USE OF POTASSIUM NITRATE ON MANGO FLOWERING

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The mango (*Mangifera indica* L.), a member of the Anarcardiaceae, is a popular fruit of the tropics and occupies a position in the tropics similar to that of apples in temperate regions. Originating in the Indo-Burma region, the mango has since spread to nearly all tropical areas of the world. On the Indian subcontinent, it has been under cultivation for at least 4,000 years.

In the tropics, mangos are usually grown at elevations between sea level and 1,200 meters, but does best below 610 meters in climates with a pronounced dry season. In Hawaii mango will grow best at elevations from sea level to 457 meters (1,500 ft) (Chia et al. 1988). Mangos grow best at temperatures between 27–24°C and are susceptible to frost damage. Annual rainfall in growing areas ranges from 25 to 250 cm. In the wet-humid tropics, persistent rains and high humidity during flowering can cause a reduction in pollination and fruit set.

Flowers are borne on inflorescences (panicles) which are usually terminal, but panicles may also arise from axillary buds. Flowers are either male or hermaphroditic and may number from 300 to 3,000 on each panicle, depending on cultivar. The percentage of hermaphroditic flowers varies with cultivar and upon early or late emergence of the panicles (Chanda and Pal 1986).

Flowering period in mango is mainly related to weather patterns and to some degree to cultivar differences under the same climatic conditions (Singh 1960, 1977; Whiley 1985). Flowering in Hawaii usually begins in January, with fruit maturing from May–June through September (Hamilton et al. 1992; Yee 1979). In the milder southern and western regions of India, flowering begins in November or December; however, in northern areas where harsher climates prevail, flowering is more precise and occurs later, in February or March (Chanda and Pal 1986). Flowering in the U.S. occurs between January and March and in the Philippines from December to January.

Recent studies in Florida suggest that low temperature is the environmental factor with the greatest influence on flower induction (Nuñez-Elisa and Davenport 1992). It was concluded that water stress was not responsible for flower induction, but could enhance the response to cool temperatures. Similar conclusions have also been obtained by workers in Australia (Whiley 1992).

Reliable flowering is necessary to obtain consistent mango production in the tropics. In Hawaii, the Pacific, and the Caribbean, where land is a limiting factor, mango is a potentially important fruit crop if increased production, reliable bearing, and off-season bearing can be achieved. In Hawaii, biennial bearing is common; a heavy crop one year may prevent further fruiting for two years or longer. In the Hawaiian Islands, leeward sections, which are drier during the winter months, are considered ideal for mango production (Yee 1979).

Regulating Mango Flowering

Tropical climates are conducive to year-round vegetative growth of perennial tropical fruit crops, but flowering and fruit set are usually seasonal. Flowering from one season to the next is unreliable, because the environmental signals for flower initiation are often inconsistent, subtle, or poorly defined. An alternative to dependance upon environmental signals for flower initiation is the development of management strategies that can substitute for these signals.

In Hawaii, one method to extend the availability of fruit within or slightly beyond the ripening period of May-June to September is by growing different cultivars. There are usually some seedling and off-season fruits available at other times. Figure 1 illustrates the bearing pattern for important mango cultivars in Hawaii. Bearing patterns in Hawaii show that 'Harders' produces late-season fruits in the fall; 'Keitt' and 'Rapoza' are also late season cultivars that mature from August through October (Hamilton et al. 1992). In Hawaii and other tropical areas with high rainfall, flowering, fruit set, and fruit quality are often diminished by pathogens favored by wet conditions that occur during or soon after the flowering season.

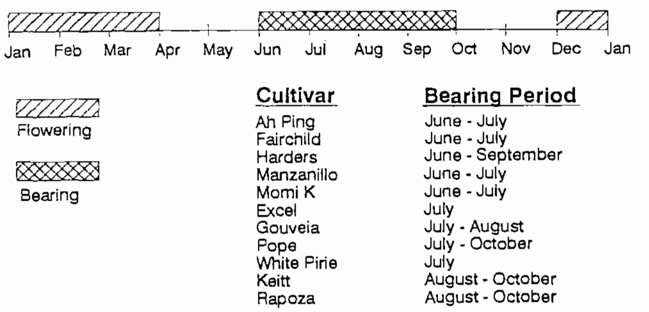

Figure 1. Flowering and bearing pattern of mango cultivars in Hawaii.

Success has been achieved in stimulating mango flowering with chemical treatments. In the Philippines, smudging has been used to obtain earlier and increased flowering of 'Carabao' and 'Pico' mango (Dutcher 1972; Gonzales 1923; Madamba 1978). Ethylene has been identified as the active agent responsible for flowering during smudging (Dutcher 1972). Smudging is done continuously for several days and is stopped if flower buds do not appear within two weeks. The process may be repeated 1–2 months later, but results are uncertain. The ethylene-generating agent, ethephon, applied at 125–200 ppm, induced flowering of 'Carabao' mango in the Philippines within six weeks after treatment (Dutcher 1972). Flower induction also occurred at concentrations between 500 and 1,000 ppm; however, defoliation was also experienced at the higher concentrations (Bondad 1976). Ethephon has also been successful in India for increasing flowering of 'Langra and 'Deshehari' during "off" years (Chacko et al. 1972, 1974; Chanda and Pal 1986) and for inducing earlier production in juvenile plants (Chacko et al. 1974). In 10-year-old 'Haden', 500-1,000 ppm applied one month before the normal flowering date increased flowering by 40–55 percent (Nuñez-Elisea et al. 1980). These results are contrary to those obtained by Pal et al. (1979), who found ethephon ineffective after five consecutive years of treatment, and by Sen et al., who reported an increase in flowering during "on" years but failed to stimulate flowering during "off" years. Applications of giberellic acid (GA) to mango trees have been inhibitory to flowering (Bakr et al. 1981; Tomer 1984). Higher GA levels have been extracted from "off"-year shoots than from "on"-year shoots, suggesting that failure to flower was associated with higher GA levels in shoot tips (Pal and Ram 1978). Analysis of the xylem sap at various stages during shoot development have shown that low gibberellin content was associated with periods during flower bud formation (Chen 1987). Application of paclobutrazol, an inhibitor of GA synthesis, caused precocious flowering in young trees and promoted flowering in bearing trees (Kulkarni 1988). This finding supports the hypothesis that endogenous GA may play a regulatory role in mango by inhibiting flowering.

The first studies to demonstrate that potassium nitrate could induce flowering of mango trees were from the Philippines (Barba 1974, Bondad and Linsangan 1979; Bueno and Valmayor 1974). Flowering was evident within seven days after treatment and was effective on shoots that were between 4.5 and 8.5 months old when treated. Bondad and Linsangan (1979) reported that concentrations of potassium nitrate between 1 and 8 percent stimulated flowering of seedling 'Carabao' and 'Pahutan' trees and 'Pico' trees within one week after sprays were applied. The treatment was effective for stimulating flowering of trees that had remained vegetative well beyond normal bearing ages, for advancing the flowering and fruiting periods, and for breaking the biennial bearing habits of trees. Potassium nitrate is currently recommended in the Philippines for inducing uniform flowering and for the production of off-season fruits in the 'Pico' and 'Carabao' cultivars (Madamba 1978). In India, workers have reported variable results with potassium nitrate (Pal et. al 1979). Areas that have reported success with potassium nitrate include Trinidad with 'Tommy Atkins' (James et al. 1992), the Ivory Coast with 'Kent' and 'Zill' (Goguey 1992) and Mexico with 'Manila' and 'Haden' (Nuñez-Elisea 1985; 1986).

In Mexico, studies by Nuñez-Elisea (1986) have shown that 'Haden' shoots should be six months of age or older. In the case of 'Manila', shoots could be as young as 3-4 months of age and be responsive. Leaves should be dark green with a mature, "woody" texture and well developed terminal buds. Upon treatment with a 4 percent potassium nitrate solution, slight leaf wilting can be observed within two days, and at 10 days buds begin to swell. A second application is made at 15-20 days after the first application if the response is poor. Application should be made prior to emergence of the flowers, because flowers are

Table 1. Percent terminals flowering after foliar treatments of seedling mango trees at Kalapana, Hawaii. Treatment date: Feb. 6, 1986.

	Weeks after treatment				
	1	2	3	4	5
Control	0.4	1.9	7.7	12.4	17.2
Potassium nitrate					
2%	0	0.8	39.2	58.0	66.2
4%	1.2	1.6	51.0	76.3	83.7
Ethephon					
1000 ppm	0	0.6	0.6	0.6	0.6

Table 2. Percent terminals flowering after potassium nitrate foliar treatments of seedling mango trees at Kalapana, Hawaii. Treatment date: May 29, 1986.

	Weeks after treatment				
	2	3	4	5	6
Control	0	0	0	0	0
Potassium nitrate					
2%	1.3	4.4	11.1	12.1	13.1*
4%	1.0	4.0	10.0	11.9	15.9*

*Vegetative flushes also stimulated by potassium nitrate.

usually damaged by the potassium nitrate sprays. Harvesting occurs at about five months after treatment. Advancing the flowering season in Mexico has enabled growers to get fruits into the market at an earlier date, extend the harvest season, and harvest crops during the drier periods.

Work in Mexico showed that mango flowering could also be stimulated with ammonium nitrate sprays (Macias-Gonzales et al. 1992; Nuñez-Elisea 1988, Nuñez-Elisea and Caldeira 1992). Concentrations of 2 percent ammonium nitrate were sufficient to promote early flowering in 'Haden', 'Tommy Atkins', 'Kent', 'Diplomatico' and 'Manila'. The similar results between ammonium and potassium nitrate indicate that the nitrate ion is the active portion of the molecule.

Experiments in Hawaii by the authors showed that 2 and 4 percent potassium nitrate sprays applied to mature seedling trees early in the flowering season (February, 1986) stimulated flowering (Table 1). A single application stimulated flowering within three weeks after treatment, and maximum response was observed at about four weeks. A stimulation in flowering was not observed on terminals treated with 1,000 ppm ethephon.

Off-season flowering was also stimulated when application was made to seedling trees in May after the flowering season was completed (Table 2). Nearly 16 percent of the terminals treated with 4 percent potassium nitrate flowered by six weeks after treatment. Our results also showed that terminals that flowered were associated with specific trees; some trees in the test exhibited no response, while others produced vegetative terminals after treatment.

These results suggest that potassium nitrate did not induce flowering, but probably stimulated growth of terminal buds. Flowering was determined by the condition of the terminal bud or the environmental conditions at the time potassium nitrate application was made. Our results with seedling trees also showed that genotypic differences among trees exist with regard to flowering responses to potassium nitrate. Some trees were highly responsive to the treatment and flowered, while others produced vegetative shoots instead of panicles.

Potassium nitrate application to mature 'Haden' trees in Pahala and Waimanalo also showed that flowering was stimulated in October and November (Table 3 and 4). Stimulation of

Table 3. Percent flowering of 'Haden' mango terminals at three weeks after treatment with 4.0 percent potassium nitrate spray at Waimanalo, Hawaii. Treatment Date: Oct. 31, 1986

Control	0
Potassium nitrate	17.1*

*Significant at P = 0.05.

Table 4. Mango cultivar flowering response to potassium nitrate treatment. November 16, 1992; Pahala, Hawaii.

Haden	+ + +
Fairchild	+ *
Keitt	–

*Mixed panicles produced.

flowering during these periods could enable producers to obtain fruits five months later (April), which would be about two months earlier than the usual seasonal production in Hawaii. Preliminary tests with other varieties show that 'Fairchild' was not as responsive as 'Haden' to applications made in November, while no response was observed with 'Keitt' (Table 4). The mode of action for potassium nitrate during flower induction is not fully understood; therefore, an explanation for the variable results between cultivars and application periods remains unclear. The influence of endogenous GA levels (possible flowering inhibitors) and the interaction between shoot age and environmental conditions on the response to potassium nitrate are not known.

Critical to obtaining reliable seasonal and off-seasonal flowering in Hawaii is the identification of varieties that are responsive to potassium nitrate, determining the influence of application times and the type of shoots that will respond to potassium nitrate, and the development of management strategies that force development of responsive shoots at any period during the year. To use chemical treatments effectively to control mango fruit production, application should be assessed in relationship to the plant's growth phenology. The overall objective of future studies should be to develop a management system that ensures consistent seasonal yields. A successful management system could stabilize production by eliminating biennial bearing and by altering the time of production to off-season periods.

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Q: Will any form of nitrate work?

A: We suspect that the nitrate is the active part. Ammonium nitrate has been used in Mexico because it is cheaper than potassium, and the concentrations used were the same, about two percent.

Dr. Davenport: Roberto Nuñez-Elisea has looked at many different salts, and it appears that the nitrate is the active part. You can substitute the cation and still get the stimulatory effect as long as the nitrate is present, but without the nitrate, with potassium chloride for example, there is no effect. Ammonium nitrate is cheaper but you have to use about half the concentration, 2 percent, compared to the 4 percent routinely used with potassium nitrate. If more than 2 percent ammonium nitrate is used, they get leaf burn.

A: There are some reports that urea has a marginal effect, but that may vary with locations.

Q: What is the critical factor influencing the plant to change toward flowering or vegetative growth.

A: We need to speculate about that, but it is likely temperature. Dr. Davenport's work indicated that water stress is not the factor. The actual temperatures and durations required may be specific to variety. The variation we observed in response to spraying in a seedling orchard indicates a strong genetic component.

Q: What has to be affected by the temperature, the leaves, the roots, or both?

Dr. Davenport: The leaves. The promoter is in the leaves.

Q: Could you cool them by spraying with cool water at night?

Dr. Davenport: I have not done any experiments with that, but it is possible that misting to bring about evaporative cooling could have an effect.

Q: How low do night temperatures get in the summertime in Hawaii?

A: Perhaps the low 70s on a clear night.

Dr. Davenport: I can tell you that if you have a variety that responds to spraying, you can have a grove with rows that flower starting in early October and with other rows stimulated to flower every two weeks afterward, on a schedule. In the following year, you have the potential to move that schedule three months forward if you want to, because it will take about nine months to go through the reproductive process and get a new flush of leaves. This is being done. You can manage sections of your orchard to flower at any time you choose. You must be careful, however, about your rainy season, so that your flowers are not getting rained on. You have to be aware of your seasonal effects and the disease control you need to exercise to get quality fruits.

Q: Is there any regulation affecting our use of potassium nitrate sprays?

A: I spoke with the Hawaii Department of Agriculture about the legality of spraying the trees. I interpret it as applying foliar fertilizer, and there seems to be no problem with that.

Q: Why does nitrate sprayed on the leaves stimulate flowering while nitrate applied to the ground stimulates vegetative growth?

A: No one knows what the potassium nitrate does. It appears that this only works with mangos.

Dr. Davenport: It has also been used with grapes, which is where the idea came from to try it with mangos. But it is not true that fertilizing mangos with nitrogen will always promote vegetative growth and suppress flowering. Actually, nitrate applied to the ground also can stimulate flowering; if you stimulate the tree to grow at a time when it is capable of flowering, it will flower. In Jamaica, a person who thought it was the potassium that was stimulating flowering was applying potassium chloride to the soil. He fertilized his trees at the right time and got early flowering. This is why water stress will appear to work as well. If you have an extended period of water stress with none of the flushing that might have occurred during that period, the leaves maintain their capability for induction and the trees will flower when they are watered.

Q: How can growers using paclobutrazol in Central America export mangos to the U.S., where the chemical is not approved for mango?

Dr. Davenport: Actually, the grower I mentioned is exporting his mangos to Europe. The people at ICI claim that there are no residues in the fruit, even if the chemical is applied through the root system. This claim is consistent with results from research with deciduous fruits like apples and pears. Under the conditions that we are proposing to use it, as a foliar spray during vegetative growth phases, it is even less likely that it will be found in the fruits. As long as the inspection agencies find no residue, then there will be no problem exporting the fruits to the U.S. But there is always the risk, the possibility, that they will find a residue and refuse a whole shipment.