

PROSPECTS OF MECHANICAL HARVESTING AND ABSCISSION IN CITRUS

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Harvesting of fruit and vegetables has always been held an important operation. Appropriate and timely harvest determines the net profit of the producer and also the reach of commodity in proper form in the hands of consumer. Therefore, methods of harvesting have been changed from time to time and improved in view of the purpose, resources and technical know how. Citrus fruit unlike other fruit like mango, guava, apple, etc., does not develop abscission layer at ripening. Pull force required to detach the fruit from stem lies in the range of 14 -23 lbs. Losses of harvesting and other operations were not given much attention in the earlier stages of commercial citrus cultivation due to the low price of the commodity and less cost of production. That's the reason, the fruit were hand picked and still most of the world's citrus crop is harvested manually using ladders. Use of wooden ladders was started in 1830, because large sized trees could not be hand picked. Light aluminum ladders soon replaced these wooden ladders as later took 20-30% time in porting, while former one enhanced the efficiency of picking. Orchardists restricted using aluminum ladders because of electricuted of some workers during the work. The need of proper harvesting equipment lead to the use of long light rods with wire loop at one end. But frequent plugging was observed and this plugging damaged up to 50% fruit. Later on, lifting machines were introduced

which could carry one or two workers. Although, efficiency was increased up to 30% but high initial cost hindered the popularity of the machine. High cost of production and high prices now awoke the need that each and every fruit must be protected from bruises and blemishes. Need for careful harvesting was aggravated with the advent of cold storages and shipment of citrus fruit to longer distances, but this was not possible with conventional methods of harvesting. This need was partially fulfilled by the introduction of mechanical harvesters.

Although mechanical harvesters improved efficiency but plugging and stemming of fruit remained as a serious problem. This drew attention to evolve a technique to overcome these problems. With the discovery that ethylene evolution is followed by abscission, by Wilson and Handershot (1967), extensive research started in this area. Several chemicals were tested by different scientists like Manganese (Morgon *et al.*, 1966), iodoacetic acid (IOAC) (Wilson and Handershott, 1967), cycloheximide (Ables and Holm, 1967), Cu EDTA (Rasmussen and Jones, 1968), hexamic acid and ascorbic acid (Wilson, 1969), Cu and Fe chloride (Ben and Biggs, 1970), Ethylene, Ethephon and Cycloheximide (Ismail, 1971), ABG-3034 (Wilson, 1973).

Meanwhile, research on mechanical harvesting continued from 1960s to 1980s in Florida but no mechanical harvesting system was commercially

adapted. Since 1994, a vigorous harvesting research and development program was initiated and administered by the Florida Department of Citrus to facilitate the development of mechanical harvesting technologies for the purpose of reducing grower costs. Several mechanical harvesting methods have been investigated. These include: 1. area canopy shake-to-the-ground; 2. canopy pull-and-catch; 3. trunk shake-and-catch;

harvester removed 84-94% of oranges shaking for 5-10 second per tree with machine capacities up to 10 t/h. The fruit pickup machine picked up oranges at 15-20 t/h at 97% efficiency and caused 3-7% split peels from handling.

Mechanical harvesters alone are not cost effective as in most of the cases, oranges left on the trees or those missing the catch frames increase the cost of harvesting in terms of gleaning by hand,

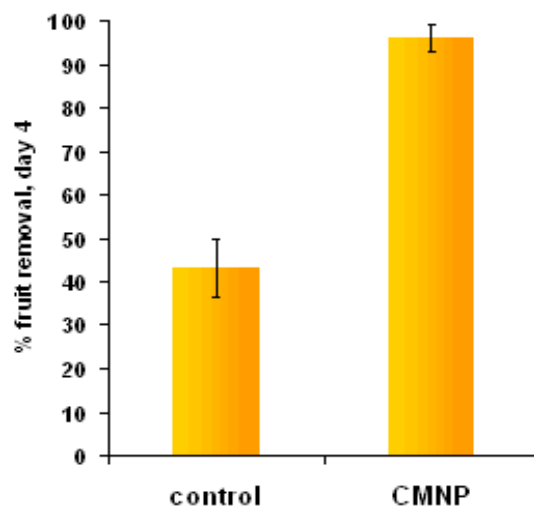


Fig. 1: Effect of CMNP on mechanical harvesting of Valencia oranges

4. trunk shake-to-the-ground; 5. continuous canopy shake-and-catch; 6. continuous canopy shake-to-the-ground; 7. continuous air shake-to-the-ground; 8. mechanical fruit-pickup. Various researchers studied the merits and demerits of these mechanical harvesters.

Whitney (1999) conducted mechanical harvesting tests with a canopy shaker, a trunk shake-catch harvester and a fruit pickup machine. The canopy shaker, which moved continuously down one side of tree row canopy, operated at 1.2-2.4 km/h. Orange removals ranged from 55% (in larger tree canopies) to 95% (in smaller tree canopies) with machine capacities up to 25 t/h. The trunk shake-catch

so limiting their use, especially of trunk-shake catch system (Whitney *et al.*, 2000). So, various abscission chemicals like Prosulfuron, metsulfuron-methyl and CMN-pyrazole were tested. By using these chemicals, removal efficiencies increased 10-15%, when orange detachment forces were reduced to 50-80% (Fig. 1).

Keeping in view the findings of Whitney *et al.* (2000), more stress was given to evaluate the performance of various chemicals as abscission agents. Kender *et al.* (2001) applied Methyl jasmonate (MJ) and CMN-pyrazole alone and in combination, to Hamlin and Valencia orange trees (*Citrus sinensis*) in seven separate experiments to induce

abscission of mature fruit for mechanical harvesting. MJ alone significantly reduced fruit detachment force (FDF) of Hamlin oranges at concentration of 10 mM and higher. However, MJ at 20 and 100 mM caused significant defoliation. For Hamlin oranges, combination of 10 mM MJ + 50 mg/l CMN-pyrazole, and 20 mM MJ + 25 mg/l CMN-pyrazole, were most effective. Valencia oranges did not respond to 10 mM MJ treatment alone or in combination with CMN-pyrazole and required MJ at 20 mM in combination with CMN-pyrazole to loosen this late-maturing variety to below 50 N, but excessive defoliation occurred.

Hartmond *et al.* (2000) also evaluated ten jasmonate derivatives, (including methyl jasmonate and jasmonic acid) and 25chloro-3-methyl-4-nitro-1H-pyrazole (CMN-pyrazole) structural analogues for their abscission activity in 10-year-old orange cv. Valencia trees. Within the 3-week experimental period, methyl jasmonate (MJ) and jasmonic acid (JA) (applied to 2 whole trees at 1 or 0.7 mM) caused reductions in the required fruit detachment force and caused approximately 10% of the oranges to drop to the ground. Application of jasmonates at 10 mM to canopy sections in 3 trees reduced FDF, but did not cause fruit drop. Increasing the concentration of jasmonates applied to the abscission zone from 5 to 10 and 20 mM improved FDF reduction. Application of the jasmonates MJ (10 and 20 mM) and LA-210 (20 mM) to abscission zones was comparable to the fruit loosening activity of CMN-pyrazole (positive control) without causing significant canopy injury. CMN-pyrazole analogues were applied to 2 replicate canopy sectors at 100, 1000 or 2000 mg/liter. Of

these analogues, only LA-111 @ 2000 mg/liter showed abscissic activity similar to CMN-pyrazole, but caused severe canopy injury. LA110, an isoimer of LA-111, also reduced FDF below the control level, but showed less phytotoxicity.

Kender *et al.* (1999) studied 11 citrus cultivars for their response to the experimental abscission material, metsulfuron-methyl @ 2 mg/liter, as an aid to mechanical or hand harvest. Cultivars evaluated included Ambersweet, Glen Navel, Hamlin and Valencia oranges, Robinson tangerine, Sunburst tangerine, Murcott and Temple tangors (*C. reticulata* X *C. sinensis*), Orlando tangelo (*C. reticulata* X *C. paradisi*), Ray Ruby and Marsh grapefruits. Fruits of 6 of the 11 cultivars were effectively loosened by metsulfuron-methyl (Hamlin, Valencia, Orlando, Murcott, Temple and Ray Ruby). Addition of an adjuvant was necessary for abscission activity in fruit and leaves. Trees sprayed with metsulfuron-methyl in combination with an adjuvant (Kinetic) had higher percent cumulative fruit drop, higher internal ethylene, and lower fruit detachment forces than the trees sprayed with metsulfuron-methyl alone. Sunburst tangerine responded poorly to the abscission material in the presence or absence of Kinetic. Leaf loss was greatest in trees sprayed with metsulfuron-methyl and adjuvant, intermediate in trees sprayed with metsulfuron-methyl alone and least in control trees. Twig dieback was observed in Valencia and Marsh sprayed with metsulfuron-methyl. The peel of some cultivars had irregular coloration and developed pitted areas after harvest.

While studying the response of various chemicals to abscission of citrus

fruit, amount and volume needed for a particular area was still to be evaluated. Therefore, Kender *et al.* (1999) conducted a field experiment to determine the effects of concentration and spray volume of metsulfuron-methyl as an abscission aid for mechanical harvesting of citrus. Concentrations of 1, 2 or 4 mg metsulfuron-methyl /liter were applied to Hamlin-orange trees at 470, 1900 and 4700 liters/ha (0.5-19 g a.i/ha). Effective fruit loosening was achieved with all applications >1.9 g/ha (4 mg/liter at all volumes, 2 mg/liter at 1900 and 4700 liters/ha and 1 mg/liter at 4700 liters/ha). Heavy defoliation and twig dieback were observed on trees receiving 2 or 4 mg/liter at all volumes. Defoliation and dieback became more severe and, flower development and fruit set were inhibited as fruit loosening increased. The use of metsulfuron-methyl as an abscission agent for Hamlin oranges is not recommended until conditions for its safe application can be determined.

As excessive leaf drop in chemical-mechanical harvesting is a great

problem, therefore, attempts were made to reduce this problem. Burns *et al.* (2003) studied the role of alpha2-adrenergic agonists in reducing leaf abscission without reducing the efficiency of an abscission compound. Within this class of compounds, guanfacine and clonidine were the most effective, when each was used @ 2mM, in combination with ethephon (200 mg/l) or metsulfuron methyl (2 mg/l) (Table 1 a & b).

Currently no abscission agent is registered for use in citrus, therefore, it would be advantageous to adapt ethephon as an abscission agent because it was already registered for use on several food crops and is relatively inexpensive to apply. Therefore, Pozo *et al.* (2004) carried out the studies on improving the selectivity of ethephon for mature citrus fruit. They stated that the selectivity of ethephon for mature citrus fruit can be improved by targeting the differential response of leaves and mature fruit to the ethylene binding inhibitor 1-methylcyclopropene (1-MCP). They observed that 1-MCP

Table 1a: Effect of alpha2-adrenergic agonists on abscission activity of ethephon

Chemical	FDF (kg)	Leaf drop (%)
Control	9.5 a	3 c
Ethephon	4.5 b	52 a
Ethephon + clonidine	4.6 b	21 b
Ethephon + guanfacine	4.3 b	14 b

Table 1b: Effect of alpha2-adrenergic agonists on abscission activity of Metsulfuron

Chemical	FDF (kg)	Leaf drop (%)
Control	9.4 a	2 d
Metsulfuron	2.8 c	75 a
Metsulfuron+clonidine	3.5 b	60 b
Metsulfuron+guanfacine	3.8 b	20 c

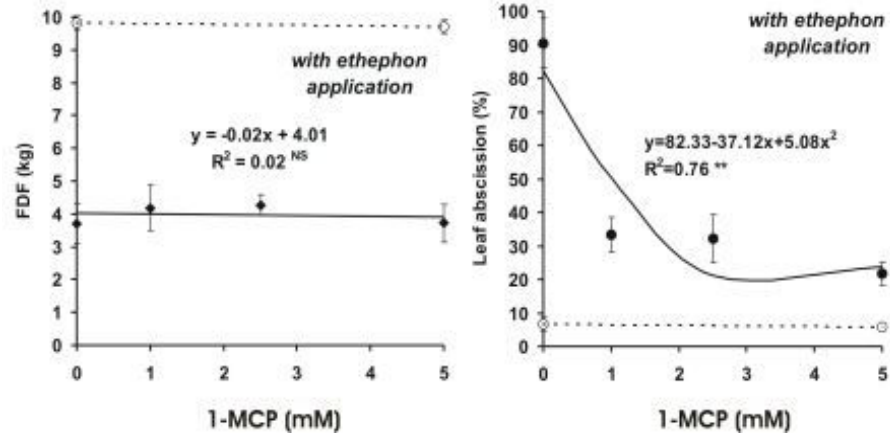


Fig. 2: Effect of 1-MCP on the efficacy of ethephon

reduced leaf abscission to almost 20% while keeping FDF at 4 kg (Fig. 2).

Several mechanical harvesting technologies mentioned above are capable of removing 50-90% of the total tree fruit. The above results indicated that none of the abscission chemicals and mechanical harvesters could work efficiently separately, but when both are used in a proper way, harvesting is too much facilitated. Still more advancement in this area is required and there is a bright future for finding abscission agents and additives to reduce defoliation. This research should continue to find out selective, non-phytotoxic, manageable, environmentally and toxicologically safe and cost effective abscission chemicals, additives to reduce leaf abscission as well as a harvester, which could harvest with minimum damage to bark and roots of the trees. Moreover, accurate conditions for safe and dependable use of already available chemicals should be defined.

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