Papaya Evaluation Handbook

Productivity and fruit quality traits

Second edition/ August 2021

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Introduction

Productivity traits and visual appearance are the first quality determinants made by growers, wholesalers, retailers or consumers. After consulting with a reference group of papaya growers, breeders and marketers from Queensland, important traits which should be considered in applied papaya breeding were identified. They include those relating to a tree's productivity: total saleable yield, consistent fruit set over time (i.e. no yield gap), consistent fruit size, ease of harvest and disease resistance, and to fruit quality traits: appearance, fruit shape, flesh colour, sweetness and flavour. These traits are varied and quantitatively expressed in papaya germplasm.

The first edition of Papaya Handbook was published in July 2017. It was referred to IBPGR (1988) and Kanchana-udomkan (2015). The aim was to provide a standard evaluation procedure for routine selection. The information in the handbook was provided by experienced growers, researchers, breeders and marketers.

The second edition is developed to publish the updated version that applied to PP18000: National Papaya Breeding and Evaluation Program. This edition includes weighting index for each trait, the formula to calculate breeding index for the crop, the colour scale was compared to the Royal Horticultural Society colour chart and given the colour code, and table for recording data is provided.

Objectives

The main objective of this handbook is to develop a standard protocol to evaluate papaya tree productivity and fruit quality for robust, reliable and practical evaluation.

Overview

Evaluations of papaya trees are to be performed three times over the tree development. The list of traits to be assessed in each evaluation is presented in Table 1.

Table 1: List of traits for evaluation for papaya fruit quality and tree productivity.

No.	Tree age	Productivity traits	Fruit quality traits
1	5 months	Sex type Height to first fruit Trunk circumference Number of side shoots Peduncle length	
2	10-12 months	Peduncle length Saleable yield Yield gap Number of non-marketable fruit Fruit size (fruit length, width and weight) Cavity size (cavity length and cavity width)	Skin gloss Skin freckle Skin colour Fruit firmness Fruit shape Teat shape Stalk insertion Cavity shape Flesh colour Flesh colour consistency Flesh thickness Flesh texture Flesh sweetness (°Brix)
3	15 months	Same as the 2nd evaluation	Same as the 2nd evaluation

Fruit and Tree Handling Procedure

Tree Evaluation:

Papaya trees are labelled using a permanent marker to write down on the tree trunk for an individual line number.

The trees are recorded for sex type, measured for trunk circumferences and height to first fruit in centimetre using a measuring tape, counted for number of side shoots for large (more than 10 cm), medium (between 5-10 cm) and small (less than 5cm), and recorded for peduncle length. A table to record this dataset is presented on page 28. The detail methods to evaluate each trait are presented in Productivity traits section (Page 9-16).

Fruit Evaluation:

At a trial site: three papaya fruit per tree are labelled using a permanent marker to write down on the skin. The fruit are then to harvest and place in a cardboard box.

In a laboratory: Papaya fruit are cleaned using a damp cloth. The fruit are then evaluated for external appearance including skin characteristic, shape, fruit firmness, fruit weight. After that the fruit are then longitudinally section to assess for fruit size, cavity and flesh characteristic. A table to record this dataset is presented on page 28. The detail methods to evaluate each trait are presented in Productivity traits section (Page 17-27).

Clean fruit using a damp cloth

Evaluate for external appearances: skin characteristics and shape

Hand pressure for fruit firmness and weight the fruit on a digital scale.

Fruit is longitudinal sectioned and evaluated for internal appearances including fruit width and length, and flesh characteristics. Then, the fruit is cross sectioned to assess cavity characteristics.

Fruit is cut in in 3 x 3 cm cube to be assessed for flesh texture and °Brix

Figure: Summary of fruit evaluation procedure in a laboratory

Weighted breeding index

Following consultation with the breeders and marketers, a raked list of breeding priority traits was produced. This was then used to develop a weighted selection index. This was also achieved by incorporating the method of Herrington et al. (2012), who suggested to include cost of production and profitability of the crop and then weight the traits according to investment.

Step 1: Identify traits and their industry/consumer-derived preferred value or range. Traits and details are presented on Table 1.

Table 2: Traits and their industry/consumer-derived preferred value or range

Traits and their industry/consumer-derived preferred value or range	
Fruit weight:	Yellow: 0.9 – 1.5 kg
	Red: 0.9 – 1.2 kg
Peduncle length:	Medium or long
Fruit shape:	Yellow: Round shape
	Red: Elongate shape
Stalk insertion:	Flattened (#2)
Teat shape:	Flat (#3)
Cavity shape:	Round (#1)
Flesh colour consistency:	100% flesh colour consistency

Weighted breeding index

Step 2: Comparing traits with the value of industry standard varieties either red or yellow papaya and calculate weighted selection indices using the formula on Table 2.

Table 3: Traits and calculation of breeding index for tree productivity and fruit quality traits

Traits expected to have a higher value than in the industry standard		**Traits expected to have a lower value than in the industry standard**	
Weighting score (A)	**List of traits:**	**Weighting score (B)**	**List of traits:**
1	Saleable yield	0.75	Height to first fruit
0.25	Trunk circumference	0.5	Number of side shoots
1	Flesh ratio	0.75	Skin freckle
0.25	Skin gloss	1	Number of non-saleable fruit
0.25	Skin colour		
0.75	Fruit firmness		
0.75	Flesh colour		
1	Flesh thickness		
0.5	Flesh texture		
1	Flesh sweetness		
Calculation of weighted selection index:		**Calculation of weighted selection index:**	
$\text{Index} = A \times \frac{\text{Value of breeding line}}{\text{Value of standard variety}}$		$\text{Index} = B \times \left(2 - \frac{\text{Value of breeding line}}{\text{Value of standard variety}}\right)$	

Step 3: All the weighted selection indices will be summed up, and then divided by the total score to achieve one breeding index for each variety. The index more than 1.0 = better than industry standard varieties

Productivity traits

Sex type

Papaya trees were classed as either dioecious (male and female flowers on separate trees) or gynodioecious (hermaphrodite flower on the same tree)

Figure 1: Female flower

Figure 2: Hermaphrodite flower

Figure 3: Male flower

Productivity traits

Height to first fruit

Height to the first fruit is measured in centimetre (cm) from the ground to the first marketable fruit

Figure 4: Measurement of height to the first marketable fruit

Productivity traits

Trunk size

Trunk circumference is measured in centimetre from 15 cm-height above the ground using a measuring tape.

Figure 5: Measurement of trunk size

Productivity traits

Number of side shoots

Side shoots are counted after the tree reaches its maturity (at 5 to 6 months after field planting). It is categorised in three groups by length of the side shoots.

Small = length of the side shoots is less than 5 centimetres

Medium = length of the side shoots is between 5 and 20 centimetres

Large = length of the side shoots is more than 20 centimetres

Figure 6: Side shoot of papaya

Figure 7: Three categories of side shoot, left: a small side shoot, middle: a medium side shoot, right: a large side shoot

Productivity traits

Peduncle length

Peduncle or stem length is scored using the 1, 3 and 5 rating scale; where

1 = short peduncle (less than 3 cm),

3 = medium peduncle (between 3 and 5 cm) and

5 = long peduncle (greater than 5 cm).

Figure 8: Measurement of peduncle length

Figure 9: Three categories of peduncle length, left: short peduncle; middle: medium peduncle; right: long peduncle

Productivity traits

Saleable yield

Saleable yield is estimated in kilograms (kg) by counting the total number of marketable fruit per tree within 45 cm column starting from the peduncle of the lowest fruit. Fruit weight of each tree is obtained from average fruit weight of three to five mature marketable fruits. Saleable yield for each tree is calculated using formula

Saleable yield (kg) = number of fruits per tree x Average fruit weight (kg)

Figure 10: Yield on papaya trees. The white bars indicate the length of fruit column at 45 centimetre for counting number of saleable fruit

Productivity traits

Number of non-marketable fruit

Number of non-marketable fruit are counted for carpelliod and wasted fruit within 45 cm column at the same time when evaluating saleable yield.

Figure 11: non-marketable fruit, *left:* Carpelloid fruits, *right*: wasted fruit

Productivity traits

Yield gap

Yield gap is estimated by the pattern of fruit set of each tree and scored between 1 and 5; where there is

1 = no space observed between two harvesting times

3 = less than 50% of a fruit space between two harvesting times

5 = greater than 50% of a fruit space between two harvesting times

Figure 12: Gap of yield on papaya trees. Left: rating at 1 as there is no space on the fruit column; middle: rating at 3 for the gap on the fruit column less than 50%; right: rating at 5 for the gap on the fruit column less than 50%.

Fruit quality traits

Maturity and ripening stages

Maturity and ripening is rated the numeric system detailed below;

1 = mature green

2= 25% colour

3 =50% colour

4 =75% colour

5 = full ripe

Figure 13: Five fruit maturity and ripening stages

Fruit quality traits

Skin Characteristic

Skin colour

Skin colour was visually observed and recorded using a numeric rating system as detailed:

1 = light green: equivalent to the colour code 139D of the Royal Horticultural Society (RHS)

2 = green: equivalent to the colour code 137C of RHS

3 = dark green: equivalent to the colour code 137A of RHS

4 = green/slight yellow: equivalent to the colour code 151A of RHS

5 = yellow/slight green: equivalent to the colour code 153D of RHS

6 = yellow-orange: equivalent to the colour code 22A of RHS

7 = orange: equivalent to the colour code 26A of RHS

8 = orange-red: equivalent to the colour code 34B of RHS

9 = red: equivalent to the colour code N34B of RHS

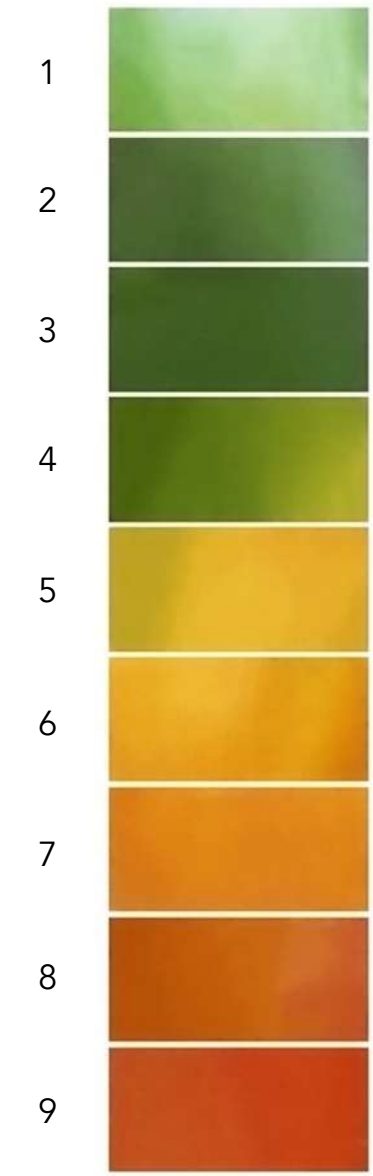

Figure 14: Rating for skin colour

Fruit quality traits

Skin Characteristic

Skin gloss

Skin gross is visually observed and scored using a rating system; where

1 = dull

2 = average

3 = glossy

4 = very glossy/ excellent skin quality

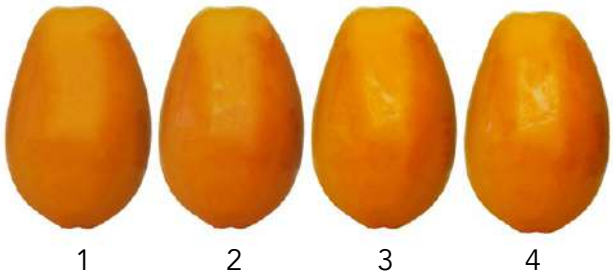

Figure 15: Rating for skin gloss

Skin freckle

Skin freckle or winter spots are observed on mature fruits at the ripe full colour stage. The severity of freckle is recorded using a rating system of 1 to 5 where

1 = winter spots cover less than 1% of the surface

2 = winter spots cover 1% to 25%

3 = winter spots cover 26% to 50%

4 = winter spots cover 51% to 75%

5 = winter spots cover more than 75%

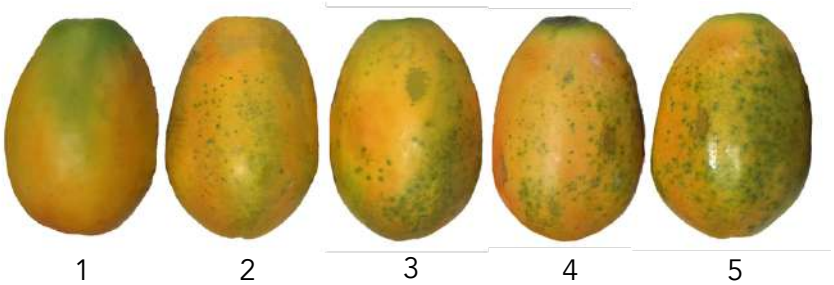

Figure 16: Rating for skin freckle

Fruit quality traits

Shape

Fruit shape

Papaya fruit is grouped into irregular shape, round shape and elongate shape. Each fruit is scored in numeric system as detail below:

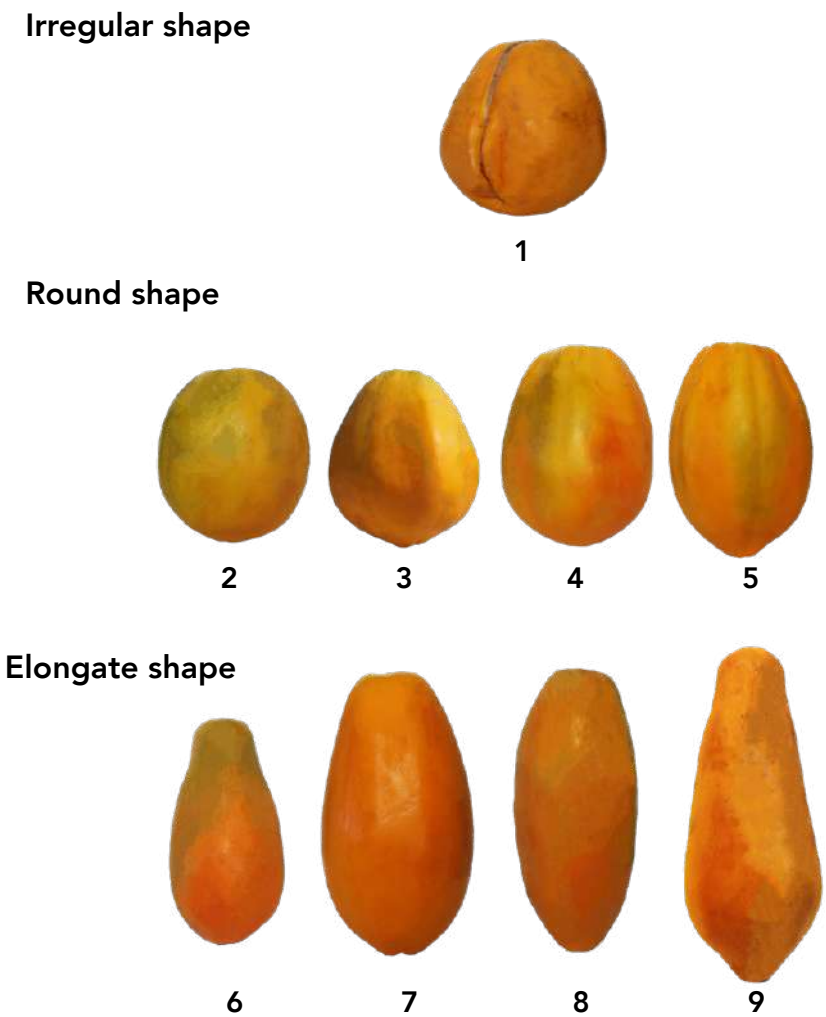

Figure 17: Rating for papaya fruit shape

Fruit quality traits

Shape

Teat shape

Teat of each fruit is scored in numeric system as below

1 = blossom end defect

2 = sunken

3 = flat

4 = pronounced

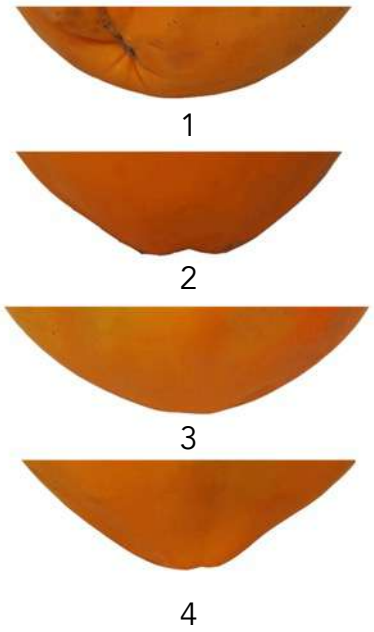

Figure 18: Rating for teat shape

Stalk insertion point

The insertion point of the stalk of each fruit is scored using the numeric system detailed below;

1 = depressed

2 = flattened

3 = inflated

4= pointed

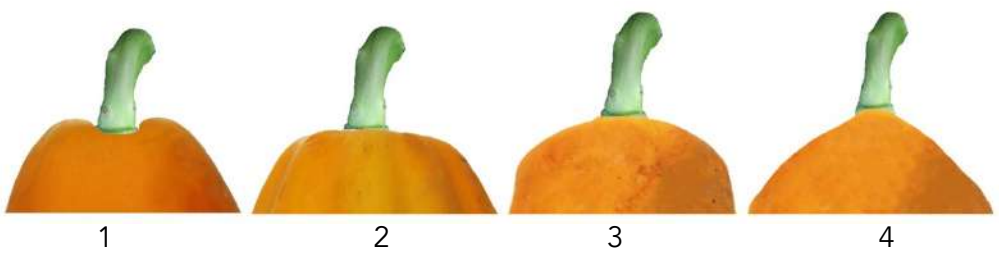

Figure 19: Rating for stalk insertion point

Fruit quality traits

Fruit firmness

Fruit firmness is assessed at ready to eat stage by using a firmness tester and by hand pressure at the centre of the fruit.

Fruit is assessed by holding a fruit with both hands and pressing centre fruit with the thumps and rating the firmness as

1 = soft

2 = intermediate/ rubbery

3 = firm/hard

Figure 20: Evaluation of fruit firmness, rating by using thumb pressure.

Fruit size

Fruit weight

Fruit weight is recorded in gram using a measurement from a digital scale

Figure 21: Fruit weight on a digital scale

Fruit quality traits

Fruit size

Fruit width

Fruit width is measured by measuring the diameter (cm) at the middle part of the papaya fruit using a ruler.

Fruit length

Fruit length is measured by measuring the length (cm) at the middle part of the papaya fruit using a ruler.

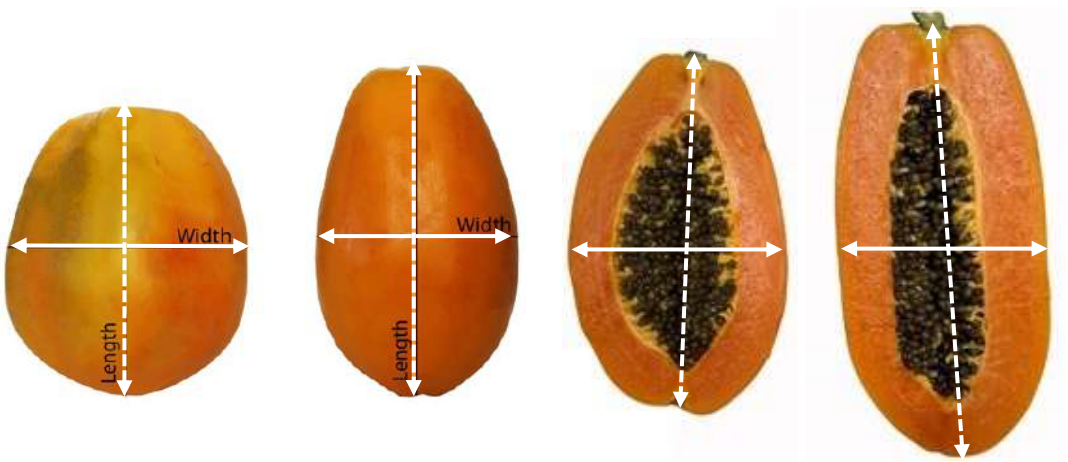

Figure 22: Determination of fruit width (solid white arrow) and length (dot white arrow)

Fruit quality traits

Cavity

Cavity width

Cavity width is measured between one flesh wall to another at the central cavity of each fruit using a ruler.

Cavity length

Cavity length is measured between one flesh wall to another at the central cavity of each fruit using a ruler.

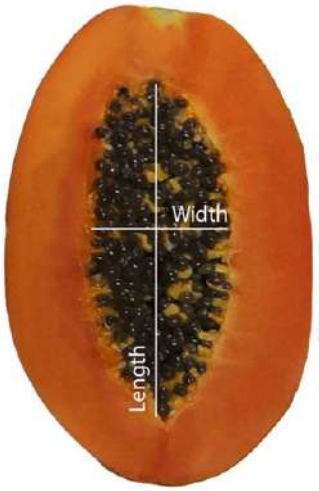

Figure 23: Measurement of cavity size

Cavity shape

Each fruit is cross-sectioned laterally. The central cavity of each fruit is scored as detailed below;

1 = round

2 = angular or pentagon

3 = slightly star or star

4 = flower

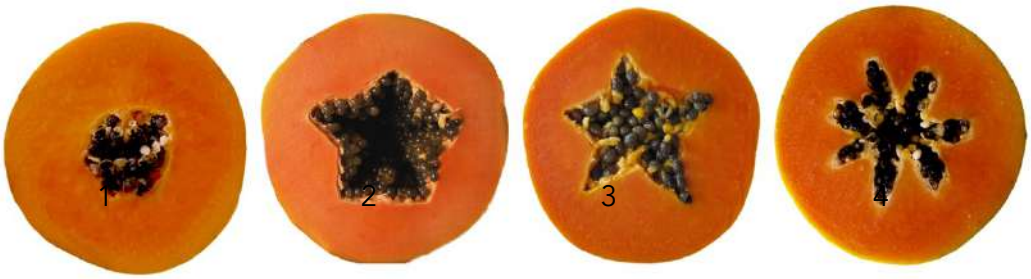

Figure 24: Rating for cavity shape

Fruit quality traits

Flesh characteristic

Flesh ratio

Flesh ration is calculated using fruit and cavity with and length using the formula below:

$$\text{Flesh ratio} = 1-\left(\frac{\text{Cavity width x Cavity Length}}{\text{Fruit width x Fruit Length}}\right)$$

Flesh colour

Each fruit is cross-sectioned in half laterally, and scored for flesh colour as

1 = white: equivalent to the colour code 11D of RHS

2 = creamy white: equivalent to the colour code 1D of RHS

3 = slight pink: equivalent to the colour code 27C of RHS

4 = pale yellow: equivalent to the colour code 6B of RHS

5 = yellow: equivalent to the colour code 153D of RHS

6 = yellow-orange: equivalent to the colour code 22A of RHS

7 = orange: equivalent to the colour code 26A of RHS

8 = orange-red: equivalent to the colour code 34B of RHS

9 = red: equivalent to the colour code N34A of N34A RHS

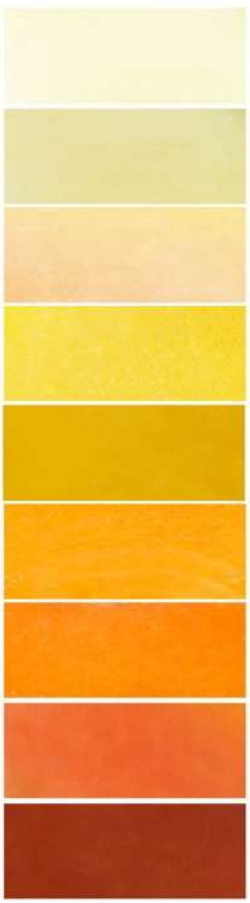

Figure 25: Rating for flesh colour

Fruit quality traits

Flesh characteristic

Flesh colour consistency

Each fruit is cross-sectioned in half laterally and scored for consistency of flesh colour as detailed in the numeric rating scale for consistency of flesh colour; where

1 = less than 50% colour consistency

2 = colour inconsistency is between 50-75%

3 = flesh colour is more than 75% consistency

1 2 3

Figure 26: Rating for consistency in flesh colour

Flesh thickness

Flesh thickness is measured in centimetre from the skin to the seed cavity using a ruler

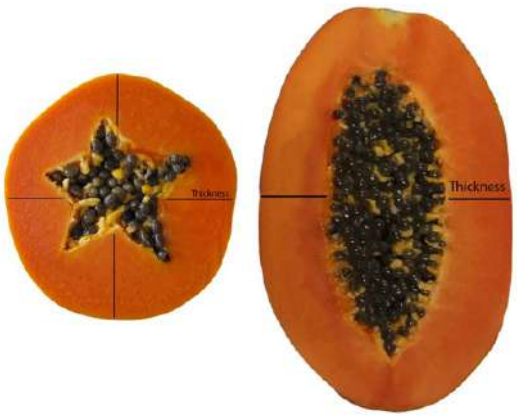

Figure 27: Measurement for flesh thickness

Fruit quality traits

Flesh characteristic

Flesh texture

Flesh texture is assessed at ready to eat stage by using a firmness tester and mouth feel.

Mouth feel. Fruit sample is cut into a small cube and the flesh texture is assessed by mouth sensory to score as

1 = soft texture

2 = intermediate/ rubbery

3 =firm

Flesh sweetness (°Brix)

Total soluble solid (SS) is measured on ripe fruits using a digital refractometer. The measurement is recorded in a °Brix scale.

Figure 28: Measurement for flesh sweetness using a digital refractometer

Table to record tree and fruit data

Evaluation 1: Tree evaluation

Date			**Location**						
Line	Tree#	Sex	Height (cm)	Trunk (cm)	# Side shoot			Peduncle length	Note
					S	M	L		
	1								
	2								
	3								

Evaluation 2 and 3:
Tree evaluation

Date			**Location**			
Line	Tree#	Peduncle length	# Total fruit	# non-marketable fruit	Yield gap	Note
	1					
	2					
	3					

Fruit evaluation

Date			**Location**						
Line	**Tree #**	**Fruit #**	**Skin Characteristic**				**Shape**		
			Colour	**Gloss**	**Freckle**	**Disease**	**Fruit**	**Teat**	**Stalk**
	1	1							
	1	2							
	1	3							

Line	**Tree #**	**Fruit #**	**Fruit Firmness**	**Weight (g)**	**Measurement (cm)**				
					Fruit width	**Flesh thickness**	**Cavity width**	**Fruit length**	**Cavity length**
	1	1							
	1	2							
	1	3							

Line	**Tree #**	**Fruit #**	**Cavity Shape**	**Flesh**					**Note**
				Colour	**Consistency**	**Texture**	**Brix**	**Flavour**	
	1	1							
	1	2							
	1	3							

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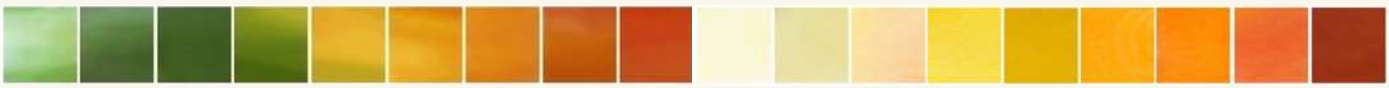

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