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A SHORT REVIEW OF RECENT RESEARCH ON THE IMPACT OF CLIMATIC CONDITIONS ON THE POSTHARVEST QUALITY OF SOUTH AFRICAN EXPORT AVOCADOS

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SUMMARY

The quality of South African avocado fruit varies considerably between seasons and at different times during a season. Studies aimed at identifying the climatic conditions responsible for quality deviations and the development of pre-emptive control strategies are therefore of primary importance to the industry. 'Fuerte' and 'Hass' are presently the most important export cultivars and we therefore initially concentrated on these cultivars for the accumulation of baseline information on fruit maturity and the annual incidence of physiological disorders. The results indicated that oil acquisition is primarily influenced by temperature and rainfall. In years of exceptionally high rainfall the oil content increases at an extraordinarily rapid rate. In 'Hass' which produces fast metabolising fruit, the build up of oil is more rapid than in 'Fuerte' which produces fruit with a slower metabolism. The time and incidence at which internal disorders occurred also seemed to correspond with periods of excessive rainfall at a specific stage in the development of the fruit. Again, the symptoms manifested faster in Hass than in Fuerte, although the symptoms are generally more severe in the latter cultivar. The potential of a number of preharvest practices and postharvest techniques are currently being investigated to overcome the rainfall induced problems. Our research efforts are presently being concentrated on the Pinkerton cultivar which develops grey pulp and external black cold injury when exported by ship. Grey pulp is the more important disorder of the two and manifests as cold storage associated intense greying of the pulp. The incidence of the disorder varies considerably from area to area, within an area and between seasons. Epidemiological and physiological analyses indicated that over-mature fruit, from warmer areas, that are marketed too late in the season are most vulnerable to grey pulp. Close scrutiny of environmental and physiological parameters are therefore required each season. Earlier harvesting at a higher moisture content is recommended for 'Pinkerton'.

KEY WORDS: *Persea americana* Mill., pre-harvest conditions, quality.

INTRODUCTION

The South African avocado export industry is well structured and feedback is annually provided to members by statutorily appointed and in-house quality control bodies (Bezuidenhout *et al.*, 1995; Eksteen *et al.* 1998) as well as an overseas based technical officer (Nelson, 1999). Notwithstanding these measures, the quality of South African

export avocado fruit varies considerably between seasons and also within a season, especially with certain cultivars.

Information on the seasonal incidence of physiological disorders such as grey pulp and pulp spot in export fruit is gathered through the inspection of fruit landed in Europe and also through simulations conducted under export conditions. These observations have been conducted from the early nineteen eighties (Smith, 1983a 1983b; Bezuidenhout, 1983) and some trends, such as the development of greypulp in late season 'Fuerte' has been shown. However, not much has been reported on the causes of the seasonal variation in the incidence of physiological disorders. Consequently it is as yet not possible to predict what the quality of fruit will be during a particular year.

In this paper, a short review is given of research conducted by the Agricultural Research Council's Institute for Tropical and Subtropical Crops (ITSC) in collaboration with the South African Avocado Growers' Association to establish the effect of climatic conditions on avocado fruit quality. The first part is concerned with the effect of excessive rain on the rate of oil acquisition and ultimately, the internal quality of avocados. The second is an account of research currently being conducted on the effect of seasonal variation on the storage potential of 'Pinkerton'.

The effect of rainfall on the rate of oil accumulation and the incidence of physiological disorders in 'Fuerte' and 'Hass'

Moisture and oil content are used in South Africa as maturity parameters for establishing the harvest period and also the temperature at which avocados are to be exported by sea. This information is included in a guide (Hardy *et al.*, undated) for use by packinghouse managers and exporters and is updated from time to time.

As it was deemed essential to obtain accurate information on fruit maturity, a project was launched by the ITSC at a packinghouse in the Hazyview area of the Mpumalanga Province of South Africa during 1994 (Kruger *et al.*, 1995). Information about the weather in the area was obtained from an ITSC weather station at an experimental farm in the area.

The bulk of the information was gathered during the 1994, 1995 and 1996 seasons and the prevailing weather conditions for the above mentioned seasons are therefore herewith briefly described: Except for a short period during the second half of April, the average daily temperatures were generally warmer during the first half of 1994 when compared with 1995 (Kruger & Claassens, 1996a). Between 200 and 300 mm of rain fell at regular intervals during the first quarter of both years, with 1995 being slightly wetter. In contrast, the first 4 months of 1996 were cooler than the previous two years but were characterised by exceptionally high rainfall, with more than 1000 mm falling during the first quarter of the year (Kruger and Claassens 1997).

As expected, the oil content of both 'Fuerte' (Figure 1) and 'Hass' (Figure 2) was found to increase at a faster rate during the warmer 1994 season than during the cooler 1995 season. However, the aspect that was most interesting, was the effect that the abnormal rainfall during the 1996 season had on the moisture reduction and oil accumulation rates of the fruit. In experiments where irrigation was withheld, we have previously noticed that, in contrast with popular opinion at the time, increased soil water did not lead to a reduced

rate of moisture loss in the fruit (Kruger, 1996b). Instead, elevated soil water was found to lead to increased oil production. Increased accumulation of oils during the 1996 season (Kruger and Claassens, 1997) was therefore expected. However, the extraordinary rate at which oil accumulation took place in both 'Fuerte' (Figure 1) and 'Hass' (Figure 2) was unexpected.

During the 1996 season, most rain fell during February with the cumulative total increasing from just over 200 mm to more than 800 mm. In both 'Fuerte' (Figure 1) and 'Hass' (Figure 2) the largest difference in oil content between 1996 and the previous two years were found to occur towards the end of the second half of May. This infers that it takes at least two months from the high rainfall period before the increased oil content is registered.

Considering the above, the next step was to establish whether the exceptionally high rainfall may cause an increase in the incidence of physiological disorders. Export simulations are conducted by various packinghouses in South Africa. During these simulations, the fruit is kept at the recommended temperature for the duration of a sea export period before being evaluated. As the high rainfall during the 1996 season occurred over the whole production area, it was possible to use the results of a packinghouse in the Tzaneen district of the Northern Province, that keeps accurate records, for this purpose. Comparison of the rainfall in the Tzaneen area during the 1996 season with the incidence of physiological disorders indicated that a relationship exists between periods of high rainfall and the emergence of physiological disorders. In 'Fuerte' (Figure 3) the incidence of pulp spot in consignments of export fruit reflected the rainfall pattern of the preceding months while in 'Hass' (Figure 4) it was correlated with grey pulp (Kruger and Claassens, 1997). The time taken for the symptoms to emerge was temperature dependent and was shorter in 'Hass' than in 'Fuerte' (Figure 5). In 'Fuerte', this period was found to be approximately two months in fruit harvested in April, while it increased to nearly two and a half months in fruit harvested towards the end of May. In 'Hass' the period was approximately a month and a half for fruit harvested during the beginning of June and nearly 2 months when harvested in July or August. The period between the rainfall and the emergence of the symptoms lengthened as the mean daily temperature decreased during winter. It should be pointed out that, although the temperature was lower, the period was shorter in 'Hass' than for 'Fuerte'. It is interesting to note that it has previously been noticed that 'Hass' has a faster rate of metabolism than 'Fuerte' (Blanke and Whiley, 1995; Kruger, 1996).

It is important to mention that the symptoms did not compound. In other words, the grey pulp appeared after a specific period following very heavy rain, but if harvested at an earlier or later harvest date the pulp spot/grey pulp was not registered during the export simulations. This may indicate that a specific proportion of the fruit was at a "critical stage" at either the time the rain fell and/or at harvest. The former is more likely as it has previously been shown in South African orchards that excessive irrigation may lead to reduced calcium uptake as well as increased levels of abscisic acid in avocado fruit (Bower, 1987; Bower *et al.*, 1986), the latter being suspected of causing grey pulp (Cutting and Bower, 1987; Cutting *et al.*, 1986).

In contrast to irrigation which may be scheduled, little can be done in the orchard to minimize the negative effect of excessive rain. The emphasis should therefore be on postharvest measures which may be employed to inhibit the development of physiological

disorders in export avocados. The effect that controlled atmosphere (CA) has on the quality of avocados is well known and has been evaluated under South African conditions (Truter and Eksteen, 1987, Truter *et al.*, 1991) with the positive effect being confirmed in recent work with 'Pinkerton' (Truter and Kruger, in preparation). Timing of CA shipments is, however, a problem to the industry as CA is more expensive than conventional reefer containers and does not automatically ensure premium prices. The question currently being posed is when conventional containers should be used and when to make use of CA. Our recommendation to the industry is to use CA during the critical periods as described above.

It should be noted that many of the deductions made in this section of the paper are based on observations made during a single year. Although good rains have since fallen over specific areas, it couldn't be compared with that of the 1996 season. On the other hand, according to the statistics at our disposal, with the exception of 'Pinkerton', the quality at the beginning of the harvest season was good for all cultivars. This concurs with our present deductions. The development of grey pulp towards the end of the harvest season in certain cultivars is due to other reasons that are discussed hereunder.

Effect of seasonal orchard temperature variations on cv: Pinkerton quality

The Pinkerton cultivar was introduced to South Africa primarily on account of its high yielding characteristics and it proved to be a good bearer under South African conditions. The cultivar, however, has certain shortcomings. It is characterized by an extended flowering period (Sippel *et al.*, 1992; Sippel *et al.*, 1994) and also has limited storage potential in terms of export by ship. The main postharvest problems encountered are grey pulp and black cold injury. Of the two disorders, grey pulp is the most important as it is internal and can only be detected after ripening and therefore does not allow for re-sorting, in the country of importation, as is the case with black cold injury fruit.

A comprehensive study was recently launched to address the physiological problems encountered with 'Pinkerton'. The study spans several fields of which epidemiology, specifically the relationship between quality and climatic conditions, is one.

The epidemiological study indicated the problems to mainly occur in fruit from producers in warmer production areas. In these areas, the incidence of the disorder further varies considerably from one season to the next. In certain of the warmer areas, the problem emerges every year while in other areas it only occurs during certain seasons. For instance, consignments of fruit from certain farms in the lower lying areas of the Hazyview district in the Mpumalanga Province almost invariably show grey pulp when landed in Europe. On the other hand, fruit from higher lying areas in the same region and from cooler regions in the same province, generally show considerably less grey pulp symptoms during export.

The results of laboratory simulations conducted over the last two years indicate grey pulp to be associated with over-mature fruit. It would appear that farmers in warmer areas market their fruit too late. For instance, producers in the high risk Hazyview production area, traditionally harvest their fruit during June. Sea export simulations done over 30 day periods at one week intervals from April to July 1999 indicated grey pulp to be absent during April when the moisture content (percentage of fresh mass) of the fruit

was in the high seventies. However, at the beginning of June when the moisture content was in the lower seventies, a proportion of the crop developed severe grey pulp (Figures 6).

A number of additional corroboratory observations which require confirmation can be mentioned here. For instance, during a survey on the nutrient status of 'Pinkerton' trees, we found fruit from heavy bearing trees in high risk areas to develop less grey pulp during simulated storage than fruit from light bearing trees. Also, certain producers in cooler areas delayed harvesting of their bumper crop of 1998 resulting in poor flowering and fruit set during the 1999 season. Although the winter temperatures did not differ much between 1998 and 1999, grey pulp was already recorded in laboratory simulations with fruit from this area during the second week of July in 1999 while it was only noticed during the last week of August in 1998. In addition, it was recorded that in an area of an exceptionally high prevalence of grey pulp, the fruit from a producer who had, due to unforeseen circumstances, water stressed his fruit, the incidence of grey pulp was significantly lower. Casual observations made by members of the industry that may concur with the above is that fruit from young trees producing their first crop are more susceptible to grey pulp. In all four cases we are of the opinion that slower maturation and consequent harvesting of less mature fruit result in less greypulp, but this requires further research.

Considering the variations in temperature recorded from one season to the next, it is understandable that the prevalence and spatial distribution of grey pulp will vary considerably between seasons. Establishing an earlier 'Pinkerton' harvest window for problematic areas is therefore an appropriate solution to the problem. However, the sentiment towards a specific cultivar can become quite negative due to inconsistent quality. South African 'Pinkerton' is a good example of this as certain sectors of the European market have become hesitant to deal with this cultivar. The proposed advancement of the harvest season in warmer areas implies that the market period for 'Pinkerton' must also be earlier. This means that 'Pinkerton' is to be marketed with 'Fuerte'. Producers and exporters are at present sceptical as to the ability of 'Pinkerton' to compete with 'Fuerte' on the open market. We are, however, of the opinion that if the quality of 'Pinkerton' can be maintained at a constantly high level by means of scientific management, this highly productive cultivar is bound to become a successful early season contender.

The above results are provisional and further work is recommended to establish appropriate maturity parameters. We are, nevertheless, of the opinion that current South African avocado maturity regulations which stipulate that 'Pinkerton' is only to be harvested at a moisture content lower than 75% are incorrect and require reconsidering.

CONCLUSION

In many cases, the results referred to in this paper are provisional or require confirmation in practice. Previous studies on the effect of climate on fruit physiological disorders have proved to be quite valuable to the industry. A good example is the work conducted by Swarts (1982) which indicated orchard temperatures to influence the susceptibility of avocado fruit to black cold injury. Swarts demonstrated that declining orchard temperatures condition fruit to withstand lower storage temperatures. This

furnished the Perishable Products Export Control Board, who controlled shipping temperatures at the time in South Africa, with information on when to lower storage temperatures. However, modern cooling facilities have become so efficient that this aspect, like the topics mentioned in this short review, require continuous scientific research.

The overriding effect of climate on the quality of South African export avocados is only now beginning to be understood. In certain instances, nothing or very little can be done to curtail the effect of climatic conditions on quality. However, in other cases effective control procedures are possible. The use of CA during high risk periods following excessive rain and advancing the harvest window during hot seasons are two examples of remedial strategies. One of the aims of future research should be to minimize the effect of climate on quality. This should be done, not only by improving postharvest management, but also by producing quality fruit with good storage potential. The studies by Bower (1986) on the effect of irrigation on fruit quality and that by Koen *et al.* (1990) on the relationship between the physiological disorders of avocados and plant nutrition practices are good examples. The lessening of the effect of climatic conditions by means of sound pre- and postharvest management should be a major goal for the South African avocado industry.

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Figure 1. Dry mass based increases in the oil content of 'Fuerte' fruit during 1994, a relatively warm season, and 1995, a cooler season (Kruger & Claassens, 1996) as well as during 1996, a season of exceptionally high rainfall (Kruger and Claassens, 1997).

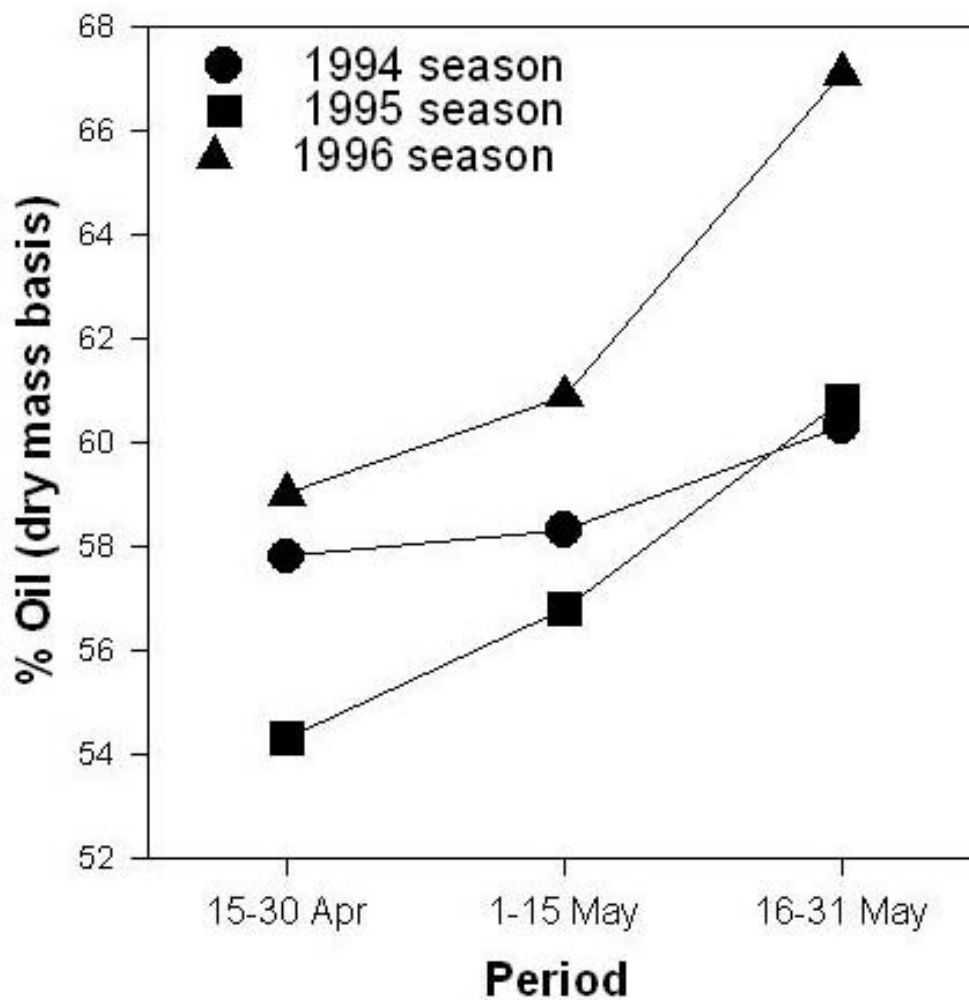


Figure 2. Dry mass based increases in the oil content of 'Hass' fruit during 1994, a relatively warm season (Kruger and Claassens, 1996) as well as during 1996, a season of exceptionally high rainfall (Kruger and Claassens, 1997).

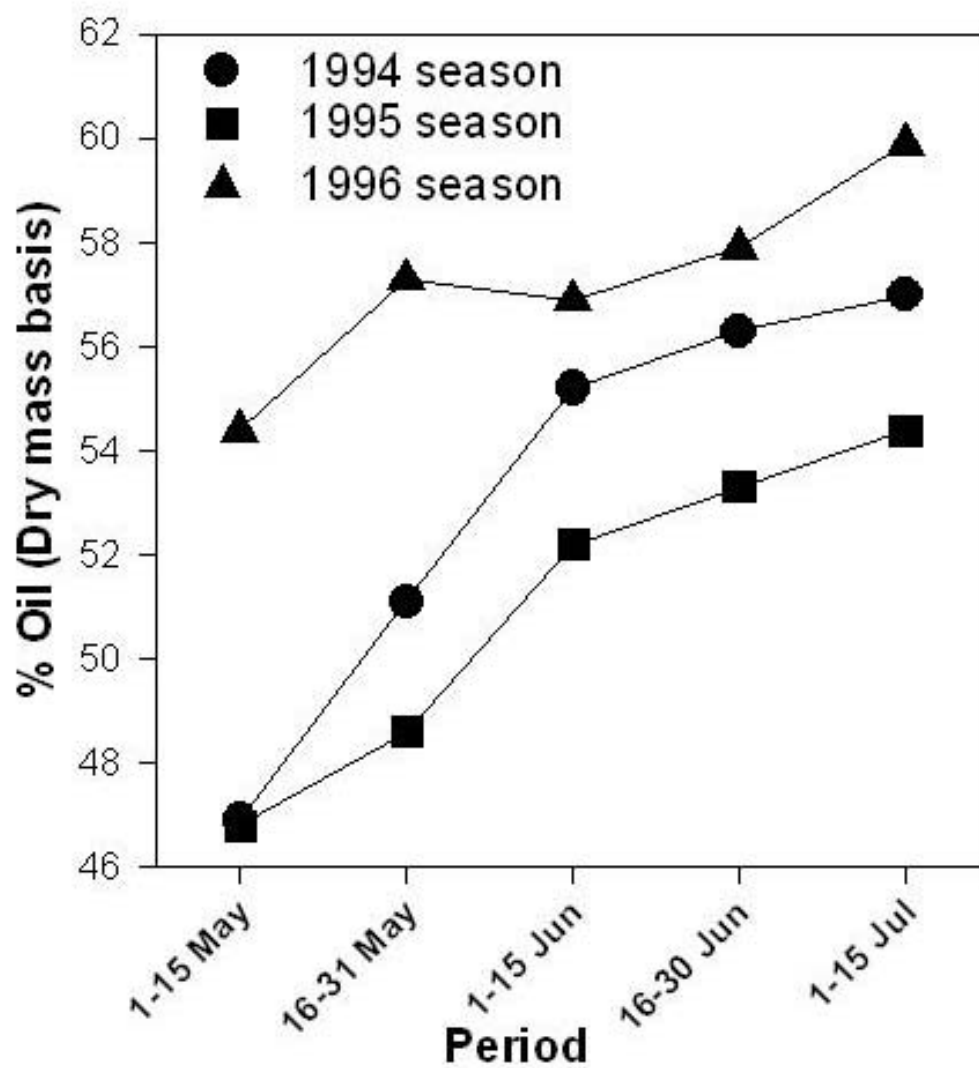


Figure 3. Relative incidence of pulp spot in simulation cold stored 'Fuerte' fruit from the Tzaneen area during 1996, a year of exceptionally high rainfall.

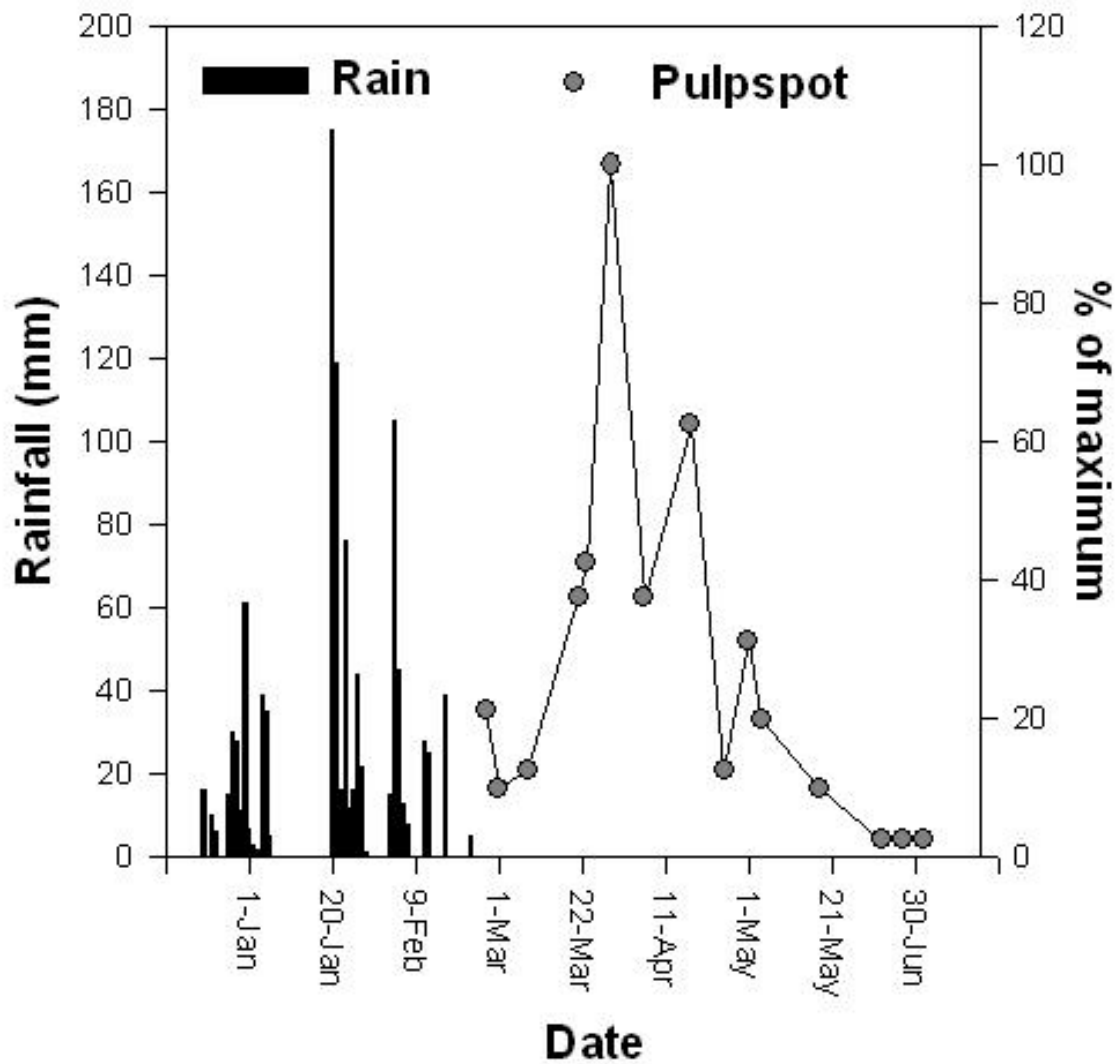


Figure 4. Relative incidence of grey pulp in simulation cold stored 'Hass' fruit from the Tzaneen area during 1996, a year of exceptionally high rainfall.

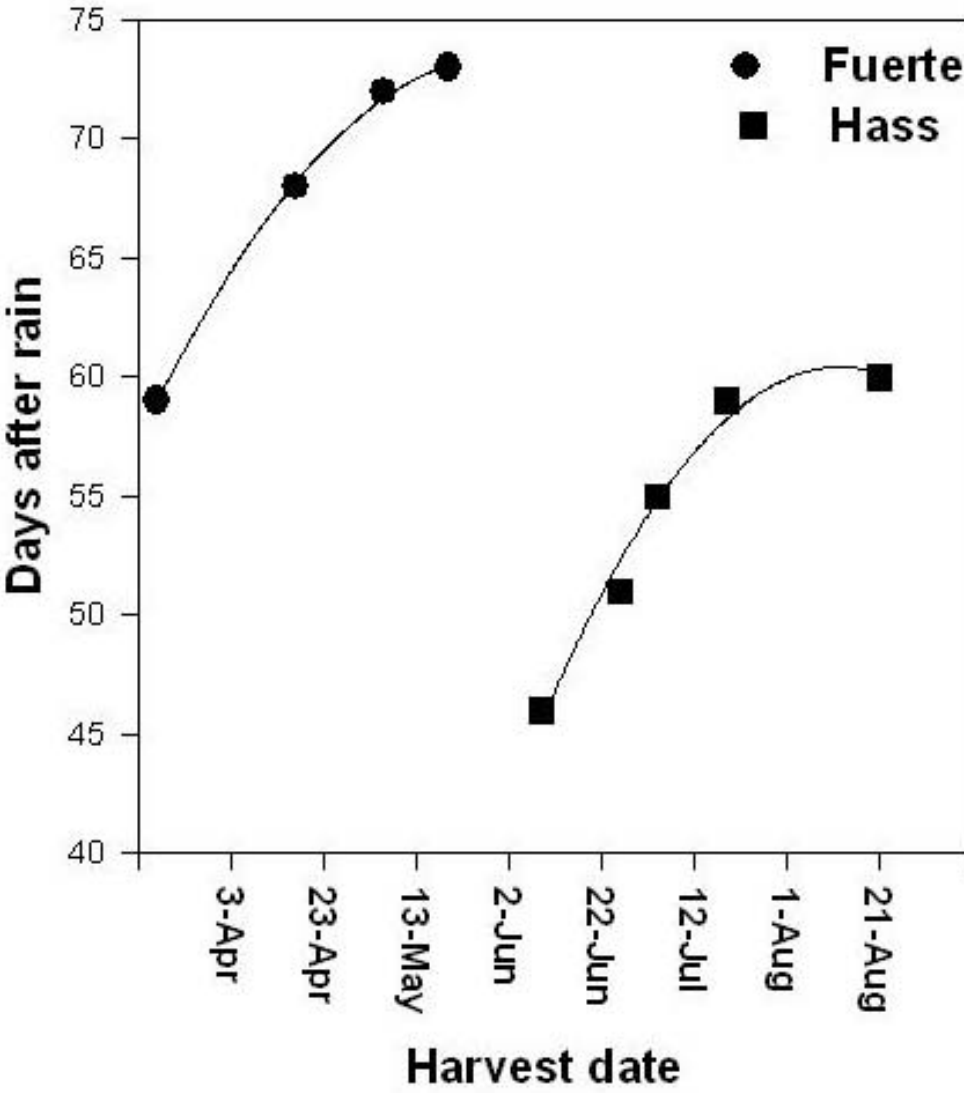


Figure 5. Time lapse between heavy rains in the 1996 season and the emergence of the internal physiological disorders of 'Fuerte' and 'Hass' indicated in figures 3 and 4 and described in the text.

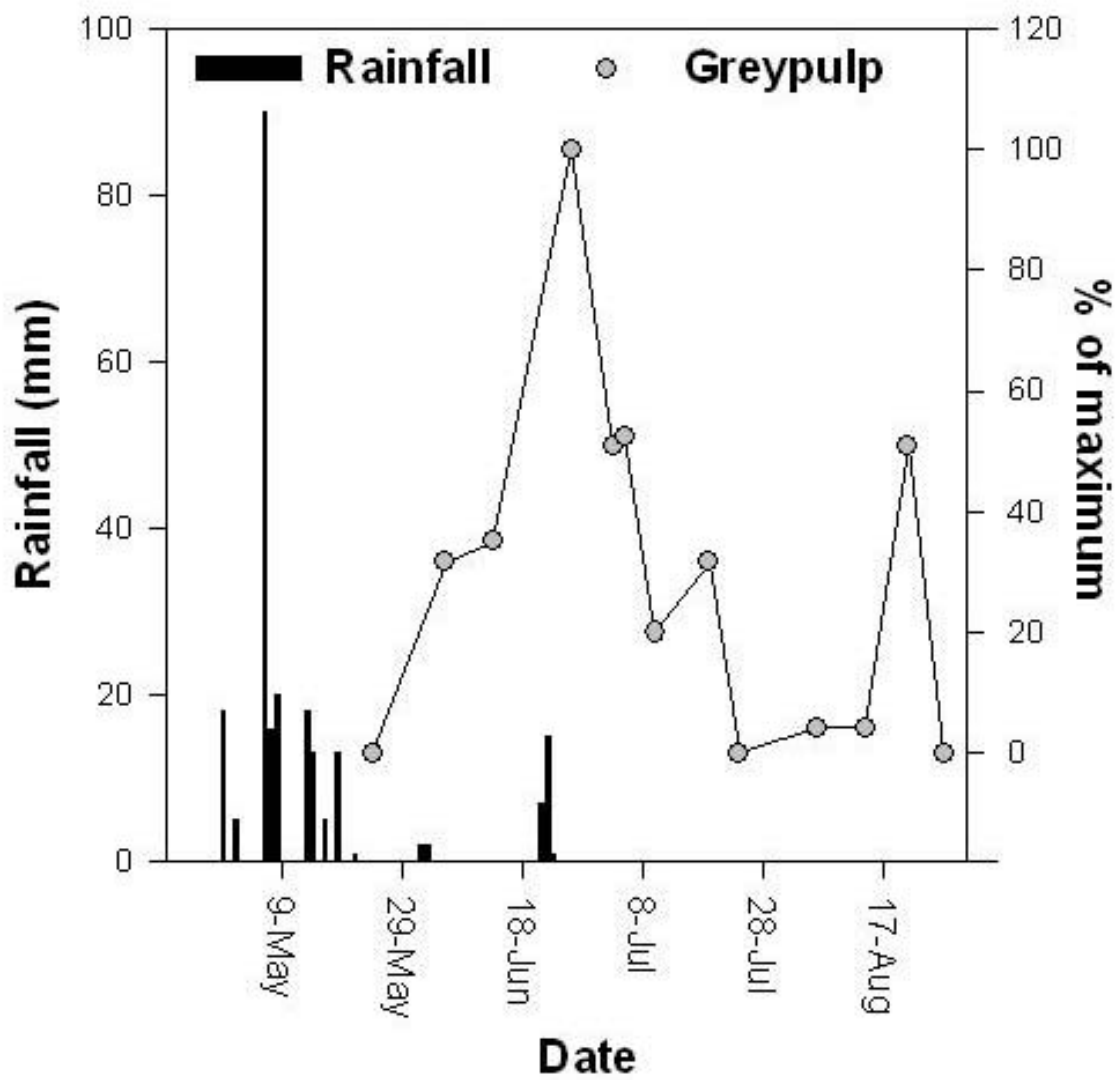


Figure 6. Increasing incidence of grey pulp in cold stored 'Pinkerton' fruit harvested from the end of April to the beginning of June 1999 in a warm production area.

