Further observations and recommendations on the manifestation and control of vascular staining and grey pulp in 'Maluma' avocado fruit

FJ Kruger, GO Volschenk and L Volschenk

Lowveld Postharvest Services,
PO Box 4001, Mbombela (Nelspruit) 1200, SOUTH AFRICA

E-mail: fjkruger58@gmail.com

ABSTRACT

During the last season, a number of observations were made regarding the epidemiology of vascular staining and grey pulp in 'Maluma' avocado fruit. It would appear that vascular staining is caused by the diffusion of pigment, from the seed coat into the vascular bundles during prolonged storage at low humidity conditions. It is recommended that cold rooms be filled to capacity so as to minimise the amount of moisture extracted from individual fruit. It is further important not to store small numbers of 'Maluma' fruit in large cold rooms for extended periods. Cold rooms must further have adequate cooling capacity to ensure that high relative humidity levels are maintained. In terms of grey pulp, it is firstly important to adhere to previous recommendations regarding, especially, the non-export of fruit with dead seeds. It is further important that an end-of-season maturity cut-off point be introduced. A maximum dry matter content of 28% is suggested for orchards with a low nitrogen status, while this must be lowered to 26% for orchards with a high nitrogen status.

INTRODUCTION

This report deals with a number of observations made regarding the manifestation of vascular staining and grey pulp in 'Maluma' avocado fruit during the 2017 and 2018 seasons. It further contains recommendations aimed at reducing the incidence and intensity of the disorders during export.

Vascular staining

Mhlophe & Kruger (2012) reported on the prevalence and manifestation of a physiological disorder they referred to as vascular staining (not to be confused with vascular browning which is a pathological disorder). They found the incidence of the disorder to correlate with fruit maturity and recommended that harvesting of 'Maluma' should only commence after a dry matter content of 23% is reached.

The present report deals with further observations made regarding vascular staining during the 2018 season.

During the first study, the origin of the stain was carefully traced. Close inspection revealed that the pigment originates from the seed (Fig. 1). During seed maturation, the seed coat turns from creamy white to dark brown. During this process, a reddish pigment is produced that imbibes the seed coat. Under certain conditions, the pigment enters the vascular bundles. It then migrates by means of capillary action and may diffuse as far as the pedicel. As the pigment migrates in the vascular bundles, it first turns a rusty colour and then black (Fig. 1). It may also diffuse out of the vascular bundles into the surrounding tissue where it may leave an unsightly stain (Fig. 2).

During our experimental trials we found that vascular staining is not prevalent when the fruit are stored in pallets in full commercial cold rooms or shipping containers that are filled to capacity. Neither is it problematic when experimental cartons are stored in a small experimental fridge. We, however, found the disorder to be prevalent when a small number of cartons are stored in a large commercial cold room for an extended period. It would seem that under these conditions, the moisture inside the vascular tissue is extracted from the bundles, thus inducing the pigment's migration out of the seed coat into the capillaries.

Interesting results in support of the above observation were generated during trials aimed at establishing what effect the proportional time periods that

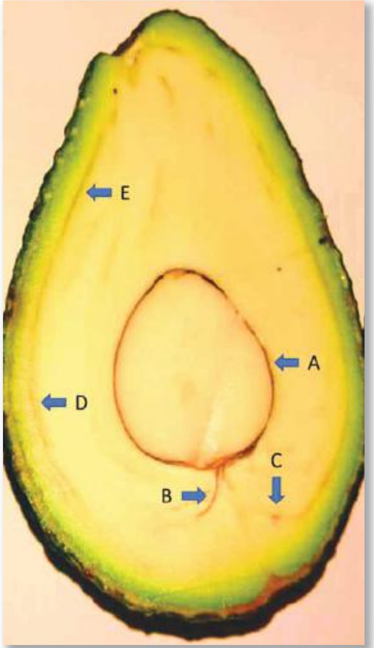

Figure 1. Visual appearance of vascular stains in the flesh of a 'Maluma' fruit stored for 30 days at 5.5°C under RA conditions. (A = unbound red pigment located in the seed coat; B = diffusion of the red pigment from the seed coat into the vascular bundles; C = diffusion of the red pigment from the vascular bundles into the fruit flesh; D = change of colour of the pigment from red to a rust colour; E = change of colour from rusty to black).

the fruit are kept under regular and controlled atmosphere have on fruit quality (Kruger *et al*., 2019). As may be deduced from Table 1, when the fruit are placed into a high humidity controlled atmosphere (CA) container within 4 days, vascular staining did not develop. However, when placed into CA at a later stage, the incidence of the disorder sharply increased. This is most probably due to the longer period the experimental fruit spent in a sparsely filled commercial cold room where the moisture was more easily extracted from the vascular bundles, than in the CA chambers where the humidity is higher.

It was further interesting to note that the incidence of the disorder was lower when the fruit were kept under regular atmosphere (RA) for the full 30 days storage period (Table 1). This was

Figure 2. Severe vascular staining in a 'Maluma' sample after storage for 30 days in an empty (30 pallet) commercial cold room.

Table 1. Incidence of vascular staining in 'Maluma' fruit stored for different time periods at 5.5°C under either regular atmosphere (RA) or controlled atmosphere (CA) conditions.

Storage period (days)		Vascular staining (%)
RA	CA	
1	30	0
4	26	0
8	22	92.9
12	18	85.7
16	14	85.7
30	0	14.3

Table 2. Incidence of vascular staining in 'Maluma' fruit (stored for 30 days at 5.5°C under RA conditions) from trees that were sprayed with a plant growth regulator at two application rates.

Treatment	Fruit with vascular staining (by stain colour) (%)	
	Red stain	Black stain
Control	38 a	63.1 a
Growth regulator: rate 1	42.1 a	64.8 a
Growth regulator: 2 x rate 1	12.5 b	77.3 b

probably due to the accumulation of, ripening-process related, moisture in the vascular bundles that impeded the migration of the red pigment from the seed coat into the vascular bundles.

Indirect support for the above capillary diffusion hypothesis came from an orchard-based trial which aimed to establish what effect growth regulator sprays have on yield and fruit size (confidential report). A growth regulator was sprayed at two rates (Rate 1 and 2 x Rate 1) in the orchard. The fruit were hereafter stored in an empty commercial cold room at export simulation temperatures for one month. The incidences of the red and black stains were hereafter separately recorded for each fruit.

As may be deduced from Table 2, the percentage of fruit with red stains decreased while those with black stains increased in the treatment that received the double rate. Our current hypothesis is that meristematic tissue growth induced narrowing of the vascular bundles, resulting in the pigment migrating further along the vascular bundles in fruit that received the double rate. This caused a higher proportion of black pigment.

In terms of the prevention of vascular staining, we recommend the following:

- Fill cold rooms to capacity so as to minimise the amount of moisture extracted from individual fruit.
- Don't store small numbers of 'Maluma' fruit in large cold rooms for extended periods. Cold rooms must further have adequate cooling capacity to ensure that high relative humidity levels are maintained.

The current results infer that the present 23% dry mass maturity recommendation may possibly be relaxed. A preliminary study, aimed at characterising the ripening, taste and vascular staining incidence of less mature fruit, was subsequently performed in an early maturing orchard in the Burgershall area. The fruit were at 19.87% (Table 3) dry matter at the time of sampling. They ripened satisfactorily when stored for, respectively 0, 14 and 28 days (Fig. 3) in a laboratory fridge. The taste of all fruit was acceptable (Table 4) and no vascular staining occurred (Fig. 4).

Table 3. Dry mass content readings of individual fruit harvested from an early 'Maluma' orchard in the Burgershall area.

Fruit no	Dry mass (%)
1	20,3
2	20,8
3	19,2
4	18,9
5	20,7
6	20,1
7	19,2
8	19,6
9	19,8
10	20,1
Mean	**19,9**

Table 4. Percentage of early season 'Maluma' fruit (dry matter 19.9%) with either "acceptable" or "good" taste scores after, respectively, 0, 14 or 28 days storage at 5.5°C under regular atmosphere conditions.

Storage period	'Acceptable' tasting fruit (%)	'Good' tasting fruit (%)
0 days	39	61
14 days	38	62
28 days	50	50

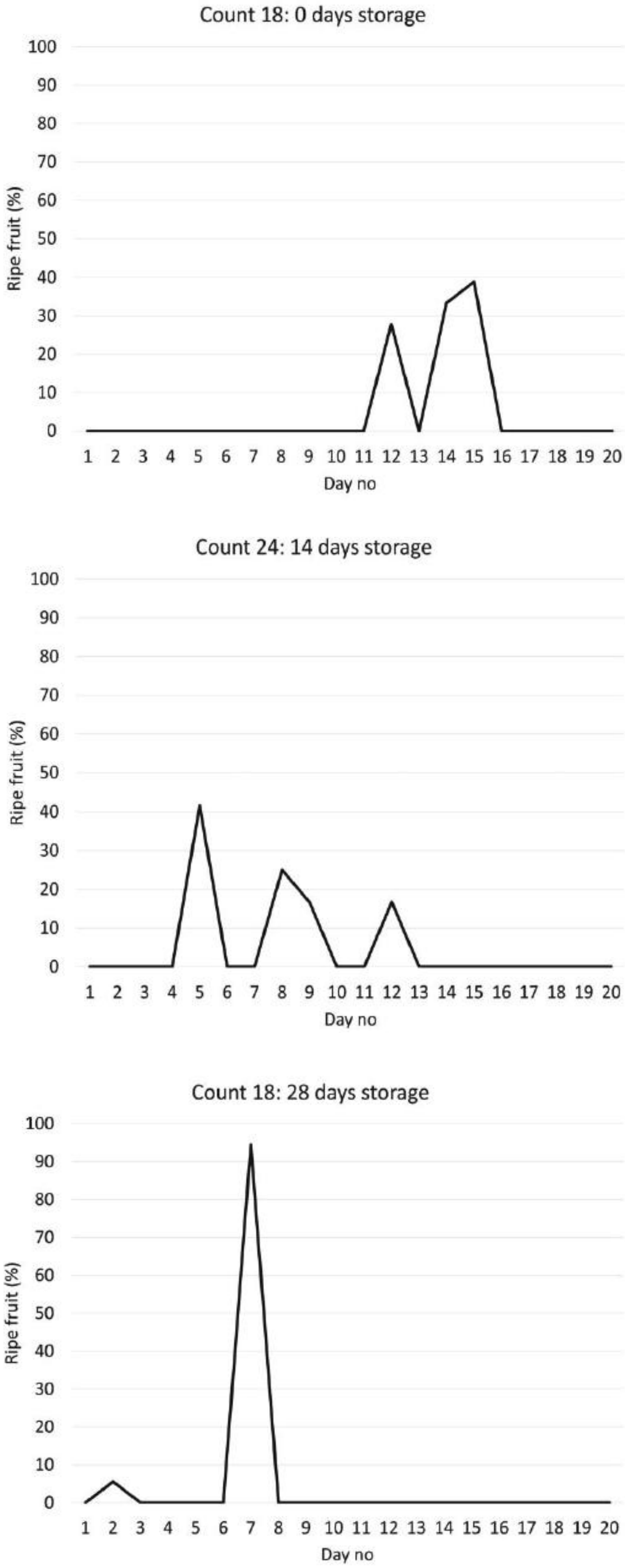

Figure 3. Ripening rates of early season 'Maluma' fruit (dry matter 19.9%) from the Burgershall area after, respectively, 0, 14 or 28 days storage at 5.5°C under regular atmosphere conditions.


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Grey pulp

During previous studies, we have concentrated on the following causes of grey pulp in 'Maluma' fruit:

- The period from harvest to cooling (Kruger *et al*., 2017).
  - The recommendation was made that fruit from correctly fertilised orchards be placed into cool storage within 8 hours, while fruit from orchards with a high nitrogen status be placed into cool storage within 4 hours of harvest.
- The period from cooling to transfer into controlled atmosphere (Kruger *et al*., 2019).
  - Based on our results, a fair recommendation would seem to be around 4 days.
- The incidence of dead seed coats per count (Kruger *et al*., 2018).
  - It was recommended that smaller counts with a high proportion of dead seed coats (Fig. 5) not be exported. Packhouses should therefore inspect a representative sample of fruit of each count from every grower contributing to a specific batch in order to establish whether the fruit must be exported or locally marketed.

It is important to be aware that the above recommendations will not prevent, but only delay the development of grey pulp in over-mature fruit. Up to now, no recommendation has been made regarding a maximum maturity cut-off point. During the 2018 season, the incidence of grey pulp was recorded for each consignment exported from a packhouse in the Tzaneen area. To do this, the feedback received from importers was carefully studied. In Figure 6, the results of a mean maturity calculation (lowest and highest dry matter content in consignment divided by 2) of a number of containers are plotted against the packing date. From the results, we recommend that 'Maluma' fruit from correctly fertilised orchards not be exported at a dry matter content higher than 28%. In the case of fruit from orchards with a high nitrogen status, we provisionally recommended that the end of harvest window be lowered to 26%.

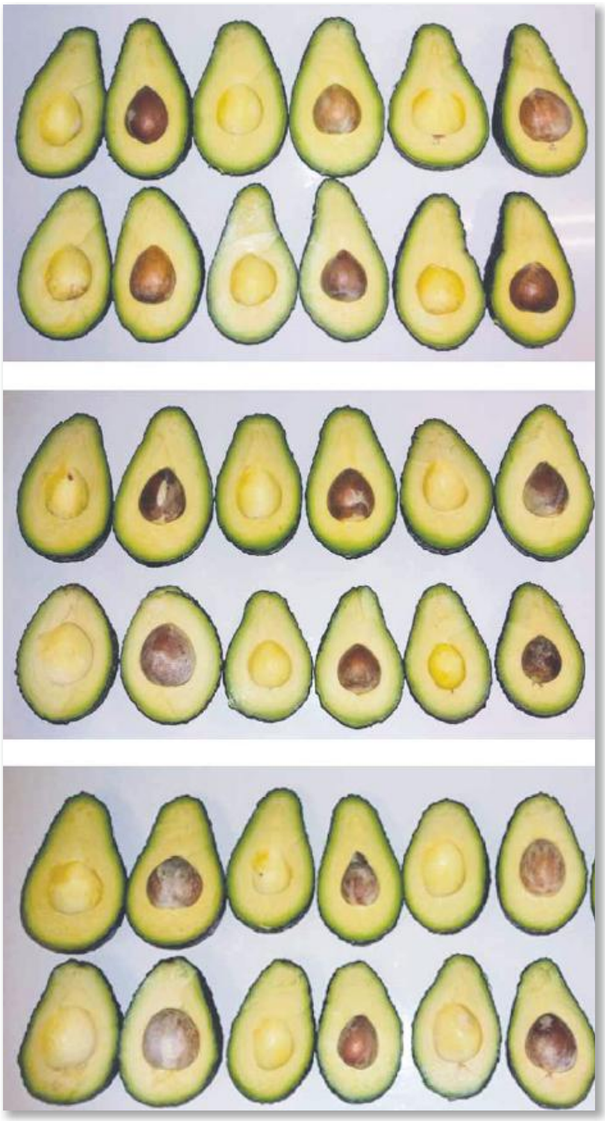

Figure 4. Appearance of early season 'Maluma' fruit (DM 19.9%) from the Burgershall area after, respectively, 0, 14 or 28 days storage at 5.5°C under regular atmosphere conditions.

Figure 5. Absence and presence of grey pulp in 'Maluma' fruit with, respectively, live and dead seeds after export from South Africa to Europe.

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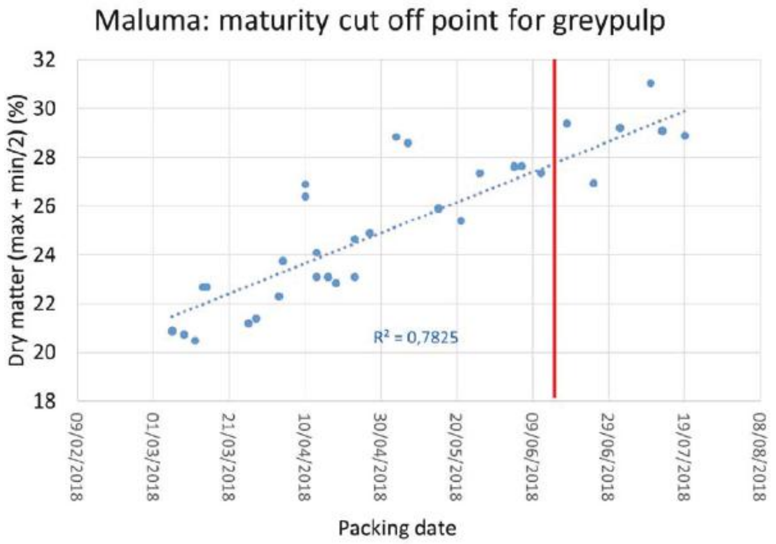

Figure 6. Dry matter content of 'Maluma' consignments from a packhouse in the Tzaneen area exported to Europe during the 2018 season. All consignments to the right of the red line had grey pulp.

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