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The Response of Avocado and Mango to Soil Temperature[1]

Ibrahim M. Yusof[2,3], David W. Buchanan[2] and John F. Gerber[2]
University of Florida, Gainesville, Florida

ABSTRACT. Mexican avocado seedlings and grafted 'Irwin' mangos grown under soil temperatures of 21, 27 and 32°C responded differently. The soil temperature statistically influenced the growth of the avocado seedlings but not the mangos. A soil temperature range of 21 to 27° was best for the growth of the avocado seedlings but temperatures greater than 27° reduced growth. The number of growth flushes was greater at 27° than either 21 or 32°. The avocado seedlings were tall and upright at 21° and were short and spreading at 32°.

The mineral composition of both the avocado and the mango leaves changed with soil temperatures. The content of N and P in avocado and mango leaves was highest at 32° and lowest at 27°. The K content of the avocado leaves increased with temperature, but the Fe and Zn content decreased. In the mango Mg and Fe content was highest at 27° and lowest at 21°. Calcium content of the mango leaves decreased with soil temperature.

The effects of soil temperature upon the growth and nutrition of avocados and mangos are largely unknown. Field observations (3, 4, 5, 6, 7, 8, 9 and 10) are numerous but not specific because most are based upon generalized temperature and gross observations and not upon specifically measured parameters. Haas (3) reported that 'Puebla' avocado seedlings showed the greatest fresh and dry weight of leaves and trunk when the soil temperature was near 31 °C. The root fresh weight was greatest at 24°. Soil temperatures ranging from 24 to 31° produced the largest plants. However, Leal and Krezdorn (9) found the 'Brogden' and 'Mexicola' avocado cuttings rooted best when no bottom heat was used. The 3 races of avocado, Mexican, Guatemalan and West Indian, come from different climatic regions and may show different responses to soil temperature. Mangos, on the other hand, may be less responsive to such temperatures.

The purpose of this investigation was to determine the effects of soil temperature upon the growth and nutrition of the Mexican race of avocados and upon grafted mango trees. These plants were chosen because they are both of significant commercial importance in tropical fruit production and they might represent different responses to

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[2] Research Assistant, Assistant Professor and Associate Professor, respectively. Research completed in partial fulfillment of requirements for MSA degree at the University of Florida.
[3] Presently working on doctoral program in Department of Horticulture, Louisiana State University.

soil temperature. A recent comprehensive review of fruit nutrition does include acceptable levels for the major and minor elements for avocado but not mango leaves.

Material and Methods

One-year-old Mexican avocado seedlings, *Persea americana*, Mill, and 1½-year-old grafted 'Irwin' mangos, *Mangifera indica*, L. on Turpentine rootstocks were planted in cylindrical metal pots 13 inches deep, and 6 inches in diameter with a 3/8 inch drain pipe. The potting media was sterilized Arredondo fine sand. The avocados were cut to 20 cm and the mangos to 35 cm above the soil level. Root systems were pruned to uniform size. The plants were grown in the greenhouse for 2 months after which 20 avocados and 16 mangos were placed in each of 3 temperature tanks. Initial shoot length stem circumference measurements were taken then and at 30 days thereafter.

Table 1. The inorganic composition of leaves of young Mexican avocado seedlings and budded Irwin mango as related to different soil temperature.

Soil temp	N % dry wt	P % dry wt	K % dry wt	Mg % dry wt	Ca % dry wt	Fe Fe ppm	Mn Mn ppm	Zn Zn ppm
				*Mexican Avocado**				
32°C	2.06a	0.17a	1.32a	0.39a	0.23a	54.1a	76.3a	40.4b
27°C	1.74b	0.12b	0.98b	0.37a	0.24a	58.7ab	85.1a	43.9b
21°C	1.86ba	0.14b	0.91b	0.38a	0.25a	67.2b	79.9a	62.3a
				*Irwin Mango**				
32°C	2.16f	0.25f	0.90f	0.24fg	0.74f	31.19f	86.9f	33.12f
27°C	1.91g	0.20g	1.04f	0.25f	0.53g	46.12g	84.5f	27.31f
21°C	2.03fg	0.23f	0.99f	0.21g	0.89f	46.70g	87.9f	26.25f

*Means in the same column not followed by like letters differ statistically from each other at the 5% level (Tukey's Test).

Soil temperatures were controlled by immersing the metal pots in tanks of water maintained at the desired temperature. The tanks had a central drainage system to which the individual pots were connected by rubber tubes. The water temperatures were thermostatically maintained at 21, 27 and 32° ± 1°C by the addition of hot and cold water. The air temperature was regulated by a thermostat which operated both an evaporative cooler and a forced air heater.

The plants were fertilized every 14 days with 150 ml of complete nutrient solution made by adding 25 g of a soluble fertilizer (Nutri-leaf) to 3.78 liters of water and were watered with tap water

When the experiment was terminated, the total fresh weight of the plant, the fresh weight of the shoot, fresh weight of the root, dry weight of the plant, dry weight of the shoot, dry weight of the root and the height of the plant were measured. A sample of 20 mature leaves from the second most recent flush was taken from each plant. The leaves were washed, dried, ground and analyzed for mineral content. Total N was determined by the semi-micro-kjeldahl method. P was determined on the electro-photometer using a modification of the molybdenum-blue method. K and Ca determinations were made with a flame spectrophotometer. Mg, Fe, Mn, and Zn determinations were made with a Unicam SP-90 single-beam atomic absorption spectrophotometer. All data were analyzed by analysis of variance according to Snedecor (12).

Results and Discussion

The different soil temperatures in the experiment produced several measurable differences in the avocado seedlings. These differences did not follow a definite pattern in all cases; in general a soil temperature of 21 °C produced the largest avocado plants on a dry weight basis but not fresh weight. The highest soil temperature (32°) produced the smallest plants, on a dry weight basis. The growth patterns are shown in Table 2. Measurements of growth which showed statistically significant differences were: fresh root weight, total dry weight, dry shoot weight, height and stem circumference. The first 3 indices listed showed a depression at 32°, the height increased significantly at 21° and the stem circumference was depressed at 32°.

Table 2. The effect of soil temperature on the growth of Mexican avocado and Irwin mango.*

Soil temp	Total fresh weight	Fresh weight shoot	Fresh weight root	Total dry weight	Dry weight shoot	Dry weight root	Shoot root ratio	Height	Total length shoot	Stem circum
C	g	g	g	g	g	g		cm	cm	cm
					Mexican Avocado					
32°	363.6a	201.6a	160.3a	95.3a	53.9a	41.4a	1.6a	79.6a	80.5a	2.0a
27°	457.0a	219.0a	240.0a	107.4b	70.2b	37.2a	2.1a	85.3a	99.1a	2.8b
21°	453.1a	203.4a	241.3b	113.0b	71.1b	42.0a	2.0a	94.4b	102.2a	2.9b
					Irwin Mango					
32°	341.2f	233.1f	115.2f	108.7f	68.2f	33.3f	2.5f	51.8f	51.6f	1.9f
27°	343.1f	227.2f	119.9f	101.2f	74.5f	26.7f	2.9f	55.8f	66.5f	2.1f
21°	333.3f	213.2f	107.3f	99.4f	71.1f	28.3f	2.6f	53.1f	51.6f	2.2f

*Means in the same column not followed by like letters differ statistically from each other at the 5% level (Tukey's Test).

There did not appear to be an obvious explanation of the shifting patterns of growth. It was obvious that height alone could have led to a different conclusion than if dry weight alone had been used. Moreover, time had a pronounced effect upon the measures of growth, for example total shoot length (Fig. 1). Had the experiment been terminated on October 1, the 27° soil temperature would have produced significantly more total shoot length than the other 2 temperatures. However, at the termination of the experiment and at all other times there was no difference. This indicates the difficulty of using a single growth parameter as a measure in cyclically growing plants. A normalized growth index is needed in order to make true comparisons. Several of these have been used, such as the ratios of height to stem circumference, shoot to root, and leaf to fruit yield. In this experiment soil temperature may have had an influence upon the phase of cyclical growth as well as upon the total growth. As a result, the out-of-phase growth curves generate variance similar to out-of-phase sine waves. Consequently, both statistical and non-statistical differences may be encountered, depending upon the time of observation. This could be interpreted as reduced precision of the experiment, or it could mean that there were no differences in total growth over a long growing period, only shifts in the time of appearance of flushes of growth, and in habit of growth.

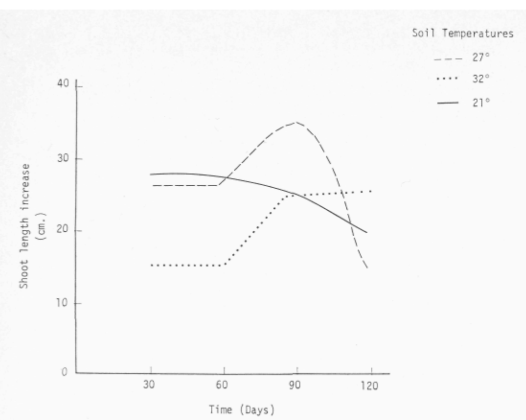

Fig. 1. The effect of 3 soil temperatures upon the shoot growth of Mexican avocado seedlings.

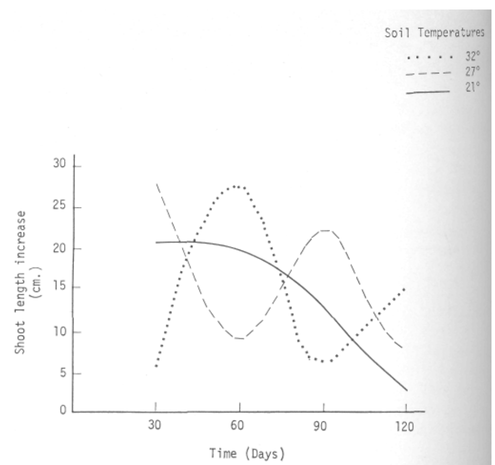

Fig. 2. The effect of 3 soil temperatures upon the shoot growth of budded 'Irwin' mangos.

Visual observations indicated that the different soil temperatures did produce different growth habits of the avocados even though total growth was not changed. Plants growing at 32°C appeared to be short and spreading, while those at 21° were tall and upright. Bailey and Jones (1) observed the same phenomena on blueberry plants grown at different soil temperatures.

The general effect of temperature upon the Mexican avocado seedlings was an indication that soil temperatures in the range of 20 to 27° were better suited for growth of this particular race of avocado than were the higher temperatures. The Mexican avocado is a native of the highlands of Mexico where temperatures are somewhat cooler than 32 °C, which was the highest temperature used in this experiment. As a result, it is reasonable to expect this particular race of avocado to show some preference for lower soil temperatures. The growth of 'Irwin' mangos was not changed by the different temperature regimes (Table 2). However, Fig. 2 indicates there was a considerable amount of variation in the growth rates. There is a strong indication that the cyclical growth patterns were out of phase and that the period as well as the amplitude may have shifted. Plants grown at 32° seemed to have gone through one growth flush and had started upon the second when the experiment was terminated. Plants grown at 27° seemed to have gone through a distinct flush about 1 month later and were in a quiescent period; those grown at 21° seemed to have ended one flush, and had gone into a period of inactivity with no indication of entering into a new growth flush. The result was an increase in variance and no significant statistical differences. At the end of August the differences were significant, growth being least at 32° and significantly higher at 27°. A month later the amount of growth at 27 ° was significantly less than at either of the other temperatures. In all probability mangos would demonstrate less dependence upon temperature than avocados especially the Mexican race which originated in the cool highlands of Mexico. Mangos are considered to be a true tropical crop. This evidence indicates such a tendency although there was a distinct shift in cyclical growth phases. Reports of unfruitfulness of mangos and difficulty in bringing about adequate bloom and fruit set are numerous. If there were a distinct change in the soil temperature caused either by rain or by a cool winter, there is an indication that the phase of the cyclic growth would be shifted and as a result flowering and fruiting may be initiated. Unfortunately, the plants used in this experiment were too small to demonstrate flowering and fruiting. The lowest soil temperature (21°) demonstrated a definite slowdown of growth oscillations and an extension over a longer period of time. Consequently, plants grown at 21° demonstrated only part of a flush cycle, which indicates a general masking effect of natural periods of flushing by reduced soil temperatures. Thus, environmental control over the growth cycle of mangos may be, in part, related to soil temperatures.

Soil temperature affected the mineral content of the leaves of both avocado and mango (Table 1). Growth of the avocado was slightly changed; that of the mango was not (Table 2). In spite of constant nutrient application, the mineral content of the leaves was significantly different. N content was lowest at 27° in both genera. Soil temperatures of 32° produced leaves with higher N content (Table 1). The smallest avocado plants had the highest leaf N content, even though the differences in total fresh weight (approximately 20%) were not significant. Since the 32° soil temperatures produced plants with the highest N content, it is probable that this was not a temperature-N relation. The other genera showed the same effect with little difference in growth. Consequently, there is some indication that there was a real depression in N uptake at 27° and real enhancement at 32°.

P showed a parallel depression at 27° in the mango and at both 21 and 27° in the avocado. Potassium was highest at 32 ° only in the avocados, which were the smallest plants. The Ca content showed a large (approximately 33%) depression at 27° but only in the mango.

Of the 3 minor elements, Fe, Zn, and Mn, only Fe and Zn were different at the 3 temperatures. Zn differed only in the avocado, but Fe differed in both genera. Zn was higher at 21° in the avocado than at the other temperatures. Fe was highest in both genera at 32°.

Of the mineral elements in Table 1, Ca showed much lower values for the avocado than is commonly found in the literature. At no time through the experiment were there any obvious deficiency symptoms for Ca, and the Ca added in the nutrient solution was always maintained at recommended levels. The soil pH was lower (4.9) than is desirable for field grown avocados.

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