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HortResearch & SOFRI Dragon Fruit Assessment Manual

(Version 1: June 2006)



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INTRODUCTION

This protocol seeks to provide a standard methodology for the experimentation and assessment of Dragon fruit (*Hylocereus undatus* (Haw.)) in the collaborative project funded by the New Zealand ADAF project (Vietnam Quarantine Barriers Assignment). This will aid in the exchange of information between New Zealand and Viet Nam, and also within Viet Nam (e.g., between SOFRI, PPD and SIAEP). It also provides a means of standardizing assessment in future research, and may be further revised in order to capture our increasing understanding of Dragon fruit behaviour and quality postharvest.

The manual focuses on the postharvest assessment of the main cultivar currently grown in Viet Nam, 'Binh Thuan'. This is a white-fleshed fruit, which has small black seeds interspersed throughout the flesh, and a bright red skin when mature at harvest. The fruit is also known by its Vietnamese name, 'Thanh Long'. This translates as 'Green Dragon' – the colour of the flesh when the fruit is immature, coupled with the 'dragon-like' appearance of the bracts or scales on its surface – and is the name used locally when purchased in the market. 'Binh Thuan' is the principal cultivar/clone grown in Viet Nam and was introduced by the French in the late 1800s. Binh Thuan is also the name of the province in Viet Nam in which the greatest amount of Dragon fruit is produced.

Red-fleshed cultivars (known as Thanh Long 'Ruot Do' or red flesh) are also beginning to be grown commercially using planting material imported from countries such as Thailand and Taiwan (see Yen et. al., 2002, and Hoa & Hien, 2002). Limited amounts are available for export and fetch a high price in Asian markets. The assessments in this manual refer specifically to the white-fleshed cultivar, and in most instances, they will be readily transferable to other cultivars. Obviously, difficulties will arise when trying to assess the impact of heat treatments on internal flesh quality, where the intense colouration of the flesh will mask effects such as translucency.

FRUIT SOURCE

Fruit should be sourced from local growers, hand-harvested, and handled carefully. Fruit should be of good quality (sound with no physical injuries), be of uniform maturity (colour), and of uniform size. The time from flowering (days), grower, and any other relevant information (such as rainfall prior to harvest) should be recorded. Where treatments such as heat are to be applied, these should be carried out within 2 days of harvest, but preferably the day after harvest.

FRUIT PREPARATION

After harvest and before fruit are assigned to treatments, they should be thoroughly washed in clean water. Particular attention should be paid to removing shrivelled detritus and blackened material adhering to the inside of the blossom cavity. This is best done using a small bottle-brush or test-tube brush. A rag can be used to remove residual deposits left on the fruit surface from pesticide or fungicide sprays, or where water spraying has been used to irrigate the plants (Fig. 1a).

Stem pruning will be required to remove excessive amounts of attached cladode (Fig. 1b). Following preparation, fruit should be dried under ambient conditions.



1a. Washing



1b. Stem pruning for removal of excess cladode

Figure 1. Preparation of fruit before assessment.

ASSESSMENT OVERVIEW

HARVEST SAMPLE

On arrival at the lab, a sample of fruit should be analysed to determine maturity and fruit quality at harvest. These consist of a series of non-destructive, then destructive measurements, details of which are included in the sections below.

Non-destructive assessments of Dragon fruit include:

1. Fruit mass
2. Skin colour
3. Bract (or scale) appearance
4. Stem appearance
5. External rots
6. Overall body appearance

Destructive assessments include:

1. Fruit firmness
2. Internal appearance (translucence and rot penetration)
3. Soluble solids concentration
4. Titratable acidity
- 5.** Taste acceptability

FINAL ASSESSMENT

At the end of a storage or shelf-life period, all measures should be carried out in the following order:

1. Fruit mass
2. Skin colour
3. Bract appearance
4. Stem appearance
5. Rots (external)
6. Fruit firmness
7. Rots (internal penetration)
8. Translucence
9. Taste acceptability
10. SSC/TSS (brix)
11. Titratable acidity

OBJECTIVE ASSESSMENTS

FRUIT WEIGHT AND WEIGHT LOSS

The weight of individual fruits currently being accepted for export lies in the range 350 to 700 g per fruit. Fruit used for trial purposes should be within this range, or more narrow limits depending on fruit availability, the number of fruit required, and where they are being sourced from. Fruit harvested from a single grower, for example, will tend to have a wide range of weight, whereas packed fruit obtained from a packhouse/exporter could fall within a very narrow range of weights.

For selected treatments, the weight loss from treatments may be of interest. Individual fruit should be labelled and weighed at the start of the experiment, then at appropriate times in the experiment (e.g., end of storage or shelf-life period). Alternatively, weight loss can be measured on a tray or box of fruit without the need to identify and track the weight of each fruit individually.

SKIN COLOUR

Measurement is carried out using a Minolta chromameter CR 300 and the D65 filter option. The unit is set to measure three times (Minolta set to 'multi-measure') and with output of the average result. The three readings sites are located around the equator, avoiding bracts and body rots wherever possible.

The Minolta output consists of measurements in five different colour spaces. We suggest that the more commonly used LCH system be used as the standard colour space for reporting results from this crop, where:

L* = Lightness - colour intensity changing from light to dark (0 = black to 100 = white);
 C* = Chroma / Vividness - as chroma increases the colour becomes more intense;
 h° = Hue angle - the basic tint where 0 = red, 90 = yellow, 180 = green and 270 = blue.



Figure 2. Variation in fruit colour. In winter, colour break occurs at about 30 days after flowering (DAF), and fruit are harvested at 33 – 34 days. In summer, colour break occurs at about 26 days and picking at 30 DAF. Hue angles in the following photographs using off-season fruit may give a false sense of colour since the hue measurement is the average of three readings from around the fruit equator. Hue readings are 121.7° (~ 20 DAF), 28.9° (~30 DAF), 26.8° (~ 34 DAF, and harvest-ready), 11 days after harvest – 19.5°.

FLESH FIRMNESS

In general, there are no large changes in fruit firmness of Dragon fruit postharvest. Two measurement methods are suggested.

1. *Effigi Penetrometer*. Firstly make a small, shallow, lateral slice through the outer skin to expose the white inner flesh. Pull or cut away a slice of skin from the fruit, then measure the flesh firmness using an Effigi penetrometer (0-5 kg with large (11 mm) probe) (Fig. 3a). Three measurements are made at the equator.

2. *Imada Penetrometer*. Flesh firmness with the skin intact can also be determined using an Imada Seisakusyo penetrometer (8 mm diameter conical head). Puncture measurements are made without removing the skin (Fig. 3b) and three measurements are made around the fruit equator.

Initial results comparing the relationship between both types of measurement on the same fruit imply there is a poor correlation between the two techniques. This is mostly because the Effigi penetrometer is measuring primarily flesh firmness, while the Imada tends to provide an overall measure of the fruit firmness (taking into account both skin and flesh textural responses).



3a. Effigi penetrometer



3b. Imada penetrometer

Figure 3. Two methods of measuring fruit firmness of Dragon fruit.

SOLUBLE SOLIDS CONCENTRATION

There are gradients in SSC from top to middle and bottom to middle, and side to middle with the highest levels being in the middle of the fruit (Chang Wu & Shu Chen, 1997). Complete pulping of the entire fruit flesh is the most reliable method of measuring overall SSC, but is time-consuming, and other methods might be used.

1. *Entire fruit measure.* The pulp from either half the fruit (longitudinal slicing), or the whole fruit is collected on a narrow mesh nylon fabric supported on a funnel in an Erlenmeyer flask. The juice is expressed by hand. The number of fruit included in each measure can vary from one (individual fruit measures), or pooled samples (thus giving average values). Using this system, aliquots of the resulting juice can be used for both SSC and TA measurements.

2. *Stem-end measure.* A more rapid technique is to express juice from flesh cut from the stem end of the fruit (~ 2 cm from the base of the fruit). This however will give a different value to whole-fruit pulp measures, but is still useful for within-experiment comparisons.

3. SSC is determined on this liquid using a refractometer and measured at 20°C (or corrected for temperature).

TITRATABLE ACIDITY

TA is expressed as the amount of free acid (mainly as anhydrous citric acid) in the product (g/100 ml).

- Pipette 10 ml of juice into a 250 ml Erlenmeyer flask. Add 50 ml water, and 5 drops of phenolphthalein indicator (1% solution in ethanol), then neutralise with 0.1 M NaOH to a faint pink colour.
- Titrate against 0.1 M (40g g/l) NaOH quite rapidly until pH 6, then add alkali slowly to achieve a pH of 7. The titration is completed by adding alkali 4 drops at a time until pH 8.1 or when a pink colour appears and is stable for at least 15 s. An end point of 8.2 should be used if this procedure is carried out using an autotitrator.
- Read the volume of NaOH used from the burette (V ml)
- TA expressed as grams of citric acid = $V \times 0.0064$
- TA expressed in g /100 ml = $V \times 0.064$

SUBJECTIVE ASSESSMENTS

EXTERNAL QUALITY

The external appearance of the fruit is rated subjectively.

Overall Acceptability

At the time of assessment, each fruit is rated as 'sound' or 'unacceptable' at an overall level. This takes into account the appearance such that no disorder is considered unacceptable, or all disorders do not combine to achieve an unacceptable level.

STEM APPEARANCE

Stem ratings are based the degree of shrivel and colour change that occurs in the residual piece of attached stem. The rate at which changes occur depends on the stem size. The following scale provides a rating for stem appearance, with representative photographs in Figure 4.

- 0** stem green and healthy
- 1** green colour fading to yellow at the boundary edges of the cut
- 2** fading of green to yellow colour over much of the stem surface; tissue is sunken and shrivelled
- 3** shrivel and dessication of the tissue more advanced; tissue a uniform pale yellow-green colour over the stem surface
- 4** tissue completely shrivelled / dessicated and very brittle; colour is strongly yellow with almost no green present. In some instances the tissue will be completely dry and brown.



Rating 0 (no defect)



Rating 3



Rating 1



Rating 4



Rating 2



Rating 4

Figure 4. Ratings scale for appearance of the stem (0, 1, 2, 3, 4).

BRACT APPEARANCE

Bract (or scale) appearance is a key issue in the quality of Dragon fruit. The 0 to 5 scale (Table 1) has been developed in order to rate the appearance in a rapid manner. Because we have noted differences in the aging of bracts depending on whether they were heat-treated or not, we have developed a scale for both heat-treated, and non heat-treated (control) fruit. Figures 5a (whole fruit) and 5b (close-up) contain representative pictures for control (non heat-treated) fruit. Heat-treated Dragon fruit are show in Figures 6a (whole fruit) and 6b (close-up).

Table 1. Bract assessments: Description of rating system of Dragon fruit bracts for control and heat-treated fruit. Photographs are provided for control (Figure 5a and 5b), and for heat-treated (Figure 6a and 6b) Dragon fruit.

Bract Rating Scale	Colour (for control fruit)	Colour (for heat treated fruit)	Firmness / Dryness	Straightness	Shrivel
0	Bright green, yellow and red colours No Browning/blackening	Bright green, yellow and red colours No browning / blackening	Firm	Straight or slightly curved, well away from side of fruit	None
1	Green colour fading Moderate yellow Slight browning of margins	Green darkening Some yellow Slight browning of margins	Medium	Moderate in-curling of bracts	Slight
2	Green tips Most bract is yellow Moderate browning	Dark green No yellow Moderate browning	Very soft Slight drying	Severe in-curling of bracts	Slight-moderate
3	No green Sever yellowing and/or browning, and some blackening of margins All red colour remaining	Some green left Severe browning, and some blackening of margins All red colour remaining	Moderate drying	Severe in-curling, lower bracts lay flat on fruit	Moderate-severe
4	No green Complete yellowing &/or browning / blackening Red Colour remaining only at base	No green Complete browning / blackening Red colour remaining only at base	Severe drying	Completely curled to base	Severe (but not to base of bract)
5	Black	Black	Completely dry		Complete



Rating 0 (no defect)



Rating 3



Rating 1



Rating 4



Rating 2



Rating 5

Figure 5a. Rating scale for bracts for non heated fruit. Whole fruit (0 to 5).



Rating 0 (no defect)



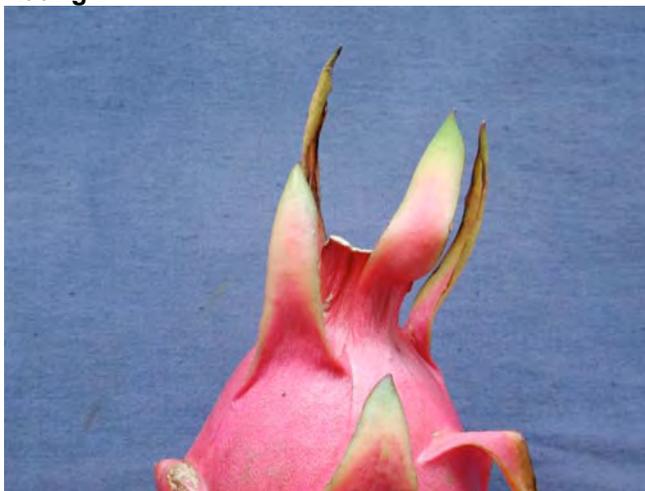
Rating 3



Rating 1



Rating 4



Rating 2



Rating 5

Figure 5b. Rating scale for bracts for non heated fruit. Close-up fruit (0 to 5).



Rating 0 (no defect)



Rating 3



Rating 1



Rating 4



Rating 2



Rating 5

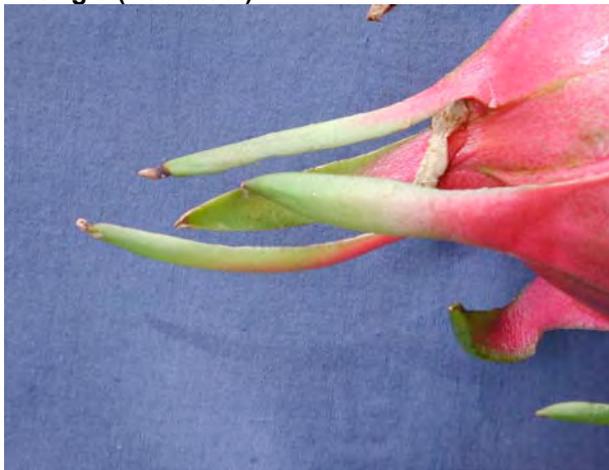
Figure 6a. Rating scale for bracts for Heat-Treated fruit. Whole fruit (0 to 5).



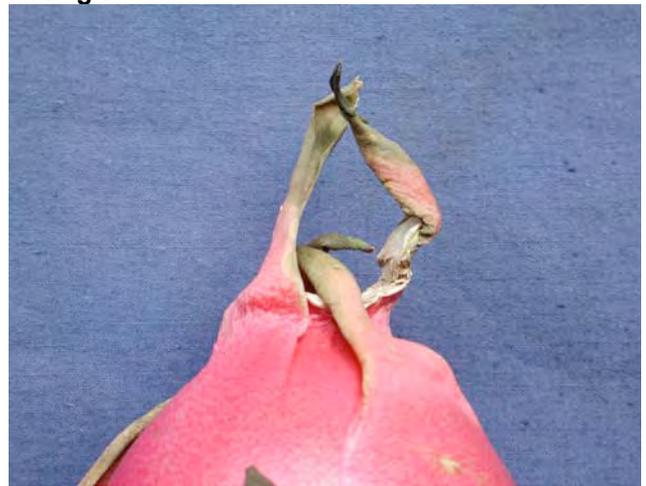
Rating 0 (no defect)



Rating 3



Rating 1



Rating 4



Rating 2



Rating 5

Figure 6b. Rating scale for bracts for Heat-Treated fruit. Close-up fruit (0 to 5).

Blossom End Rots

Rots entering through, or around the floral end of the fruit (distal end). See Figure 7 for representative photographs. NB: Here the rating is of that portion of the circumference around the blossom end which has some rot. It is not a rating of how far the rot moves down the fruit. This is rated in the 'Total Rots' category (see below).

- 0** No rots around the blossom end tissue
- 0.5** Trace: rots on <5% of the circumference of the blossom end
- 1** Slight: rots on >5-10% of the circumference of the blossom end
- 1.5** Slight–moderate: rots on >10-15% of the circumference of the blossom end
- 2** Moderate; rots on >16-25% of the circumference of the blossom end
- 2.5** Moderate–severe: rots on >25-50% of the circumference of the blossom end
- 3** Severe: rots on >50% of the circumference of the blossom end.

Stem End Rots

Unlike other fruits such as mango or kiwifruit, where there is an obvious picking scar that allows entry of pathogens after harvest, the development of specific rots around the stem end of the fruit (basal or proximal end) is not common. This is in part because a small section of plant stem remains attached to the fruit after harvest, which prevents easy access to the flesh. From trial work at SOFRI with many fruit, rots at the blossom end of the fruit, and scattered over the body surface, are much more prevalent and will have rendered the fruit 'unacceptable' well before any rots begin developing around the stem. Our current suggestion is that it is unnecessary to categorise rots at this location specifically, and where they do occur, they can be assessed collectively as part of the overall 'Body Rots' category (see below).



Rating 0.5



Rating 2



Rating 1



Rating 2.5



Rating 1.5



Rating 3

Figure 7. Ratings scale for blossom end rot (0.5 intervals).

Body Rots

Rots entering into the side of the fruit (all other than blossom end rots). This includes the base of the bracts and the base of the fruit. See Figure 8 for representative photographs.

- 0** No rots on the skin / body of the fruit
- 0.5** Trace: rots on <5% of the area of the fruit surface
- 1** Slight: rots on >5-10% of the area of the fruit surface, or shrivelled flesh at the basal end of the fruit
- 1.5** Slight–moderate: rots on >10-15% of the area of the fruit surface (just acceptable)
- 2** Moderate; rots on >16-25% of the area of the fruit surface (unacceptable)
- 2.5** Moderate–severe: rots on >25-50% of the area of the fruit surface
- 3** Severe: rots on >50% of the area of the fruit surface circumference



Rating 0.5



Rating 2



Rating 1



Rating 2.5



Rating 1.5



Rating 3

Figure 8. Rating scale for body rots (0.5, 1, 2 and 3) (excluding rots originating at the blossom end of the fruit).

Body Appearance

This rates the appearance of the body of the fruit in terms of the amount of shrivel present (especially at the basal end) and the extent of colour development on the fruit surface (Figure 9). It does not include rots, which have already been assessed separately. Two factors may affect the colour of the fruit surface: 'regreening' – a physiological process associated with over-mature fruit left on the plant, and incomplete colour development – caused by insufficient light.

'Regreening' refers to a process whereby ripe fruit left on the plant beyond the point they first reach maturity (skin colour changes from green to red), cycle through a second green – red colour change (> 40 days after flowering). These fruit are sweeter than normal, and despite the colour of their skin, are eating ripe. This feature is only associated with the white-fleshed cultivar, and would not normally be encountered in fruit harvested specifically for trial work.

Dragon fruit can also show incomplete colour development when they first reach maturity. At this time their skin colour should change rapidly over a period of a few days from a solid green colour to red. This process is dependent upon the amount of sunlight the fruit receives. Thus fruit in total shade, and the side of fruits not directly exposed to sunlight (shade-side), may not undergo the full sequence of colour development. The symptom is visible on immature fruit (bracts fully green). It can be described as a green-pink colouration (hues between ~ 55 – 75) covering the fruit surface. In fully mature fruit that have been retained on the plant (full red colouration extending up the inside and outside of the blossom-end bracts ~ 40 days after flowering), the green colouration may be more pronounced on the suture lines interconnecting the bracts on the fruit surface. At present there is no scientific information quantifying a presumed chlorophyll degradation process, and/or increased red pigmentation, with levels of incident radiation. Grower observations suggest the problem is worse during periods of protracted rain (extended cloud cover). Fruit colour is also regarded as being 'better' in provinces like Binh Thuan, where sunlight hours are greater.

It is this situation that is more likely to have an impact on body appearance ratings, rather than 'regreening'.

- 0** No shrivelling or green colouration of the skin
- 0.5** Trace: shrivelling or green colouration on <5% of the area of the fruit surface
- 1** Slight: shrivelling or green colouration on >5-10% of the area of the fruit surface
- 1.5** Slight–moderate: shrivelling or green colouration on >10-15% of the area of the fruit surface (just acceptable)
- 2** Moderate; shrivelling or green colouration on >16-25% of the area of the fruit surface (unacceptable)
- 2.5** Moderate–severe: shrivelling or green colouration on >25-50% of the area of the fruit surface
- 3** Severe: shrivelling or green colouration on >50% of the area of the fruit surface circumference.



Shrivel: Rating 1



Green colouration: Rating 2

Figure 9. Rating scale for body appearance (not including rots) for shrivel and green colouration.

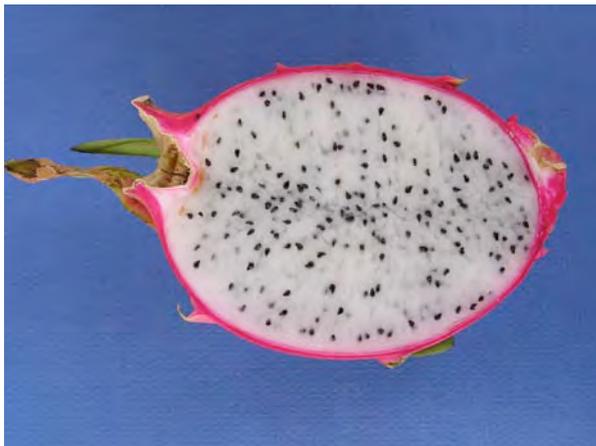
INTERNAL QUALITY

Once assessed externally, fruit are cut in half longitudinally to examine the internal fruit quality.

Flesh Translucency

Fruit tissue changing from white, to increasingly translucent, which occurs primarily immediately under the skin in instances after fruit have been heat treated. See Figure 10 for representative photographs.

- 0** No translucency in the flesh tissue
- 1** Slight: translucency just noted around the margin of the fruit under the skin (~2 mm)
- 2** Moderate: translucency extending ~ 4 mm into flesh (unacceptable)
- 3** Severe: obviously clear tissue extending > 6 mm under the skin (in severe instances brought about by heating fruit in water, red pigments from the skin may leach into the flesh).



Rating 0



Rating 1



Figure 10. Rating scale for flesh translucency (0-3).



Rating 2



Rating 3



Figure 10 cont. Rating scale for flesh translucency (0-3).

TASTE

Overall Acceptance

Because of compositional gradients within the fruit, tasting is done on a specific piece of fruit taken from a longitudinal segment (Fig. 12).

Fruit assessors use a 9-point hedonic scale to provide an overall acceptance rating.

- | | |
|----------|------------------------------|
| 9 | Extremely good |
| 8 | Like very much |
| 7 | Like |
| 6 | Like with reservation |
| 5 | Neither like nor dislike |
| 4 | Dislike with reservation |
| 3 | Dislike |
| 2 | Dislike very much |
| 1 | Dislike intensely (strongly) |

Note: taste scores should improve post-harvest as the acidity level decreases with shelf life. The Vietnamese prefer their fruit to be less acid for fresh eating.



Figure 12. Like a badminton racquet, the sweet spot of Dragon fruit is in the middle! This is the location chosen for routine taste-testing.

Taste Panel

If desired, a panel can be used to determine response to the following;

<i>Appearance</i>	Acceptability or otherwise of the overall external appearance
<i>Aroma</i>	Acceptability or otherwise of the overall aroma of the cut fruit
<i>Taste</i>	Acceptability or otherwise of the overall taste
<i>Acidity</i>	Acceptability or otherwise of the acidity level of the flesh
tissue	
<i>Sweetness</i>	Acceptability or otherwise of the sweetness of the flesh
tissue	
<i>Sweet / Acid Balance</i>	On a scale of 0 to 100 (0 = sweet, 100 = acid)

OTHER FACTORS AFFECTING THE EXTERNAL APPEARANCE OF THE FRUIT

Other factors such as insects and mechanical damage also affect the external appearance of fruit. They are included here to assist in the identification of possible problems.

The major pests identified by Cuc (2000) as being a problem on Dragon fruit in the Mekong Delta area include: *Protaetia* spp. (a beetle), ants (*Solenopsis geminata* Fabr., and *Cardiocondyla wroughtoni*) and fruit fly (*Bactrocera* spp., specifically *B. dorsalis* and *B. correcta*). In Binh Thuan province, slugs occasionally cause problems on fruit, but outbreaks are sufficiently rare that visual inspection and removal of slugs by hand is the only control measure required. *Mictis longicornis* (bo xit) is listed as a beneficial species associated with Dragon fruit as a predator and biocontrol agent for ants.

Damage caused by ants is manifest as white-tipped pimples surrounded by a dark-green aureole. This is a superficial condition and does not extend through the skin into the flesh (Fig. 13a). In other cases, ant damage to the fruit surface early in growth gives rise to raised black scab-like spots on mature fruit (Fig. 13b – c). Again, these do not affect the flesh.

At its earliest stages fruit fly infestation is manifest by the appearance of small raised mounds on the fruit surface, which contain minute holes left by the insect's ovipositor. A little later the mounds become more pronounced and release an orange-brown exudate. Puncture holes ~ 1 mm in diameter become evident (Fig. 13c), and the mounds develop into suppurating pustular protrusions as the underlying tissue is increasingly affected. The flesh at sites of infestation feels pulpy and soft at the surface. The rotted flesh beneath may be opaque to yellow-coloured (Fig. 13d). Flesh may be affected from as little as 5 mm under the surface, through to the centre of the fruit. Affected fruit are commonly found in the April – July period when fruit fly are active.

Damage caused by beetles (*Protaetia* spp.) appears to be restricted to chewing of the bracts as opposed to the fruit surface (image not shown).

Wind and mechanical damage (rub) may also affect fruit. Desiccated crater-like areas may occur at the site where bracts were broken off during growth (Fig. 13e). The underlying flesh is not affected.



13a. Ant damage



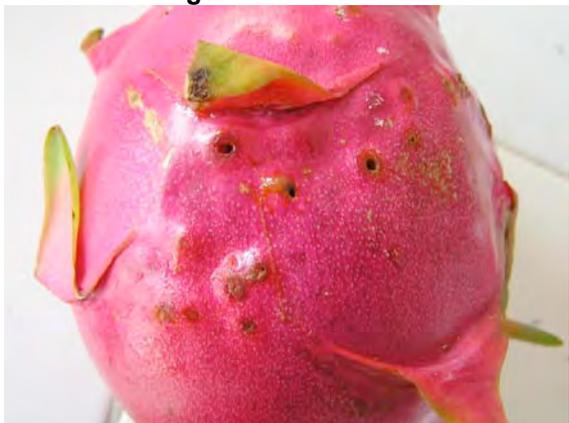
13b. Ant damage



13c. Ant damage



13d. Mechanical damage



13e. Fruit fly infestation



13f. Fruit fly infestation

Figure 13. Fruit disorders, other than pathogens include: damage by ants (a – c), mechanical damage or rub (d), and fruit fly infestation (e – f).

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