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CULTURAL MANAGEMENT FOR MACHINE HARVEST OF MARKET TOMATOES ON MULCHED BEDS

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Abstract. **Mechanical harvest of market tomatoes is inevitable. Considerable progress with commercial production practices in Florida has been made in the past 10 years. A significant yield improvement has occurred because of plastic mulching practices which are now used on about 90% of the Florida tomato acreage. However, some management practices that could concentrate crop maturity, increase yields and reduce mechanized harvest problems have not been implemented and are not included in most production systems.**

This paper summarizes cultural management information and implications for market tomato production on mulch covered beds for mechanical harvest. Experience may improve certain practices in the future; meanwhile, this report can be a guide to those contemplating machine harvest of market tomatoes.

Uniform plant emergence and a concentrated set of large, smooth, firm, pest free tomatoes with good flavor are important for tomato production for machine harvest. Most of these characteristics are dependent on proper cultural management of the crop as well as the choice of cultivars.

Rapid urbanization and the high value of land suited for tomato production have reduced the land area that can be devoted to tomato production in Florida. The use of plastic mulch and soil fumigation have almost precluded the practice of moving to new locations after one or two tomato crops to avoid pest problems (12, 13, 16, 20). Thus, the establishment of permanent farms has become more common as predicted in 1972 (14).

Many farmers have converted to gondolas for bulk movement of fruit from the field to the packing house. This system improved labor efficiency in the field and the packing house, reduced fruit losses from mishandled bins and allowed easy conversion to mechanical harvest. Many of the current inbred and hybrid cultivars have jointless fruit pedicles with firm, smooth fruit and other characteristics acceptable for machine harvest.

Integrated pest management (IPM) has gained acceptance by some growers who have been able to reduce amounts and costs of pesticides over the last 3 years. Weed control and fumigation practices have improved with the use of plastic mulch, more effective chemicals and proper application methods over the past 10 years.

Most sand land farmers use containerized transplants; those on rockland use plug-mix planting to obtain better plant stands, more vigorous plants and higher yields than direct seeding methods (10, 17). However, concentrated maturity is still lacking for machine harvesting. Sowing of pregerminated seeds provide a way to obtain a more uniform plant stand and a concentrated harvest maturity (12, 25).

Higher plant populations (2 rows/bed) were tried by several growers, but because of inadequate disease control this practice is not widely used currently. Poor results are attributed to heavy vine growth, excessive nitrogen and use of sprinkler irrigation. Drip irrigation, controlled release fertilizers, growth regulators, and IPM systems may result in better disease control and higher yields for machine harvest (7, 11, 21).

Mechanical vine trainers have been used infrequently in Florida, primarily due to fear of foliar disease spread. Preharvest conditioning with ethylene-producing compounds to artificially induce senescence in the plants and the preharvest cutting of vines to allow wilting before harvest have resulted in easier fruit removal and less mechanical damage on machine harvested fruit (9).

Over the past decade, growers have adopted some beneficial cultural methods that have improved production of tomatoes for machine harvest. However, other systems could be adapted or utilized more effectively to improve production and increase profits.

This paper suggests some production and handling systems that will benefit tomato growers considering machine harvest of market tomatoes.

Site selection. Inflation and high costs of establishing a farm indicate that grower control over the farming land should exist for no less than 5 years. The farm site should have good roads with moderate distances to the packing house, be away from urban sprawl, have access to electricity and telephone lines, possess high quality and quantity of irrigation water and consist of level land with uniform soil type (14).

Farm plan. Beds should be 1.7 to 2 m wide and 200 m or more long with a minimum 10 m turn space at the bed ends. Land should be leveled when possible and lateral water lines should be 15 to 25 m apart on sand land. On rockland, wells should be installed on roads parallel to beds to give good sprinkler coverage. Drip irrigation would require fewer roads and smaller pumping systems. Tomato—Pangolagrass rotation and intensive cropping systems were described in 1972 (14).

Bed preparation and fertilizer. Beds 1 to 1.2 m wide on 1.5 to 2 m bed centers should be free of stumps and rocks and other debris on the plastic mulch surface. Height of beds should be 12-20 cm on rockland and 20-25 cm on sandy soil. Beds should be flat on top.

High nitrogen fertilizer rates promote vine growth, speed maturity and retard fruit-vine separation. On sandy soils with full-bed mulch and single row tomatoes 170 to 225 kg N/ha is placed as follows: 10-7-13 (N-P-K) fertilizer at 250 kg/ha in a 75 to 100 cm wide strip on a false bed about 10 to 12 cm below the final bed surface and 18-0-21 at

800 to 1000 kg/ha in 2 narrow bands 20 to 30 cm to each side of the bed center about 3 cm deep. Soils low in phosphorus should have 500 kg/ha of superphosphate broadcast and mixed prior to bedding. Micronutrients can be added with the 10-7-13 or the superphosphate fertilizer. On rock soils incorporate 110 to 170 kg N/ha and double this rate of P and K + micronutrients. Supplemental N and K can be added if excessive rain or irrigation leach out the nutrients. If two rows per bed are used, 70-80% of the fertilizer should be incorporated in the center 30 cm of bed and the remainder incorporated in the plant rows.

If drip irrigation is used, dry N and K levels can be reduced by 30 to 40% and liquid or water soluble N-K fertilizers can be injected through the drip irrigation lines. This system allows better control of plant growth because the nutrient levels are increased as the plant requirements increase. Osmocote (15-2-17 or similar formulations) with 4 month release time can be supplemented for 50% or more of the fertilizer and may be practical in the fall when heavy rainfall might leach out regular fertilizer.

Soil fumigation and weed control. Methyl bromide-chloropicrin formulations and Vorlex at recommended rates, applied 10-15 cm deep with 3 to 4 chisels per bed before mulching are suggested fumigants for nematode, soil borne disease and weed control. Paraquat, metribuzin, chloramben and diphenamid, at recommended rates, may be used for weed control in areas between strips of plastic mulch. Paraquat should be applied to young weeds 10 to 15 cm high. The next two herbicides are for pre-emergence or early post-emergence applications and the latter for a pre-emergence spray.

Mulches. Embossed polyethylene film 1.5 to 1.8 m wide, 37.8 μm thick is suggested for sand and rockland soils. White on black film should be used in late summer and early fall (before November) plantings to reflect heat from the bed. Black mulch could be used if painted with aluminum or white latex paint after application. Black film is less expensive and could be used in plantings after early November. Timed destruct film from Canada was used effectively in the Palmetto area last year; however, the film destructed prematurely in Homestead in the fall of 1980, perhaps due to higher UV light levels in Homestead. The latter results were similar to several tests of photodegradable film conducted over the last 4 years. Low methylbromide (MB) transmission mulches have recently been developed, but no known information about its efficacy has been developed in the south Florida area.

Planting method. Transplants are used in most sandy soils. Field seeding by plug-mix on rock soils is recommended to obtain uniform germination, emergence, early growth and fairly concentrated yields. The plug-mix seeder plants in hills, cuts holes through mulch and deposits plug-mix at the proper depth (17). An excess of seed is planted and thinned by hand to 1 or 2 plants per hill. Container-grown plants are suggested for transplanting because they can withstand adverse weather conditions and give a more uniform stand and growth than bare root transplants. Transplants should not be in a lush growing condition, but they should be vigorous and stocky when transplanted.

A new seeding method, fluid drilling of pregerminated seeds, is being tested on mulched beds in Florida and South Carolina. A commercial planter (Skipper) from Canada has been evaluated for planting through plastic mulch. The machine, originally electronically controlled, was modified for mechanical planting (25). An experimental planter was developed by a local Homestead machine shop and has been tested successfully with growers in southern Florida. It has good potential for fluid drilling of pregerminated seed under Florida conditions.

Plant population. Marketable yields from once-over harvest can be increased by increasing the number of plants per ha. In some tests, highest single harvest yields were obtained with population densities in the range of 35 to 40,000 plants/ha (11). Spray coverage can be more difficult with these high plant populations. However, if nitrogen levels are not excessive, smaller plants develop without reduction in yield/unit area with no excessive increase in disease. Single-row beds with plants 40 to 50 cm apart in the row should be maintained for machine harvest on sandy soils. Two rows (35-40 cm apart) per bed with an in-row spacing of 35-45 cm is suggested for rock soils. Either 1 or 2 plants may be left in each hill.

Irrigation. Seep irrigation is used on most sandy soils for tomato production. This system uses extensive amounts of water and this method may be restricted in certain areas in the future. Sprinkler irrigation predominates in the rockland soil area. This system requires less pumping of water for the crop than the seep system, but it has a higher evaporation rate and keeps the foliage wet for long periods of time accentuating disease problems. Solid-set sprinkler systems offer good frost protection when operated properly. Drip irrigation has been shown to improve crop yields on rock soil. It utilizes 20 to 50% of the water required for seep-irrigated and sprinkler-irrigated tomatoes, respectively (11). Yields with drip irrigation on sands in south Florida have not been as good as with seep irrigation. It is an efficient system for watering crops and offers opportunities for injecting nutrients, nematacides, fungicides, growth regulators, bio-stimulants and other water soluble chemicals into the plant bed (7). Chlorine injection before filtering can eliminate clogging problems from microorganisms and organic slimes (15).

Growth regulators and bio-stimulants. Plant growth regulators and bio-stimulants applied to tomatoes have been shown to enhance plant growth, fruit size and fruit quality (1, 2). Timing of the application can be critical and adverse responses may occur if the chemical is applied at the wrong time. Favorable responses have occurred when certain chemicals have been applied during various stages of plant growth:

1. *Seed*—a) Plug-mix: humic acids derived from leonardite improved seedling growth and marketable yields (2). b) Gel: a new formulation of humic acids (Agro-lig®) is a mixture of long and short chain acids, when mixed with gel as a carrier for sowing pregerminated seeds, it has improved seedling vigor and marketable yield of tomatoes (19).
2. *Seedling*—Applications of daminozide, ethephon and an alpha keto acids mixture (AG-50Y®) to young seedlings with 2 to 4 true leaves was shown to concentrate fruit set, improve fruit size and increase marketable yields (2, 5). Graywall was reduced when daminozide and ethephon were used (5).
3. *Flowering*—Yields were increased when AG-50Y® was applied to seedlings up to first flowering; however, the greatest responses occurred when application was to the young seedling at the 2 to 4 true leaf stage. Cytex®, a product derived from seaweed and containing cytokinis, sprayed on plant at initial flowering or injected through drip irrigation lines at the same stage of development, resulted in increased yields of marketable and large fruit on rock soils (unpublished report).
4. *Fruit set*—Application of daminozide to plants with 30-40 fruit set (about 10 to 20 days preceding harvest) has resulted in flower drop from the top of the plant and increased size of remaining fruit at harvest (8). Daminozide has shown some incompat-

ability with certain copper compounds and should not be sprayed within 10 days of a copper application. Citcop® 4E was the safest copper used in conjunction with daminozide. Ethephon applied at this stage resulted in flower drop, but it also initiated ripening processes in the fruit and resulted in smaller fruit compared to untreated plants (18).

5. *Pre-harvest*—Ethephon, at low rates applied to plants and fruit 5 to 8 days before harvest when about 5% of fruit were beginning to turn pink, advanced and concentrated fruit maturity of market tomatoes. Fruit size response was inconsistent (9).

IPM. Integrated pest management is an approach to controlling pests which emphasizes minimizing crop losses by all means at the producer's disposal i.e., resistant varieties, cultural methods, biological control, and application of chemicals. An IPM program was established for Florida tomatoes in November 1976.

The program's initial objectives included: (1) the development of sampling methods to detect and estimate populations and/or severity of infestations of pests, (2) train scouts to identify pests, (3) disseminate damage level (threshold) information, (4) estimate beneficial organisms present in fields and (5) identify data gaps in the research needed to make continual improvements in integrated management technology, (6) aid in applied research carried out in response to identified needs.

The tomato IPM program was first described by Pohronezny and Waddill in 1978 (21) and later updated by Pohronezny et al. in 1980 (22). These reports contain detailed guidelines for scouts and extensive lists of pests and beneficial organisms likely to be encountered.

Some major changes in commercial practices among several growers were recorded in 1977-78 (23). Spray applications based on detailed biological information, treatment at economic threshold values only and use of insecticides with low toxicity to beneficial insects produced acceptable control of insect pests in commercial fields. Yields for IPM plots were comparable to more conventional programs and costs were reduced substantially in several cases.

Pilot programs in both the Homestead and Bradenton areas have led to establishment of private scouting companies that are now contracting with individual producers. These companies have expanded somewhat into other vegetable commodities. Acceptance by the growers to date has been very good. Perceived critical needs for the future include more extension programs for growers on interpretation of the large amounts of scouting data and an increase in private consultants who can make specific IPM recommendations.

Preharvest conditioning. Vine trainers have been used experimentally 2 to 4 weeks preceding harvest to position plants on the beds and away from the furrow. This keeps fruit off the bare soil and facilitates mechanical harvest. Pre-harvest cutting of the main stem at the ground level a few minutes to a few hours before harvest results in easier fruit removal with less bruising and mechanical damage of the fruit epidermis than fruit from unwilted plants (9). An anti-transpirant (Vaporgard®) applied to plants 10-20 days before harvest reduced water use and improved fruit size (unpublished data).

Harvesters for market tomatoes. Button-Johnson, FMC and Blackwelder harvesters have been modified for harvesting market tomatoes from plastic mulch and were brought to south Florida for grower testing in 1977, 1978 and 1979, respectively. The Button-Johnson machine was modified by adding a tomato plant cutter developed by the University of Florida and two rotating brushes which lift the plants onto the elevator as the blade severs the plant above the mulch. The brushes were added by Glade & Grove Supply Company in Homestead (24). The FMC harvester utilized a single flat disk to cut the plant above the mulch and the Blackwelder harvester used a straight sickle-bar reciprocating cutter.

All machines did a fair job of cutting the plants above the mulch; however, there were some problems with cutter height control, rocks on top of the mulch and damage to fruit by the cutter blade. A workable system for pre-cutting the plant vines above the mulch to allow wilting before harvest would eliminate the need for a cutter on the harvester and reduce damage to fruit caused by excessive removal force.

Multiple cropping. A mulch-drip system with fumigation is a sizable investment. Removing the crop from the plastic and planting another crop on the same mulch would allow a large saving, even if nutrients have to be added through the drip irrigation or through holes in the film. Pepper, eggplant, watermelon, cantaloupe, cucumber, squash and okra are a few crops that would fit a multiple cropping system (6).

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VALIDATION OF A HYPOTHESIS FOR SCOUTING AND MONITORING PESTS BASED ON CELERY GROWTH IN AN INTEGRATED CROP MANAGEMENT SYSTEM[1]

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Abstract. **Studies on the ontogeny of the celery plant,** Apium graveolens **L., indicated that organ formation during the vegetative cycle (after transplanting) has 2 distinct periods. Leaves initiated during the first half of the growing period are seldom marketable, whereas leaves initiated during the second half are marketable. It was hypothesized that in an integrated crop management system (ICM) designed to optimize yield and quality by scouting and monitoring components of the celery agroecosystem, assessment of pest dynamics should be intensified in the second half of the growing period. An 11.3 ha (28 acre) ICM field was scouted every other week in the first half of the growing period and every week in the second half. An adjacent 11.3 ha field where pesticides were applied in a more routine manner was the control field. It was established that the hypothesis was well founded. The scouting methods and intervals used adequately monitored plant growth, arthropod populations, and disease trends. The information obtained allowed decisions for satisfactory pest control. These resulted in a marketable product with U.S. No. 1 Grade, similar to that of the control field, but with production and pesticide costs substantially reduced.**

Quantifying population dynamics of pests in a celery agroecosystem is the backbone of any practical integrated crop management system on which management decisions are made. Celery is a biennial that grows vegetatively the first year, overwinters, and produces seed the second year. Commercial produce is grown in the first year. In Florida, seedlings are transplanted in the field and grown for about 12 weeks before reaching fresh market maturity. This work was concerned with the segment of growing the transplant to market maturity. Studies on the ontogeny of the plant (5, 6) indicated that most of the leaves (called also petioles) that are initiated during the first half (ca. 6 weeks) of the growing period after transplanting are senescent or seldom marketable. In this period, leaf formation is nearly constant at 2 leaves/week. Leaves initiated in the second half (ca. 7-12 weeks) are marketable, and the rate of initiation increases to 4 leaves/week near harvest (5). Celery markets require that leaves have no pest damage and present a wholesome, fresh, green appearance. For this reason, any damage or blemish during the second half is of great concern. The ICM key tactic is to manage pests with the least impact to the environment, and since the second half of the growing period is the most important, scouting and monitoring should be intensified in this period. It was hypothesized that scouting for pests could be done at intervals based on petiole development in relation to marketability of the plant. Furthermore, pest populations are likely to be about the same in adjacent fields soon after transplanting because of the continuous nature of the operation and the use of almost pest-free seedlings. Thus, weekly scouting of every other field or a field every two weeks may be sufficient during the first half of the growing period. When plants begin to bunch, which usually occurs during the second half of the growing period, the interval between inspections can be shortened to a field every week, or intensified further if required.

Materials and Methods

A section of organic soil was flooded for two months (June to August, 1979). Lettuce was planted in the fall, harvested at the beginning of winter, and followed with celery in the spring. The first block of 11.3 ha (28 acres) was the ICM field, which was transplanted to the cultivar 'Junebelle' on March 6-11, 1980. This field had a heavy weed flora on the north, east, and west ditchbanks. An adjacent control field of 11.3 ha was transplanted to 'Junebelle' on March 11-16. Each field measured ca. 762 x 140 m (2500′ x 460′) and had 762 m (½ mile) long rows from east to west.

Standard methods (4) of fertilization, irrigation, weed control, and other cultural practices were followed in both fields except when other pesticides were used. Pesticides were applied with a ground sprayer when needed in the ICM field, whereas they were applied on a more routine schedule in the control field. Heavy grass infestation occurred in about 10 rows of the north and south sides of the ICM field, which was partially controlled by hand weeding 7 weeks after transplanting. Celery plants were slightly smaller where grass infestation had been heavy. The control field did not have weeds in significant populations. Each field was harvested and processed through commercial

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