multiple row beds. Additional research on clump planting is needed before it can be recommended for fresh market machine harvested tomatoes in Florida.

Vine Training

To minimize fruit damage from the plant cut-off mechanism of the harvester, plants should not be allowed to grow beyond the width of the pick-up-elevator component of the harvester, nor into the water furrows. Plant size can be controlled by avoiding excess nitrogen fertilizer, the use of vine trainers, and by hedging. If winds blow plants over onto one side of the plant bed, they should be immediately pushed up into the bed center with vine trainers. To delay means the plants will orient themselves to the one-sided positions and are then difficult to move.

Literature Cited

1. Anonymous. 1971. 'Raincoat' slows nutrient leaching, boosts crops yields. Univ. of Fla. Sunshine State Agr. Res. Rep. 16(3):10-11.
2. Averre, C. W., III, J. A. Winchester, and J. W. Strobel. 1965. Soil treatments for tomatoes growing under plastic mulch in calcareous soils. **Proc. Fla. State Hort. Soc.** 78:120-124.
3. _____, J. W. Strobel, and J. D. Dalton. 1966. New methods solve "old land" problems. Univ. of Fla. Sunshine State Agr. Res. Rep. 11(3):12-15.
4. Bryan, H. H., J. W. Strobel, and J. D. Dalton. 1967. Effects of plant populations, fertilizer rates on tomato yields on Rockdale soil. **Proc. Fla. State Hort. Soc.** 80:149-156.
5. Deen, W. W., Jr., N. C. Hayslip, H. H. Bryan, and P. H. Everett. 1970. Recent advances in mechanization of fresh market tomato harvesting in Florida. **Proc. Fla. State Hort. Soc.** 83:131-135.
6. Everett, P. H. 1971. Evaluation of paper and polyethylene-coated paper mulches and fertilizer rates for tomatoes. **Proc. Fla. State Hort. Soc.** 84:124-128.
7. _____, and W. W. Deen, Jr. 1972. Machine harvest of 'Florida MH-1' tomatoes: Effect of harvest on yield, fruit size and maturity. **Proc. Fla. State Hort. Soc.** 85:166-168.
8. Geraldson, C. M., A. J. Overman, and J. P. Jones. 1965. Combination of high analysis fertilizers, plastic mulch and fumigation for tomato production on old agricultural land. **Proc. Soil and Crop Sci. Soc. of Fla.** 25:18-24.
9. Halsey, L. H., R. C. Fluck, and J. F. Beeman. 1967. Influence of plastic mulch on sand and soil rot on tomatoes. **Proc. Fla. State Hort. Soc.** 80:200-203.
10. Hayslip, N. C. 1972. A 'plug-mix' seeding method for field planting tomatoes and other small-seeded hill crops. Univ. of Fla., Fort Pierce ARC Mimeo Rep. RL-1972-2. 5 pp.
11. _____, E. M. Hodges, D. W. Jones, and A. E. Kretschmer, Jr. 1964. Tomato and pangolagrass rotation for sandy soils of south Florida. **Univ. of Fla. Agr. Exp. Sta. Circ.** S-153.
12. _____, and J. R. Iley. 1966. Use of plastic strips over fertilizer bands to reduce leaching. **Proc. Fla. State Hort. Soc.** 79: 132-139.
13. _____, and _____. 1967. Influence of potassium fertilizer on severity of tomato graywall. **Proc. Fla. State Hort. Soc.** 80:182-186.
14. Montelaro, J., and M. E. Marvel. 1970. Chemical weed control for Florida vegetable crops. **Univ of Fla. Agr. Exp. Sta. Circ.** 196C.
15. Navarro, A. A. and S. J. Locascio. 1971. Influence of population density, row arrangement and fertilizer rate on the single-harvest yield of fresh-market tomatoes. **Proc. Fla. State Hort. Soc.** 84:127-131.
16. Overman, A. J., J. P. Jones, and C. M. Geraldson. 1971. Soil preparation for tomatoes on old sand land. Univ. of Fla., Gulf Coast Sta. Mimeo Rep. GCS 71-6. 4 pp.

CONDITIONING TOMATOES FOR FRESH MARKET MACHINE HARVEST

H. H. BRYAN AND W. W. DEEN, JR.

IFAS Agricultural Research and Education Center
Homestead and Belle Glade

P. H. EVERETT AND N. C. HAYSLIP

IFAS Agricultural Research Center
Immokalee and Fort Pierce

Abstract. **Preharvest applications of Ethrel (ethephon) to induce earlier more uniform ripening for mechanical harvesting of tomatoes would improve harvest efficiency and fruit quality. Ethrel applied one week before harvest increased the proportion of ripe fruit mechanically harvested but it did not affect removal characteristics of tomatoes with jointless pedicels. Cutting plants one to eight hours before harvest reduced the number of stems attached to mechanically harvested fruit, thus requiring fewer graders on the harvester and improving harvest efficiency. 'Florida MH-1' had 25% to 40% fruit with stems from plants not cut before harvesting compared to 5% to 15% from plants cut before harvesting. Preharvest cutting (PHC) induced wilting, reduced limb breakage as well as the effort required to remove fruit on the IFAS experimental semi-harvester. PHC of plants will be essential for efficient mechanical harvesting of fresh market tomatoes with cultural practices now being used.**

It is evident from research over the past five years that mechanical harvesting of fresh market tomatoes will require profound changes in growing and manipulating the crop prior to harvest. Tomatoes for multiple hand harvest require higher

Florida Agricultural Experiment Station Journal Series No. 4717.

fertilizer rates than those for a single mechanical harvest (2). *Excess* fertilizer keeps plants in an active state of growth thus extending maturity over a long period. Excessive foliage, brittle branches and the high incidence of harvested fruit with attached stems caused by excess fertilizer create severe harvesting problems which reduce efficiency. Jointless cultivars have fewer stems attached to the fruit after mechanical harvesting than those with jointed pedicels (3, 9). Ethrel has been shown to accelerate fruit maturity and provide a larger harvest of ripe fruit (6, 8). The percent of fruit mechanically removed without pedicels from some jointless breeding lines increased with advancing maturity and with increasing dehydration time (3).

Ideal weather and management conditions should provide: 1) a concentrated fruit set with a predominance of large fruit; 2) plants approaching fertilizer deficiency at harvest time and 3) low soil moisture 5 to 7 days before harvest. Under these conditions, concentrated yields of 'Florida MH-1 fruit can be easily removed from the vines with few stems attached and little mechanical damage. Florida's high humidity and rainfall which frequently occurs before and during harvest prevent the slow decrease of plant turgor and growth that can be accomplished in California by withholding irrigation one to six weeks before machine harvest (7). Since these conditions seldom exist in Florida, it is necessary to prepare or condition plants for mechanical harvesting. Chemical and mechanical methods to condition tomatoes before harvest and their effects are discussed.

Materials and Methods

Chemical treatments. Chemicals as sprays were applied one to six weeks before harvest to determine their effects on fruit size, maturity and removal of 'Florida MH-1' tomatoes. Chemicals tested were succinic acid, 2,2-dimethylhydrazide (Alar); 2-chloro-ethylphosphonic acid (Ethrel) and the experimental compounds Niagara 10656 and Dupont X-1840. Fruit were harvested by hand or by machine and separated into size and maturity grades.

Mechanical methods. Plants were cut just below the soil surface at different intervals (0.5 to 32 hours) before harvest (Preharvest cutting:PHC) to determine the effect of wilting on fruit turgor, limb breakage, fruit removal and damage during mechanical harvesting. Tractor drawn cutter bars of several designs and other tools were used in tests for PHC. Fruit samples were obtained from IFAS experimental harvesters and commercial harvesters (1); from the IFAS stationary shaker (3) and by vertically shaking individual plants by hand to simulate mechanical fruit removal. Fruit of marketable size were graded into maturity categories (red, pink, mature green), then mechanical damage and percent fruit with stems were determined. Four to ten samples of 50 or more fruit were counted and/or weighed for each treatment evaluation. Tests were conducted in Homestead, Immokalee, Fort Pierce and Bradenton.

Statistical significance was determined by the new multiple range test (4).

Results and Discussion

Chemical treatments. Ethrel applied to 'Florida MH-1' plants and fruit one week before machine harvest increased the proportion of pink and red fruit compared to control fruit (Table 1). Preharvest Ethrel sprays did not affect the percentage of mature green fruit harvested with stems attached.

Treatments of 5000 ppm Alar, 250 and 500 ppm Ethrel and 500 ppm NIA 10656 applied one week before harvest increased size and yield of pink fruit compared to the control; however, total marketable yields were not affected by the treatments (Table 2).

Vine-ripened tomatoes often bring higher prices than mature green fruit ripened after harvest. Ethrel, now approved for preharvest sprays on tomatoes, accelerates maturity and increase the coloration of fruit for a once-over destructive harvest. Modifications of commercial and experimental harvesters enabled us to harvest firm 'Florida MH-1' fruit with a high percentage of pink and ripe tomatoes acceptable for fresh market (5).

Mechanical methods. Extensive cloud cover,

Table 1. Effect of Ethrel spray 1 week before harvest on maturity of 'Florida MH-1' and percentage of fruit with stems at Immokalee in May 1972.

Ethrel (ppm)	Maturity grade			MG with stems
	Red	Pink	MG[z]	
	---------- % ----------			
0	12	20	68	11
1500	29	32	39	11

[z] MG - mature green

Table 2. Effect of chemical sprays 1 week before harvest on fruit size and yield of 'Florida MH-1' at Homestead, April, 1972.

Chemical	(ppm)	Color % 6x6+	Yield (lb/plot)[z] Color	Mkt.
		**	*	N.S.
Water		31 c	8.0 b	33.8
Alar	5,000	51 ab	14.4 a	43.3
"	10,000	33 c	12.3 ab	42.9
Ethrel	250	47 ab	13.8 a	39.9
"	500	51 ab	14.4 a	40.9
DPX-1840	500	44 abc	12.4 ab	48.4
"	1,000	42 abc	7.9 b	35.1
NIA 10656	500	56 a	16.4 a	43.6
"	1,000	39 bc	13.4 ab	41.3

*,** numbers in each column followed by a different letter are significantly different at the 5% (*) or 1% (**) probability levels.

[z] plot size = 20' x 6'.

high fertilizer rates and high soil moisture at harvest time hindered harvesting by keeping plants turgid and growing which extended crop maturity and increased the proportion of fruit with stems after harvest (Table 3). PHC plants before harvest reduced the percent of harvested fruit with stems regardless of weather or cultural conditions. 'Walter' and 'Homestead,' cultivars with jointed pedicels had a high percent of fruit with stems and more labor would be necessary to remove stems on the harvester. New breeding lines have a potential to provide harvested fruit with a small percentage of stems even when climatic and cultural conditions are adverse.

After PHC the percent stems on machine harvested tomatoes decreased rapidly as time advanced from 0 to 8 hours (Fig. 1). With a longer time interval between PHC and harvesting the percent fruit with stems began to increase; however, this was more evident with '2144' than with 'Florida MH-1.' For each cultivar the fruit with stems from plants with no PHC did not change with time. The cultivar 'MH-1' had fewer fruit with stems than '2144' but the response to preharvest wilting was similar.

Rainfall lessened the effect of preharvest cutting; however, percent fruit with stems remained lower for PHC plants than no PHC for a 24 hour period (Fig. 2). A test started in wet soil showed

Table 3. Effect of climatic conditions, soil moisture, fertilizer rate, cultivar, and time of preharvest cut on % of fruit with attached stems following mechanical harvest of mature green tomatoes.

Location	Date	Cultivar	Cloud Cover (%)	Wind (mph)	Temp. F.	Fert.[z] rate	Soil[y] moist.	Hrs. cut	Frt. with stems (%)
1. Fort Pierce	6/9/71	'6783'	10	10	85	M	M	0	20
	"	"	10	10	"	M	M	3	12
	12/1/71	'MH-1'	30	10	80	H	W	0	38
	"	"	30	10	"	H	W	1	22
2. Immokalee	3/18/72	'MH-1'	30	0	80	H	W	0	38
	"	"	30	0	"	H	W	4	9
	3/19/72	"	0	4	"	H	W	24	16
	5/10/72	"	70	4	85	M	W	0	40
	5/11/72	"	0	0	"	M	W	16	11
3. Homestead	1/31/72	'MH-1'	0	4	70	H	M	0	23
	2/7/72	"	0	0	"	H	D	0	19
	3/8/72	"	0	4	75	M	M	0	21
	"	"	0	4	"	M	M	0.7	11
	4/27/72	"	10	4	80	M	W	0	28
	5/7/72	"	10	4	"	M	D	0	15
	3/10/71	"	20	10	68	M	D	0	25
	"	Walter	20	10	"	M	D	0	76
	"	HS-24	20	10	"	M	D	0	100
	2/22/71	908	10	10	70	H	W	0	12
4. Bradenton	5/14/71	Walter	10	10	80	H	M	0	79
	"	'MH-1'	10	10	80	H	M	1	12

[z] Fertilizer rates: M = medium, H = high.

y Soil moisture: M = moderate; W = wet; D = dry.

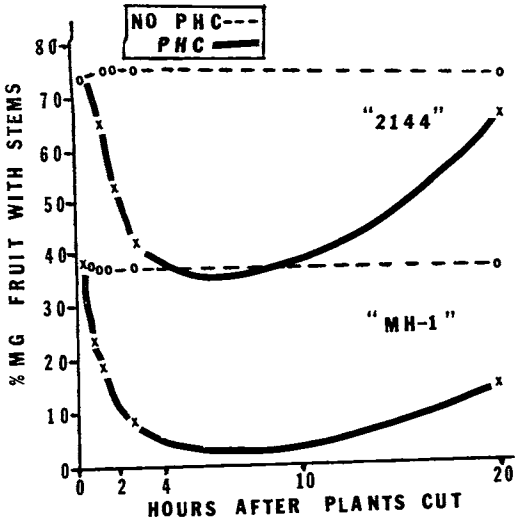

Fig. 1. Effects of preharvest cutting (PHC) and cultivar on mature green (MG) tomatoes with stems.

the typical rapid reduction of fruit with stems up to 4 hours after severing the plants (Fig. 3). Slight and severe wilting of the leaves was obvious 2 and 4 hours hours, respectively after PHC. An overcast condition occurred in the afternoon and the percentage of fruit with stems began to increase before dark. The rate of increase was greater after a rain that occurred during the night and percent fruit with stems began to decrease again at 9:00 o'clock the following morning when moisture had evaporated from the surface of the plants, and continued to decrease to a level attained the previous day. Plants should not be cut too far ahead of harvest operation because exposed fruit on hot, clear days are subject to sunburn which lowers fruit quality.

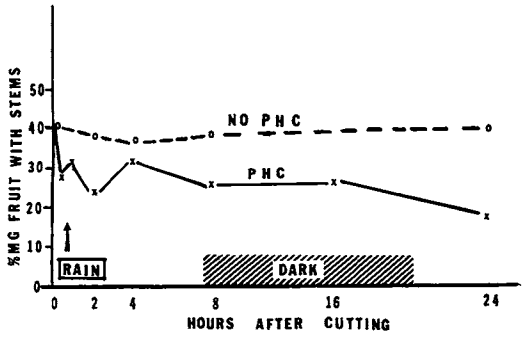

Fig. 2. Effects of preharvest cutting (PHC) of 'Florida MH-1' plants, time and rain on fruit removed with attached stems.

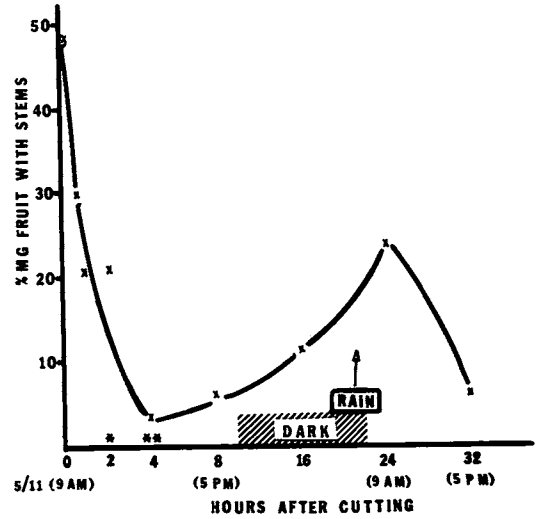

Fig. 3. Effects of preharvest cutting (PHC) time and rain on 'Florida MH-1' fruit removed with attached stems.

Plants wilted by PHC were less brittle and branches did not break as readily as those from fresh harvested plants. The wilted foliage allowed easier fruit removal and only one vertical shake of individual plants was necessary to remove all the fruit compared to 2 or 3 shakes to remove all the fruit from fresh plants.

Mechanical and sand damage to fruit from PHC plants was less than that from fresh machine harvested plants (Table 4). The percentage of US No. 1 fruit from PHC plants was similar to that from hand harvested plants and fresh plants had more US No. 2 and cull fruit than PHC plants. The reduction of damage probably resulted from reduced turgor which allowed the fruit to withstand some of the impact received during harvest without damage.

Preharvest cutting of tomatoes for machine harvest offers advantages of reduced labor require-

Table 4. Effect of preharvest cutting on mechanical damage to mature green tomatoes as reflected by fruit grade.

Cultivar (Date)	Harvest method	Hours cut	Grade (%) US1	US2	Cull
'6783'	Hand	0	100	0	0
(6/6/71)	IFAS Semi	0	78	20	2
	" "	3	87	13	0
'Fla. MH-1'	Hand	0	97	3	0
(3/29/72)	Hart-Carter	0	79	19	2
	" "	2.5	96	4	0

ments and less mechanical damage to the fruit. It is a practice that will be essential for efficient machine harvest of fresh market tomatoes with the cultural methods now being used.

Literature Cited

1. Deen, W. W., Jr. 1970. Recent advances in mechanization of fresh market tomato harvesting in Florida. **Proc. Fla. State Hort. Soc.** 83:131-135.
2. Everett, P. H., H. H. Bryan and N. C. Hayslip. 1972. Growing Fresh Market Tomatoes for Machine Harvest. **Proc. Fla. State Hort. Soc.** (this volume).
3. Fluck, R. C., J. W. Strobel and H. H. Bryan. 1968. Field evaluation of fruit detachment of machine harvest tomato varieties with a portable shaker. **Proc. Fla. State Hort. Soc.** 81:126-31.
4. Harter, H. L. 1960. Critical values for Duncan's new multiple range test. **Biometrics** 16:671-685.
5. Hicks, J. R., P. H. Everett and R. H. Dougherty. 1972. Consumer acceptance of machine harvested Florida MH-1 tomatoes and results of taste panel comparisons of MH-1 and Walter tomatoes. **Proc. Fla. State Hort. Soc.** 85:184-186.
6. Robinson, R. W., H. Wilczynski, F. G. Dennis, Jr. and H. H. Bryan. 1968. Chemical promotion of tomato fruit ripening. **Proc. Am. Soc. for Hort. Sci.** 93:823-830.
7. Sims, W. L., P. G. Smith, R. Scheuerman and D. Ririe. 1971. Mechanized growing and harvesting of fresh market tomatoes. **Univ. Calif. Agri. Ext. Circ.** AXT n4.22 pages.
8. _____, and R. F. Kasmire. 1972. Ethephon response favorable on fresh market tomatoes. **California Agriculture** 26(5):3-4.
9. Villalon, B. and H. H. Bryan. 1970. Evaluation of fruit-pedicel separation of fresh market tomato varieties for mechanical harvest. **Proc. Fla. State Hort. Soc.** 83:127-130.

MECHANICAL PROPERTIES OF TOMATOES AFFECTING HARVESTING AND HANDLING DAMAGE

RICHARD C. FLUCK

IFAS Agricultural Engineering Department
Gainesville
and

DWAIN D. GULL

IFAS Vegetable Crops Department
Gainesville

Abstract. **Homestead, Walter and MH-1 tomatoes were compared in impact and slow loading and puncture tests over the full maturity range. Force generated during impact decreased with maturity, firmness decreased with maturity and puncture energy increased with maturity for the typical variety. The flesh of MH-1 retains firmness at the red stage moreso than Walter or Homestead but has an intermediate firmness at the mature green and breaker stages. Homestead was indicated to be less resistant to sand penetration when red but more resistant when mature green. Cold mature green and breaker tomatoes are firmer than warm ones and require more energy for puncture. No differences were detected in abrasion resistance between cold and warm tomatoes.**

One important factor in the selection of tomato varieties is their resistance to damage from harvesting and handling abuse. Varieties which are most resistant to damage are desired over varieties which are more likely to sustain bruises and punctures. Fruit maturity is another important variable affecting damage susceptibility.

Florida Agricultural Experiment Stations Journal Series No. 4607.

As noted by Mohsenin (9) research on resistance of tomatoes to mechanical damage has been somewhat limited. Hamson (6), in reporting the development of the Cornell Pressure Tester, described shipping tests in which red fruit of six firm lines resisted damage better than turning fruit of two less firm lines. McColloch (8) described the internal and external bruising which results from static and impact loads and related this damage to commercial handling practices. Halsey (5) showed varietal firmness differences as measured by a primitive slow loading technique. He indicated negligible correlations of firmness and fruit weight to impact damage from drop tests.

Tomato damage resistance can be measured through the use of controlled tests which measure pertinent mechanical properties. Such measures include the response to loading at different rates and with various surfaces. This paper reports on the responses of single whole fruit of three varieties over the full range of maturities. They were subjected to slow loading between flat plates, to impact loading between flat plates and to puncturing with a small diameter probe simulating an individual grain of sand.

Materials and Methods

Homestead 24, Walter and MH-1 cv were grown during the 1971 spring season at the Horticultural Unit near Gainesville. Fruit were hand picked at the desired maturities of red, pink, breaker and green and transported to the laboratory for testing.