An investigation of excessive fruit drop in the Eastern and Western Cape during the 2016/17 season

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INTRODUCTION

In 2017 citrus producers in the Eastern and Western Cape reported abnormal levels of premature fruit drop in a range of different citrus cultivars. In some orchards fruit drop levels of up to 80% of the total yield were recorded. This report is based on an investigation conducted in May 2017 which considered as many potential contributing factors as possible. It aimed to describe the nature of the fruit drop problem and provide future recommendations.

1. GENERAL FINDINGS

The excessive premature drop of citrus fruit during the 2016/17 season was most likely caused by the development of abnormal stylar-end characteristics in non-'Navel' cultivars, and by large secondary navels and navel-end openings in 'Navel' orange fruit. Nearly all abscised fruit had a fissure at the stylar- or navel-end of the fruit, and were split open. For 'Navels' in the Sundays River Valley (SRV), the majority of fruit still on the trees had large secondary navels and were about to drop, or would most probably have to be culled in the packhouse.

Severe fruit splitting and premature fruit drop in the Citrusdal area were confined to 'Navel' oranges and some late mandarin varieties such as 'Valley Gold', 'Orri' and 'Mor', and to a lesser degree, 'Midknight' Valencia oranges. In other non-'Navel' cultivars such as 'Nules' Clementine and 'Delta' Valencia, reports of fruit splitting and/or premature fruit drop were not abnormal when compared with other seasons.

Table 1. Leaf mineral nutrient status of the major nutrients during 2016/17 for different citrus cultivars at Dunbrody Estates in the SRV. All nutrients were within the commercial threshold values, but severe fruit splitting and fruit drop occurred in all these orchards.

Cultivar	N	P (%)	K (%)	Ca (%)	Mg (%)
		% leaf DW			
'CaraCara' Navel	2.32	0.15	1.21	4.49	0.61
'Lane Late' Navel	2.60	0.16	1.57	4.37	0.57
'Salustiana'	2.55	0.16	1.89	3.69	0.50
'Turkey' Valencia	2.66	0.16	1.83	4.58	0.52
'Delta' Valencia	2.36	0.15	1.30	4.09	0.63
'Midknight' Valencia	2.43	0.15	1.17	4.31	0.59

In both production regions, the primary cause of the excessive fruit drop was unrelated to, or not associated with, sunburn damage of the fruit surface, fruit size, fruit insect damage, or general tree health. Some abscised 'Navel' fruit in the SRV showed symptoms of navel-end rot caused by a secondary infection of Alternaria [Alternaria alternata (Fr.: Fr., Keissl.)], but this cannot be considered as the primary cause (Stander et al., 2017). No relationship could be drawn between soil water content logged by soil irrigation probes and the incidence of fruit splitting on such a broad scale. Low leaf potassium (K) and calcium (Ca) levels are generally associated with poor rind integrity of citrus fruit, but none of the leaf mineral nutrient analyses in the SRV revealed either deficiencies or toxicity (Table 1 as an example) and fertilization practices were similar to previous seasons.

In Citrusdal, some affected 'Navel' orchards developed abnormal deficiencies of leaf copper (Cu) and magnesium (Mg) as early as December. However, in the majority of severely affected orchards, leaf content of all the major mineral nutrients were optimal and the correlation between certain mineral nutrient deficiencies, such as Cu, and fruit splitting were not consistently meaningful (Table 2).

Table 2. Leaf copper (Cu) content of citrus orchards in Citrusdal that experienced different intensities of fruit splitting and premature drop.

Cultivar	Cu (mg/kg)
Less severely affected orchards	
'Nules' clementine	3
'Bahianinha' navel	30
'Bahianinha' navel	5
'Bahianinha' navel	6
'Delta' valencia	4
'Valencia Late'	75
'Valencia Late'	7
Severely affected orchards	
'Lina' navel	13
'Palmer' navel	34
'Washington' navel	7
'Washington' navel	2
'Robyn' navel	16
'Robyn' navel	2
'Midknight' valencia	247

In both production regions for 'Navels' in general, fruit splitting and fruit drop were less severe in mid- and late-season cultivars compared with early 'Navels', but still overly excessive compared with previous seasons. Fruit-splitting and large navel-end openings were evident throughout different parts of the tree canopy (Fig. 1), but in general, a higher number of split fruit and open navel-ends were found on the outside of the tree canopy, in the canopy tops, and on the sun-exposed row-side, compared with lower-hanging fruit in shaded canopy areas. The fruit-splitting incidence was similar for different scion x

Fig. 1 Split fruit and large navel-end openings were evident throughout the tree canopy (A), as well as in different cultivars such as 'Turkey' Valencia, in the SRV (B).

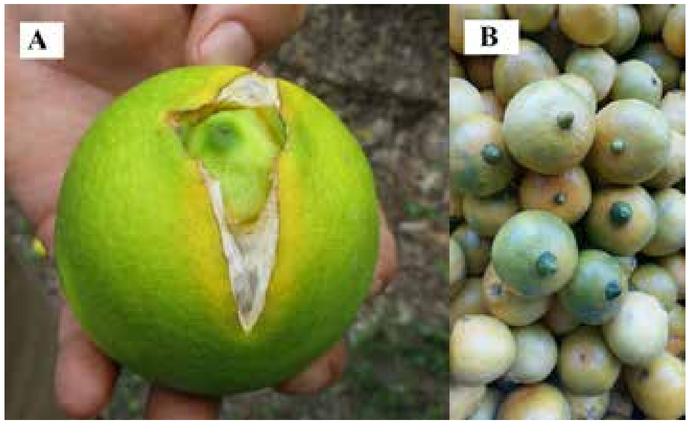

Fig. 2 Fruit drop in 'Midknight' Valencia, was related to an abnormal navel-like structure that developed at the stylar-end of the fruit (A), and in 'Satsuma' mandarin fruit (B), a similar, but protruding navel-like structure developed.

rootstock combinations and across orchards of different ages, different row-orientations and tree spacing.

In the SRV, fruit drop in non-'Navel' cultivars such as 'Midknight' Valencia, was in most cases related to an abnormal navel-like structure that developed at the stylar-end of the fruit (Fig. 2A). A similar, but protruding navel-like structure developed in 'Satsuma' mandarin fruit (Fig. 2B), but this was generally not related to fruit splitting and premature fruit drop in that cultivar. In the SRV, other non-'Navel' cultivars such as 'Delta' Valencia and 'Nules' Clementine, also had severe fruit drop that appeared to be related to abnormal development of the stylar-end of the fruit, which resulted in fruit splitting and premature fruit drop. No abnormal fruit drop was reported for lemons in any of the areas when compared with other seasons.

The severity of fruit drop of easy-peelers and sweet oranges in the SRV was similar in three of the four areas evaluated, viz. Sunland and SRCC, Dunbrody Estates (Unifrutti) and the Wesbank area (Sitrusrand landgoed). In the Barkley Bridge area (a production region located near Addo town) fruit splitting and fruit drop was reported to be severe in certain blocks of 'Cambria' 'Navel' and in 'Nova' mandarin, but the severity of fruit drop appeared to be less serious, and higher fruit yields are expected compared with orchards in the other three production areas, although not compared with historic yields of the same orchards. In one 'Navel' orchard under permanent 20% white shade nets the severity of fruit splitting and the number of fruit with open navel-ends appeared to be lower compared with adjacent rows outside nets, but the effect will be quantified at time of harvest in July.

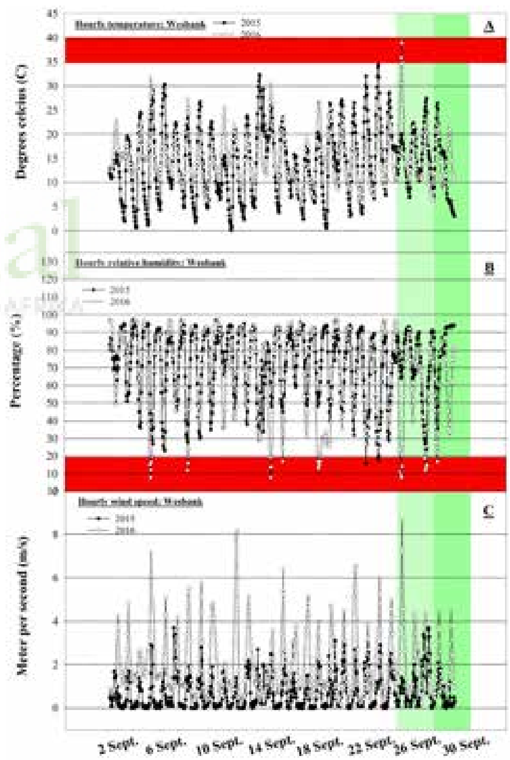

Fig. 3. The hourly air temperature (A), relative humidity (B), and wind speed (C) for the Wesbank area in the SRV for September 2015 and 2016. The green bars indicate the date of full bloom. The light green bar represents date of full bloom for early 'Navels' and the dark green bar, the full bloom date for mid- and late season navels. The Sunland and Dunbrody area experienced similar weather conditions.

In general, the 2016 flowering period in the SRV was extended by up to 3 weeks. It is important to note that many producers at SRCC and the producer at Sitrusrand landgoed recorded a slightly earlier flowering time for early 'Navels' in general (more specifically for 'Newhalls'), compared with mid- and late-season 'Navel' types. However, time of full bloom in the majority of the cultivar types across the SRV and in Citrusdal was recorded in the last week of September of 2016. In certain 'Navel' blocks in the SRV, experimental foliar 2,4-D treatments to reduce the size of the navel-end opening (Mupambi et al., 2015) were applied during the first and/or second weeks of October, but no significant differences in fruit splitting and fruit drop could be observed in treated blocks compared with untreated. In some 'Navel' orchards in Citrusdal and Clanwilliam, the numbers of split fruit and fruit with large navel-end openings were recorded as lower in orchards that received experimental 2,4-D treatments, compared with untreated orchards, but the severity of fruit splitting and premature drop in treated orchards were nevertheless higher compared with previous seasons.

In three of the four areas in the SRV, viz. Wesbank, Dunbrody and Sunland, abnormal climatic conditions were recorded for August and September 2016 (only September shown for Wesbank in Fig. 3, compared with the corresponding period in 2015. On 26 September,

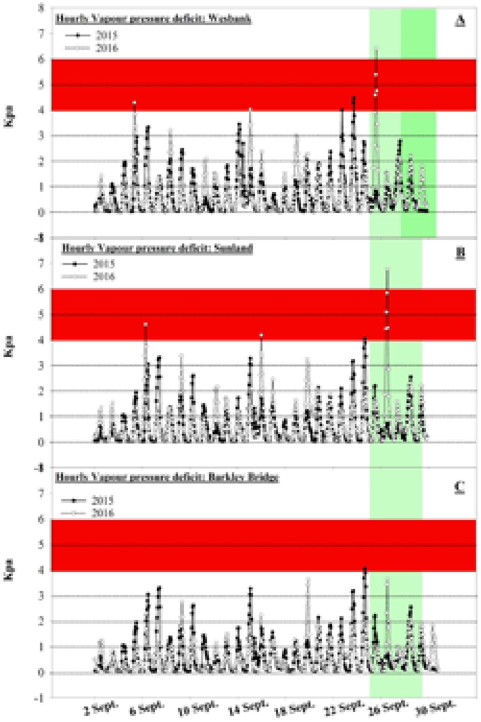

Fig. 4 The hourly estimated leaf vapour pressure deficit (VPD) in September 2015 and 2016 for A) Wesbank, B) Sunland, and C) Barkley Bridge. The green bars indicate the date of full bloom in 2016. The Dunbrody area experienced similar VPD levels to A and B.

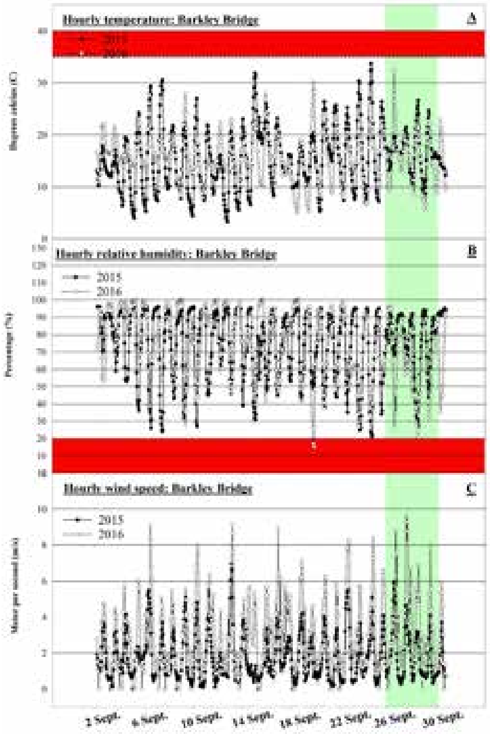

Fig. 5 The hourly air temperature (A), relative humidity (B), and wind speed (C) for the Barkley Bridge area for September 2015 and 2016. The green bars indicate the date of full bloom.

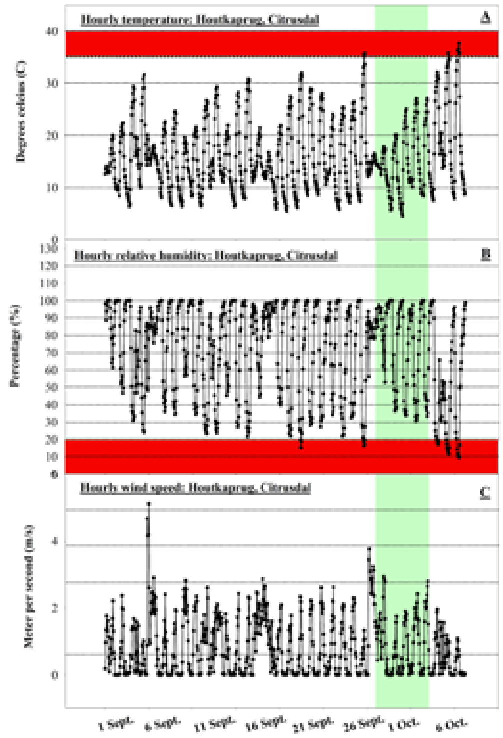

Fig. 6 The hourly air temperature (A), relative humidity (B), and wind speed (C) for Citrusdal for September and the first week of October 2016. The green bars indicate the date of full bloom.

during full bloom, afternoon temperatures reached a maximum of 40°C, relative humidity was at a low of ±8% and wind speeds reached ±30 km/h. Similar weather conditions were recorded at Sunland and Dunbrody on the same day (not shown). In addition, leaf vapour pressure deficit (VPD) levels reached abnormally high levels on 26 September, of between 6 and 7 kPa (Fig. 4). Citrus has a characteristic sensitivity towards high VPD levels as an increase in VPD leads to a steady decrease in stomatal conductance and thus lower photosynthetic rates (Medina et al., 2002). VPD seems to be the most limiting factor of photosynthetic rate in citrus trees under natural conditions. Even in well-watered soils, stomata can readily close at VPD above 1.5 kPa (Ribeiro and Machado, 2007).

The Barkley Bridge area showed more moderate climatic conditions compared with the other three areas in the SRV, but these were nevertheless more extreme compared to corresponding periods of the previous season (Fig. 5). Barkley Bridge is closer to the Indian Ocean than the other three areas and generally experiences cooler spring temperatures and more regular winds.

In the Western Cape, the fruit splitting and premature fruit drop problem in 'Navel' orchards were less severe in the Swartland and Piketberg areas, compared with the Sandveld and Citrusdal areas. In Citrusdal, abnormally high temperatures (36 to 40°C), and low relative humidity (8-9%) for spring were recorded for two consecutive afternoons, 7 to 14 days after full bloom during early October (Fig. 6).

2. Fruit splitting and drop of 'Navel' oranges

The 'Navel' flower is unique from other cultivars, in that the navel inside the primary fruit also has a fruit style. Thirty to 40 days before full bloom, this secondary fruit style develops from cells located inside the primary fruit (Fig. 7A). During flower development the secondary fruit style extends and eventually fuses with the style of the primary fruit (Fig. 7B). If the secondary and primary fruit styles fuse successfully, the navel-end is closed subsequent to petal drop. The abscission event simultaneously results in both the abscission of the secondary and primary style, resulting in solid rind tissue at the navel-end of the fruit (Fig. 7C).

Under extreme weather conditions such as during warm, dry and windy days, the primary fruit style abscises prior to fusion with the secondary fruit style in the majority of the fruit (Wager, 1939, Lima and Davies, 1984). This results in the formation of a cavity between the primary and the secondary fruit (Fig. 7D).

Upon initiation of fruit growth in December, the expansion of the primary fruit's pulp results in the tearing open of the rind tissues at the navel-end of the primary fruit. When the secondary fruit reaches its peak growth rate in February (Fig. 8), the further pressure exerted on the navel-end by growth of the secondary fruitlet results in the splitting open of the primary fruit, which can lead to excessive fruit drop (Lima and Davies, 1984). Under mild flowering conditions or when synthetic auxins such as 2,4-D are applied prior to abscission of

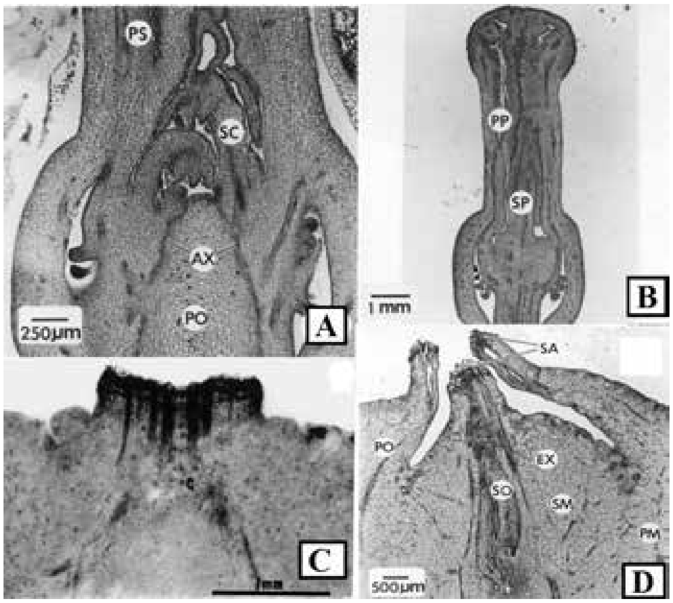

Fig. 7 *(A) Thirty to 40 days before full bloom, the secondary fruit style (indicated as "sc") develops from cells located inside the primary fruit. (B) The secondary fruit style (indicated as "sp" extends and eventually fuses with the style of the primary fruit (indicated as "pp"). (C) If the secondary and primary fruit styles fuse successfully, the navel-end would be closed subsequent to petal drop. If the primary fruit style abscises prior to fusion with the secondary fruit style a cavity forms between the primary and the secondary fruit (D). *Adapted from Garcia-Luis et al. (2001) and Lima and Davies (1984).*

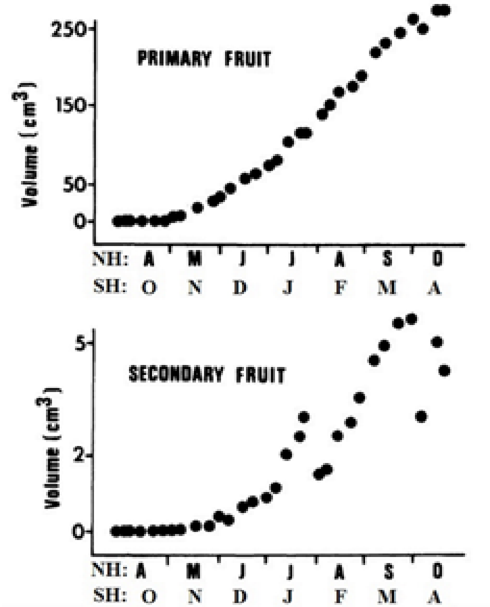

Fig. 8 *Upon initiation of fruit growth in December, the expansion of the primary fruit's pulp results in the tearing open of the rind tissues at the navel-end of the primary fruit. When the secondary fruit reaches its peak growth rate in February, the further pressure exerted on the navel-end by growth of the secondary fruitlet results in the splitting open of the primary fruit in March. *Adapted from Lima and Davies (1984).*

the primary fruit style, the secondary style and primary style successfully fuse and result in a closed navel-end which makes the fruit less susceptible to splitting (Mupambi et al., 2015).

It appears that the abnormally high temperature (40°C), low relative humidity (±8%) and relatively high wind speed (30 km/h) recorded during flower development in Citrusdal, and in three of the four areas in the SRV, caused the primary fruit style to dry out and abscise prematurely, which resulted in an inhibition of fusion between the secondary and primary fruit styles. This is consistent with Fig. 9A and B, in which exposed, secondary fruit styles were already clearly visible at the end of October. The majority of 'Navel' flowers were exposed to the same extreme climatic conditions when they were fully open, and this probably explains their increased susceptibility to split and eventually drop. The reports of higher fruit splitting incidence and fruit drop in 'Newhall' navels in the SRV are consistent with this hypothesis, since the cultivar generally flowered earlier and the majority of flowers were therefore open on that particular day. The Barkley bridge area in the Eastern Cape experienced substantially milder climatic conditions on the same day, which likely explains the resulting lower incidence of fruit splitting and fruit drop.

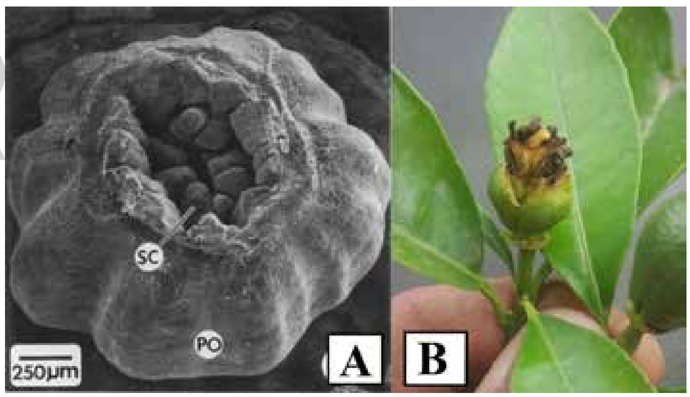

Fig. 9 *It appears that the abnormally extreme weather conditions recorded during full bloom on 26 September caused the primary fruit style to dry out and abscise prematurely, which resulted in an inhibition of fusion between the secondary (indicated as "sc") and primary fruit styles as depicted in (A). This is consistent with (B), in which exposed, secondary fruit styles were already clearly visible at the end of October. *Picture A adapted from Lima and Davies (1984), and picture B provided by Dave Gerber.*

3. Fruit splitting and drop in other cultivars in the SRV

In cultivars that do not normally develop a distinguishable secondary fruitlet (navel) at the stylar-end of the primary fruit, the floral apical meristem naturally extends into a column within the fruit style of the primary fruit (García-Luis et al., 2001). In non-split-prone mandarin hybrids and 'Satsuma', slow flower development

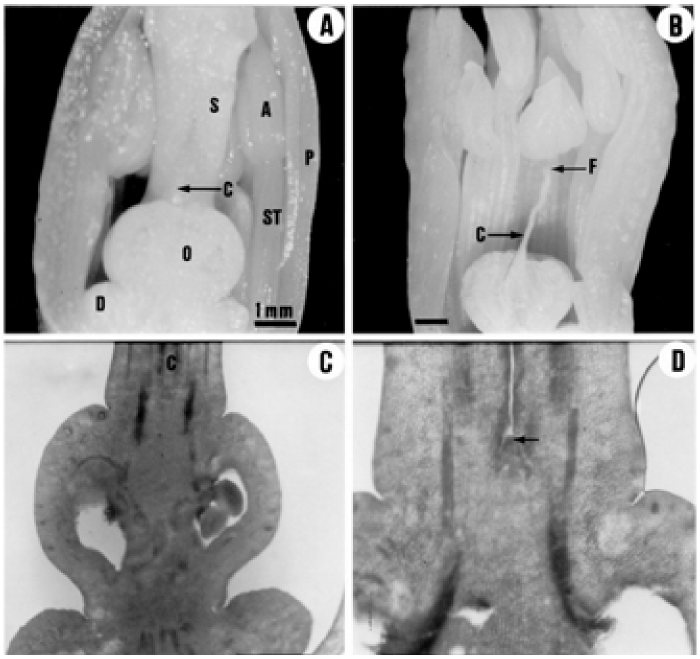

Fig. 10 *In non-split-prone cultivars such as 'Satsuma', slow flower development under mild weather conditions allows for the floral apical meristem (indicated as "c" in A and B) to fuse with the primary fruit style (indicated as "s" in A). When the fruit style abscises during petal drop, the rind tissue at the stylar-end of the fruit is solid and strong (C and D), and therefore does not split. * Adapted from Garcia-Luis et al. (2001).*

under mild weather conditions allows for the floral apical meristem to fuse with the primary fruit style (Fig. 10). When the fruit style abscises during petal drop, the rind tissue at the stylar-end of the fruit is solid and strong, and therefore does not split (Fig. 10).

When the floral apical meristem does not extend within the column of the primary fruit style, or when the primary fruit style abscises prior to fusion with the floral apical meristem, a cavity develops at the stylar-end. This occurs naturally in split-prone 'Nova' mandarins (Fig. 11), but can occur in other cultivars when open flowers are prematurely exposed to extreme weather conditions (García-Luis et al., 2001; Lima and Davies, 1984). Upon abscission of the style, the floral apical meristem thus develops a navel-like structure with oil glands and pigments (Fig. 11).

Lack of fusion between the apical floral meristem and the fruit style can also lead to a navel-like structure developing in other mandarin types (Spiegel-Roy and Goldschmidt, 1996), as well as in 'Valencia' oranges (Stewart and Klotz, 1947) and in grapefruit (Stewart and Parker, 1947).

The splitting and drop of non-navel cultivars in the SRV appears to be related to either of the following scenarios:

1) A cavity that developed between the floral apical meristem and the primary fruit (as in the case of 'Delta' Valencia and 'Clementine' cultivars); or

2) an abnormal secondary navel-like structure which likely developed as a result of a lack of fusion between the floral apical

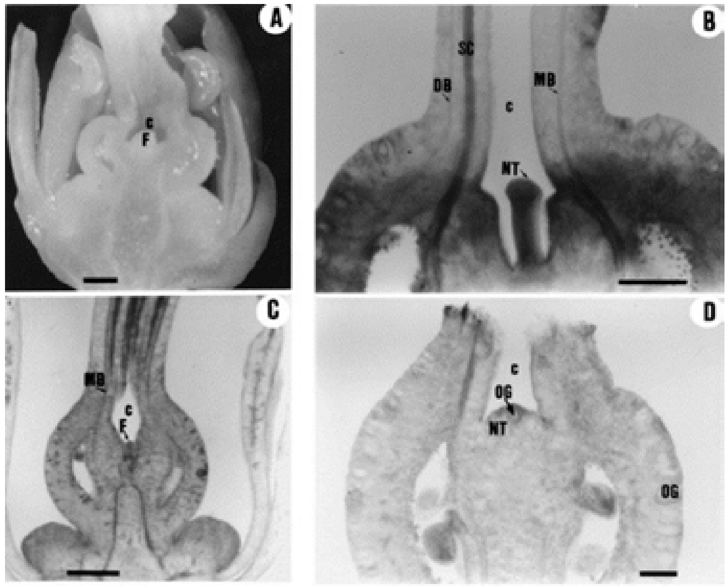

Fig. 11 *When the floral apical meristem (indicated as "c" in A) does not extend within the column of the primary fruit style (B), or when the primary fruit style abscises prior to fusion with the floral apical meristem, a cavity develops at the stylar-end (C). Upon abscission of the style, the floral apical meristem thus develops a navel-like structure with oil glands and pigments (D). *Adapted from Garcia-Luis et*

meristem and the fruit style, which explains the abnormal development of secondary, pigmented navel-like structures in 'Midknight' Valencia (Fig. 2A) and in 'Satsuma' mandarin fruit (Fig. 2B).

The most likely cause of these unnatural occurrences is that of abnormal and extreme weather conditions recorded during full bloom, on 26 September 2016.

4. Conclusions and recommendations

Overall, normal cultural practices were applied as in other seasons, and no relationship could be found between commercial foliar sprays of any kind, and tree phenological events and the level of fruit splitting intensity. The severe premature drop of citrus fruit in the SRV is reported in different cultivars and across orchards and production areas exposed to seasonally consistent, but variable and area-independent cultural practices. Poor cultural practices may have exacerbated the problem in some cases, but do not appear to be the primary cause. In all evaluations, the consistent abnormal stylar-end characteristics and subsequent development of large stylar- and/or navel-end openings and fruit splitting appeared to be the primary cause of the severe premature fruit drop problem. The current excessive fruit drop appears to be related to abnormal, extremely dry, warm and windy weather conditions during and immediately after flowering time.

A follow-up study is underway to quantify the severity of the problem and identify strategies for the future. Considering the early abscission of up to 80% of fruit in many affected orchards, extreme flowering intensity can be expected during return bloom in spring of 2017, if sufficient flower induction conditions occur during winter. Winter pruning is a highly recommended cultural practice prior to an expected "on" year (See: Bester and Warrington, SA Fruit Journal April/May 2017). Physiological fruit disorders are a common occurrence in heavily-fruiting years, and often associated with abnormal mineral nutrient relations. The abnormal early lack of fruit in 2017 can permit earlier replenishment of important leaf mineral nutrients such as N, P, K, Ca and Mg prior to and during flower development in autumn and early winter. Growers are advised to consult their annual leaf nutrient analyses reports, and ensure that pre-blossom fertilization practices in severely affected orchards where fruit is lacking, are aimed at obtaining the optimum leaf nutrient range as quickly as possible.

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