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ACCEPTED AND PERCEIVED LIMITING FACTORS TO AVOCADO PRODUCTION IN ISRAEL - SOLUTIONS AND SETBACKS

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Historically, avocado production in Israel alternated and yielded less than 10 metric tons per hectare (approximately 9,000 Ibs/acre). About 10 years ago, the industry recognized that productivity was declining, canopies were getting older, taller, and denser, and returns for avocados were declining. Additionally, several years of drought and bad weather had brought about cutbacks in irrigation and cultural care. Since that time, all sectors of the Israeli avocado industry—growers, packers, merchandisers, researchers, extension specialists, and government agencies—have joined together in a serious and comprehensive search to identify, correct, and improve the industry. This report is a description and analysis of their progress and also a wake-up call to our industry to recognize that we are in a similar boat, and that we should observe and learn from the Israeli experience.

The avocado industry in Israel in many ways parallels our industry in California. Similar varieties are grown, although not in the same proportions as in California, where over 90% of the avocados produced are the 'Hass' variety. The major varieties grown in Israel are summarized below.

Variety	% of Industry	Production Trend
Ettinger	25	Increasing
Hass	30	Increasing
Fuerte	25	Decreasing
Nabal	4	Decreasing
Reed	6	Increasing
Pinkerton	5	Increasing
Ardith	5	Increasing

It is interesting to note that the 'Ardith' is a rejected California variety. The varieties percentages vary by region: 'Hass' in Western Galilee represents 35-40% of the total acreage, while in the hot region of the Sea of Galilee 'Hass' is not commercially grown.

Although Israel is a small country, there is great variability in the growing regions: a relatively mild and humid coastal strip, particularly in the mid- to upper-northern region; a warmer and less humid central interior; the northern desert, with mild to warm temperatures and with somewhat lower relative humidity; a hot northern interior mountain region with low humidity; and finally the extremely hot interior region of the Jordan Valley. Soil types are also variable, ranging from sandy loam to extremely compacted clay soils.

The main water source for much of Israel is the Sea of Galilee, an interior lake fed mainly by the Jordan River, and winter runoff. Underwater salt springs, although mostly diverted away from the lake v ia canals, help contribute to a chloride level of 220-250 ppm at the water works' aqueduct. Other water sources, wells, aquifers, reservoirs and reclaimed water, range greatly in their water quality and salinity levels. Rapid population growth additionally impacts the availability of quality water for agriculture, and for salinity sensitive avocados in particular.

Dr. Avraham Ben Ya'acov, in a colossal study observing over 100,000 trees over many years, identified and selected numerous rootstocks with salt tolerance. The majority of his selections are of the West Indian race. West Indians are the preferred rootstock in Israel. Conversely, in California we use almost 100% Mexican race rootstocks with an occasional 'Lula', which is Guatemalan x West Indian. Mexican rootstocks are highly salt sensitive, with 200 ppm chloride as a limiting upper range. West Indians thrive in such saline conditions, and many can handle at least twice that level.

Ben Ya'acov simultaneously looked at scion/rootstock compatibility and showed that certain varieties on particular rootstocks were definitely more productive. 'Pinkerton' on the VC66 rootstock, for example, in the Sea of Galilee area is 30% more productive relative to the next

best rootstock. Others, such as VC 55, VC805, and VC801, are other productive rootstocks which are highly salt tolerant and also perform well under *Phytophthora* root rot conditions. It is true that the West Indian race as a group is more cold sensitive than the Mexican or Guatemalan races, but not to the point of wholesale rejection of all West Indian types. Israel experiences cold temperatures and freezes and yet continues to plant on West Indian rootstocks. It is possible that the bad name accorded them in California stems mainly from the work of Halma, who studied mostly seedlings of the 'Waldin' variety, a typical West Indian.

Halma's work is rather sketchy, with not enough samples or good documentation. It would be wise to revisit the use of West Indian rootstocks in California from the three points mentioned above—salinity tolerance, productivity, and *Phytophthora* resistance. An added benefit, particularly in some of the Nahlat group of rootstocks of West Indian origin, is their relative small tree size when compared to the sa me variety grafted onto Mexi can rootstocks. Some, such as Ma'aoz, may be too degenerating, but substantive studies of these "dwarfing" types, alone or as an interstock, should be initiated.

The following discussion is centered around the limiting factors for productivity as seen by the Israeli avocado community, and their approach to enhance and maintain high production.

Weather. Early freezes can damage fruiting wood for the upcoming crop and can cause current fruit drop. In more severe instances, multi-year damage can also occur. Cold temperatures are detrimental in many ways: a late freeze can damage the current bloom and new set. Parts of Israel experienced such a freeze in April 1997 in the midst of an otherwise very favorable spring. Cold average air temperatures are another limiting factor of fruit set. Cold soil temperatures inhibit root growth and the uptake of water and nutrients during the extremely critical bloom period. Both stomatal conductance and leaf xylem water potential could be significantly reduced in response to soil temperatures below 13°C, as shown by Whiley *et al.*

(Acta Horticulturae 275, 1990. Tropical and Subtropical Fruits). Dr. Uzi Kafkafi has shown that the bloom can be damaged when a very cold night is followed by a bright and warm day. This is

due to low soil temperature in the root zone. He indicated that the inability of roots to conduct water in low soil temperatures, coupled with the high moisture demand of the flowering avocado tree, can potentially cause the bloom to desiccate in as little as three hours.

Chamsin, very hot and dry weather similar to the California Santa Ana condition, is occasionally experienced in Israel during late bloom and early fruit set. These conditions can decimate a promising crop. When Chamsin is predicted, growers pre-irrigate, and then cycle water in the grove continuously. Since many farms are on drip irrigation, this practice is not as effective in minimizing the effects of the Chamsin as when microsprinklers are us ed. (Chaim Arditi, the subtropical orchard manager of Kibbutz Ma'abarot, told me about an overhead cooling system he once installed that lowered the air temperature of the canopy by 7—8°C during Chamsin and helped retain more fruit than the trees without the system.)

Pollination. Honeybees are almost exclusively used as the vector for avocado pollination in Israel. During avocado flowering, citrus and wildflowers are als o blooming and compete for the honeybees . During this period of competition, termed the "hole," there is very limited bee activity in the avocado orchards and practically no fruit set. Rainy springs, such as the one experienced in Israel this season, produce an overabundance of wildflowers, and thus deepen and lengthen the "hole" and its effects on fruit set and productivity. The Israelis believe that pollination is a significant limiting factor and continue to spend much time and resources searching for answers and alternatives. Dr. Gad Ish Am[3] has been trying to understand optimal pollination rates, honeybee behavior in the avocado orchard, and alternatives to the honeybee. The honeybees were also found to be inefficient pollinators, since most of the field workers forage on a limited area of one to three trees. Only the "scout" bees, which constitute 35% of the field workers, accomplish cross-pollination at a distance greater than two to three trees. Dr. Ish Am has been introducing commercially raised bumble bees as either a supplemental vector to the honeybee or as a stand alone pollinator. He has found that the bumble bee is a superior pollinator and is not easily distracted by other competing flowering species. Together with Professor Shmuel Gazit and Dr. David Roubik, he frequently visits Mexico to find and identify native pollinating vectors in the avocado's natural habitat.

Pollinizers. To help insure that pollination is effective, and to provide the young fruitlet a better chance for survival, the I sraelis, with no exception, plant approximately 20% of their groves to 'Ettinger'. Although 'Ettinger' is a thin skin greenskin, it is in good demand in certain European countries. Dr. Chemda Degani and Professor Gazit, using isozyme analyses, have clearly shown that the mature 'Hass' avocados are almost exclusively the product of cross-pollination. They also showed in a study comparing various pollen donors that the 'Ettinger' is a superior pollen donor. More importantly, 'Ettinger' progenies were the fruits that survived to maturity. Although there is controversy over the need for cross-pollination, the placement, and spacing of pollinizer trees within the orchard, the Israelis, in their conditions of unpredictable weather and other factors, consider the addition of pollinizer trees such as 'Ettinger' necessary as an insurance policy. They claim that there is a direct and significant correlation between the availability of abundant foreign pollen to effect efficient cross-pollination and the resulting fruit set and fruit retention to harvest.

Light. In Israel, as in California, there was a surge of planting avocado trees during the late 'seventies and early 'eighties. Trees were planted exclusively on flat land with trees spaced at 5 or 6 meters (16-20 ft.) between trees and 6 or 7 meters (20-23 ft.) between rows. As productivity of existing groves declined, the Israelis soon understood that it was their aging canopies that we re affecting production by the lack of light penetration into the overgrown and closed canopies. Light is import ant for bloom, fruit set, photosynthesis, and bee activity; therefore, insufficient light is a major limiting factor.

Canopy size and age. Avocados in Israel are picked with cherry pickers, which are essentially moving platforms. As the trees grew taller, larger machines were needed to reach higher and higher into the tree canopy. Ultimately, this did not solve the height problems of the aging trees. Tree removal was only a temporary solution; they still had tall trees, just fewer of them per acre. Tree rejuvenation was also recognized as an issue to be addressed. They saw that when trees were stumped a rejuvenated orchard resulted, with lush canopy and large fruit. (Fruit size, particularly of 'Hass', is a major problem in both Israel and South Africa, since their customer, Europe, demands large fruit.) The common practice was to allow the stumps to regrow, and the only manipulation was to allow three or four main branches to grow. Stumping trees, however, set the growers back with no income for three years—a proposition most could not afford to accept. Pruning was not racticed in avocados. As a result of the need to keep the canopies to the height of their picking machines, 4.5 and 5 meters (1516 ft.), the need for rejuvenation and the extreme need for light in their groves, the whole industry embarked on an ongoing avocado canopy management effort, which is in my view the most significant change they have brought to practice. Today, there is no commercial avocado plantation in Israel that is not being pruned on at least a yearly basis. Tree removal is not considered a viable solution, particularly when viewed as part of a comprehensive canopy management program.

Today, there are two dominant schools of thought on how, what, and when to prune avocado trees. There are many variations in between, but no one questions the need to prune. There is a lot in common between the two schools, mainly the need for rejuvenation and light and height management. They each look at their approach as an integrated system, a concept of total orchard management, with an established protocol and follow up maintenance.

One school of thought is advocated by Dr. Yitzhak Adato, who is located in the interior northeast regions and the Jordan Valley. He sees the row or hedge as the undivided quantum which must be achieved, by phases, in two to three years. His goal is to increase sustained yearly productivity to at least 25-30 metric tons per hectare (approximately 22,000-27,000 Ib/acre), and at the same time improve fruit quality— mainly in terms of premium sizes—to 60-80% of the production. He believes that fruit size, after 18 tons per hectare (approximately 16,000 Ib/acre) could drop to 25% premium fruit, which is not acceptable. He favors machine topping and hedging. He feels that labor shortages and the vast effort of pruning large blocks required during a very short time can only be accomplished by machine, rather than manual tree manipulation. He wants to begin and end the spring pruning job early and rapidly. His goal is to create a wall of very active and healthy tree canopy where, by continuous rejuvenation and avoidance of any stress whatsoever, he encourages a larger root— to—canopy ratio. He wants an excessive root system to rejuvenated canopy; the worse the appearance of the trees, th e more he cuts back. He attacks alternate bearing by encouraging plenty of summer growth. The idea is to prolong the period of flushing to as late as possible so that this late flush will not

bloom and will contribute to the photosynthetic effort. Israel has three, and as many as four, distinct shoot flushes, and he recommends the removal of at least the second and part of the third flush, or even the entire third flush, thus limiting the amount of subsequent flowering. This concept appears to be similar to flower pruning practiced in South Africa and Spain. Adato applies, during maximum bloom, one application of the plant growth regulating hormone, "Magic". The purpose of this application is to slow down, for 4-6 weeks, the vegetative growth, thus reducing competition for limited re sources. A 30-50% increase in avocado production in Israel is credited to the use of this product. It allows for a major pre-bloom application of needed nitrogen (one third of total yearly N), without the consequence of promoting vegetative vigor. (A heavy pre-bloom application of N followed by a foliar application of the plant growth regulator "Cultar" during peak bloom is also practiced in Australia. To avoid any stress, he recommends keeping the trees vigorous at all times with an ample supply of water and nitrogen. Adato believes that optimal trees will not experience stomatal closure, and therefore advocates continuous water supply to eliminate the possibility of any stress which will bring about stomatal closure and leaf drop. Adato does not favor girdling of 'Hass' at all, but has been experimenting with a 3 mm wide girdle in August for 'Pinkerton' and 'Fuerte' only. He wraps the girdle with polyethylene to hasten healing and to avoid any stress response. He claims that in this manner he eliminates the "recollection" by the tree that it was girdled, and thus avoids leaf drop which is normally associated with girdling.

The second school of pragmatic thought and practice is that led by Eli Kaluski. He is an extension advisor and a successful farmer in his own right, operating in the central coastal plains and the nearby valleys. Like Adato, he has a total program centered around light management and canopy rejuvenation, but Kaluski's approach is the micro management of the individual tree. His goal is to restructure the tree in three years, lower the canopy to four meters (13 ft.), and achieve a totally juvenile tree with the oldest branch not older than two to three years. Kaluski's approach is a combination of branch removal, girdling, frequent pruning, and tree manipulation. The farmer first marks the branch to be removed, preferably one facing southeast. The remaining two branches are girdled: one in autumn, usually during October, with a 5 mm wide cut; the remaining branch is girdled in spring, during bloom, with a 2 mm knife or saw blade. The purpose of girdling is to stop or minimize alternate bearing. Kaluski utilizes polyethylene film to wrap around the girdle of weak trees. He also strives to achieve a higher root t o canopy ratio. His argument for individual tree pruning is threefold: 1) the cost of pruning is the same or less than the mechanical approach; 2) mechanical pruning is undiscriminating and removes 15-25% of flowering wood and 3) you don't need to wait for the whole block to be ready before you begin to prune the individual tree. The regrowth is continuously manipulated to encourage lateral growth and to slow down apical dominance. Kaluski also advocates the application of "Cultar" (paclobutrazol), a plant growth regulator similar to "Magic". He applies one half of the recommended dose twice; one at peak bloom, and second at the end of bloom. He applies pre-bloom nitrogen in similar volume as Adato, but does not recommend the irrigation regime advocated by him. Kaluski follows the evaporation pan readings and applies water at a 0.7 crop coefficient throughout the summer months beginning in July.
Both advocate the application of 250-400 kg of actual N per hectare (223-357 Ib. actual N/acre). Kaluski begins his fertilizer application at the end of the rainy season, normally at the end of February or early March. Other than the pre-bloom nitrogen application in the form of ammonium nitrate, his preferred fertilizer is 12-3-6. He applies 50-60% of the total N by mid—

June, while 40— 50% is applied in early September. Potassium is also applied with equal ratio of K 2O to N in heavy soils and as much as twice the N value in light soils. There is renewed interest in phosphorus application, particularly in autumn, as presented by Leo Winer during the Third World Avocado Congress. Micronutrients, particularly iron, are usually applied only when leaf analyses levels are at the lower limit of the optimal range. Boron applications, as recommended by Dr. Tony Whiley, are being practiced by at least some farmers in Israel.

The Israelis are the first to admit that they do not have all the answers; the fact that there is continuous debate and multitude of practices only confirms that. Canopy management and tree rejuvenation, though, is the underlying common denominator practiced in all 7,600 hectares (19,500 acres), no matter the variety or age. There have not been enough years to conclude that a certain method was directly responsible for increased productivity, and this may be the underlying reason for the "complete concept" and the implementation protocol advocated by Adato. They just don't know for sure. Too many variables are being attacked and simultaneously changed to give a real explanation to what is taking place. This, however, does not stop them from trying in a global way to implement their current understanding and await science to come with explanations later. The attitude is to oversupply and not be short on any perceived or known variable; and once the optimum is reached, then allow time to judge and regress.

A PRICE TO PAY

There is price to be paid with this type of pragmatic farming, particularly when the advocates are highly charismatic individuals, extremely self assured, successful, and are encouraged and supported by scientists. The following is a discussion of the shortfalls I perceive with the "concept" and its implementation.

Israel's weather during the spring in the last two years was very favorable and may have much to do with the increase in productivity. There is an apparent decrease this year in at least 'Fuerte' and 'Hass' that cannot be explained by bad weather alone. Additionally, certain practices may work well in the initial years but could easily become limiting, and even detrimental, in the long term.

1. **Irrigation.** Advocating irrigation to maximum soil capacity to avoid stress at any cost is a formula for disaster. Avocado roots require high levels of oxygen, and continuous saturation will insure the opposite. The roots are forced to grow closer to the surface and are exposed to fluctuation in temperature during critical periods. Cold temperatures will negatively affect root growth and particularly inhibit roots to supply the tree adequately with its water and nutritional needs during bloom. Roots at the 5-10 cm (2-4 inch) depth could be several degrees colder than the ones at the 20 cm (8 inch) depth. A tree that is kept in a "euphoric" state is not hardened; a severe and instant change in the weather, such as a sudden increase in air temperature by as much as 20°C (36°F), can bring a shock-like reaction, and the tree will respond differently than a hardened one. Probably the most significant detriment to such irrigation practices, not to mention the increases in water cost, is the real potential for *Phytophthora* root rot (PRR) infestation. To date, PRR has not been a problem in Israel, as compared with the problems avocado growers face with this fungus around the globe.

PRR became a problem few years ago in Israel during an unusually rainy season, and gave the growers a real scare. Israelis are quick to adjust and to forget; and as normal years returned, the issue became secondary except in the minds of Dr. Ben Ya'acov and Dr. Miriam Zilberstaine. Now, as water puddles between the raised rows— paths compacted and rutted by farm equipment and plowed by wild boars—it is not a question of if PRR will reappear, but when and with what intensity. Ignoring the PRR issue is the one item on which I totally disagree with the advocates of unlimited irrigation. Very wet conditions on flat, compacted land, with equipment moving around freely, will terrify any experienced avocado grower. To hide one's head in the mud between the rows and to say that there is no PRR in Israel is suicidal at best.

2. **Girdling.** The practice of girdling avocados has been tried by many for years with little evidence that there is a net gain in productivity. This is definitely true for 'Hass'. Autumn girdling causes extensive leaf drop and excessive early bloom. Spring girdling does not appear to cause as severe a leaf-drop as does an autumn girdling. During a mild spring, defoliation may not be of major consequence, even though mature leaf drop, by all accounts, can be limiting to good production. The consequence of an earlier than normal bloom due to girdling could be very damaging: 1) no effective fertilization will take place during cold winter months and the bloom and resources are virtually wasted, and only a small number of fruit will set; 2) early bloom and set could be exposed to a late freeze, similar to the freeze that occurred in several areas in Israel in April 1997, and damaged much of the advanced bloom and set; 3) exposed flowers and fruitlets, due to defoliation, are susceptible to sunburn and desiccation during hot and dry Chamsin weather experienced in Israel during lat e spring; and 4) the ungirdled branch appears to set less fruit than it would have otherwise set if girdling of its neighbors did not take place.

3. **Fertilization.** Using such high levels of nitrogen can only hurt the environment by leaching excess nitrogen into the underground water supply. The "Catch-22" is that trees which are alternating will become more vigorous and vegetative, and potentially will alternate even more. The 'Ardith' variety is a good example of late competition for resources, carbohydrates or hormones or both, between growing fruit and vigorous vegetative growth. 'Ardith' trees set heavily and carry a substantial amount of fruit into August, when a very strong vegetative flush occurs resulting in significant fruit drop. One of the ways to reduce this fruit drop, I believe, would be to cut back on excess nitrogen fertilization, and even irrigation, of this variety. (Many in Israel who grow 'Ardith' have been "scoring" the trees in mid-June to slow down the vegetative vigor. Reports from extension specialists such as Miki Noy, Upper Galilee, and Kaluski indicate significant fruit retention when compared to unscored trees. It will be a worthwhile experiment to see if "June drop" experienced in 'Hass ' and 'Gwen' could be reduced by a similar method).

4. **Pollination.** The placement of pollinizer varieties within the grove as an insurance for fruit set, and surely for fruit retention, is logical. Mixing two or more varieties within a block can be a problem, both from cultural and postharvest management perspectives. Although pruning will reduce the size of the trees of all varieties, their cultural requirements may not be the same. 'Ettinger' and 'Hass' have different phenologies, different nutritional and water

requirements, and different harvesting and canopy management periods, particularly if mechanical pruning and harvesting are contemplated. The equipment will have to be brought once at the end of the 'Ettinger' harvest (end of November) and a second time at the end of the 'Hass' harvest (March), which will further compact the soil. In the last few years, growers have been planting 'Ardith' as a pollinizer for 'Ettinger'. If the Israelis discover that the way to control 'Ardith's vigor and its excessive August fruit drop is by modifying the irrigation and fertilization practices in late spring and early summer, then a mixed block will be very difficult to maintain. Although farmers in Israel and researchers such as Drs. Gazit, Ish-Am, and Degani are adamant that proximity to pollinizers contributes to increased production, there are at least some around the world who question this premise. If proximity to pollinizer trees could be shown not to be as significant as thought while accepting that cross pollination is preferred, then adjacent blocks of single varieties which can contribute to cross pollination would be a more practical solution.

The California avocado industry needs to look hard into the Israeli experience and synthesize what we can learn from it. We need to, like the Israelis, search for heavy-producing varieties that do not alternate—bear and have other outstanding qualities. We have to develop cultural practices which will permit high density orchards, lower costs, and significantly increase productivity. The markets continually demand better quality at lower prices. Our common competitors can produce abundant crops cheaply; we cannot! Only improving radically our efficiency and productivity will keep us viable in the future.

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