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The Effect of Minimum Temperature on Avocado Yields

D. N. Zamet
Acco Experimental Station, Israel.

Introduction

Looking back over the years, one can find many articles and research works which have dealt with the problem of the too frequent lack of reasonable avocado yields. Many have linked this problem with climatic irregularities. However, except for possibly Hodgson in the forties[10] and for Lomas[14] more recently, both of whom examined the records for 20 or more years, the majority of investigations have been carried out for just one or two years in the orchard or have been under the relatively unreal conditions of phytotrons, using small nursery-size trees. Yet other work has been done using various forms of microscopy. As early as 1927, Coit[6] suggested that weather conditions, expressed as heat units, affect avocado yields. Blanchard[3] in 1935 acknowledged that climatic conditions were the greatest limiting factor. Hodgson, who investigated Fuerte yields for more than 20 years[10] blamed the erratic yields of this cultivar on the interaction of the on-off years and the mean average temperature during the bloom period. He was, however, unable to predict the coming crop more than to say it would be more or less than the previous year's, but then not with certainty. In 1951, Lesley and Bringhurst[11] considered that environmental conditions affected avocado pollination. Bergh[2] in 1967 was able to cite climatic conditions as a reason for low yields of avocados, but admitted that the picture was not at all clear. Lahav and Zamet found in 1976 that low temperatures increased fruitlet abscission in the orchard[11]; however, they also found that wind intensity affected the amount of fruitlets dropping to the ground. This points out the difficulty of how to distinguish the exact reason for fruitlet fall or why they abscise. It is quite often possible to see very young fruitlets still inside the flower truss but completely dead. Thus, collecting fallen fruitlets does not necessarily give a clear picture of why and when they abscised.

In 1977, Sedgley[18] showed that temperature affects the pollination process in avocado and, together with Annells in 1981[19], gave further details of temperature effect on fruit set; but all their work was done under the very specialized conditions of the laboratory growth chamber. Argaman in 1981[1] suggested that prolonged low temperatures may greatly accentuate the harmful effects of low temperature, but he still blamed the low Israeli crop of 1980 on a high temperature period (45.5 °C), and this after what was a cold spring, as will be shown later. Gafni found in 1983[8] that low temperatures did not affect fruit set, but he worked with young orchard trees in 1982 and 1983—both years which had quite fair avocado crops in Israel. His work in the phytotron used young nursery trees and thus again, as with Sedgley, was far from the conditions of the orchard. He also stated that in his opinion high temperatures are a crucial negative factor in determining avocado yields (however, see below under Lomas).

Bucholz in 1986[4] stated that high temperatures are considered to be injurious to the fruit set process. Shoval in 1987[21] stated his opinion that pollenization was an important factor limiting tree productivity; however, he carried out his research in 1985 and 1986, the first quite a fair avocado yield year, and the latter an exceptionally high yield year in Israel.

More recently, Lomas[14] has examined the avocado yields of a single orchard and tried to explain the yield variations by means of heat stress, but was only able to explain 50% by this method.

It is possibly only Shnir[20] who has come close to answering the problem of avocado productivity when he suggested that possibly several cool nights previous to the flower opening are the cause of its subsequent abscission, but he took this thought no further.

In Israel, the years 1980-1990 have been years with very great differences in avocado yields, from what have been considered very high yields (1986) and also very low (1980, 1988). It has been so far impossible to explain these differences. This author has recently reported[24] that over the ten year period 1980-89, a very high correlation (0.90) was found between avocado yields of the Western Galilee and the minimum temperature during the April to beginning of May period (Figs. 1, 2). This period has been called the "critical period." This previous report compared the yields from an area of over 2,500 hectares of avocado orchards under various soil, microclimate, and cultural activity (taken as one unit) to the minimum temperature at the Acco Experimental Station expressed as the number of occasions when the five day average fell below 10° during the critical period. This period of April-May was chosen as it is in this period that the minimum temperature fluctuates considerably above and below the 10° level. Work in the phytotrons has indicated that 10° is approximately the critical temperature[1,18,19]. The five day period was chosen initially for the ease in drawing temperature gradients. Having found the above high correlation, it was considered advisable to try to evaluate what effect the choice of the 10° level and the five day period had had on the results.

Methods and Materials

For the present investigation, only six years of yields were considered (Table 1). However, these encompass a wide range of yields and also excluded the two "frost" years originally included. The yearly yields were compared to various minimum temperatures taken from the standard meteorological station at Acco and to various lengths of day groupings. The average temperature was computed on a simple chronological system and not by adding and subtracting one day at a time. For each combination of temperature and day period, the correlation, the R^2, and the statistical significance were obtained (Table 2). It should be clearly understood that by minimum temperature is meant the average of all those temperatures below a given level for the period.

Fig. 1. Maximum and minimum temperature gradients averaged for each five day period. The dotted line in the middle indicates the "critical period."

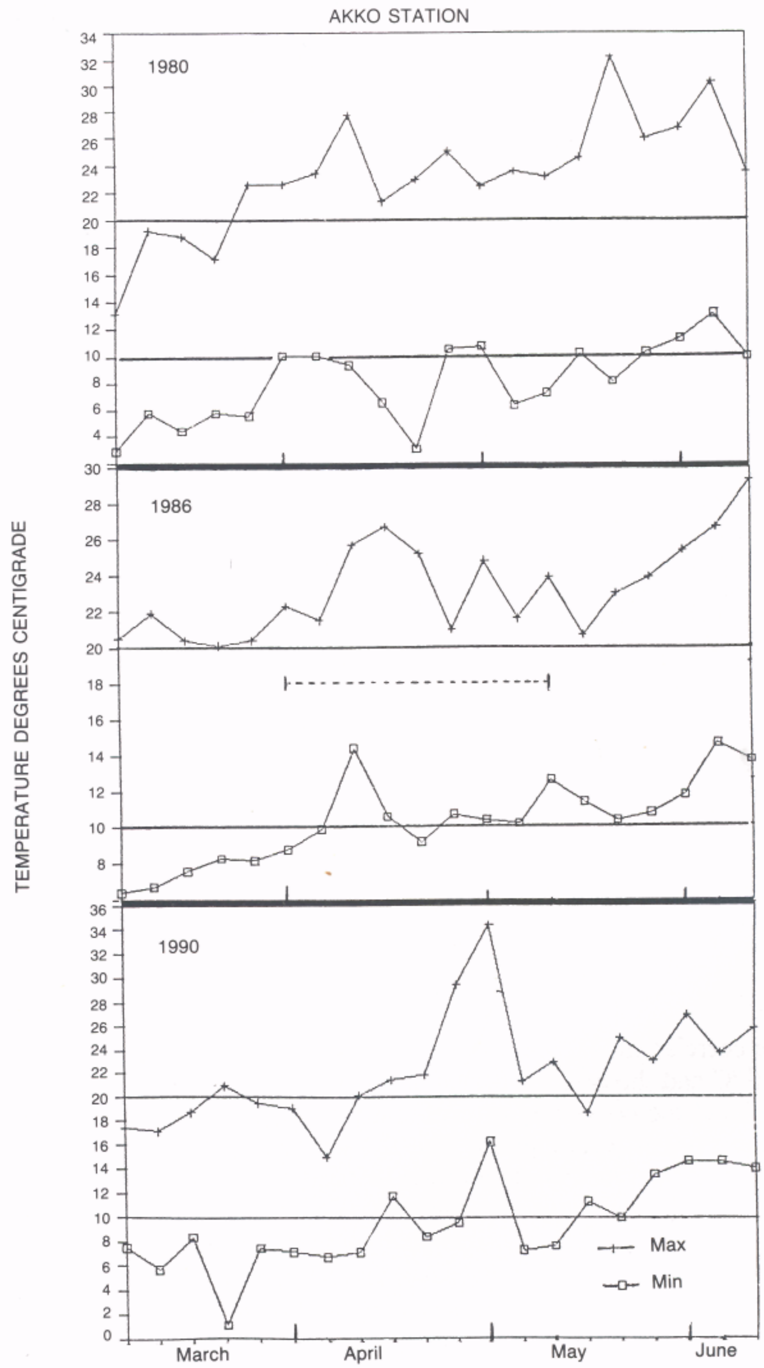
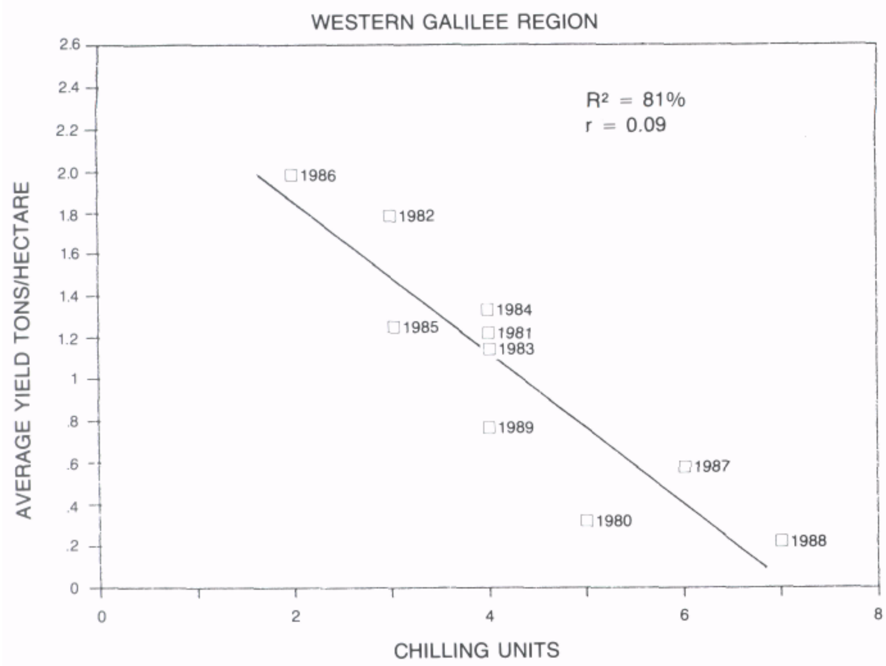


Fig. 2. Avocado yield as a function of chilling.



Results and Discussion

The correlation, R^2, and the significance are shown in Table 2. While the 9.5 °C and the two day period gave the best results with a correlation of 0.97 and the possibility of explaining the results of a high 93% (R^2), on an average it would appear that the ten degree level gives a slightly better result; and this would indicate that this temperature is indeed close to the critical temperature for the average avocado yields in the Western Galilee. It is of course possible that each cultivar has its own critical temperature—the vast differences in yield between the various cultivars could indicate that this is indeed so. The situation with regard to the length of the period for calculating the average minimum is less clear, though even here there does seem to be an indication that five or six days of warmer nights would give a higher yield. The growth of the pollen tube takes at most only a few hours to reach the ovule[18,19,20]. At this point commences the most important part of the fertilization process: the fertilized ovule has to reach the stage at which it becomes "parasitic" on the tree and able to draw nutrition to itself. Could it be that this takes about five to six days at a minimum temperature above 10°C, and that shorter periods and lower temperatures will sooner or later cause the young fruitlet to abscise? Even trees with light initial fruit set can still suffer from fruitlet drop[11].

Table 1. Average yields in tons per hectare of the four main cultivars grown in the Western Galilee together with the chilling units for each year (based on five day critical period and below 10°C.) Years used in present article are underlined.

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Yield	3.2	12.1	17.9	12.0	13.2	12.6	19.8	5.6	2.2	7.6	low
Chilling units	5	4	3	4	4	3	2	6	7	4	6
Special remarks						frost				severe frost	

Table 2. The significance, probability, and correlation between the avocado yields and the temperatures below the given levels for various lengths of day groups.

Days \ Degrees C.	6	8	8½	9	9½	10	12	Avg.	
1	0.131	0.043	0.034	0.008	0.012	0.013	0.362	0.086	SIGNIFICANCE
2	0.067	0.083	0.057	0.038	0.001	0.013	0.231	0.070	
3	0.061	0.004	0.143	0.098	0.074	0.056	0.071	0.072	
4	0.384	0.111	0.014	0.116	0.111	0.021	0.041	0.114	
5	0.084	0.062	0.023	0.023	0.015	0.006	0.051	0.038	
6	0.084	0.037	0.011	0.005	0.009	0.009	0.098	0.036	
Avg.	0.135	0.057	0.047	0.048	0.037	0.020	0.142	—	
1	47.3	68.1	71.7	85.7	82.4	81.7	20.9	65.4	R^2 PROBABILITY
2	60.8	57.0	63.7	70.1	93.7	81.9	33.2	65.8	
3	62.6	90.4	45.2	53.7	59.1	63.9	59.8	62.1	
4	19.3	50.9	81.2	50.1	50.9	77.4	68.8	56.9	
5	56.7	62.3	76.5	76.3	80.8	87.3	65.6	72.2	
6	56.7	70.4	83.2	88.4	85.1	85.1	53.6	74.6	
Avg.	50.5	66.6	70.3	70.7	75.3	79.6	50.3	—	
1	0.68	0.82	0.84	0.93	0.91	0.90	0.45	0.79	CORRELATION
2	0.78	0.75	0.80	0.84	0.97	0.91	0.58	0.80	
3	0.79	0.95	0.67	0.73	0.77	0.80	0.77	0.78	
4	0.44	0.71	0.90	0.71	0.71	0.88	0.83	0.74	
5	0.75	0.79	0.87	0.87	0.90	0.93	0.81	0.85	
6	0.75	0.84	0.91	0.94	0.92	0.92	0.73	0.86	
Avg.	0.70	0.81	0.83	0.84	0.86	0.89	0.70	—	

One of the difficulties in examining avocado productivity is the fact that from flower to mature fruit takes at least six months, during which fruit can drop off the tree due to *invisible* reasons, in the same way that radioactivity can cause death of humans years after exposure.

The idea that the fruitlet needs a certain length of time under "warm" conditions in order to "cross the barrier" to continued and successful growth is met with quite frequently in biological material. Seeds and their need for stratification[15] or desert annuals which will only germinate after a certain amount of rain has fallen are examples. In humans, a baby which for some reason fails to creep and crawl will in later life have many problems, such as difficulty in reading and writing.

As mentioned above, it is possible that each cultivar has its own critical temperature and maybe also its own period needed for the fruitlet to obtain proper hold on the tree, or to become "parasitic." Different cultivars have differing abilities to yield, even under the same conditions and with equal flowering time and intensity. It is known that girdling can increase yields[11,23] and also increase the carbohydrate level[22] in the girdled branch or tree. Girdling has been known to be effective even in "cold" spring years such as 1980 and 1990 (unpublished information). It is therefore suggested that the variation in ability to bear crops is due to differences in the carbohydrate level of the various cultivars and that the success of girdling lies in its increasing the carbohydrate level, which negates in some way the effect of low temperature. Girdling, although for many years[10] a recognized means of increasing yields in avocado, does not always give positive results, and has therefore never become a really standard procedure. Could it be that it only works well in relatively cool springs, and less well in warmer springs?

Working with citrus trees, Goldshmit and Golomb have shown that the carbohydrate level is important in control of cropping levels[9].

Using a graph such as in Figure 2, it is possible to estimate the coming crop at least six weeks earlier than this can be done by field estimation.

Treatments which would raise the temperature on cool nights or raise the carbohydrate level in the tree could give rise to considerable increases in crop yields.

It seems reasonable to assume that rootstocks which give better yields do this by raising the carbohydrate level in the scion. It may be also the reason for the success of Cultar (Paclobutrazol) in increasing yields on an experimental basis.

Knowledge of the minimum temperature on a particular prospective orchard site can assist in deciding which cultivars to plant. Up till now, this has been done only as regards frost damage[17].

The fact that the minimum temperature, as has been shown here, plays such an important role in controlling avocado yields gives the avocado plant breeder a very good tool for estimating the cropping potential of an interesting seedling, and also where would be the best place to grow it for maximum crops.

The avocado tree can have more than one million flowers[12] and it flowers for usually at least one month. If we consider that 300 fruit (75 kilograms at 250 grams per fruit) is quite a good crop, this would mean that on an average, 10 flowers must be set properly each day to give such a crop. Such a very low fruit set would be within the capabilities of one single visit per day of one bee around the tree. Thus, it would seem rather incongruous that so much emphasis has been placed since at least 1923[5] on the need for many bee hives in the orchard. Sedgley was very close to the mark when she stated[18] that "with suitable temperature and adequate bee activity, pollination processes do not appear to be a limiting factor in fruit set." If the minimum temperature is "unsuitable" for adequate bee activity is a question that remains unanswered so far.

Although the results brought here are from only six years, or in the case of a previous article[24] ten years, in more than 35% of the instances in Table 2, the R^2 is above 75%, while about 88% of the instances are above the 50% level, which was the result obtained by Lomas examining heat stress[14]; thus, the negative effect of low minimum temperature at least during the "critical period" is far more definite.

Argaman[1] in discussing the crop of 1980, although agreeing that the spring was a cold one, still blamed the low crop on a short period of very high temperature (up to 45.4°C). A similar situation is found with 1988 with a generally cold spring, but a short period of very high temperatures in May being blamed for the low crop. In 1987 and the present year of 1990, both years of low crops, there were no extreme heat waves, but they were cold generally. Thus, we have in these four years heat stress explaining 50% of the low crops as found by Lomas[14] and cold springs explaining 100% of the crops as has been put forth in this article.

Due to the variation in the daily minimum, the flowers or fruitlets are affected slightly differently and abscise at different times during the month following flowering. Most drop as unfertilized flowers, others just after set, yet others dropping in response to some other climatic or in-tree balance according to the level of weakness built into the fruitlet by the low temperatures. The maximum yield of each year is, however, determined by the level of the minimum temperature during the critical period, at least as regards the conditions obtaining in the Western Galilee. This does not prevent high temperatures being a main factor in controlling yields in those areas where the minimum temperature falls little, if at all, below 10°C.

The timing of the critical period may differ between different cultivars, with the timing found here only true of the combination of the four cultivars included in the average yields of the Western Galilee[16]. Cultivars such as 'Fuerte' and ‘Pinkerton', which can commence blooming early, could give a good crop in spite of bad conditions during April and early May if previously there had been a period of 5-6 days at least with minimum temperatures above 10°C, as occurred in the Western Galilee in 1990.

The results brought here do not indicate at what stage of the fertilization process (or before it begins) the low temperatures cause the processes to cease or to initiate processes which will bring about the cessation of development at a later time, but it is suggested that they do point closely to the culprit of the erratic yields in the avocado.

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