Crop Time Line for
Fresh Market Tomatoes in California

Mr. John LeBoeuf
AgriDataSensing, Inc.

March 12, 2002

Prepared for the U.S. Environmental Protection Agency
Office of Pesticide Programs
Washington, D.C.

Table of Contents

Introduction

This time line has been written to provide specific information on crop production of fresh market tomatoes in California and to give a general review of key pests and also worker activities normally expected in crop production. This time line has also been prepared to provide information to help assess worker risk and to hopefully identify benefits of pesticide applications where concerns may have arisen. Differences in crop production of bush and pole type tomatoes are identified with their associated cultural activities and pesticide applications. Methods of application of pesticides are being provided to allow insight into common practices that may vary somewhat by the five different production regions, identified in Figure 1, which have varying geographical influences and weather patterns.

Table 1 identifies the different classes of pesticides with the most commonly used materials in fresh tomato production in California. Table 2 identifies the time line of various crop events, worker activities, key pests, and typical pesticide applications for the main production regions associated with bush type, mature green tomatoes that occur in the Sacramento (Area I), San Joaquin (Area II), Salinas (Area III), and Imperial Valleys (Area V). Table 3 is similar to Table 2 but information presented here is specific to the pole type, vine ripe tomatoes produced in the South Coastal area (Area IV).

Fresh tomatoes are considerably different from processing tomatoes in varieties used, production practices, and worker and harvesting activities. This report provides information on field grown fresh tomatoes and does not cover greenhouse grown (hothouse) tomatoes, which had minimal production on two acres (5) nor does it cover processing tomatoes.

Crop Production Facts

·Depending upon which total acreage figures are used for comparison, California usually ranks second in the nation, behind Florida, in production of fresh market tomatoes. Acreage plantings for the year 2000 from the USDA National Agricultural Statistics Summary show California ranked number one with 42,800 acres which is slightly ahead of Florida's 42,000 planted acres (23).
·In the U.S., approximately 35.5% of fresh market tomatoes are grown in California (23).
·In 2000, fresh market tomatoes ranked twenty-second in value among all California agricultural commodities (17).
· The County Agricultural Commissioners's Data show California with 38,650 harvested acres in 2000 with a total of 584,707 tons of fresh market tomatoes. The average yield was 30,300 pounds (15.15 tons) per acre (5).
·The average price paid for packed and loaded fresh tomato in 2000 was $0.23 per pound. The total cash value of the 2000 crop was $269,782,600 (5). This would equate to an average cash value (gross) of $6,980 per acre.

·It should be noted that the fresh market tomato industry is extremely competitive as production and marketing involve a highly perishable commodity with approximately 15% exported to Canada, Japan, and Mexico. Approximately 60% of the mature green tomato crop is marketed west of the Mississippi River with the other 25% sold east of the river (7).

The tomato plant, *Lycopersicon esculentum*, is a warm season annual plant that has been cultivated with hybrid varieties dominating the market. Tomatoes belong to the botanical family Solanaceae and thus, some newer technical references will show *Solanum lycopersicum* as the genus species name. The bush type tomato has a determinate growth habit that is harvested usually in one pick but may be picked a second time if market conditions are favorable. The majority of bush varieties are round types with less acreage of Roma types. The pole (or stake) type tomato has an indeterminate growth habit that allows multiple harvests of pink fruit stage tomatoes that are marketed as vine ripe (7). Almost all fresh tomato fields are brought into production with transplants instead of direct seeding. Speciality tomatoes for small niche markets include cherry, heirloom, and greenhouse cluster tomatoes with the calyx still attached (3).

Production Regions

The main fresh market tomato-growing areas in California are shown in Figure 1 on page five (10). Area I located in the northern San Joaquin Valley and lower Sacramento Valley grows approximately 60% of the state's fresh market tomatoes—mostly produced in Merced, San Joaquin, and Stanislaus counties with minor plantings in Sacramento, Santa Clara, and Contra Costa counties (5). Nearly all the fresh market tomatoes produced in this area are from bush varieties. Planting of fresh market tomatoes is from February to June with harvest from mid-July to late October. Production in this area has increased from 1998 as 45% of the state's acreage was produced in this region in 1998 (22). Rainfall varies from about 26 inches per year in the Sacramento Valley to about 16 inches per year in Modesto in the northern San Joaquin Valley (2).

Area II, the southern San Joaquin Valley produces about 27% of the fresh market tomatoes. Production of bush type tomatoes occurs in Fresno, Kern, Kings, and Tulare counties. Fresh market tomatoes are planted from February to June with a harvest period from mid-June into late October. Production in this area has slightly decreased from 1998 as 30% of the state's acreage was produced in this region in 1998 (10). Fresno County also produced 47% (170 acres) of the state's cherry tomato crop of 363 acres which is pole type (5). Fresno receives about 10 inches of rainfall per year while Kern County can receive about three inches per year (2). Furrow irrigation is very common in Areas I, II, and III, though there is some subsurface drip irrigation.

Area III, the Central Coast, produces about 3% of the state's fresh market tomatoes. The planting period is from March to May and harvest occurs from August to October. Production occurs in Monterey and San Benito counties. Production in this area has decreased from 1998 as 10% of the state's acreage was produced in this region in 1998 (10). Monterey County produced 9% (31 acres) of the state's cherry tomato crop (5). Average rainfall is 20 inches per year (2).

Area IV, the South Coastal area, grows about 9% of the state's fresh market tomatoes. Spring pole tomatoes are planted from mid-January through March and picked from May through July. Summer crops are planted from March through May and harvested from July to October. The fall

crops of fresh market tomatoes are planted in June and July and harvested from September to December. Production mainly occurs in San Diego and Orange counties. This area produced approximately 10% of the state's 1998 fresh crop, so acreage has remained stable. San Diego County produced 27% of the cherry tomato crop (5). Surface drip irrigation is utilized across the rolling terrain. Typical rainfall amounts are 11-12 inches per year (2).

Area V, the Imperial Valley, grows about 1% of the state's fresh market tomatoes with production centered in Imperial County. Planting starts in January and goes to March, with harvests from May into June. Production in this area has decreased from 1998 as about 5% of the state's acreage was produced in this region in 1998. This area produces bush type tomatoes with less than four inches of rainfall per year (2). Furrow irrigation is used though there may occasionally be drip.

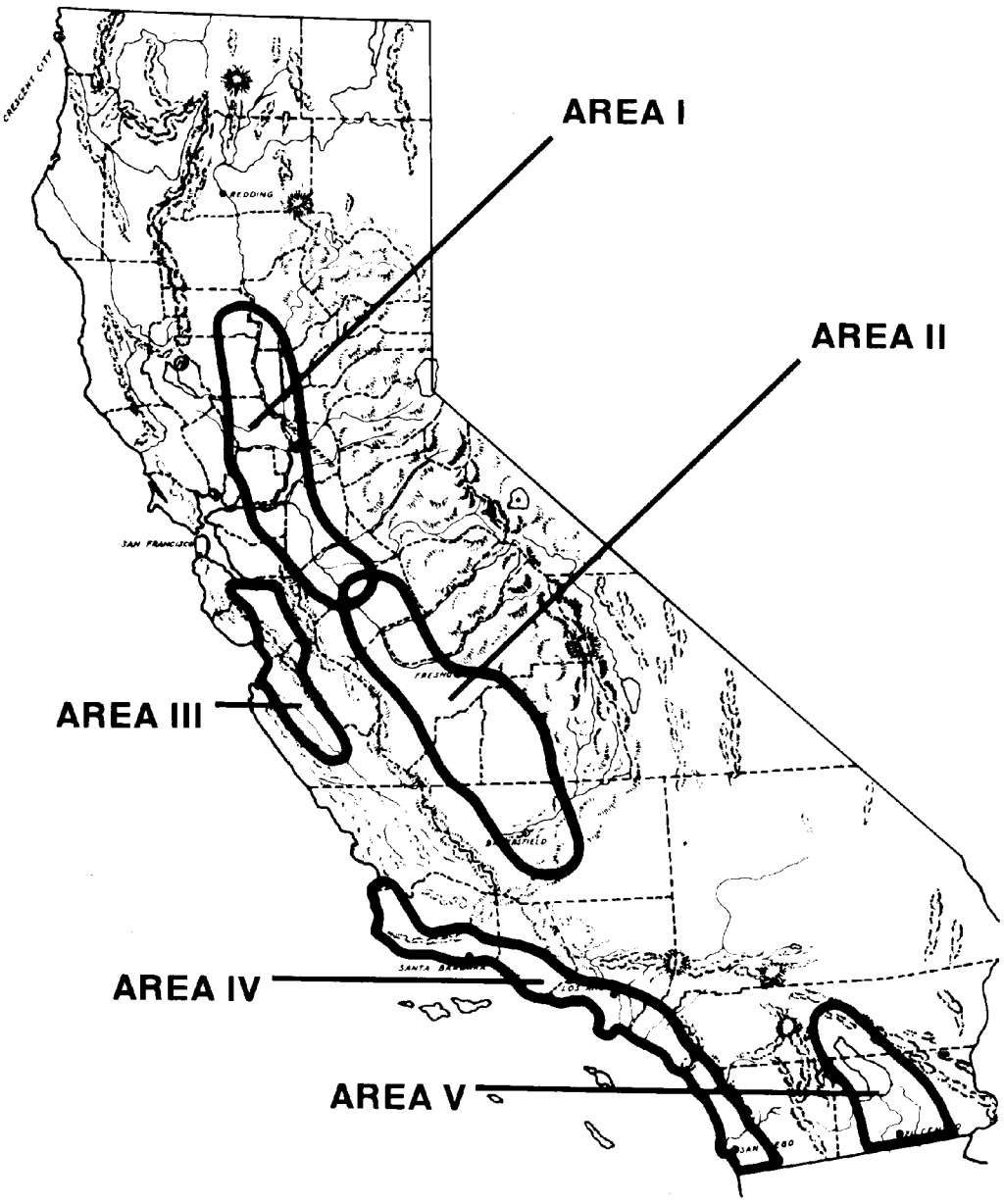


Figure 1. Major tomato producing areas in California (10).

Worker Activities

Land preparation is the first step before planting tomatoes. Almost all bush tomatoes are planted on raised beds in California. This facilitates cultivation and irrigation of the tomato crop, as well as improving drainage, which minimizes root diseases. Land preparation consists of discing, chiseling and subsoiling to break up compacted layers and triplane leveling for proper grading (particularly if furrow irrigation is used). Listing of beds, cultivating and bed shaping for final bed preparation usually is done in the November of the year that precedes planting (15). Tomato beds are most often 60 inches wide. Fallow bed herbicide treatments of oxyfluorfen or metribuzin by ground rig or aerial applications are sometimes used to prevent winter weed growth, and allow early spring tomato planting (22). Spray applications made by ground rigs, with a preplant herbicide such as trifluralin, followed by incorporation into the soil is common prior to three row transplanting in the spring.

Land preparation for pole tomatoes differs in that stakes and plastic row covers are used for temperature control with mid-January to February transplants in Area IV. Wooden stakes are set into the ground every two to three plants up the row with an average plant spacing of 18-20 inches. An apical wire is then stapled to the stakes and anchored at the row ends. Black plastic is used to form half tent like structures around the plants to absorb solar radiation. Sometimes methyl bromide is used after drip systems and plastic mulch is in place but always prior to transplanting. Less than 5% of the entire state's fresh tomato acreage was treated with methyl bromide in 2000 (16).

Planting Method differs by tomato type and the slope of the terrain. About 98% of the fresh market tomatoes are transplanted. Transplanting provides the tomato plants a head start on weeds and reduces stand establishment problems. However, transplants have a weaker taproot and more secondary roots than do direct seeded tomatoes. Transplants are also more subject to virus problems (10). The use of transplants has eliminated the thinning of plants from direct seeding. There are two ways that transplanting occurs. Tractors pull the transplanting rigs with workers handling the plants and placing one plant into precut openings by hand when plastic mulch is used. If plastic mulch is not used, then the machinery lifts plants out of transplant rack and places an individual plant into the field. Generally, there are 6 people on a machine covering 3 rows. The workers alternate placing the individual plants into the field (2 people per row alternate for each plant). Most growers order transplants from commercial greenhouses but some of the larger and vertically integrated operations grow their own transplants. The average field size would be in the range of 50-60 acres as growers stagger their plantings so as to avoid too much produce ripening at any one time so although the tomato fields may be much larger, only part of the field is utilized at one time. This also gives them access to a longer period in the marketplace where prices can fluctuate with supply and demand.

Tomatoes may be direct seeded in one row per bed. Single rows are easier to cultivate and are used to reduce weeding costs. Growers frequently use a high seeding rate when planting in a single row to ensure a good stand. Several weeks after tomato seed emergence, a hand labor crew would be sent in to thin the stand around the third true leaf stage (7).

Pruning/Tying/Staking is only performed with pole tomatoes. Bush type tomato characteristics include a self pruning growth style (10). Workers prune pole plants to one shoot below the first flower cluster and then tie plants between stakes with twine in one-foot intervals of plant growth up the stake. Depending on the slope of the field and the depth and quality of the soil, plants can be tied anywhere from four to six times per season as the plant height will vary from four to six feet high (8). As the plants grow taller, workers add another layer of twine to the stake. Tying would be performed during the first 80 days of plant growth and finish prior to first harvest. Pruning is usually performed three times per crop with staking only once.
Tying activities are performed during the dry times of the day in late morning or early afternoon to increase pollination and fruit sets as tying vibrates the plant and flowers and is aimed at the time when pollen is less sticky (7). This means that work crews don't typically work with wet foliage. A typical work day of eight hours for these activities would cover one to two acres per day (8). The number of people in a work crew varies.

Cultivation of tomato beds is usually performed two to three times per crop by tractor pulled implements. This is usually followed by hand weeding crews two to three times per season on immature plants prior to full canopy. Weed crews would work on approximately 10 acres per day.

Fertilization also varies between bush and pole types. Bush tomatoes grown on furrow irrigated fields would be side dressed by tractors with shanks into the sides of the beds once or twice with nitrogen fertilizers. This field operation would typically follow a cultivation for weed control and a thinning crew if direct seeded so this activity is performed several weeks before full canopy. Pole tomatoes would receive fertilizers through drip systems with an average of about 10 pounds of nitrogen per week.

Irrigation is used for all California tomatoes. Furrow irrigation is commonly used in California tomatoes. Proper grading is critical for good drainage and for reducing disease levels. Furrows must be maintained throughout the season to avoid flooding the tops of beds due to an increase in weed emergence and the risk of fruit diseases. Furrow irrigation is commonly performed every seven to 14 days depending upon weather conditions as deep and infrequent irrigations are preferred for the relatively deep root system. Workers can use siphon tubes or plastic liners to move water from ditches along the perimeter of the field into each row. This method would take several days to irrigate all rows in a field with the worker staying along the outsides of the field. Sprinkler irrigation with movable lines can be used to germinate a direct seeded crop. Sprinklers are rarely used after fruit set, as the use of sprinklers increases fruit diseases, such as early blight, late blight, bacterial speck and spot, and molds. If speck and spot plant diseases show up, copper sprays would be utilized for pathogen control. Drip irrigation is used on all of the pole tomatoes. Drip irrigation provides for good water management and allows hand harvesting at regular intervals. Subsurface drip irrigation is used on some bush tomatoes but this method should not be used when salty soils are encountered. By maintaining a dry bed surface during the summer growing season, weed emergence and water use is reduced. Damage from coyotes chewing on drip irrigation equipment is frequently encountered and adds to maintenance and repair costs. Workers may check on drip irrigation systems throughout the growing cycle and many ride on all terrain vehicles to cover fields quickly. They are not in contact with foliage as they ride up and down rows and the only direct contact would be if a repair was needed.

Scouting of both bush and pole type tomatoes occurs across the entire season with all stages of plant growth checked for pests twice a week due to the high value of the commodity. Scouts would be expected to cover 40-50 acres per hour (8). Pest Control Advisers (PCAs) are either independent and self employed, work for a chemical supplier or a private pest control business, or work in-house for a grower/packer/shipper with the industry split into an approximate equal number in each category. Independent PCAs tend to specialize in several crops and frequently would contract for services with several tomato growers. Independent PCAs may have seasonal workers, many of them college students majoring in agriculture, help them in scouting of fields. Individual growers and also Ag chemical suppliers do not hire nearly as many seasonal scouts as the independent PCAs (Personal experience).

Harvest of bush tomatoes is by hand crews who pick fruit into buckets which are emptied into bins or gondolas for transport from the field into the packing shed. Most bush tomato fields are only picked once with fruit picked at about 10% red fruit to maximize the amount of green mature fruit. A second pick may be performed if market conditions are very favorable. At the packing shed, fruit is then rinsed, sorted, and graded into bulk packages of 25 pound cartons. Harvest of pole tomatoes is also by hand crews who pick fruit into lug boxes between breaker and pink color stages with typical harvests one to three times a week across a period of approximately 70-90 days for the early plantings in Area IV. This harvest period can then last anywhere from 90-120 days for the Fall crop if conditions allow for favorable picks. In recent years, insect and plant disease pressure have increased and this harvest period for some fields has been cut down to about 30-60 days with hand harvest every two to three days. There are no mechanical harvesters for fresh market tomatoes in California at this point in time, although growers have expressed interest in mechanical harvesters to lower labor costs (3).

Postharvest activities involve washing of tomato fruit in wash or dump tanks where chlorine is added to water which is slightly warmer in temperature than the product in order to prevent water uptake and also entry of decay-causing organisms (14). Washing is performed prior to sorting and packing operations. After packing, most bush type mature green tomatoes are held in a storage facility for ethylene treatment (100 ppm) for 24-72 hours at 68 degrees Fahrenheit (20 degrees Celsius) (14). If color development is not uniform after this ethylene treatment, tomatoes can be re-packed in the shed. Food grade wax may be applied to tomatoes to replace naturally, occurring waxes removed in the washing and cleaning operations, while also improving appearance and reducing water loss (13).

Forced air cooling is used on vine ripe tomatoes and also with cherry tomatoes. The air temperature is usually no lower than 50 degrees Fahrenheit (10 degrees C).

Pesticides

The most common pesticides applied to fresh market tomatoes during 2000 are listed below in Table 1. Not all materials would necessarily be used on a single crop.

Table 1. Pesticides Typically Used in Fresh Market Tomatoes, 2000.

Insecticides	Fungicides	Herbicides
Methomyl	Chlorothalonil	Glyphosate
Bt (Bacillus thuringiensis)	Sulfur	Oxyfluorfen
Esfenvalerate	Azoxystrobin	Trifluralin
Dimethoate	Mancozeb	Metribuzin
Imidacloprid	Copper hydroxide	
Methamidophos	Ziram	
Spinosad	Propamocarb hydroxide	

Source: USDA Agricultural Chemical Usage, Vegetables Summary. July 2000.

Insecticides are used on about 79% of all fresh tomatoes grown in California compared to 87% of the total US fresh tomato crop (1). Treatments are applied to the tomato foliage after crop emergence with most sprays made to protect the crop after about one inch size fruit. Fresh market tomatoes receive an average of three insecticide treatments (18). The primary pests targeted by these treatments include stink bugs, beet armyworm, tomato fruitworm, aphids, whiteflies, thrips, and leafminers (10). A search of the 2000 database for methamidophos applications showed that 62% of applications in the state of California were made by aerial applicators with the other 38% made by ground rigs (19). These statistics may be indicative of other insecticide applications but it certainly cannot be guaranteed for systemic materials that may be applied through drip irrigation systems. Contact materials usually require excellent coverage for effective control and ground rigs are preferred up until water runs in furrows, which prevents tractors from entering fields. Most aerial applications are made by fixed wing aircraft with closed cockpits as helicopters are used by fewer pilots and pest control operations in row crop production. Typical tank mixes for aerial applications would use 5-10 gallons per acre while ground rigs would use about 25-40 gallons per acre for a full canopy application. Ground rigs with electrostatic sprayers are used in the desert region for whitefly control as coverage of the underside of leaves is crucial.

Fungicides are used on approximately 74% of the fresh market tomatoes grown in California compared to 86% of the total US fresh tomato crop (1). Fresh market tomatoes generally receive 1.5 to two fungicide treatments per year (18), with the majority applied as foliar treatments. The major disease organisms targeted by these treatments include late blight, powdery mildew, *Phytophthora* root rot, black mold and *Botrytis* grey mold, bacterial speck and spot (10).

Herbicides are used for weed control on 56% of the tomatoes grown in California compared to 63% of the total US fresh tomato crop (1). Typically, a preplant or preemergence herbicide application of Trifluralin is made on a six to 10-inch band centered on the seed line (22). The area outside this seed line is cultivated to control weeds up to the time of layby. Layby is considered the last stage of tomato growth when cultivation equipment can still be used; tomatoes are five to 10 inches tall at layby. At layby, a preemergence herbicide is often applied to the area outside the seed line to control late emerging weeds, when cultivation can no longer be used (22).

The **Plant Growth Regulator** Ethephon (Ethrel) is sometimes used to hasten or accelerate fruit ripening to increase early yields of mature green tomatoes. Ethephon generates ethylene that

promotes earlier coloration and maturity of tomatoes thereby providing for a more efficient harvest as only a single pick can be expected from treated areas. This limits its use as Ethephon will not ripen immature green fruit. About 5% of the acreage is treated with Ethephon each year (16).

Insect Pests

Numerous insect pests attack tomatoes in all of the growing regions of the state and can occur at damaging levels most seasons. The insect pests can be divided into fruit and foliage pests such as true bugs and lepidopterous larvae, other foliage pests such as aphids and leafminers, and seedling pests such as wireworms, cutworms, and garden centipedes.

Stink bugs Consperse stink bug (*Euschistus conspersus*), Southern stink bug (*Nezara viridula), Says stink bug (Chlorochroa sayi),*and several other species are a serious threat to fresh market tomatoes, especially in the Merced region of Area I. Many PCAs and growers consider them as the hardest insect species to control when populations threaten tomato fruit by inserting their mouthparts during feeding and secreting digestive fluids. In addition to secretions, foreign substances such as bacteria and yeast can be carried on the piercing and sucking mouthparts of stink bugs and inserted into tomato fruit, causing rapid decay. The various species of stink bugs are all similar in life cycles and all cause the same type of crop damage. The Consperse stink bug is the most common species in California and is the most important species in the Sacramento and northern San Joaquin valleys which also has the southern green stink bug that has been fairly well controlled by an imported parasite. Say's and Uhler's stink bugs are commonly found on the West Side of the San Joaquin Valley. Treatment for stink bugs is usually necessary due to the very low threshold for damage. There are two generations of stink bugs per year with most of the fruit damage coming from offspring from the migrating adults (10). PCAs consider methamidophos to be the best pesticide for stink bug control since waterway restrictions prevent users from choosing endosulfan for most applications. Stink bugs may hide in soil cracks and therefore contact materials such as insecticidal soaps have been ineffective (22). Pheromone trapping can be used in field monitoring to detect migrations of Consperse stink bug into tomato fields. PCAs report poor results with the use of pheromone traps in mixed species populations. Some biological control of stink bugs takes place in tomato fields from several parasites. Cost surveys by Zalom (UC Davis) indicate available commercial parasites for augmentative releases are not economically feasible (22).

Tomato Fruitworm (Helicoverpa zea), formerly Heliothis, is a major threat as the larvae attack when fruit size increases to about one inch in diameter(10). Some biological control of tomato fruitworm takes place in tomato fields from several parasites (9). Attempts to augment the natural predator and parasite complex with inundative releases of beneficial insects and parasites such as *Trichogramma pretiosum,* for lepidopterous larval control has been very limited in scope and success. *Bacillus thuringiensis* (Bt) is oftentimes used in a tank mix, with a contact material such as methomyl, if larger-sized larval instars are present, as the material is most effective against small worms. Frequent applications are usually needed to time the pesticide when the pest is most vulnerable in the smaller instar stage. Organic tomato growers report that Bts are very important in their production fields as alternatives approved for organic production are limited. Methomyl is considered a very effective worm killer but it has been suggested that methomyl applications have

been responsible for causing *Liriomyza* leafminer and also pinworm outbreaks so this compound is used judiciously.

Cabbage looper (*Trichoplusia* ni) has become a problem in some tomato production areas, especially in the San Joaquin Valley. Absence of long killing frosts and broad overlap of tomato planting dates and numerous other vegetable host crops may be helping a pest population buildup. Small instar larvae will chew on the bottom sides of tomato leaves. Larger sized cabbage loopers are a threat as the worms chew on mature tomato fruit. Very few PCAs reported the use of pheromone traps for the monitoring of the pest though there is an effective pheromone attractant available for use (22). Some biological control of the cabbage looper takes place from several parasites (20). Attempts to augment the natural predator and parasite complex with releases of beneficial insects and parasites for lepidopterous larval control have been very limited in scope and success (12). Chemical control may include a tank mix of Bt (such as Dipel) with a contact material such as methomyl, if larger-sized larval instars are present, as the Bt material is most effective against small worms (6). Spinosad (Success) is a compound that has been increasingly relied upon since its California registration in 1998 (12). Endosulfa**n** is seldom used in furrow irrigated fields, since the 300 foot buffer restrictions are in place for applications with drainage into waterways and it does have restrictions regarding its use when irrigation water is running in the field. This restriction especially impacts Merced, San Joaquin, and Sacramento growing regions. Endosulfan is an excellent material that has activity against looper larvae and adult moths.

Tomato Pinworm (*Keiferia lycopersicella*) can become a problem in some production regions, especially in cherry tomato fields (10). Pest Control Advisers have reported that pinworms have been showing up in greater numbers the last few years compared to an occasional sighting of the pest in the past. Absence of long killing frosts and broad overlap of tomato crop planting dates combined with poor postharvest sanitation may be helping a pest population buildup. Some growers believe that there is a cyclical pattern to the pinworm's presence. Many PCAs reported the use of pheromone traps for the monitoring of the pest (22). Mating disruptants (NoMate fibers or Checkmate dispensers) are used as pheromone confusion for the adult moths but careful timing is necessary to achieve control. This control strategy is preferred over pesticide applications when release timing is coordinated with pheromone trap data. Abamectin **(**Agri-mek**)** controls tomato pinworm, russet and spider mites, and leafminers.

Beet armyworm (*Spodoptera exigua*) and Western yellow striped armyworm (*Spodtera praefica* and *S. ornithogalli*) are three species that attack tomato fruit. Beet armyworm is a pest in most years whereas the yellow striped armyworm can become an occasional problem. Pest monitoring becomes crucial as tomato fruit size increases to about one inch in diameter. Bts were generally not regarded as effective control chemicals by growers and PCAs involved in conventional fields as the timing of applications based on a larval instar stage is crucial in timing the pesticide to the stage of growth where the pest is most vulnerable. Armyworms are susceptible in the first three instars, making correct timing difficult and frequent applications costly (20). Coverage is critical and aerial application is often not adequate for stand alone control. Organic tomato growers report that Bts (Xentari) are very important in their production fields, as alternatives approved for organic production are limited (12). Some biological control of beet armyworm takes place in tomato fields from several parasites and a viral disease called nuclear polyhedrosis (20).

Hyposoter exiguae is a parasitoid on beet armyworms (10). This wasp can reduce armyworm populations if pesticide use is kept at a minimum, as the natural predator and parasitoid complex will be reduced by applications. *Trichogramma pretiosum*, a parasite on lepidopteran eggs, is available from commercial insectaries for augmentative and inundative releases of eggs. The parasite is generally not as effective against armyworms as they are against fruitworms due to the protective scales on the armyworm egg mass (10).

Silverleaf Whitefly (*Bemisia argentifolii*), Sweetpotato whitefly (*Bemisia tabaci*) and Greenhouse whitefly (*Trialeurodes vaporariorum*) can attack tomato crops, especially in Areas IV and V. Whitefly eggs and early instar nymphs are difficult to identify without the use of a hand lens as they are small insects (1.5 mm). Whiteflies typically colonize the undersides of tomato leaves where the eggs are laid. Whitefly nymphs feed on plant sap with sucking mouthparts. Whiteflies excrete copious amounts of a sticky substance called honeydew, which acts as a suitable substrate for the development of black, sooty mold. This leads to unmarketable fruit. Whitefly populations have inflicted serious crop losses in the past in the southern desert growing region to numerous crops which led to a reduction in planted vegetable acres. The pest can move to tomatoes in the spring but detrimental populations usually don't arise until later in the summer after the spring tomato crop has been harvested. Several species of parasites and predators offer effective biological control of low populations of whiteflies. Several species of ladybird beetles, including *Delphastus pusillus*, prey upon whiteflies. *Encarsia* and *Eretmocerus* wasp species parasitize some species of whiteflies but cannot be expected to control silverleaf whitefly populations in most situations. Greenhouse whiteflies have been increasing in numbers in Area IV and also in tomato production fields in Baja California (9). Efforts are made to reduce pest resistance by including insecticides like Esfenvalerate or materials of a different chemistry in a combination spray. Imidacloprid is a systemic material that works very well as a preventive for low populations and it may be applied in drip irrigation (6). Insecticidal Soap as a pesticide is a direct contact material that has adequate activity against nymphs but it is not very effective against adults (22). Complete foliage coverage is critical and is not easily achieved. Oxamyl is a systemic carbamate used postplant - if drip irrigation is used, this material can be injected into the irrigation system.

Hornworms (*Manduca quinquemaculata)*are rarely encountered in sufficient numbers to become a problem in production fields as sprays aimed at more damaging moth species such as armyworms or fruitworms control them (22). Hornworms are more common in home gardens.

Potato aphid (*Macrosiphum euphorbiae)*represents a species that has been previously viewed as a minor pest that has been showing up on a regular basis every year. This species is heat tolerant and effectively establishes itself on several tomato varieties. Some varieties tolerate or suppress aphid populations. A combination of native biological control organisms and chemical controls targeted for other pests can often keep this pest from flaring up. Another aphid species that is of concern to tomato growers is the green peach aphid (*Myzus persicae)*which rarely requires chemical control. The major threat is from virus diseases that the aphids vector. Aphids have sucking mouthparts that pierce the plant tissue during feeding. Systemic insecticides have been effective in control. Insecticidal soap is a direct contact material and thorough coverage is necessary. Ground application is needed but not often available due to irrigation schedules. The material has adequate activity against nymphs but it is not very effective against adults.

Tomato (and Potato) Psyllid, *(Paratrioza cockerelli)* is a new pest that has entered the Area IV production region as well as Baja California fields of Mexican growers. It can be very damaging to tomato crops as it inflicted severe losses to numerous growers in 2001 (9). The pest reproduces and feeds on the underside of leaves. Research is needed to identify proper control strategies (3).

Leafminers *(Liriomyza trifolii, L. sativa, and L. huidobrensis)*are small dipteran flies, 1.5 mm (0.06 inches) long, which can cause considerable damage to tomato leaves. Adult females lay their eggs in leaf tissue. Larvae emerge inside the leaves and mine their way in narrow tunnels between the lower and upper leaf surfaces. As the larvae grow, the width of the tunnels increases. Leaves may dry out and yields can be reduced in moderate infestations. Under heavy pest pressure, plants may die and entire fields can be lost if not correctly protected with insecticides. Growers are aware that it is important to try and preserve the beneficial predator and parasite complex present in a field. *Diglyphus*, a parasitic wasp, can be effective in biological control of leafminers if they are not removed from the fields from pesticide applications (20). Systemic insecticides such as oxamyl have effectively controlled leafminers. Ground rig applications usually provide better coverage and are preferred to aerial applications. Successive treatments of the same class of insecticide should be avoided as repeated applications of the same material can lead to pest resistance. Therefore, materials of different chemistries are utilized by growers if multiple applications are needed for adequate control. Abamectin controls tomato pinworm, russet and spider mites, and also leafminers. Cyromazine (Trigard) is an insect growth regulator that offers effective control of leafminers if applied at the proper time before pest populations get out of control.

Flea beetles (*Epitrix hirtipennis)* and a few other species can damage tomato seedlings as they chew holes in the leaves and stems thereby reducing photosynthetic leaf surfaces. Stems damaged during pest feeding may lead to plants falling over and reducing an overall plant stand. Flea beetles are usually only a problem on early spring plantings. The pest has been known to overwinter on various weed species or in tomato crop residues. Damage to seedlings may be more severe when tomatoes are not rotated with non host crops. Crop rotation becomes a manageable factor in reducing pest populations. Carbaryl (Sevin Bait) is an excellent insecticide that controls flea beetles and numerous other insect species such as darkling ground beetles, cutworms, earwigs, and crickets. Bait can be placed out around the perimeter of a field, be applied by ground rigs or by aircraft.

Black cutworms *(Agrotis ipsilon)* and variegated cutworms (*Peridroma saucia)* can become problems during seed germination and emergence and can attack transplants. Black cutworms and variegated cutworms are larvae of the Noctuid family of moths. Large cutworm larvae about 3.7 cm (1.5 inches) long can be found in debris in the top soil of fields. Cutworms cut off plants at the soil surface and can reduce stands. Management strategy is to avoid planting into fields with plant residues or fields coming out of pastures if adequate time has not been provided to allow for breakdown and decomposition of organic debris (22). Carbaryl controls cutworms, flea beetles and numerous other insect species such as darkling ground beetles, earwigs, and crickets. Bait can be placed out around the perimeter of a field, be applied by ground rigs or by aircraft. When large numbers of cutworms are encountered in a tomato field, Permethrin (Pounce 3.2 EC) can be applied by ground or aerial applicators.

Mite Pests

Tomato russet mites *(Aculops lycopersici)*have eight legs and therefore are not insects which have six legs. Mites are very small and are difficult to see with the naked eye. Mites feed on the stems and leaves of tomato plants. Leaves infested with mites develop a greasy appearance, curl upwards, dry out, and then become bronze in color. Mite damage is most severe in hot weather when environmental conditions favor the pest and quicken the pace of the life cycle. Tomato russet mites can infect tomato transplants in the greenhouse but most often blows into a field from neighboring areas. Mites can overwinter on weeds such as field bindweed (10, 20). Fields are monitored for bronzing on lower leaves and treatments are initiated when crop damage begins to spread (12). There are no effective nonchemical controls for tomato russet mites (20). Spider mites are usually not a problem in fresh tomato fields. Sulfur dust or wettable powder formulations are commonly used for powdery mildew control and suppression of mites too. Aerial operators make most applications at nighttime as sulfur has a fire hazard associated with air temperatures above 90 degrees Fahrenheit. Dusting sulfur is the cheapest agricultural chemical available, is considered beneficial to the soil as an amendment to offset high alkalinity, and is acceptable in organic crop production. Dicofol and abamectin are the other miticides used for chemical control. Growers can also control spider mite populations by keeping roadways around fields watered down to limit dust movement onto the plant canopy.

Diseases

Tomato production can be impacted by numerous biotic diseases caused by plant pathogens as well as abiotic diseases caused by stress from environmental factors or from toxic substance exposure (e.g., ozone injury). Biotic diseases represent the most serious threat to tomatoes. Plant pathogens can be soil borne or air borne and consist of bacteria, fungi, and viruses. Irrigation management plays an important role in reducing the threat from some plant diseases. The method of irrigation can influence environmental conditions necessary for disease occurrence or enhance conditions needed for disease expression of foliage and fruit diseases.

Late Blight (*Phytophthora infestans)* is considered by many fresh market tomato growers as the most serious plant disease that threatens tomatoes grown in all California production regions due to the potential for rapid spread. Often considered a fall disease, the pathogen hits areas which are characterized by poor air circulation and periods of overcast conditions during or just after irrigation intervals (22). The pathogen is highly dependent on free water, allowing for some management by irrigation reduction. Growers are unable to greatly reduce irrigations as yield and quality would be impacted. Early to mid-season planting dates will also reduce probability of blight, but both fresh and processed industries rely on long production periods to maximize packing and processing facilities.

Disease forecasting has recently focused upon site-specific information from weather stations placed in tomato fields aimed at using disease risk models to monitor environmental conditions such as air temperature, relative humidity, wind speed, precipitation, and leaf wetness. Growers and PCAs use fungicides in rotations and commonly use several materials across unsettled rainy periods when environmental conditions of mild temperatures and high humidity are present.

Chemical control of late blight is geared toward preventive sprays as there are no curative fungicides available (20). Chlorothalonil, Mancozeb, and Azoxystrobin are used in foliar sprays in a preventive program in rotation with propamocarb hydrochloride (Previcur Flex - Section 18 in 2001). Sulfur and copper fungicides are used in organic fresh market tomato production. Copper has been shown to suppress late blight whereas sulfur offers no effective control of late blight.

Powdery Mildew (*Leveillula taurica, Oidiopsis taurica,* and *Oidium neolycopersici)*is a disease that is expressed when the crop is stressed by environmental factors such as high temperature combined with poor soils, salts, and irrigation problems. Oidium is the newest species to show up in California (11). The disease can appear in most tomato production regions of California (12). Disease development is favored by high relative humidity associated with mild air temperatures. High daytime air temperatures favor disease expression and damage. Crop damage is primarily sunburn and resulting cull fruit or secondary mold on sunburned fruit. Best growing practices aimed at minimizing plant stress are suggested to reduce impact from the powdery mildew pathogen. Sulfur (either dusting or wettable) has been one of the standard fungicides used as multiple preventive applications are usually required if favorable environmental conditions occur. Aerial operators make most applications of sulfur with Azoxystrobin commonly used in rotation.

Black Mold (*Alternaria alternata)* is a disease of ripe tomato fruit that appears in the field after rain or periods of heavy dew. Fungal spores need three to five hours of wetness to germinate. After germination, the spores can infect fruit by directly penetrating the epidermis of senesced fruit. A crop can be heavily damaged within four to five days following a period of rain and high humidity. The fungus also readily colonizes any wounds on the fruit, including sunburned areas. Growers can reduce black mold by avoiding use of overhead irrigation late in the season and by keeping planted beds dry. Delays in harvest increase both the level of senesced fruit and the chance of exposure to rain, dew, or the incidence of black mold. Fungicides are used in a foliar spray in a preventive program in rotation with mancozeb, chlothalonil**,** and propamocarb hydrochloride (22)**.**

Bacterial speck (*Psuedomonas syringae)* survives in soil, in debris from diseased plants, and on seeds. Infection is favored by cool, moist weather and is spread by splashing rain or sprinkler irrigation onto small plants with three to five leaves (10). Disease progress is stopped during hot weather. In severe cases, infected plants are stunted, which may result in a delay in fruit maturity and yield reduction. Delay of planting in spring to avoid exposing tomatoes to cool, wet conditions is effective but not feasible for growers with early season contracts. Changing from overhead to furrow irrigation helps but this option is oftentimes not available (22). Use of resistant varieties is effective against most, but not all, isolates and resistant isolates are increasing (20). Growers can reduce pathogen incidences by not planting in a field previously planted to tomatoes. Copper-containing bactericides offer fair to partial disease control. Applications should be made at first signs of disease pressure and repeated to keep new foliage covered ahead of cool and moist environmental conditions. Copper is strictly a protectant material and must be applied before an infection period occurs. The addition of mancozeb increases the efficacy of copper.

Tomato Spotted Wilt Virus is transmitted by the western flower thrips, *Frankliniella occidentalis,* and several other thrips species. Spotted wilt virus is a major problem in Area IV and recently has been impacting on production in Area II (12). The virus has a host range that covers both dicots

and monocots. Growers have reported a difficult battle with the western flower thrips. Mild pesticides, such as Neemix and Success, are used in attempts to stay away from pesticides such as methomyl and oxamyl which would create problems in IPM programs trying to spare the natural predator and parasite complex. Some growers rogue out infected plants to prevent pathogen spread (9). Chemical sprays are targeted at controlling the thrips and systemic materials such as imidachloprid has been used as there are no other pesticide applications available for control.

Weeds

The most common weeds infesting California tomatoes are black nightshade (*Solanum nigrum),* hairy nightshade (*S. sarrachoides*), field bindweed (*Convolvulus arvensis)* which is commonly referred to as perennial morningglory, yellow nutsedge (*Cyperus esculentus),* purple nutsedge (*C. rotundus),* and dodder (*Cuscuta spp.)* as they are the most difficult to manage, as most registered herbicides are ineffective and thus, hand labor is needed to manage these weeds. Nightshades are in the same family as tomato and thus, most tomato herbicides are not effective against these weeds. Nightshade plants also resemble tomatoes, making even hand removal difficult and costly. This family represents the most troublesome weeds in fields with regular rotation to tomato. Preplant applications of metam sodium provide good nightshade control but are not practical for early season plantings. Field bindweed is a troublesome perennial weed with a vining growth habit. Field bindweed infestations can smother tomato plants and make mechanical harvest difficult. None of the currently registered tomato herbicides provide effective control of this weed, and thus growers must rely on cultivation and hand weeding for control. Bindweed also hosts greenhouse and iris whiteflies. Nutsedges**,** both yellow and purple, are perennial weeds reproducing primarily from tubers (commonly referred to as nutlets). Nutsedge infestations are very competitive and can substantially reduce tomato yields. Cultivation and hand weeding fail to provide lasting control. Pebulate provides partial control, while other registered herbicides fail to provide any control. Dodder is a parasitic weed that attacks many broadleaf crops and weeds. It germinates in the soil and attaches to the stem of a host. Once attachment occurs, the soil connection is eliminated. Soil applied herbicides used in tomatoes have not been effective against dodder. Rimsulfuron has provided partial control of this species, although dodder has been observed to survive these treatments, reproduce and set seeds. Control generally involves hand removal of the host plant. Regional differences occur in weed distribution. Velvetleaf is commonly found in the Sacramento and upper San Joaquin valleys, but is not a problem in the lower San Joaquin valley (12). Purple nutsedge is primarily limited to the areas south of Madera County. All areas of the state have tremendous weed pressure requiring numerous weed control operations each season.

Fall bed treatments are often applied to fields in preparation for early season planting (January to March). In these fields, winter rainfall may reduce the opportunity for cultural weed control and thus fall bed treatments help to maintain prepared beds free of weeds and allow tomato planting during brief winter dry periods. In later plantings (March to June), non selective herbicides (glyphosate or paraquat), cultivation and preplant incorporated herbicides can all be used (22). Growers have not observed herbicide resistant weeds in tomato fields.

Crop rotation typically involves growing tomatoes once every two to four years, with field crops such as corn, wheat, safflower, sunflower, cotton, or alfalfa grown in the other years, with the

actual crop varying by region. Cultivation is used in all tomatoes grown in California with one to five cultivation operations per tomato crop. Hand weeding is used by all tomato growers in California to manage weeds that were not controlled by herbicides. The high value of the tomato crop permits the expense of hand weeding, which would not be practical in lower value crops. Transplanting is used to provide a head start for the tomato plants, allowing them to be more competitive with the weeds. Larger tomato plants also allow tillage equipment to move more soil into the seed line to bury small weed seedlings. Weed resistant or highly competitive tomato varieties have not been developed (20).

Napropamide is used for the control of annual grasses and broadleaves in fall bed applications before weeds emerge. Oxyfluorfen is used for preemergent and postemergent control of annual broadleaves. Fall bed applications after weeds emerge would utilize Glyphosate or Paraquat which is used for control of emerged annual weeds and suppressive knockdown of perennials as these materials are nonselective herbicides.

Nematodes

Root knot nematodes (*Meloidogyne incognita*) are microscopic, unsegmented roundworms that live in soil and inside plant roots. Root knot nematode is the major species of nematode of economic importance to tomato production in California. While there are other species of root knot nematodes present in California soils, *M. incognita* is among the most common. These parasites feed upon plant roots and produce swelling in the area of feeding. The formation of galls in roots disrupts the flow of water and nutrients in the plant. This leads to stress, which can become quite severe during hot weather, especially when fruit is developing. Plants infested with root knot nematodes are less vigorous and don't respond to fertilizer as well as healthy plants. Population increases are dependent upon several factors such as local climate, soil type, and the number of overwintering nematodes present in the spring. High numbers of nematodes may build up in sandy soils where significant crop loss can be expected in susceptible host plants. Nematodes can cause a plant to develop shallow root systems with numerous laterals that cannot match evapotranspiration demands during hot temperatures. Knowledge of approximate population size and distribution across a field can help in choosing nematode control strategies. Soil samples can be collected in the field and transported to a nematode-testing laboratory for analysis of *Meloidogyne* spp. Several control strategies can then be implemented. Resistant varieties remain the best option for nematode control, as they may be just as effective as chemical control practices. Knowledge of the nematode species is also important here as resistant varieties are effective against some species but not all. *Meloidogyne hapla* is known to be very active against resistant varieties. Rotation of resistant varieties and nonhost crops should be considered to prevent nematodes from adapting to the resistant varieties. Methylcarbamodithioic acid (Metam sodium) is a biocide that is used as a preplant material. Metam sodium is commonly applied through sprinkler irrigation as shank injection applications have not adequately suppressed nematode populations.

Different species of root knot nematodes have been known to occur together in a field. Oxamyl is a systemic carbamate that can be shanked in to the beds. to control *M. incognita* though it does not control *M. javanica*. No single chemical control tactic when used alone will totally eliminate nematode populations. Soil solarization is another cultural control practice that can be employed

to reduce nematode populations., ideally during the hottest time of the year. Most production fields would not coincide with this timing, as a field would have to be fallow during the warm summer months. No relevant biological control programs have been identified for nematode control.

Vertebrate Pests

Voles (*Microtus spp*.) are sometimes referred to as meadow or field mice. They are considered a minor pest in tomato fields. A higher incidence of voles may be encountered when tomato fields are located next to alfalfa hay fields as a migration along field borders may occur once adequate plant canopy is available to provide cover. Glue boards have been used along vole runways and entrances to burrows to aid in determining the pest populations so that effective control actions are implemented. Prevention appears to be the best management strategy as it may be necessary to remove plant material along field borders. Pest exclusion would be dependent on keeping the voles out of the field by managing the habitat they live in or by physically providing a barrier that prevents entry into the field, such as a small irrigation ditch containing water alongside the field. Fencing the field perimeter is not practical. Traps may be able to reduce small populations but would require time and personnel to service them. Traps are effective when using an attractant such as peanut butter mixed with oats. There are no registered poison baits for use within a tomato field once a crop has been planted. Poison baits would need to be in place early in the season prior to planting or even in late winter before the rodent-breeding season. Baiting during winter months has proven to be effective as acceptable forage material is far less abundant compared to plant growth in the spring. Once the spring breeding season starts, the numbers of voles may quickly rise to the point where effective baiting is inadequate to reduce pest numbers. Baiting is usually performed with an anticoagulant poison, such as Ramik green, which requires multiple feedings. Bait needs to be close to the runways and burrow entrances to be effective. Several bird species such as owls and hawks are predators on voles. Owls can be encouraged to stay in an area if adequate nesting sites are provided. Voles will not explore new areas unless adequate cover is present to protect them from bird predation.

Horned Larks *(Eremophila alpestris*) are one of the most notorious bird species that are known to reduce plant stands when direct seeding is used. The birds reduce the plant population by pulling up seedlings as they walk up the planted rows during feeding. The only effective control strategy to reduce horned lark damage to seedlings is to try and protect the crop by a constant patrol of the field with movement and noise acting as a deterrent to feeding. Once they have established a feeding pattern, horned larks will not be scared away with noisemakers such as propane cannons or even shooting. If they do fly off, it may be only for a short distance. The use of Mylar tape strips attached to solid set sprinkler pipes or risers in the field has had very limited success (22). Growers who need to thin a tomato field should delay thinning activities until plants achieve three true leaves. Larks are not a very big problem when transplants are used (12).

Rabbits (*Sylvilagus spp*.) may feed on tomato seedlings in early spring. Bait stations with diphacinone baits have been effective in controlling the pest along field borders. Damage may be high when fields are located next to almond orchards.

Ground squirrels (*Spermophilus spp*.) may damage tomato seedlings in early spring planted fields that border almond orchards as they can chew on young plants. Ground squirrels usually do not

make their burrows inside tomato fields. Bait stations with diphacinone baits have been effective in controlling the pest along field borders.

Gopher activity should be monitored along field borders as this is where most gopher damage occurs in tomato fields. Special tractor driven field implements can be used to create artificial gopher tunnels for use with strychnine or anti-coagulant baits prior to planting. Predation of gophers by owls can be encouraged by providing nesting sites along field borders but this method of control hasn't been extensively established (12).

Crows damage tomatoes in the harvest ready stage as the birds peck into the fruit in attempts to get the seed. Once a single puncture has been made into the flesh, the tomato is unfit for harvest and is culled from the pack out. Once they have established a feeding pattern, crows will not be scared away with noisemakers such as propane cannons or even shooting (22). If they do fly off, it may be only for a short distance.

Coyotes can damage drip irrigation equipment by chewing through lines in order to get to a water source (12). They also do minor damage to both bush and pole grown tomatoes. No control options have been employed (22).

Postharvest Concerns

There are no major postharvest concerns that growers and shippers are concerned about from the production side of the industry. Once produce has left the shipping point, food safety concerns need to be addressed by the retail industry on the receiving side. No insect pests are of concern for marketing of fresh market tomatoes.

Bibliography

1) Agricultural Chemical Usage 2000 Vegetable Summary. Web address verified on March 6, 2002: http://usda.mannlib.cornell.edu/reports/nassr/other/pcu-bb/agcv0701.txt

2) California Irrigation Management Information System. Weather station database. Web address verified on March 10, 2002: http://www.cimis.water.ca.gov

3) California Tomato Commission. Web site verified on March 10, 2002: http://tomato.org

4) *Compendium of Tomato Diseases.* Edited by J.B. Jones, J.P. Jones, R.E. Stall, and T.A. Zitter. American Phytopathological Society Press, 1991. St. Paul, Minnesota.

5) County agricultural commissioners' data. August 2001. California agricultural statistics service. Web address verified on March 6, 2002: htpp://www.nass.usda.gov/ca

6) *Crop Protection Reference - Labels and MSDSs.* C&P Press, New York. Web address verified on March 6, 2002: http://greenbook.net/ASP/free.asp

7) *Fresh Market Tomato Production in California.* 2000. Publication 8017. M. Le Strange, W. Schrader, and T. Hartz. Web address verified on March 6, 2002: http://anrcatalog.ucdavis.edu/pdf/8017.pdf

8) Hudgins, James. Pest Control Adviser for Oceanside Produce, Oceanside, CA. Personal communication on March 7, 2002.

9) *Insect Pest Management on Fresh Market Tomatoes.* John Trumble. Presentation to the California Tomato Commission board of directors annual meeting. January 10, 2002. San Francisco, CA.

10). *Integrated Pest Management for Tomatoes.* Fourth Edition. F.G. Zalom et al. 1998. In UC DANR Publication 3274.

11) Jones, H., J.M. Whipps, and S.J. Gurr. 2001. *The tomato powdery mildew fungus oidium neolycopersici.* Molecular Plant Pathology 2(6), 303-309.

12) Pest Management Strategic Plan meeting sponsored by the California Tomato Commission and the California Minor Crops Council. Meeting held on January 29, 2002 at the University of California Cooperative Extension office in Stockton, CA. Written document is in draft.

13) Postharvest Technology, 3 rd Edition. A. Kader, Technical Editor. 2002. UC DANR Publication 3311. Postharvest Technology Research and Information Center. Web address verified on March 6, 2002: http://postharvest.ucdavis.edu

14) Recommendations for maintaining postharvest quality. T.V. Suslow and M. Cantwell. Web address verified on March 6, 2002: http://postharvest.ucdavis.edu/Produce/ProduceFacts/veg/tomato.htm

15) Sample costs to produce fresh market tomatoes. University of California Cooperative Extension. 2000. M. Le Strange, J.G. Valencia, R.J. Mullen, B. L. Weir, and K. M. Klonska. Web address verified on March 6, 2002: http://www.agecon.ucdavis.edu/outreach/crop/cost-studies/2000/freshtoms.pdf

16) Summary of pesticide use report data indexed by commodity. 2000. California Department of Pesticide Regulation. Web address:verified on March 6, 2002: http://www.cdpr.ca.gov/docs/pur/pur00rep/comrpt00.pdf

17) Summary of county agricultural commissioners' reports - Gross value by commodity groups - California 1999-2000. Web address verified on March 6, 2002: http://www.nass.usda.gov/ca/bul/agecon/indexcav.htm

18) *The Importance of Pesticides and Other Pest Management Practices in U.S. Tomato Production.* 1998. R.M. Davis et al. In National Agricultural Pesticide Impact Assessment Program Document Number 1-CA-98.

19) Thompson, Willard. MarketBuilder data search of methamidophos (Monitor) applications in California in 2000. 2002. http:/rinconpublishing.com

20) *UC IPM Pest Management Guidelines: Tomato.* F.G. Zalom et al. 2001. In UC DANR Publication 3339. http://www.ipm.ucdavis.edu

21) UC Vegetable Research and Information Center. Web address verified on March 6, 2002: http://vric.ucdavis.edu

22) USDA *Crop Profile for Fresh Market Tomatoes in California*. 2000. J.B. LeBoeuf, W.T. Lanini, E. Beckman, J. Farrar, and K. Farrar. Web address verified on March 6, 2002: http://pestdata.ncsu.edu/CropProfiles/docs/catomatoes-freshmarket.htm

23) USDA National Agricultural Statistics Service. Vegetable Acreage Summary. 2000. Web address verified on March 6, 2002: http://www.nass.usda.gov/ca/rev/veggies/101vegtb.htm

Acknowledgements

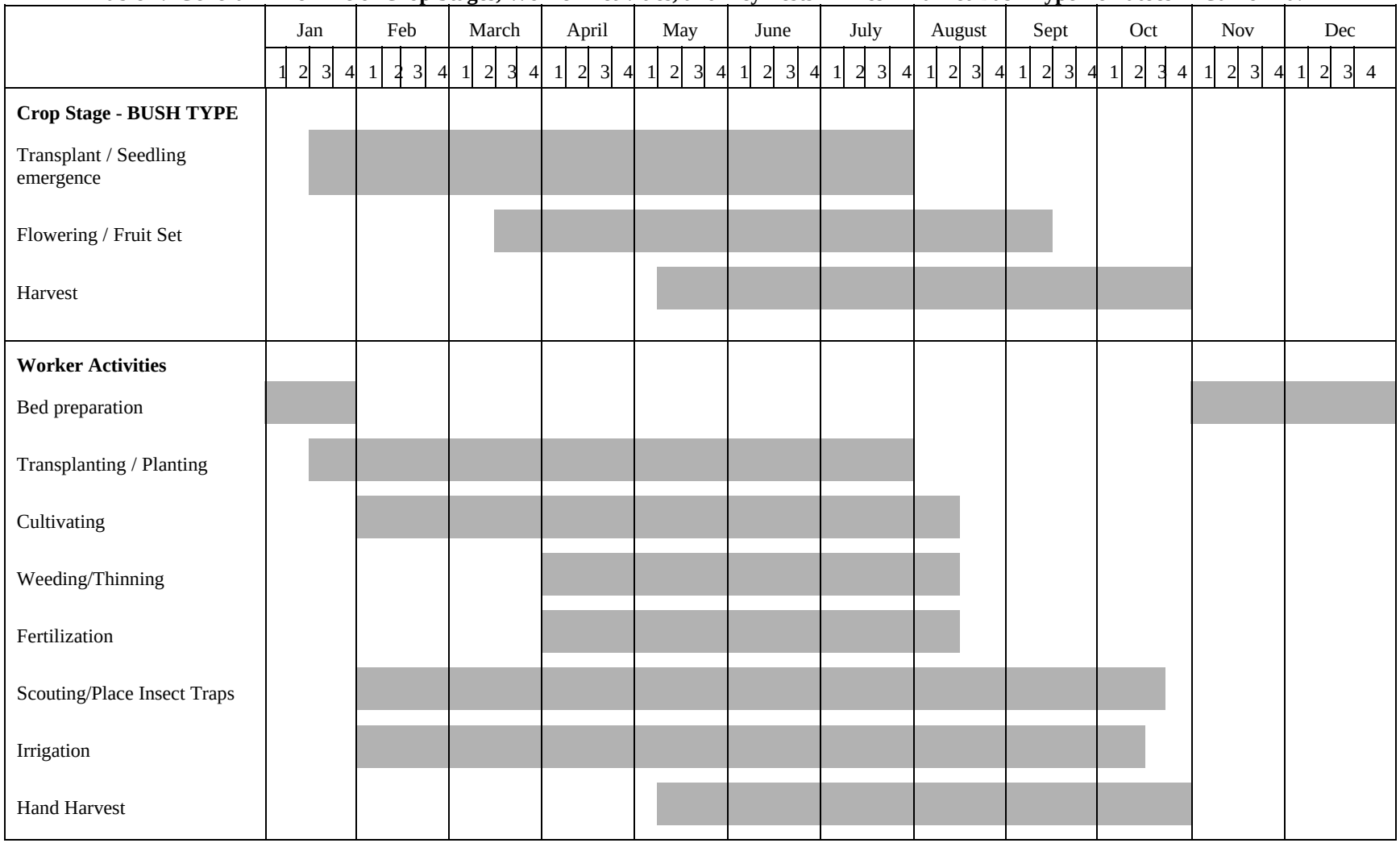
The following individual and organization were responsible for the research and collection of information on crop production and actual practices of fresh market tomatoes, and in the preparation and writing of this document: Mr. John LeBoeuf, AgriDataSensing, Inc. 8398 North Ninth Street, Fresno, CA 93720 (559) 431-2360 AgriDataSensing1@aol.com

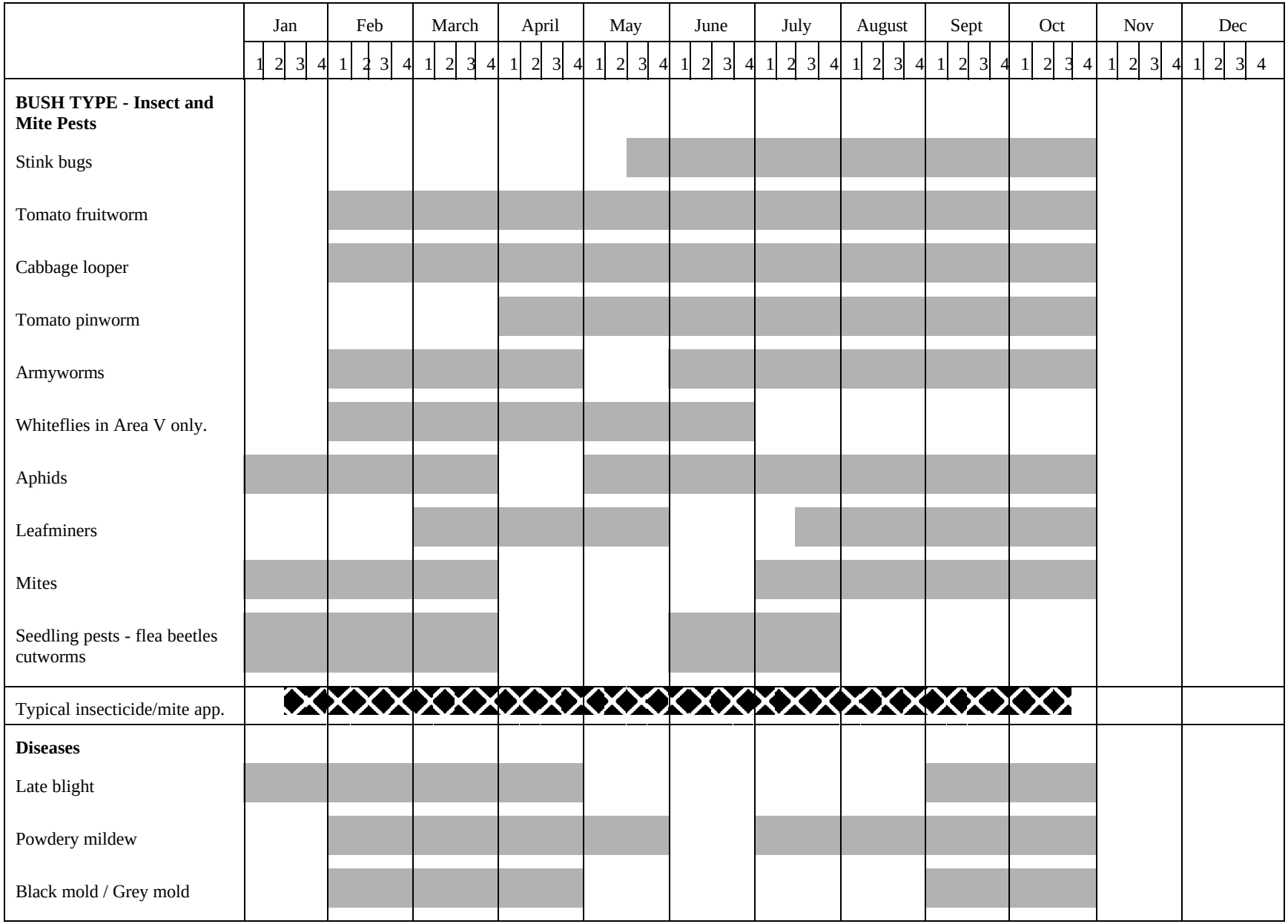
AgriDataSensing, Inc. is a small business located in the center of the San Joaquin Valley that specializes in agricultural research and consulting and in the analysis and interpretation of digital satellite imagery. The author of this report, Mr. LeBoeuf, is a Certified Professional Agronomist and a licensed Pest Control Adviser. He presently is the Secretary of the California Minor Crops Council (CMCC) where he is the industry representative for fresh tomatoes, celery, cantaloupe, honeydew and mixed melons.

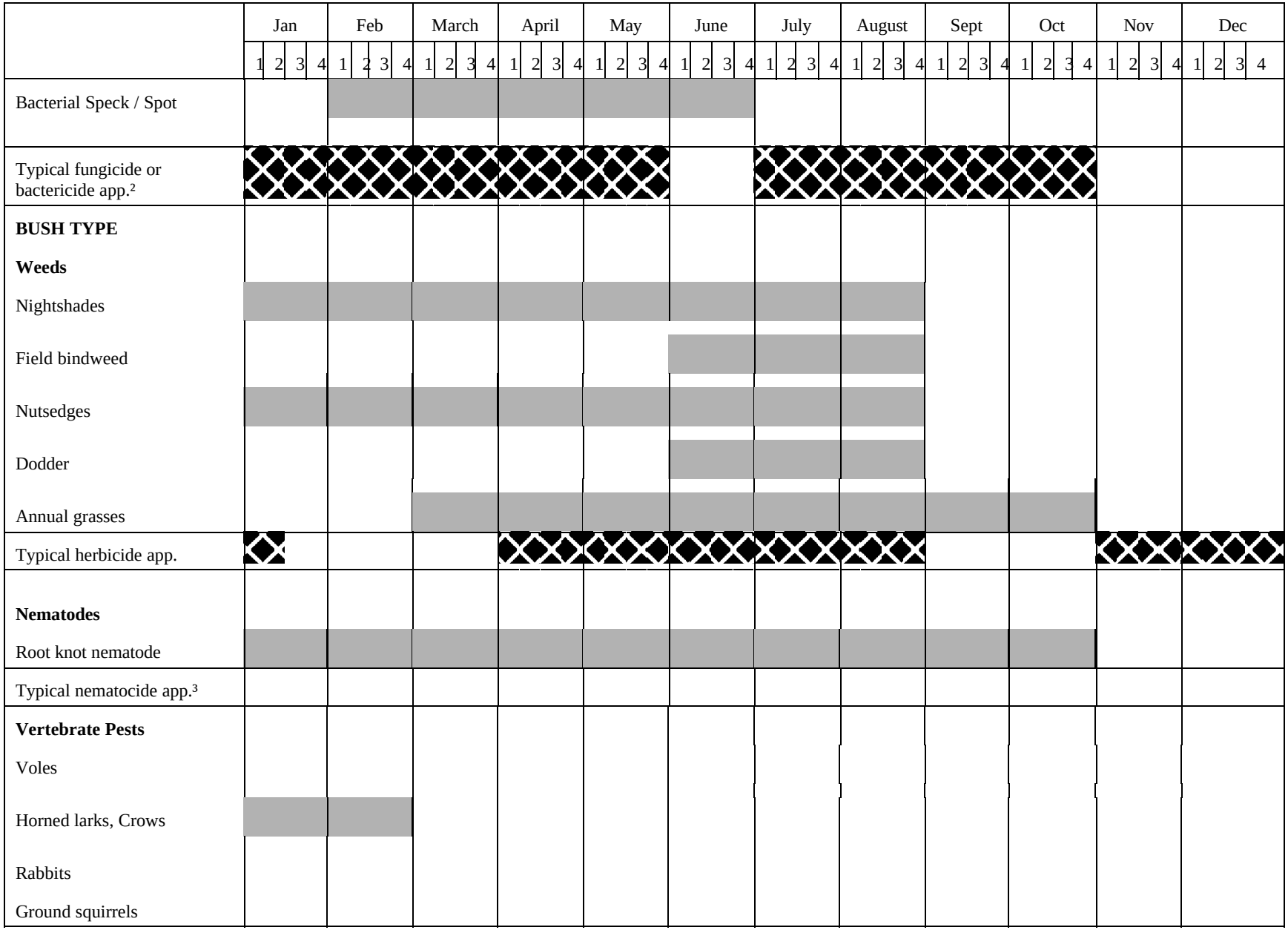
Numerous growers, shippers, farm managers, and PCAs, active in the fresh market tomato industry in California, willingly provided information on current crop production practices and materials used in pest control. Researchers from the University of California Cooperative Extension along with board members of the California Tomato Commission (CTC) who attended a Pest Management Strategic Plan meeting held on January 29, 2002 also provided valuable input on current production practices. The strategic plan meeting was sponsored jointly by the CTC and the CMCC with leadership from Dr. Lori Berger and facilitators Mr. Rick Melnicoe and Ms. Linda Herbst from the Western Region Pest Management Center located at U.C. Davis.

A special thanks is also noted for use of the table format from the Almond Time Line.

Table 2. General Time Line of Crop Stages, Worker Activities, and Key Pests in Fresh Market Bush Type Tomatoes in California.[1]




Jan
Feb
March
April
May
June
July
August
Sept
Oct
Nov
Dec
1 2 3 4
BUSH TYPE - Insect and Mite Pests
Stink bugs
Tomato fruitworm
Cabbage looper
Tomato pinworm
Armyworms
Whiteflies in Area V only.
Aphids
Leafminers
Mites
Seedling pests - flea beetles cutworms
Typical insecticide/mite app.
Diseases
Late blight
Powdery mildew
Black mold / Grey mold


Jan
Feb
March
April
May
June
July
August
Sept
Oct
Nov
Dec
1 2 3 4
Bacterial Speck / Spot
Typical fungicide or bactericide app.²
BUSH TYPE
Weeds
Nightshades
Field bindweed
Nutsedges
Dodder
Annual grasses
Typical herbicide app.
Nematodes
Root knot nematode
Typical nematocide app.³
Vertebrate Pests
Voles
Horned larks, Crows
Rabbits
Ground squirrels

	Jan				Feb				March				April				May				June				July				August				Sept				Oct				Nov				Dec			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Gophers																																															
Coyotes																																															
No typical rodenticide app.																																															

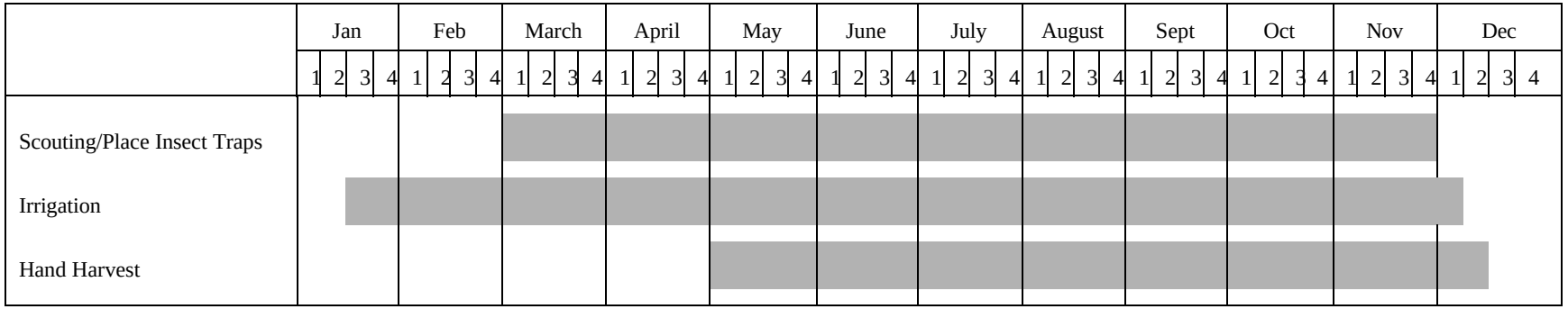
[1] The horizontal bars represent the usual range of time when the events occur for the entire crop. These times vary depending on production Areas I, II, III, and V.

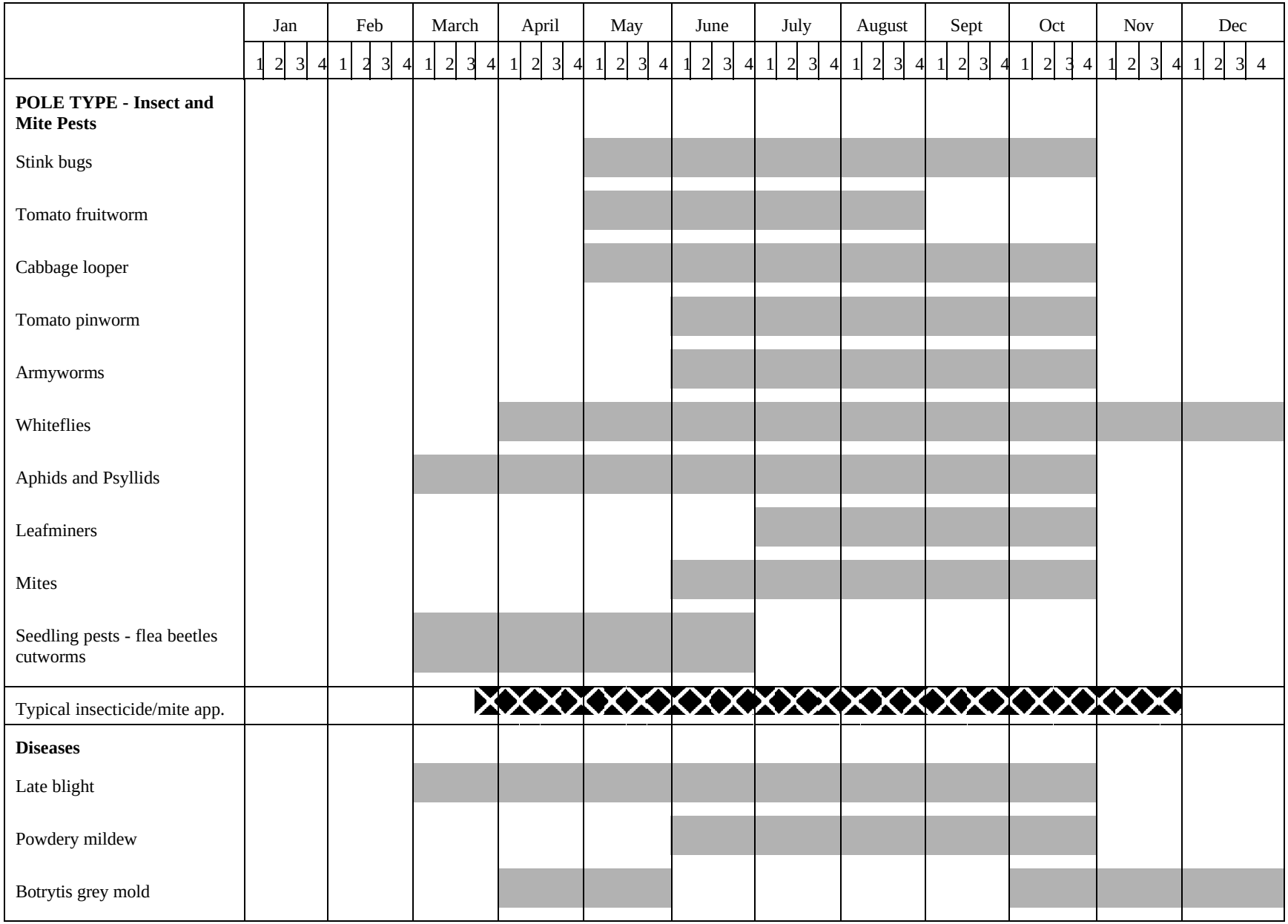
[2] Fungicide applications are applied as preventive for late blight. Bactericides are applied as curative for speck.

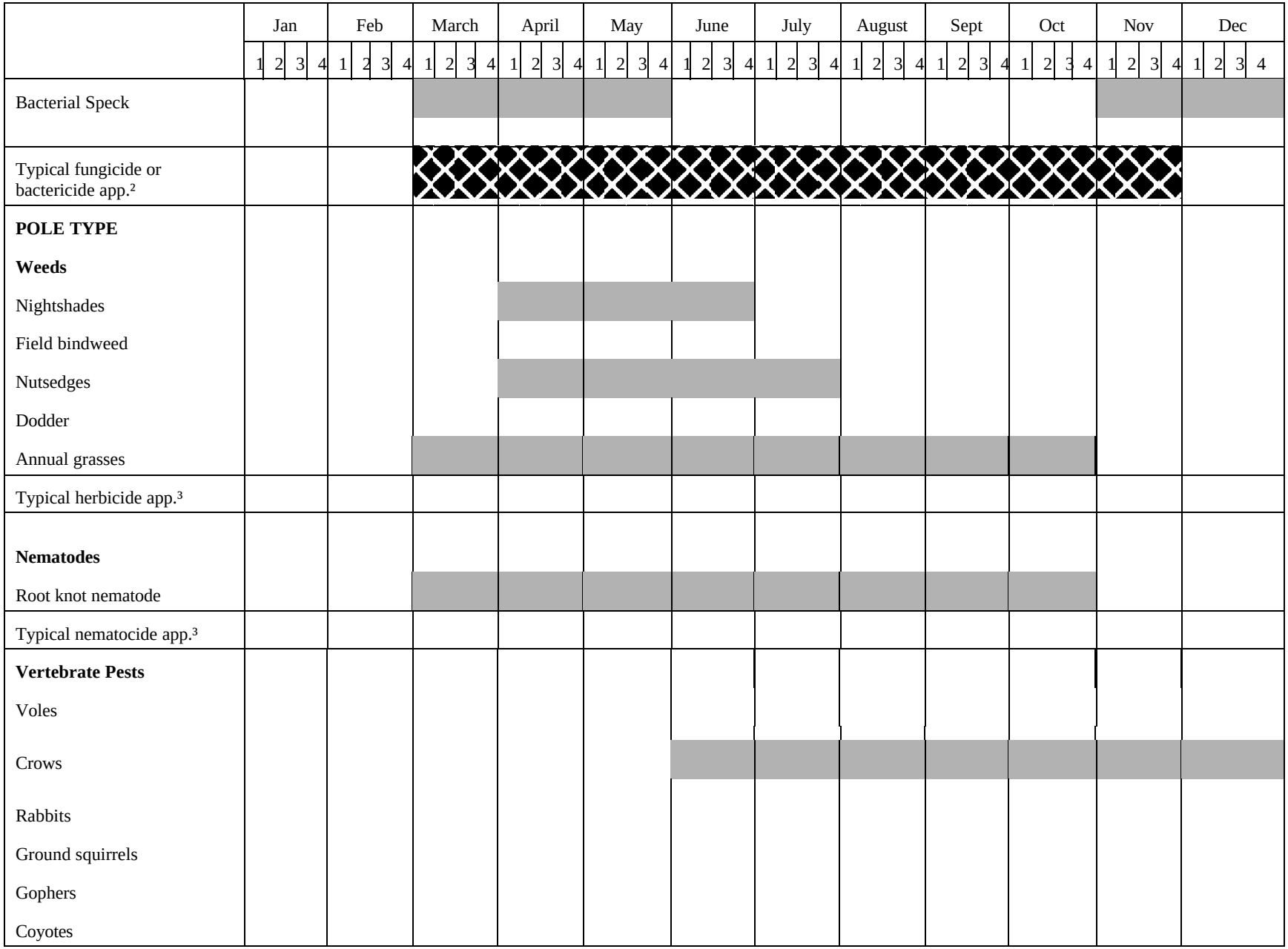
[3] No typical sprays as field specific decisions are made prior to, or during, the season.

Table 3. General Time Line of Crop Stages, Worker Activities, and Key Pests in Fresh Market Pole Type Tomatoes in California.[1]

	Jan				Feb				March				April				May				June				July				August				Sept				Oct				Nov				Dec			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Crop Stage - POLE TYPE																																															
Transplant																																															
Flowering / Fruit Set																																															
Harvest																																															
Worker Activities																																															
Bed preparation																																															
Transplanting																																															
Pruning / Tying / Staking																																															
Weeding																																															
Fertilization																																															


Jan
Feb
March
April
May
June
July
August
Sept
Oct
Nov
Dec
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
Scouting/Place Insect Traps
Irrigation
Hand Harvest


Jan
Feb
March
April
May
June
July
August
Sept
Oct
Nov
Dec
1 2 3 4
POLE TYPE - Insect and Mite Pests
Stink bugs
Tomato fruitworm
Cabbage looper
Tomato pinworm
Armyworms
Whiteflies
Aphids and Psyllids
Leafminers
Mites
Seedling pests - flea beetles cutworms
Typical insecticide/mite app.
Diseases
Late blight
Powdery mildew
Botrytis grey mold


Jan
Feb
March
April
May
June
July
August
Sept
Oct
Nov
Dec
1 2 3 4
Bacterial Speck
Typical fungicide or bactericide app.²
POLE TYPE
Weeds
Nightshades
Field bindweed
Nutsedges
Dodder
Annual grasses
Typical herbicide app.³
Nematodes
Root knot nematode
Typical nematocide app.³
Vertebrate Pests
Voles
Crows
Rabbits
Ground squirrels
Gophers
Coyotes

	Jan				Feb				March				April				May				June				July				August				Sept				Oct				Nov				Dec			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
No typical rodenticide app.																																																

[1] The horizontal bars represent the usual range of time when the events occur for the entire crop in production Area IV.

[2] Fungicide applications are applied as preventive for late blight. Bactericides are applied as curative for speck.

[3] No typical sprays, field specific decision prior to or during the season.