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Factors Affecting Fruit Set/Early Fruit Drop in Avocado

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The seasonal cycle of flowering fruit set and fruit development of the 'Hass' avocado is depicted chronologically in Figure 1. As illustrated in Figure 1, during flowering, pollination and fertilization also occur. The successful completion of these two biological processes influences fruit set. The fruit set/early fruit drop period is the most critical stage of ovary (fruit) development from the grower's/producer's point of view. Pollination is the arrival of the pollen (the male part of the reproductive cycle) on the stigma of the pistil (the female part of the flower) (Figure 2). Under optimal conditions, the pollen germinates, producing a pollen tube which grows through the stigma, style, and ovary tissues, to the ovule, which contains the egg. The pollen tube delivers the sperm to the egg. The fusion of sperm and egg is fertilization. The product of fertilization is the embryo which develops into the young avocado seedling within the ovule. After fertilization, the ovule develops into seed within the ovary, which develops into the avocado fruit (Figure 3).

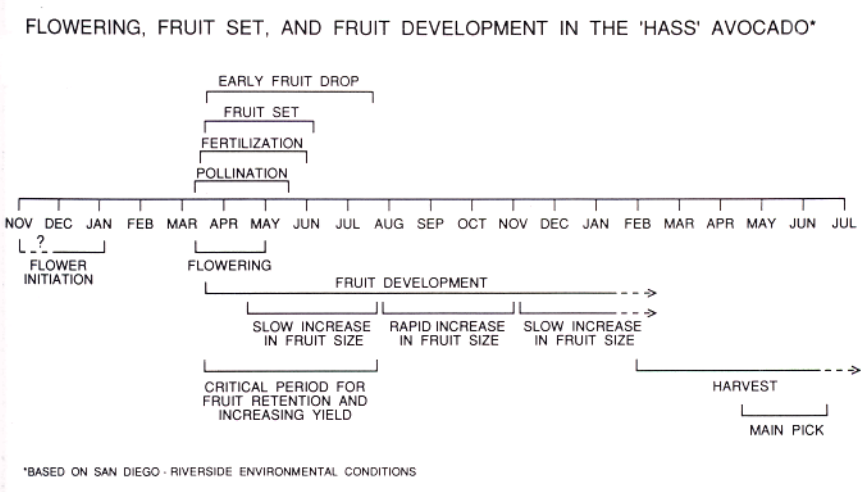

Figure 1.

Avocado fruit that fail to set can be divided into two categories: (i) fruit resulting from flowers in which pollination occurred, but subsequent fertilization failed to take place (in some crops, pollination in the absence of fertilization is sufficient to stimulate development of the ovary into a mature, seedless fruit; this rarely occurs in avocado); and (ii) fruit resulting from flowers in which both pollination and fertilization occurred, resulting in a normal embryo and seed.

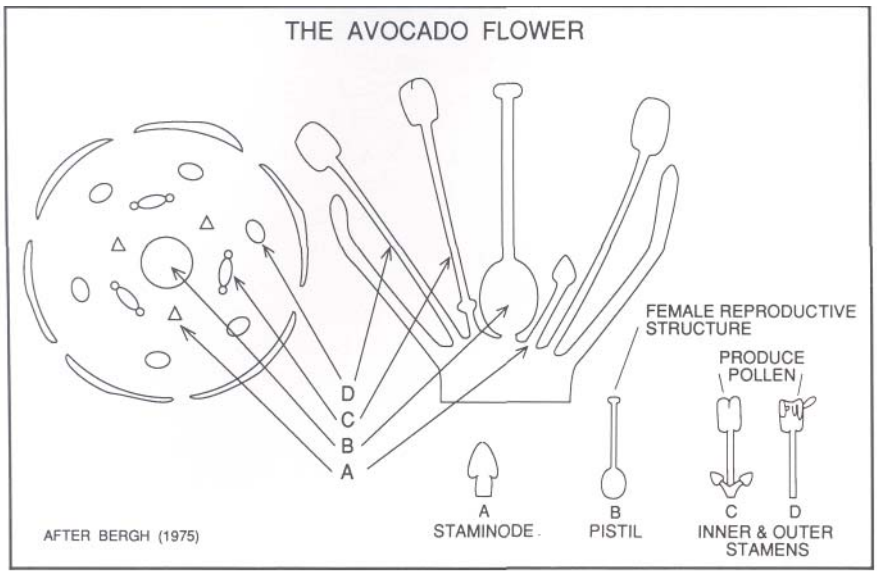

Figure 2.

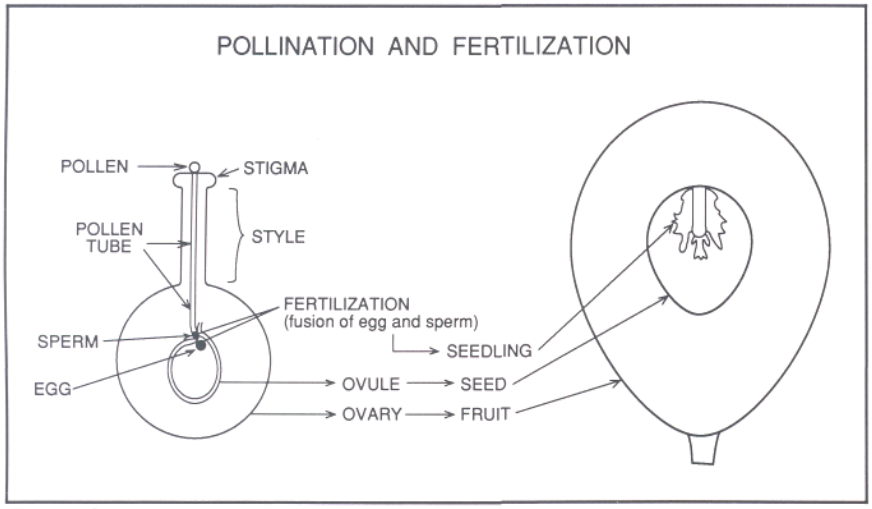

Figure 3.

Factors Affecting Fertilization (Fusion of Egg and Sperm)

At temperatures between 12 to 17 °C, only a small percentage of the flowers open in the female stage; the majority open as males only (18). When flowers do open in the female stage, there are only a few hours during which successful pollination can occur. In addition, at these temperatures pollen tube growth ceases before reaching the ovary; and thus no fertilization occurs. Pollination stimulates the ovary to start developing into a fruit, but the stimulation is exhausted within a couple of weeks and the fruitlet abscises (18). No one has attempted to identify the complement of endogenous plant growth regulators (PGR's) necessary to cause parthenocarpy[1] or to sustain stimulated-parthenocarpy[2] in avocado. Such a study could provide considerable information regarding avocado fruit development and fruit set.

The most successful fruit set occurs at temperatures between 20 to 25 °C. At those temperatures, female and male stages overlap for several hours. At temperatures above 28 °C, abscission of individual floral buds and flowers is accelerated, entire floral shoots abscise before flowers open, and flowers that do open seldom reach the male stage (18).

Temperatures prevailing during bloom are known to influence the effective pollination period of a fruit tree crop, such as avocado, and thus influence fruit set (2). The longevity of the ovule minus the length of time necessary for the pollen tube to reach the ovule in order to deliver the sperm to the egg is the effective pollination period. Cool temperatures which prevail during the flowering period decrease the viability of the ovule and increase the length of time it takes for the pollen tube to grow from the stigma to the ovule. Thus, the duration of the effective pollination period is significantly shortened and fruit set is reduced. Warm temperatures during flowering increase both ovule longevity and the growth rate of the pollen tube. This correspondingly increases the effective pollination period and fruit set.

Ovule longevity has been improved in deciduous tree crops by a summer application of nitrogen (22). The use of nitrogen to enhance ovule longevity and fruit set in avocado has not been investigated.

Boron nutrition is being examined as a possible factor influencing fruit set in avocado in South Africa. It has been known for a long time that boron is essential for pollen germination; for successful growth of the pollen tube through the stigma, style, and ovary to the ovule; and for the mitotic divisions necessary to produce the sperm (for a recent review, see 15). Boron sprays applied to trees not deficient in boron based on leaf analysis either during fall or spring have been effective in increasing fruit set in a number of deciduous fruit tree species (1, 5, 20), especially when cooler temperatures prevail during bloom (10). Preliminary results for avocado were presented by Robbertse *et al.* (12) at the International Society for Horticultural Science

Symposium on the culture of subtropical and tropical fruits and crops on the effect of boron on pollen germination and pollen tube growth. In most cases, when pistils (female reproductive structures) harvested from avocado trees receiving a foliar application of boron were pollinated with pollen from trees also sprayed with boron, pollen germination and pollen tube growth were significantly better than in flowers from untreated trees. This difference occurred despite the fact that the leaves of untreated trees contained "sufficient" boron to sustain normal plant growth. The effect of the foliar application of boron on the yield of the several avocado orchards treated is not known yet.

Recently, the question of whether insects are important as pollinators in avocado has received renewed attention (8; Gazit, personal communication). Cross-pollination and the role of insect pollinators may have been previously under-estimated as factors influencing fruit set in the light of the work of Sedgley (18), which demonstrated that self-pollination did not result in fruit set, and Vrecenar-Gaduz and Ellstrand (21), which found that outcrossing rate and yield per tree were significantly higher in interplanted versus pure groves of 'Hass' avocado.

[1]Parthenocarpy is the development of the ovary into a seedless fruit without pollination or fertilization. [2]Stimulated-parthenocarpy is the development of the ovary into a fruit in response to pollination; since no fertilization takes place, the fruit is seedless.

Factors Affecting the Abscission of Normal Fruit (*i.e.,* Those in Category 2)

The abscission of normal fruit during the early drop period is an important aspect of crop production that has been relatively neglected in avocado. The limited research that has been conducted to study early drop in avocado has concentrated on the competition between the young fruit and vegetative growth occurring during the period critical to fruit retention and yield (Figure 1). Early work by Kalmar and Lahav (12) was the first to suggest that mineral nutrient applications could cause stimulation of vegetative growth during the period critical to fruit retention resulting in increased fruit drop and loss of yield. The optimal time and quantity of nutrient applications for improved fruit set still has not been adequately investigated for avocado. Reducing vegetative growth during the period critical to fruit retention by either pruning (4, 7) or by the use of pactobutrazol (13, 14, 24) resulted in increased fruit set and, in some years, increased yield. The

effect on fruit size has been variable. In addition, pruning increased the calcium content of the fruit (Cutting and Bower, personal communication). Fruit with low calcium content are more susceptible to postharvest disorders (3).

When competition has been demonstrated to be a factor influencing fruit drop, lack of available carbohydrate has been assumed initially to be the cause. For avocado, this argument was supported by the fact that yield has been correlated with tree carbohydrate status (23, 24), but is now being challenged by the recent work of Blumenfeld *et al.* (personal communication). Experiments with other tree crops, such as citrus, for which fruit set and early drop have been studied in more depth, ultimately precluded carbohydrate availability as a key factor limiting fruit set and causing increased early drop (9).

Cultivars of *Citrus sinensis,* like avocado varieties, undergo a period of excessive fruit drop commencing during flowering, continuing through the cell division stage of fruit growth, and into the beginning of the stage of fruit growth characterized by cell enlargement. For both crops, fruit drop is completed by approximately mid-July. During this critical period, fruit retention/fruit drop in both crops is characterized by (i) competition between the young fruit and vegetative growth; (ii) sensitivity to temperature extremes; and (iii) water-deficit stress. In light of the similarities between avocado and *C. sinensis* cultivars, it should prove helpful to review the most recent research on fruit set/early drop in *C. sinensis.* The newest contributions to our understanding of fruit retention in citrus come from studies which compared changes in the concentrations of endogenous PGR's in developing fruit borne on leafy versus leafless inflorescences of 'Valencia' (11) and 'Shamouti' (9) sweet oranges. Fruit borne on leafy inflorescences are faster-growing and have a high potential to set and survive to harvest. Fruit borne on leafless inflorescences are slower-growing and tend to abscise early in their development (9, 11, 16). This provides two populations of fruit with very distinct capacities for fruit set, which can be readily identified and collected in the field for biochemical studies. This has facilitated the study of fruit set in *C. sinensis.* No characteristics have been identified in avocado that will assist in distinguishing seeded fruit with a high set potential from those with high potential to abscise.

No differences in concentrations of gibberellic acid (GA) or abscisic acid (ABA) (ng/g dry wt) were observed for Valencia fruit borne on leafy versus leafless inflorescenses. However, because fruit borne on leafy inflorescences were larger in mass than fruit of the same age borne on leafless inflorescences, fruit on leafy inflorescences had more GA and ABA per fruit. High temperatures 40 to 55 days after full bloom of 'Valencia' were associated with a large decrease in GA concentration in the fruit, but there was a lesser effect on ABA (11). Thus, a shift towards a greater ratio of growth inhibitor to growth promoter occurred during the stress. The increased ratio of growth inhibitor to growth promoter may be the cause of increased abscission. Abscission would be greater for fruit borne on leafless inflorescences because these fruit had less GA than fruit of leafy inflorescences even before the stress.

Erner (9) has proposed that fruit borne on leafy inflorescences have a greater ability to withdraw water from the transpiration stream than those borne on leafless inflorescences. Since the transpiration stream (xylem sap) of citrus contains high levels of cytokinins, fruit borne on leafy inflorescences would be expected to have a higher

ratio of this class of growth promoting PGR's to growth inhibiting PGR's than fruit borne on leafless inflorescences. In addition, it would be expected that fruit borne on leafless inflorescences would be more susceptible to water-deficit stress. Thus, fruit borne on leafless inflorescences would be expected to accumulate more ABA than fruit borne on leafy inflorescences. Since fruit of leafless inflorescences have lower levels of growth promoting cytokinins, the ratio would be shifted significantly toward growth inhibition and fruit abscission.

The hypotheses of both Hofman (11) and Erner (9) are consistent with previous research reported in earlier literature. Exogenous application of ABA to citrus fruit has demonstrated that this PGR causes fruit abscission (6). The effect of ABA on avocado is unknown. In addition, exogenous application of GA alone or with calcium dihydrophosphate or 6-benzylamino purine, a cytokinin, as whole tree sprays after full bloom or at petal fall increased fruit set, the effect on yield was variable from year to year. Calcium was effective even though trees had "sufficient" calcium for normal tree growth (19). The most recent studies on fruit set in citrus have yielded the hypothesis that the mechanism underlying early fruit drop is a stress-induced shift toward a greater ratio of growth inhibitor (ABA) to growth promoter (GA or cytokinin). This hypothesis has not yet been tested for any crop.

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