Further observations on the effect that rainfall, irrigation and fertiliser practices have on the ripening of avocado fruit

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ABSTRACT
Research conducted during the last number of seasons have shown that pre-harvest climatic and horticultural factors significantly influence the ripening patterns of South African 'Hass' and 'Maluma' avocado fruit. During the 2012 season relevant observations were made regarding this aspect during three separate trials, namely the mulch trial currently being performed by ZZ2 in Mooketsi; the Schagen based 'Hass'/'Maluma' irrigation trial and, finally, the ripening results from SmartFresh hold back samples. It would appear that fruit from irrigated orchards experiencing water stress conditions, ripen particularly slow and variably, especially when harvested during the dryer months of the harvest season. It would further appear that the effect of water stress is exacerbated when the (normally) dry winter harvest period follows a particularly wet summer season. The research has also indicated that the phosphorous (P) status of an orchard must be correctly managed, in order to ensure efficient ripening of the fruit. The above mentioned fruit metabolic and root phenological aspects will be further investigated during the 2013 season.

INTRODUCTION

During the 2011 season it was observed that fruit from poorly irrigated orchards took substantially longer to ripen than correctly irrigated orchards. Based on this observation, results from a trial of which the original aim was to study the relationship between water stress and chilling injury (black cold injury), were revisited. Further analysis of the data inferred that water stress caused avocado fruit to ripen at a slower and more variable rate (Kruger & Magwaza, 2012). It was further deduced that fruit from orchards planted on homogeneous soils ripened more evenly than fruit from orchards planted on more heterogeneous soils.

The above topic was further investigated during the 2012 season. The following three current trials are referred to:

1. The mulch trial performed by ZZ2 in Mooketsi (Nzanza & Pieterse, 2012).
2. The Schagen based 'Hass'/'Maluma' irrigation trial (Roets *et al*., 2012).
3. Ripening results from SmartFresh hold back samples.

MATERIALS AND METHODS

ZZ2 mulch trial

A SAAGA sponsored trial aimed at establishing the effect that mulches have on avocado yield and quality, is currently being performed by ZZ2 in Mooketsi (Nzanza & Pieterse, 2012). Two cultivars are involved, namely 'Hass' and 'Maluma'. Each trial consists of four treatments with three replicates each. There are thus 12 sample plots, each consisting of a row with 15 trees.

At the start of the 2012 'Maluma' harvest window, 30 fruit were sampled from each of the experimental plots. The fruit were transported to the Agricultural Research Council – Institute for Tropical and Subtropical Crops' (ARC-ITSC) Postharvest Laboratory in Nelspruit and ripened at 20°C. The number of days to ripen each fruit (DTR) was determined and the mean DTR (mDTR) calculated for each sample. The ripening profile of each sample was hereafter drawn. Soil samples were also taken of each plot and a standard mineral analysis performed.

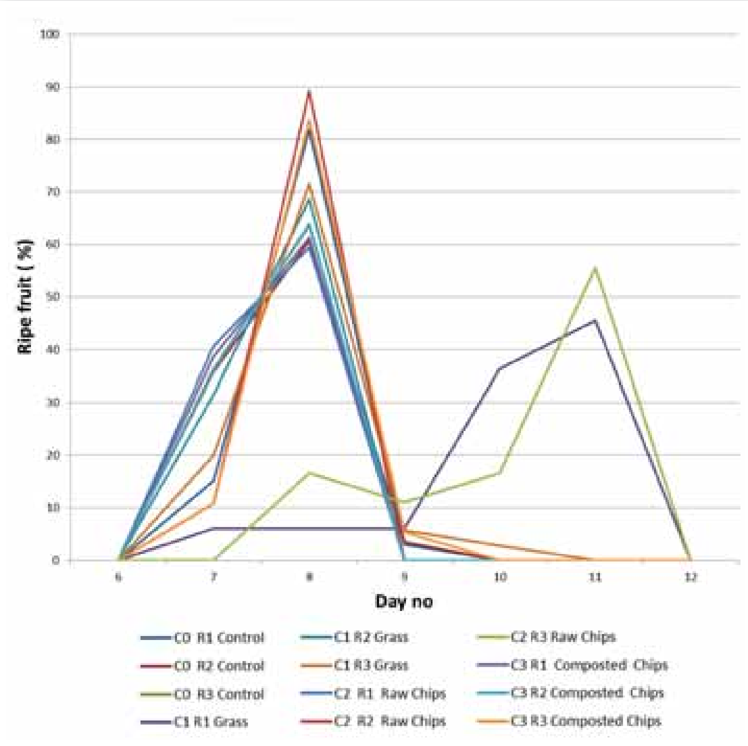

Figure 1. Ripening profiles of 'Maluma' fruit from 12 plots in the ZZ2 mulch trial.

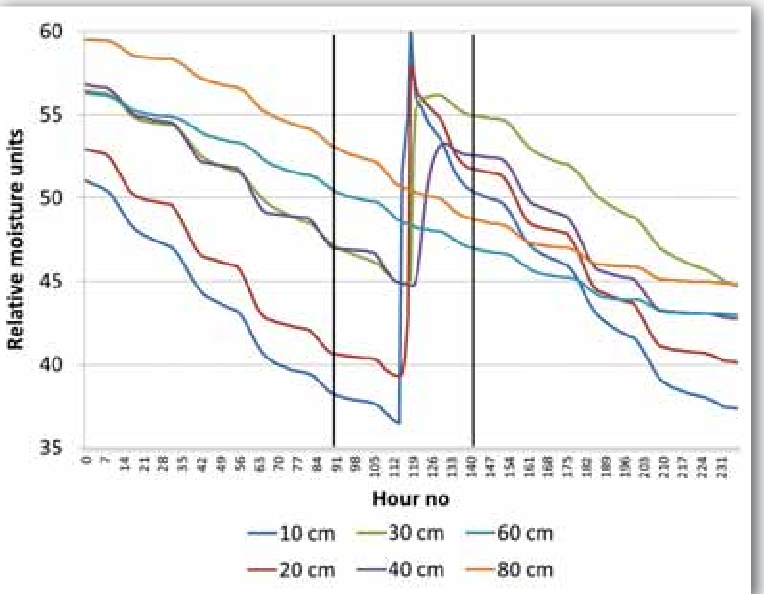

Figure 2. DFM probe moisture readings for the week during which the Schagen irrigation trial samples were taken.

Table 1. Mineral element (Ca, Mg, K and Na) concentrations of soil from higher lying/uneven ripening replicates versus lower lying/even ripening replicates in the ZZ2 mulch trial (Ca, Mg and K P < 0.01; Na P < 0.05).

	Soil mineral content (mg/kg)			
	Ca	Mg	K	Na
Two uneven ripening reps	582.3 a	172.0 a	209.7 a	21.7 a
Ten even ripening reps	912.2 b	231.2 b	293.3 b	29.2 b

Schagen based 'Hass'/ 'Maluma' irrigation trial

This trial was performed on the Hokaai farm in the Schagen area. The experimental block consisted of seven rows where 'Hass' and 'Maluma' trees were planted in an alternating pattern. This orchard was selected due to the fact that a DFM probe trial (Roets *et al*., 2012) was being performed in the block at the time and accurate soil moisture content readings were therefore readily available.

During the 2012 season, all 'Maluma' trees with more than 70 fruit per tree were identified and marked. Ten fruit per tree were subsequently used to establish the mean moisture content of the fruit borne by the specific tree. The balance of 60 fruit was sampled, respectively one day before and one day after the scheduled weekly irrigation session took place. The fruit were transported to the ARC-ITSC Postharvest Laboratory and ripened at 20°C.

While sampling each tree, a calibrated conductivity meter was used to measure the moisture content of the top soil under each tree. Ten conductivity readings were taken within the micro sprinkler zone of each tree.

SmartFresh hold back sample analyses

During the 2008-2011 seasons, two cartons each of control and SmartFresh (1-methyl cyclopropene; 1-MCP) treated 'Hass' avocado fruit were retained from each application conducted in a packing house located in the Tzaneen area. One set of samples was immediately ripened, while the second set was stored at 5°C for 30 days before being ripened at room temperature. Upon ripening, the number of days to ripen (DTR) each fruit was recorded and the mean (mDTR) calculated. The ripening profile graphs (percentage or fruit that ripened on each consecutive day) were also compiled.

RESULTS AND DISCUSSION

ZZ2 mulch trial

The ripening profiles of the fruit from the 12 'Maluma' tree plots are shown in Fig. 1. From the figure it is clear that ten of the replicates had synchronised ripening profiles, while the profiles of the remaining two replicates were delayed and spread out.

The above trial is located in an orchard planted on a slope and the fruit from the uneven ripening replicates were from the two highest lying plots. An inspection of the archived water pressure measurements taken by ZZ2, revealed that the higher lying rows are more often affected by water pressure failures than the lower laying rows.

The soil mineral analysis results are shown in Table 1. The soil Ca, Mg, K and Na concentrations of the higher lying/slower ripening replicates was significantly lower than that of the lower lying/faster ripening ten rows. The reason for this is that the orchard is fertigated and since the upper two rows received less water, it also received fewer nutrients than the lower lying rows.

The above information supports the hypothesis formulated by Kruger and Magwaza (2012) that orchard soil moisture content at the time of harvest influences the ripening of avocado fruit.

Schagen based 'Hass'/'Maluma' irrigation trial

The DFM probe readings for the week during which the samples were taken are shown in Fig. 2. As may be deduced from the figure, the top 10 cm of soil was the driest during the first sample date. Its moisture content then sharply increased on the day of irrigation. In contrast, the two deepest measurements (60 and 80 cm) which contained the highest moisture content before irrigation, did not react to the irrigation. The most important deduction to be made from the DFM graph is that, at all depths, the moisture

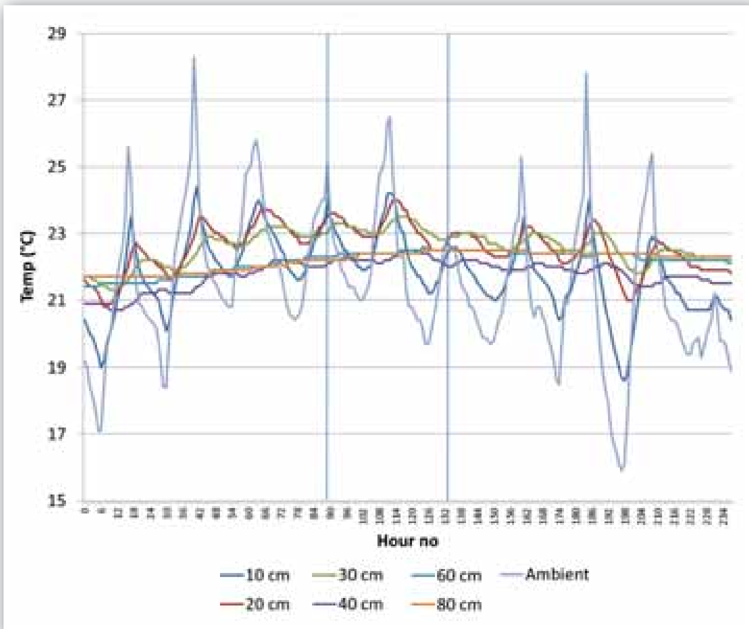

Figure 3. DFM probe temperature readings for the week during which the Schagen irrigation trial samples were taken.

Table 2. Fruit moisture content, soil moisture content and mean days to ripen (mDTR) readings of 'Maluma' avocados before and after irrigation (soil moisture content P < 0.05; mDTR P < 0.1).

	Mean fruit moisture content (%)	Mean soil moisture content (%)	mDTR (days)
Before irrigation	74.2	12.9 a	10.4 a
After irrigation		14.3 b	11.2 b

Table 3. Mean fruit maturity and mean pre-/post-irrigation soil moisture content readings of trees with single and multiple ripening peaks (P < 0.05).

Parameter	Mean fruit moisture content (%)	Mean soil water content before irrigation (%)	Mean soil water content after irrigation (%)
Multiple peak trees	74.3 a	10.7 a	11.7 a
Single peak trees	73.7 a	9.7 a	10.5 a

Table 4. Standard deviation in fruit maturity and standard deviation in pre-/post-irrigation soil moisture content readings of trees with single and multiple ripening peaks (P < 0.01).

	Standard deviation of fruit maturity (moisture content) (%)	Standard deviation of soil water content before irrigation (%)	Standard deviation of soil water content after irrigation (%)
Multiple peak trees	2 a	1.7 a	2 a
Single peak trees	1.7 a	1.2 b	1.1 b

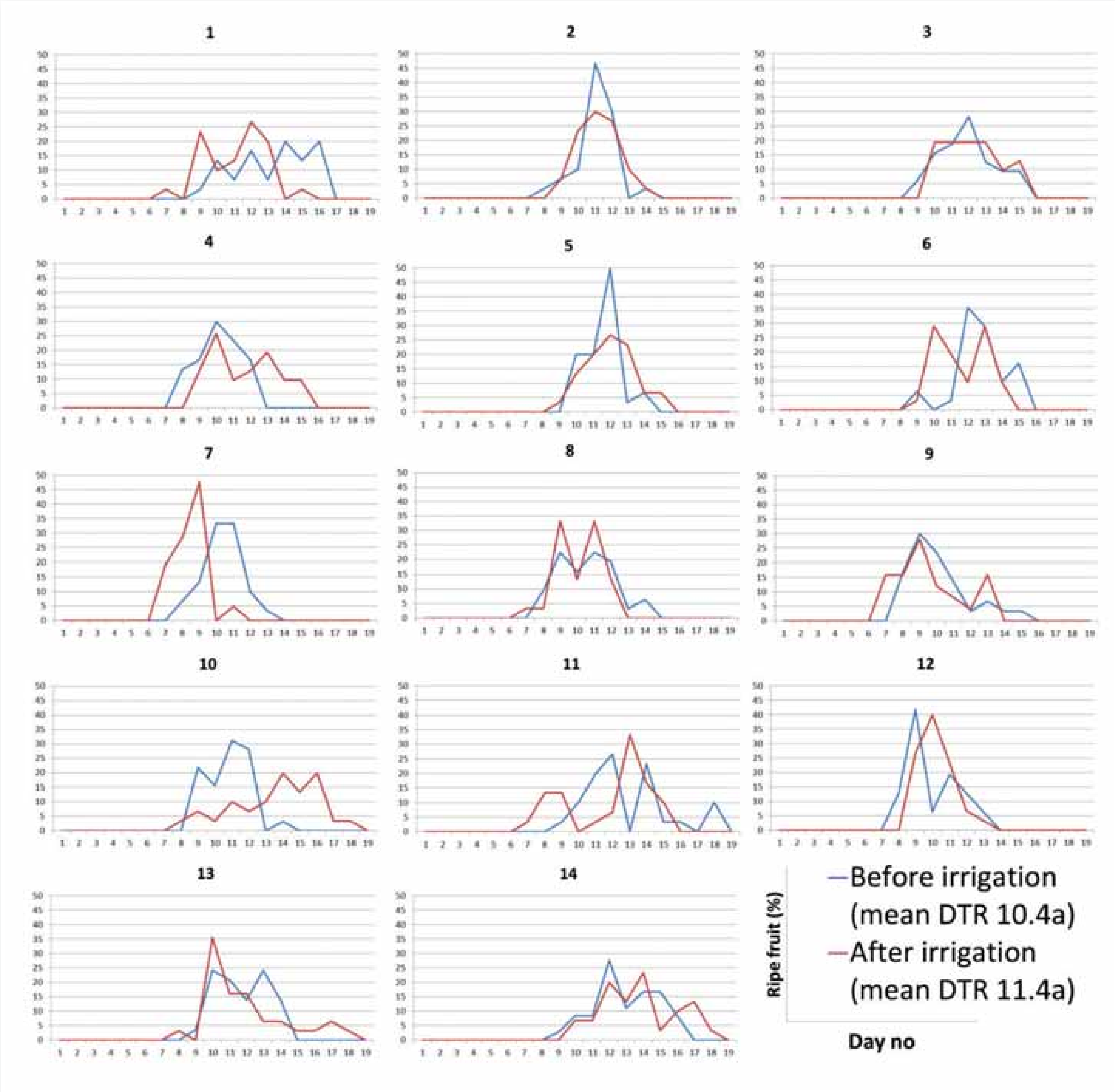

Figure 4. Ripening profiles of 14 experimental trees in the Schagen irrigation trial. The axis titles and legend are shown in the bottom right hand corner.

Table 5. Mean number of days to ripen (mDTR) 'Maluma' hold back samples from commercial SmartFresh treatments applied to fruit from two growers in the Tzaneen area during 2012. (SAAGA-OTO feedback.)

Grower no	Packing date	Count	Fruit age at start of ripening (days)	DTR (days)	STD of DTR (DTR)	Soil P (mg/kg)
1	17-Apr	12	22	11.9	4.4	< 10
2	17-Apr	16	22	3.9	1.1	Up to 90
1	23-Apr	18	28	10.7	3.8	< 10
2	24-Apr	16	27	5.6	0.5	Up to 90

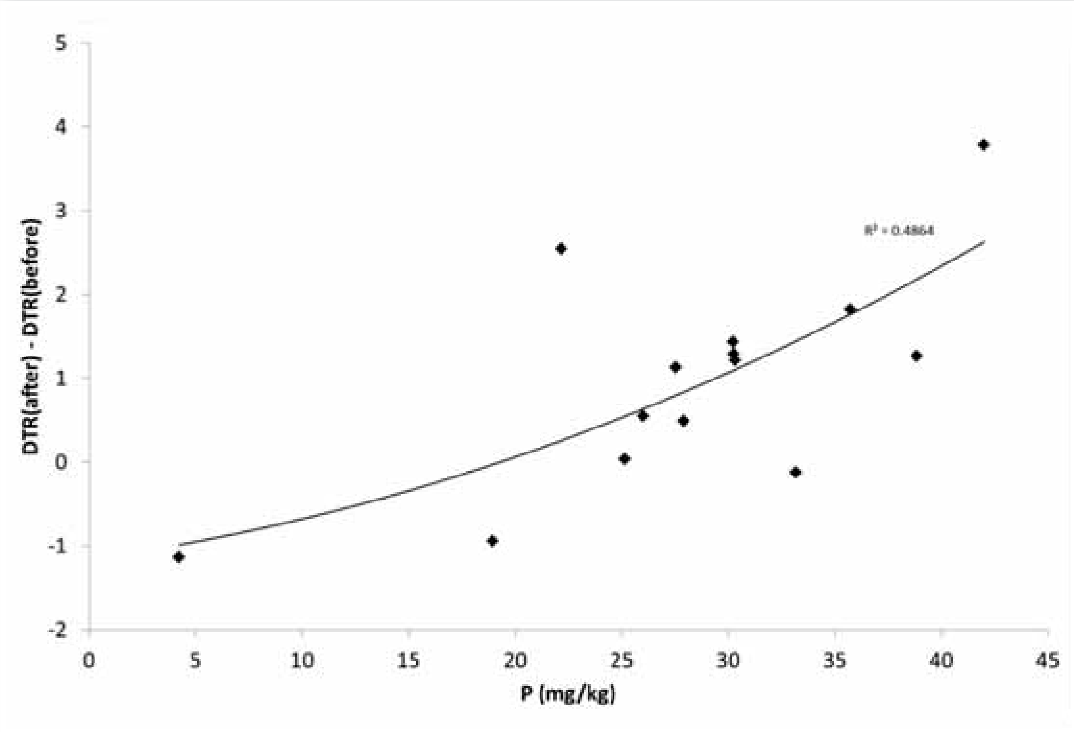

Figure 5. Correlation between the DTR differential and the P content of the soil of 14 experimental trees in the Schagen irrigation trial.

content decreased linearly over the observation period. This is an indication that the trees were not subjected to water stress conditions during the sampling period.

The mean fruit moisture content, as well as the mean soil moisture content and mDTR readings, are summarised in Table 2. The mean soil moisture content of the top layer of soil, as measured by the conductivity meter, increased from 12.9% before irrigation to 14.3% after irrigation. The mDTR of the fruit was 10.4 days before irrigation and it increased to 11.2 days after irrigation. There thus was a propensity for the fruit to ripen slightly faster before irrigation than after irrigation. This was probably due to the temperature in the orchard (Fig. 3) being higher on the first sampling day (before irrigation) than on the second sampling day (after irrigation).

The ripening profiles of the 14 experimental trees are shown in Fig. 4. It is important to take note that the ripening profiles of the trees were fairly similar before and after irrigation. In other words, if it had a single peak before irrigation (trees 2, 5, 7 and 12), it also showed a single peak after irrigation, while a multiple peaked pre-irrigation profile (trees 1, 3, 4, 6, 8, 9, 10, 11, 13, 14) remained this way after irrigation.

The fruit maturity and pre- and post-irrigation soil moisture contents readings of the single and multiple peaked trees did not differ between the two groups (Table 3). The same applies to the standard deviation (STD) of the fruit moisture content (Table 4). However, the STD of the soil moisture content significantly differed between the two groups, both before and after irrigation (Table 4). This observation infers that fruit from trees with soil moisture variations in their root zone ripened more variably than fruit from trees with more homogeneous superficial soil water content readings.

The mineral analyses readings revealed similarly interesting results. Of all the mineral elements measured, phosphorous (P) was the only element to show a correlation between the DTR differential and the soil mineral content (Fig. 5). From the graph it would appear that fruit from trees located in a higher P containing soil, ripened faster before irrigation (when higher ambient temperatures prevailed), while fruit from trees located in soils with lower P levels tended to ripen faster after the soil moisture content increased, following irrigation.

Ripening of SmartFresh hold back samples over the last five years

The seasonal ripening profiles of SmartFresh treated 'Hass' hold back samples for the last five years are shown in Fig. 6. Of the five years, the 2010 season exhibited the most favourable SmartFresh (SF) ripening pattern. During this season, the first SF treated fruit ripened approximately four days after the control, while the last SF fruit ripened before the last control fruit. The 2008, 2009 and 2011 seasons were characterised by intermediate, but still favourable SF ripening patterns. However, during the 2012 season, the SF treated fruit took significantly longer to ripen than the control fruit.

The quarterly rainfall figures for the Tzaneen area are also plotted in Fig. 6. As may be seen, the 2010 season was characterised by a very dry summer followed by a dry winter. In contrast, the 2012 season was shown to have very high rainfall during early summer after which the rain completely stopped.

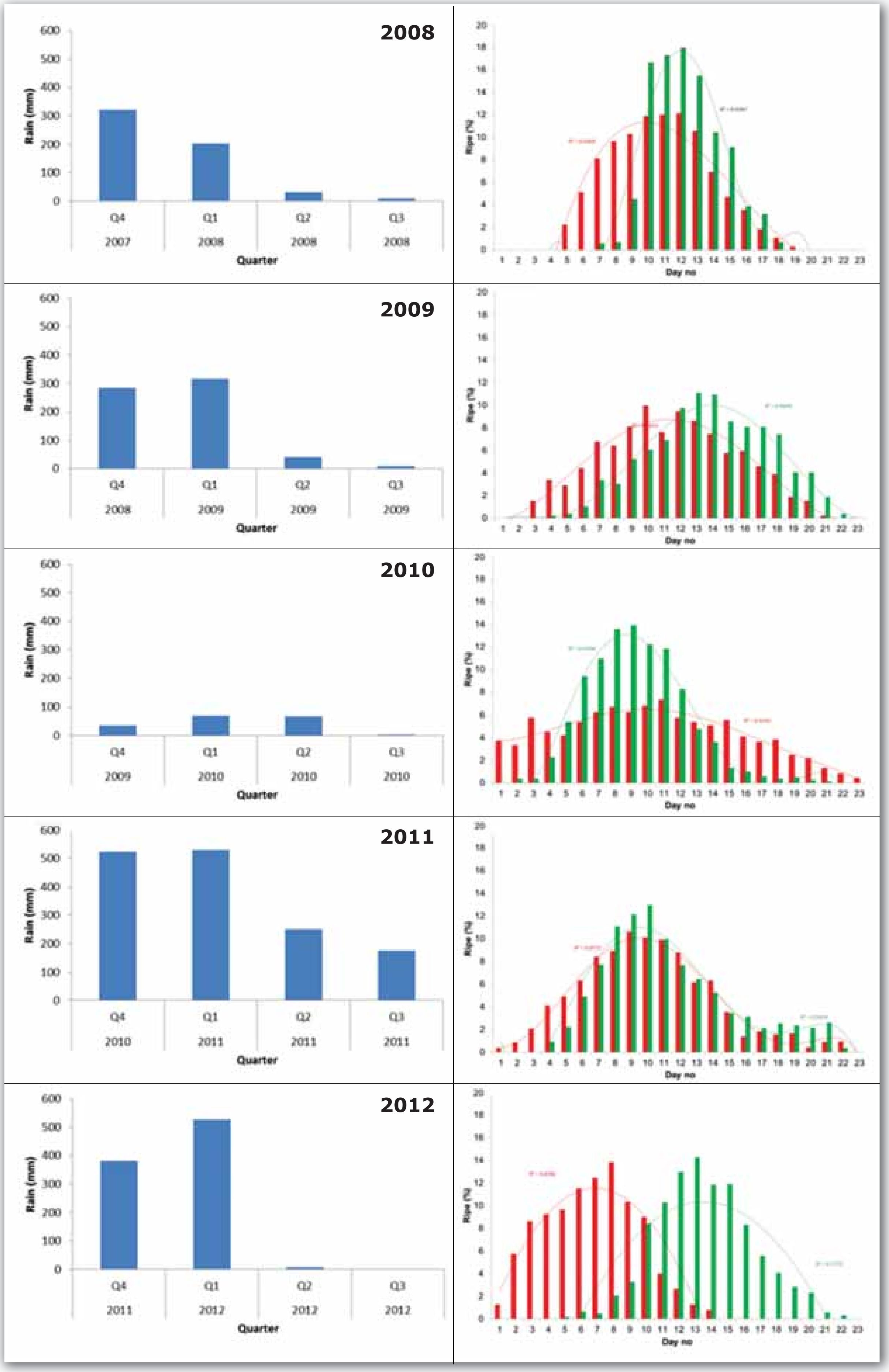

Figure 6. Seasonal ripening profiles of SmartFresh treated 'Hass' hold back samples for the last five years.

The 2008 and 2009 seasons were fairly representative of normal rainy seasons, while the 2011 season had high rainfall for both summer and winter periods.

The individual ripening patterns of all the SF applications performed at a single pack house (Tzaneen area) over the 2012 season, are shown in Fig. 7. This graph clearly demonstrates why the two normal distribution curves shown in Fig. 6 are more detached during 2012, compared to the previous four seasons. Only one application performed on 4 August had a ripening pattern similar to those registered during previous seasons, especially the 2010 season. Inspection of the producer's records revealed that the soil P values of this particular orchard were significantly higher ([P] > 250 ppm) than those of the other farms ([P] 2-60 ppm) supplying fruit to the particular pack house.

In addition to the above observations made regarding the 'Hass' cultivar, interesting commercial observations relating to the 'Maluma' cultivar were also made during the 2012 season. As part of the SAAGA-Maluma research project, the ripening patterns of all 'Maluma' consignments ripened by the overseas technical officer were compared. In Table 5, the mDTR values of 'Maluma' fruit from two shipping containers are compared. Fruit from orchards containing higher P levels was found to ripen considerably faster than fruit from orchards with low P levels.

FURTHER RESEARCH

The current results support the observations by Kruger and Magwaza (2012) that orchard moisture stress hampers the ripening of avocado fruit. Water stress would appear to not only result in delayed ripening, but also uneven ripening, especially in orchards planted in heterogeneous soils. There are also indications that climatic conditions prevailing during the period prior to harvest may also play a role.

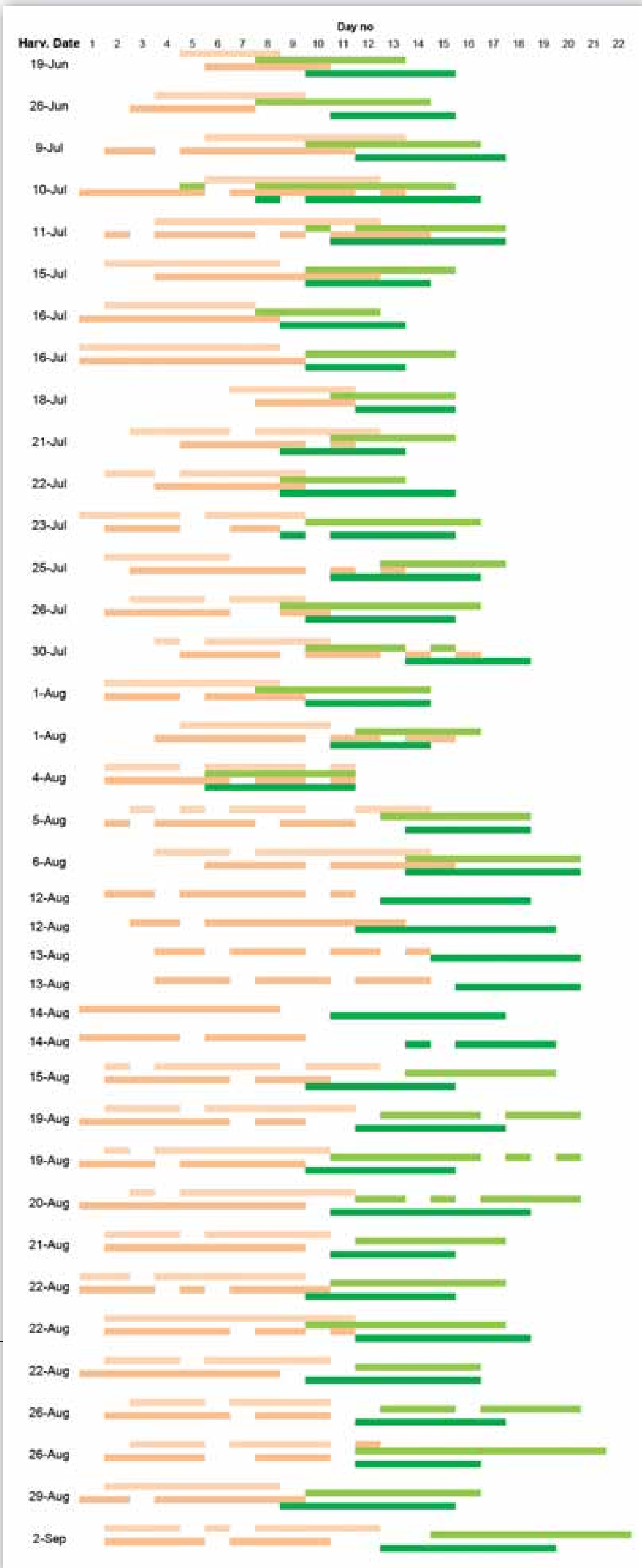

Figure 7. Individual ripening patterns of SF applications performed at a single pack house (Tzaneen area) over the 2012 season. The light beige bars represent control samples that were ripened in a ripening room set at 20°C, while the dark beige bars represent control samples that were ripened at ambient. The light green bars represent SmartFresh samples that were ripened in a ripening room set at 20°C, while the dark green bars represent SmartFresh samples that were ripened at ambient.

In order to attempt to explain the above trends, a research hypothesis needs to be formulated. According to the current results, it would appear that avocado fruit harvested and treated with SF during a customarily dry winter period following an exceptionally dry summer period, ripen relatively smoothly upon reaching the prescribed harvest maturity. We hypothesise that under these circumstances, the roots are concentrated under the micro sprinkler's coverage area and all fruit receive adequate irrigation (provided the orchard is properly irrigated). The results also indicate that when the summer is exceptionally wet and the winter dry, the fruit tend to ripen more unevenly, especially after a SF treatment. Our hypothesis regarding this is that, during the wet season the roots forage outside the normal sprinkler zone. Upon the dry season setting in, these new roots die back and the tree then becomes dependant on moisture from the original sprinkler area. Fruit that have been primarily dependent on water from roots outside the sprinkler area now have to obtain water from the roots under the sprinkler area.

Phosphorus is well known to play a role in the energy metabolism of the cell and it is also important in root development. The current observations regarding the improved ripening of fruit from high P orchards may be related to one or both of these factors. Further research regarding these aspects is obviously required.

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