences have a remarkable impact on horticultural decisions around the globe. Although preferences of the local markets within a production area will influence cultivar selection to satisfy these requirements, consideration of cultivar popularity within targeted export markets are more important (Hofman *et al*., 1997). South African producers abide by the same principles; cultivars once popular locally (e.g. 'Zill') are sacrificed in favour of cultivars with good export demand, such as 'Keitt' and 'Kent'. These cultivars do well in the major production areas of South Africa, nevertheless the potential horticultural success is not fully developed, due to seasonal constraints. Southern hemisphere summers dictate that the local production and marketing period is from late November to early April. This coincides with a number of competitors from South American and Indo-Asian countries who are targeting the same markets as South African producers (Segré, 1998). In addition, these competitors have the added advantage of a shorter export period (typically only 7 to 15 days from harvest). Furthermore, the volumes produced by these countries (Fig. 1) create an unassailable competitive advantage. This situation will become even more difficult in future, since cultivar development is steadily diminishing the seasonal limitations of all mango-producing countries (Saúco, 2004). Considering the increasing global popularity of mangoes, the seasonal niche, local production capacity and quality of South African cultivars are encouraging aspects for development of the local industry (Finnemore, 2000; Human & Rheeder, 2004). It is therefore prudent to make an effort to ensure the industry reaches its full potential.

In the South African context, the mango industry plays a significant socio-economic role within the production regions. In the 2002 season, 45.3 % of the mango harvest came from operational units in former resettlement areas, contributing 41.4 % of their annual income. According to Shabalala *et al*. (2004), some 106 000 farming operations produce mangoes in South Africa. However, in terms of all the fruit produced in South Africa, the quantities harvested and total annual income derived is less than the average for similar tree crops (Table 1). Moreover, South African mango production is also a small industry when local production of 67 metric tons (MT) and export figures (17 MT) are compared with figures for global production (25 754 509 MT) and global export (21 946 MT) (Food and Agriculture Organisation, 2002; South African Mango Growers' Association, 2004). Globally, however, industry size, potential and economic importance is not correlated. From Figure 1 it can be seen that Guatemala contributes only 0.73 % to world production, yet the high yield of 350.20 kg/Ha (Fig. 2) indicates an intensive industry. On the contrary, India produces the highest volume of mangoes (44.26 %, Fig. 1), but at a yield of only 99.49 kg/Ha (Fig. 2). Commercial mango production in South Africa averages yields of 193.59 kg/Ha that, similar to Guatemala, indicates high-density commercial operations (Food and Agriculture Organisation, 2002). Any increase in the productivity of such intense operational units will significantly increase the respective country's contribution to global production and export figures. Although mangoes are an important food source in many rural areas, increasing marketable volumes are imperative to develop prosperity.

Non-commercial cultivation for households sees large portions of harvests consumed by producers themselves, reducing their return on investment (Saúco, 2004). In 2002, it was estimated that up to 22 % of the crop produced by emerging South African farmers was consumed in this way (Shabalala *et al*., 2004). Self-consumption of marketable produce is only one of the reasons for low export volumes. Other factors that contribute to poor return on investment include important pre- and postharvest problems such as disease development, sunburn, insect damage and physiological disorders. Under preharvest conditions, these difficulties are often approached by prioritising postharvest outcomes concerned with fruit physiology, nutrition and pest control (Combrink *et al*., 1994). Crop management take the form of manipulation of both nutritional and water status, disease control by biological and chemical means, physical alteration through horticultural practices, and genetically predetermined breeding strategies (Lavi *et al*., 1997; Human & Rheeder, 2004; Saúco, 2004). Morphology, and to a lesser extend, ontogeny, is studied as part of horticultural searches to cultivar improvement (Núñez-Elisea & Davenport, 1995; Ponce de León *et al*., 2000). However, no studies considering the impact of mechanical or chemical interference on the epicuticular membrane on fruit physiology were found. As the interface with its environment, this membrane is crucial to the development of the fruit up to and after harvest (Jeffree, 1996; Kolattukudy, 1996).

Postharvest problems in general arise because fruit respiration and metabolism continues after harvest, making physiological deterioration inevitable (Yamaki, 1995). This is a natural process since fruit, once physiologically mature, contains a viable embryo that needs to be dispersed (Esau, 1977). Postharvest control measures against this deterioration involve managing disease onset, fruit physiology and fruit appearance. Applying a commercial wax to the fruit surface is an important postharvest procedure. It is intended to enhance fruit appearance, to control weight loss through reduction of moisture loss and to manipulate physiological changes (López *et al*., 1995; Manzano *et al*., 1997). To attain this level of functionality demands a complex formulation that can combine with the natural wax without negatively affecting respiration and fruit tissue (Yamaki, 1995; Manzano *et al*., 1997). Commercial wax formulations are often the first suspected point of deviance in cases of postharvest failures, as was the case with lenticel discolouration, one of the most serious problems for South African producers. The random nature of the development of the condition, however, makes it clear that such a view is over-simplistic.

It is also not clear why certain cultivars seem to be more prone to developing the condition than others, making it difficult at this stage to breed cultivars resistant against lenticel discolouration. Several cultivars are affected with varying degrees of severity, annually causing up to 20 % loss in potential export volumes (Le Lagadec, 2003). Although innocuous, the discolouration causes superficial blemishes that render fruit cosmetically unacceptable on the export markets. Preliminary chemical and morphological investigations of this condition indicate that it is a physiological reaction caused by stress and not a pathogen-induced condition (Du Plooy *et al*., 2003). Discolouration development is often delayed, affecting cultivar performance during export, which has financial as well as reputational consequences. Consignments leaving South African shores with flawless fruit may reach the importing destination with afflicted fruit, causing a downgrade of goods and resulting in financial and customer confidence losses. Understanding and alleviating this problem would make it possible for local producers to become more competitive.

Like lenticel discolouration, sunburn and insect pests diminish the export value of crop substantially. Recent developments in the control of these problems lead to the preharvest application of kaolin on pome fruit in America. (Glenn *et al*., 2002). European growers soon followed suit and recently local commercial growers showed interest in utilising this alternative approach, already applied successfully on vegetable crops (De Night, 2004).

Kaolin has characteristics which makes its application seemingly advantageous, such as high reflectivity and high dispersibility. Reportedly effective in sunburn prevention, control of insect pests in more than one life stage and accepted as an alternative organic preharvest pest control measure it is an important new option in crop management (Glenn *et al*., 1999). Very little information on pre- and postharvest effects of both commercial forms of kaolin on mangoes is available (Le Lagadec, 2003; Du Plooy *et al*., 2004), with some studies on the possible insect control (Joubert *et al*., 2002). There are no studies on interference of kaolin with commercial wax application on any of the tree crops, or on the physiological impact that this specialised clay may have, particularly on the developing epicuticular membrane.

The epicuticular membrane is a common denominator in both pre- and postharvest management of mango fruit crops. No studies of cultivar dependent variation of this structure and its components have been conducted, making it difficult to determine any structural relation between cultivar susceptibility and physiological stress. Amplification of physiological stress conditions or induction of postharvest problems through the application of preharvest pest control measures is reported to be dependent on the inherent robustness of individual apple cultivars (Knight, 1997).

Fruit cultivar development seeks out and combines desirable traits from parent generations that can lead to improved horticultural qualities, but importantly, also to enhanced physical appearance, texture, smell and taste. Cultivar differences in terms of the sensorial characteristics are well documented (Singh *et al*., 2004). However, catering for consumer preference, breeding programmes and monoculture has diminished the effectiveness of many self-defence strategies employed by the plant. One such self-defence strategy often neglected is the epicuticular wax and other surface structures of the fruit (Eigenbrode, 1996).

Providing innate protection against excessive radiation, pathogen attacks and environmental interference, plant surfaces are expensive structural barriers in terms of energy investment (Kolattukudy, 1996). Fruit, as a vital survival mechanism, is therefore initiated and matured with chemical and structural efficiency (Esau, 1977; Yamaki, 1995). During cultivar development, differences in ability for these efficiencies may be augmented and could account for some of the variances in resistance against environmentally and physiologically induced disorders. As the interface between the fruit and its environment, studies into morphological and developmental aspects of the fruit need to include surface characteristics.

The objectives of this study were to investigate the mango surface with particular reference to the epicuticular wax, to study the nature of lenticel discolouration of mango fruit and to examine the effect of preharvest uncalcined kaolin treatments on both the epicuticular wax and applied commercial wax. The impact of postharvest handling on the packline on the fruit epicuticular wax was also investigated.

To achieve these goals the following focal points were identified:

- Ontogeny and morphology of mango fruit wax
- Morphology of mango lenticels
- Chemical characterisation of mango fruit wax
- Chemical profiles of discoloured lenticels compared to non-discoloured lenticels
- Impact factors on mango fruit wax:
    - Preharvest treatment of mangoes with uncalcined kaolin
    - Effect of mechanical handling on the packline and commercial wax coating.

Each of these focal points is discussed in a separate chapter, which is presented in article format. The conclusions from each chapter will be consolidated in a final discussion, together with an outline of anticipated future research ensuing from this investigation.

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TABLES

Table 1 Statistical overview of tree crop production in South Africa, indicating the number of operational units involved in different commodities, the harvest quantities and the income generated from each (Shabalala *et al*., 2004)

| **Commodity** | **Farming operations * (X1000)** | **Quantity harvested (MT)** | **Income generated (Former homelands) (R million)** | **Income generated (Total) (R million)** |
|---|---|---|---|---|
| Mangoes | 106 | 42 | 119 | 147 |
| Peaches | 94 | 209 | 1 | 364 |
| Pawpaws | 81 | 2.5 | 2 | 3 |
| Bananas | 80 | 273 | 75 | 741 |
| Avocadoes | 66 | 175 | 31 | 197 |
| Guavas | 47 | 61 | 16 | 158 |
| Oranges & other citrus | 44 | 500 | 5 | 2116 |
| Watermelons & other melons | 26 | 141 | 3 | 3810 |
| Grapes | 24 | 1880 | - | 4586 |
| Strawberries & other berries | 17 | 4.1 | - | 3 |
| Apples | 14 | 1206 | 2 | 649 |
| Litchis | 7 | 4 | 31 | 31 † |
| Pears | 5 | 1100 | - | 859 |
| Plums | 5 | 113 | 1 | 143 |
| Other fruit | 4 | 6.8 | - | 379 |
| Pineapples | 3 | 79 | 2 | 159 |
| Tree nuts | 2 | 1.4 | - | 3 |
| Total | 625 | 5 790 | 288 | 14348 |

* : The number of operational units is not correlated to the total land area dedicated to each crop; units cultivating mixed crops are calculated per crop, probably including subsistence farmers - thus the number of operational units

†: The figure represented above is derived from information provided by the South African Litchi Grower's Association (SALGA)

**FIGURE CAPTIONS**

Figure 1 Graph of mango production as a percentage per individual country correlated against the totalled global production (100 % = 25 754 509 MT) (FAO, 2002).

Figure 2 Graph of mango yield (kg/Ha) recorded in some cultivating countries in comparison to the world average figure of 100 kg/Ha (FAO, 2002).

## FIGURES

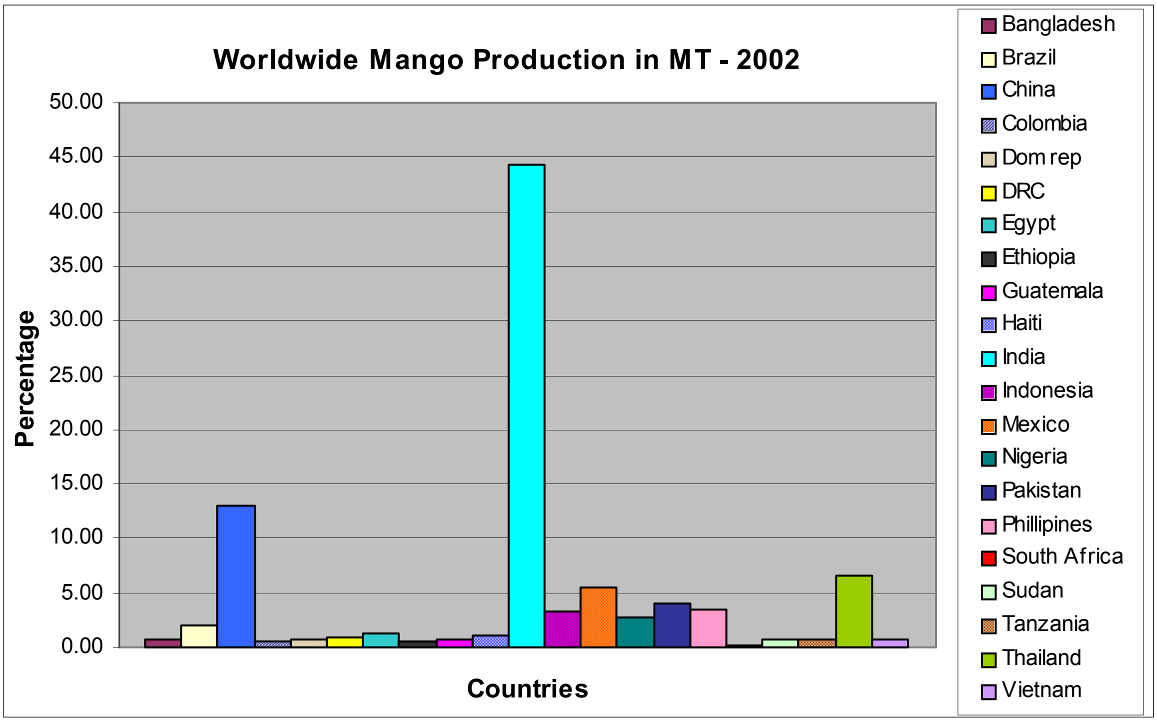


Figure 1

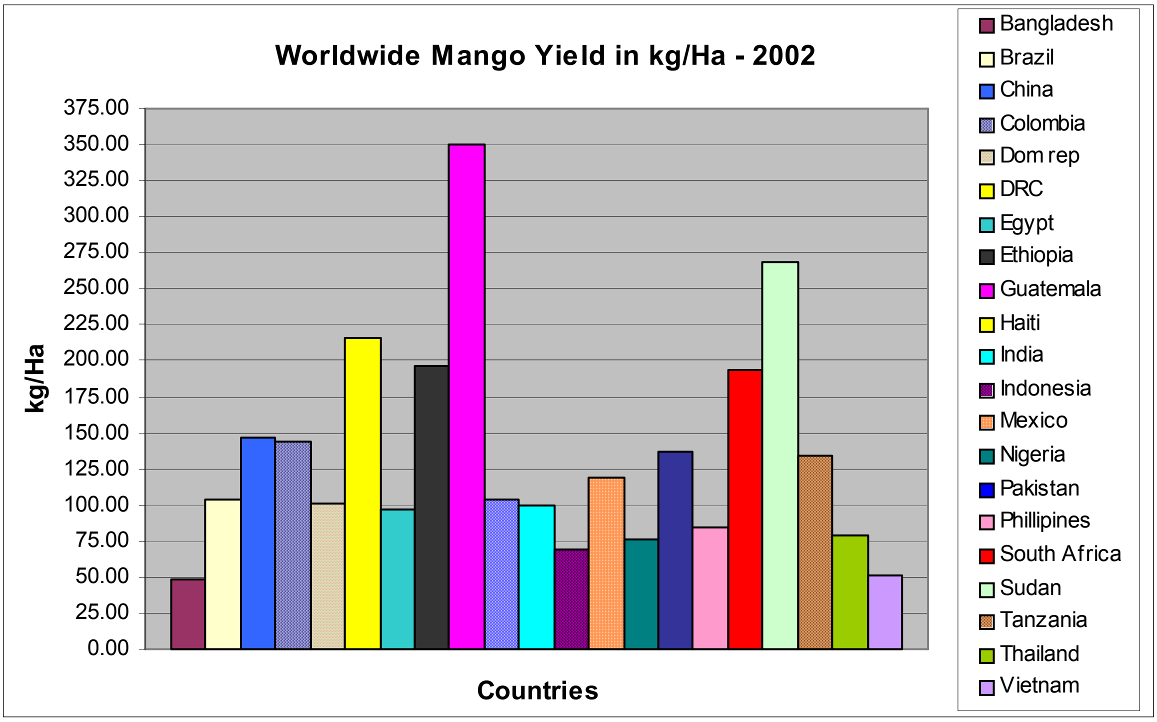


Figure 2