METHYL BROMIDE CRITICAL USE NOMINATION FOR PREPLANT SOIL USE ON STRAWBERRY NURSERIES IN OPEN FIELDS OR IN PROTECTED ENVIRONMENTS

FOR ADMINISTRATIVE PURPOSES ONLY:
DATE RECEIVED BY OZONE SECRETARIAT:
YEAR: CUN:

NOMINATING PARTY:	The United States of America
BRIEF DESCRIPTIVE TITLE OF NOMINATION:	Methyl Bromide Critical Use Nomination for Preplant Soil Use for Strawberry Nurseries Grown in Open Fields or in Protected Environments (Submitted in 2006 for the 2008 Use Season)

NOMINATING PARTY CONTACT DETAILS

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Following the requirements of Decision IX/6 paragraph (a)(1), the United States of America has determined that the specific use detailed in this Critical Use Nomination is critical because the lack of availability of methyl bromide for this use would result in a significant market disruption.

☐ Yes ☐ No

Signature Name Date

Title:

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LIST OF DOCUMENTS SENT TO THE OZONE SECRETARIAT IN OFFICIAL NOMINATION PACKAGE

List all paper and electronic documents submitted by the Nominating Party to the Ozone Secretariat

1. PAPER DOCUMENTS: **Title of Paper Documents and Appendices**	**Number of Pages**	**Date Sent to Ozone Secretariat**

2. ELECTRONIC COPIES OF ALL PAPER DOCUMENTS: **Title of Electronic Files**	**Size of File (kb)**	**Date Sent to Ozone Secretariat**

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PART A: SUMMARY

1. NOMINATING PARTY

The United States of America (U.S.)

2. DESCRIPTIVE TITLE OF NOMINATION

Methyl Bromide (MB) Critical Use Nomination for Preplant Soil Use for Strawberry Nurseries in Open Fields or in Protected Environments (Prepared in 2005 for the 2008 Use Season)

3. CROP AND SUMMARY OF CROP SYSTEM

Southeastern U.S. growers (from Maryland, North Carolina, and Tennessee) produce transplants in open fields. An individual field is planted to strawberries once every three years. Approximately 85% of transplants produced are exported to Florida.

California growers produce their transplants over a five-year cycle (see Appendix B for an extensive overview—submitted by the California Strawberry Commission—of the California strawberry nursery production system). Screenhouses are used during the first two years and open field plantings are used during the last three years. MeBr is needed in production years 2 thru 5. Individual planting sites are planted to strawberries once every three years. The fourth and fifth production years account for 22% and 77%, respectively, of the current MeBr nursery usage in California. Transplants produced are distributed widely throughout the U.S. and other countries.

4. METHYL BROMIDE NOMINATED

TABLE 4.1: METHYL BROMIDE NOMINATED

YEAR	NOMINATION AMOUNT (KG)*	NOMINATION AREA (HA)
2008	8,838	31

* Includes research amount of 454 kgs.

5. BRIEF SUMMARY OF THE NEED FOR METHYL BROMIDE AS A CRITICAL USE

The U.S. nomination is for those areas where the alternatives are not suitable. In U.S. strawberry nursery production there are several factors that make the potential alternatives to MeBr unsuitable. These include:

- Pest control efficacy of alternatives: the efficacy of alternatives may not be comparable to MeBr in some areas, making these alternatives infeasible
- Quarantine and Pre-Shipment uses are not included in this CUE

For the 2008 season, MeBr is critical for strawberry nurseries to produce plants free of diseases and nematodes to meet state and foreign certification standards, as well as prospective buyer expectations. In addition to these certification-related pest control concerns, weed control is also essential to insure maximum runner production and prevent the spread of noxious weeds. The available alternatives have not been developed sufficiently to provide effective control of the key pests to depths of 1 m. In addition, there are no markets for plants that do not meet the certification standards, which mean that losses up to 100% are possible when inadequate pest control occurs. Failure to adequately manage pests in transplants will jeopardize the viability of the transplant and fruit production industries in the U.S., as well as the viability of fruit production in countries purchasing U.S. plants (e.g., Canada, Mexico, Spain, countries in South America, and some others).

TABLE A.1: EXECUTIVE SUMMARY

Region	***California***	***Southeastern States***
AMOUNT OF APPLICANT REQUEST		
2008 Kilograms	4,690	34,934
AMOUNT OF NOMINATION*		
2008 Kilograms	4,690	3,693

* *See Appendix A for complete description on how nominated amount was calculated.*

6. SUMMARIZE WHY KEY ALTERNATIVES ARE NOT FEASIBLE

The key alternatives are 1,3-dichloropropene (1,3-D)/chloropicrin, 1,3-D/chloropicrin/metam-sodium, and 1,3-D/metam-sodium. Dazomet is also a possible alternative probably in combination with chloropicrin and/or 1,3-D. These chemicals, in addition to other strategies, such as use of high density tarps, may ultimately reduce or replace MB. However, to maintain certification quality protocols for effective use of these alternatives have not been sufficiently developed to provide adequate disease and nematode control throughout the root zone (up to 1 m deep). Additionally, these alternatives will require further study to show their consistency in providing control of yellow and purple nutsedge (*Cyperus esculentus*, *C. rotundus*) (SE states only) and a number of other critical weed pests in California (Table 10.1). The certification requirements associated with the requesting states are strict (virtually zero tolerance for any damaging diseases and plant-parasitic nematodes) in order to minimize the prospect of spreading these nematode and diseases to other states and countries where these plants are shipped. Research has been cited (e.g., Kabir et al., 2003) in this review that indicates potential alternatives for some nurseries, but the need for MeBr for 2008 is critical until alternatives have been sufficiently tested for use in commercial strawberry nursery operations.

7. (*i*) PROPORTION OF CROPS GROWN USING METHYL BROMIDE

TABLE 7.1: PROPORTION OF CROPS GROWN USING METHYL BROMIDE

REGION WHERE METHYL BROMIDE USE IS REQUESTED	TOTAL CROP AREA – 2001-2002 AVERAGE (HA)	PROPORTION OF TOTAL CROP AREA TREATED WITH METHYL BROMIDE (%)
Southeastern States	69	100
California	1,386	100

7. (*ii*) IF ONLY PART OF THE CROP AREA IS TREATED WITH METHYL BROMIDE, INDICATE THE REASON WHY METHYL BROMIDE IS NOT USED IN THE OTHER AREA, AND IDENTIFY WHAT ALTERNATIVE STRATEGIES ARE USED TO CONTROL THE TARGET PATHOGENS AND WEEDS WITHOUT METHYL BROMIDE THERE.

Pest-free standards for nursery stock make complete transition to alternatives difficult.

7. (*iii*) WOULD IT BE FEASIBLE TO EXPAND THE USE OF THESE METHODS TO COVER AT LEAST PART OF THE CROP THAT HAS REQUESTED USE OF METHYL BROMIDE? WHAT CHANGES WOULD BE NECESSARY TO ENABLE THIS?

Not applicable because the alternatives have not been proven effective for the control of the target pests in nursery production.

8. AMOUNT OF METHYL BROMIDE REQUESTED FOR CRITICAL USE

SOUTHEASTERN STATES AND CALIFORNIA- TABLE 8.1: AMOUNT OF METHYL BROMIDE REQUESTED FOR CRITICAL USE

REGION:	**SOUTHEASTERN STATES**	**CALIFORNIA**
YEAR OF EXEMPTION REQUEST	**2008**	**2008**
KILOGRAMS OF METHYL BROMIDE	34,934	4,690
USE: FLAT FUMIGATION OR STRIP/BED TREATMENT	FLAT FUMIGATION	FLAT FUMIGATION
FORMULATION *(ratio of methyl bromide/chloropicrin mixture)* TO BE USED FOR THE CUE	67:33	67:33
TOTAL AREA TO BE TREATED WITH THE METHYL BROMIDE OR METHYL BROMIDE/CHLOROPICRIN FORMULATION *(ha)*	85	18 (w/o QPS)
APPLICATION RATE *(kg/ha)* FOR THE **FORMULATION**	604	390
APPLICATION RATE *(kg/ha)* FOR **METHYL BROMIDE**	413	263
DOSAGE RATE *(g/m^2)* OF **FORMULATION** USED TO CALCULATE REQUESTED KILOGRAMS OF METHYL BROMIDE	60.4	39.0
DOSAGE RATE *(g/m^2)* OF **METHYL BROMIDE**	41.1	26.1

9. SUMMARIZE ASSUMPTIONS USED TO CALCULATE METHYL BROMIDE QUANTITY NOMINATED FOR EACH REGION

The amount of methyl bromide nominated by the U.S. was calculated as follows:

- The percent of regional hectares in the applicant's request was divided by the total area planted in that crop in the region covered by the request. Values greater than 100 percent are due to the inclusion of additional varieties in the applicant's request that were not included in the USDA National Agricultural Statistics Service surveys of the crop.
- Hectares counted in more than one application or rotated within one year of an application to a crop that also uses MeBr were subtracted. There was no double counting in this sector.
- Growth or increasing production (the amount of area requested by the applicant that is greater than that historically treated) was subtracted. The two applicants that included growth in their request had the growth amount removed.
- There was a small adjustment for use rate in one of the applications.
- Quarantine and pre-shipment (QPS) hectares is the area in the applicant's request subject to QPS treatments. Both applicants had QPS listed the amount requested and reflects the subtraction of the QPS amount.
- Only the area experiencing one or more of the following impacts were included in the nominated amount: moderate to heavy key pest pressure.

SOUTHEASTERN STATES - PART B: CROP CHARACTERISTICS AND METHYL BROMIDE USE

SOUTHEASTERN STATES - 10. KEY DISEASES AND WEEDS FOR WHICH METHYL BROMIDE IS REQUESTED AND SPECIFIC REASONS FOR THIS REQUEST

SOUTHEASTERN STATES - TABLE 10.1: KEY DISEASES AND WEEDS AND REASON FOR METHYL BROMIDE REQUEST

REGION WHERE METHYL BROMIDE USE IS REQUESTED	KEY DISEASE(S) AND WEED(S) TO GENUS AND, IF KNOWN, TO SPECIES LEVEL (AND % OF TOTAL GROWING AREA WITH MODERATE-SEVERE INFESTATION OF PEST)	SPECIFIC REASONS WHY METHYL BROMIDE IS NEEDED
Southeastern Nurseries	Weeds: Yellow nutsedge (*Cyperus esculentus*) and Purple nutsedge (*Cyperus rotundus*) (50%) Diseases: Black root rot (*Rhizoctonia* and *Pythium* spp.) (100%); Crown rot (*Phytophthora cactorum*) (<5%); root-knot nematodes (*Meloidogyne* spp.) (100%)	The major issue for pest management in the nursery is the zero-tolerance threshold for pests. To meet certification and production requirements, MeBr is critical for the portion of nursery land that cannot accomplish certification otherwise.

SOUTHEASTERN STATES - 11. (*i*) CHARACTERISTICS OF CROPPING SYSTEM AND CLIMATE

SOUTHEASTERN STATES - TABLE 11.1: CHARACTERISTICS OF CROPPING SYSTEM

CHARACTERISTICS	SOUTHEASTERN STATES
CROP TYPE: *(e.g. transplants, bulbs, trees or cuttings)*	Strawberry transplants
ANNUAL OR PERENNIAL CROP: *(# of years between replanting)*	Annual crop, replanted in same site once every three years
TYPICAL CROP ROTATION *(if any)* **AND USE OF METHYL BROMIDE FOR OTHER CROPS IN THE ROTATION:** *(if any)*	Various crops planted
SOIL TYPES: *(Sand, loam, clay, etc.)*	93% medium and 7% light soils, containing up to 2% organic matter
FREQUENCY OF METHYL BROMIDE FUMIGATION: *(e.g. every two years)*	Every year
OTHER RELEVANT FACTORS:	None identified

SOUTHEASTERN STATES - TABLE 11.2 CHARACTERISTICS OF CLIMATE AND CROP SCHEDULE

	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB
CLIMATIC ZONE	6a, 6b, 7a, 7b, 8a, 8b											
RAINFALL *(mm)*	163	124	109	87	78	146	113	202	109	116	54	76
OUTSIDE TEMP. *(℃)*	9.4	14.5	17.7	23.4	26	25.9	22.6	14.9	7.7	3.4	2.9	4.2
FUMIGATION SCHEDULE							X	X				
PLANTING SCHEDULE		X	X									
HARVEST SCHEDULE							2X	X				

* Macon, GA

SOUTHEASTERN STATES – 11. (*ii*) INDICATE IF ANY OF THE ABOVE CHARACTERISTICS IN 11. (*i*) PREVENT THE UPTAKE OF ANY RELEVANT ALTERNATIVES?

None were identified as being limiting factors.

SOUTHEASTERN STATES - 12. HISTORIC PATTERN OF USE OF METHYL BROMIDE, AND/OR MIXTURES CONTAINING METHYL BROMIDE, FOR WHICH AN EXEMPTION IS REQUESTED

SOUTHEASTERN STATES - TABLE 12.1 HISTORIC PATTERN OF USE OF METHYL BROMIDE

FOR AS MANY YEARS AS POSSIBLE AS SHOWN SPECIFY:	1999	2000	2001	2002	2003	2004
AREA TREATED *(hectares)*	82	55	67	71	75	83
RATIO OF FLAT FUMIGATION METHYL BROMIDE USE TO STRIP/BED USE IF STRIP TREATMENT IS USED	Nearly all flat fumigation	Nearly all flat fumigation	Nearly all flat fumigation	Nearly all flat fumigation	Nearly all flat fumigation	Nearly all flat fumigation
AMOUNT OF METHYL BROMIDE ACTIVE INGREDIENT USED *(total kilograms)*	33,764	22,900	27,747	29,251	30,923	34,433
FORMULATIONS OF METHYL BROMIDE *(methyl bromide/ chloropicrin)*	67:33	67:33	67:33	67:33	67:33	67:33
METHOD BY WHICH METHYL BROMIDE APPLIED	Soil injection	Soil injection	Soil injection	Soil injection	Soil injection	Soil injection
APPLICATION RATE OF FORMULATIONS IN kg/ha	619	619	619	619	619	619
APPLICATION RATE OF METHYL BROMIDE IN kg/ha*	413	413	413	413	413	413
ACTUAL DOSAGE RATE OF FORMULATIONS *(g/m²)**	61.9	61.9	61.9	61.9	61.9	61.9
ACTUAL DOSAGE RATE OF METHYL BROMIDE *(g/m²)**	41.3	41.3	41.3	41.3	41.3	41.3

SOUTHEASTERN STATES - PART C: TECHNICAL VALIDATION

SOUTHEASTERN STATES - 13. REASON FOR ALTERNATIVES NOT BEING FEASIBLE

SOUTHEASTERN STATES – TABLE 13.1: REASON FOR ALTERNATIVES NOT BEING FEASIBLE

NAME OF ALTERNATIVE	TECHNICAL AND REGULATORY* REASONS FOR THE ALTERNATIVE NOT BEING FEASIBLE OR AVAILABLE	IS THE ALTERNATIVE CONSIDERED COST EFFECTIVE?
CHEMICAL ALTERNATIVES		
Chloropicrin	Reduced efficacy on nutsedge (Locascio 1997 & 1999); in some instances it caused increased emergence of nutsedge (Motis and Gilreath 2002); Unlikely that nematode control required by state certification programs can be attained throughout the 1 m root zone. Chloropicrin is generally considered a good control measure for certain pathogens (*Pythium*, *Phytophthora*, *Fusarium*, *Verticillium*), but is not considered effective for nematode or weed control. [See also chloropicrin issues addressed in the fumigant combination entries in this section.]	No
NON CHEMICAL ALTERNATIVES		
Biofumigation	Lack of adequate data on the activity of biofumigation materials on nutsedge control; Based on studies with other crops, allelochemicals may cause phytotoxic effects (Norsworthy 2002; Johnson et al. 1993); unlikely that the level of disease and nematode control required by state certification programs can be attained throughout the 1 m deep root zone. Biofumigation is not feasible alone because it does not provide adequate, or consistent, control of target pests to produce a certifiable strawberry nursery stock. Research conducted in Florida showed some control of plant pathogens, but no control of nematodes or weeds in the soil. In cases where biofumigation have been shown to control weeds, the data are mostly for small-seeded weed species that have small carbohydrate energy sources compared to nutsedge. The data on biofumigation are too limited to consider it as a practical alternative to methyl bromide, and strategies to incorporate biofumigation with other alternatives have not been adequately developed. It is not clear that Brassica crops can be supplied in such quantity needed to control target pests. Estimates are that the biofumigant would have to occupy approximately 3 hectares for every hectare of strawberry production. Incorporation of Brassica at these levels would be likely to have allelopathic effects on the target crop.	No

Name of Alternative	Technical and regulatory* reasons for the alternative not being feasible or available	Is the alternative considered cost effective?
Solarization	Even in warm climates (Georgia) it is difficult to attain temperatures lethal to nutsedge (50-55°C) at depths below 10 centimeters (Miles et. al. 2002). However, research to enhance the efficacy of solarization with tarps is being conducted (e.g., Arbel et al., 2003). Solarization is not a feasible alternative by itself because it does not provide adequate control of target pests to produce certifiable strawberry nursery stock. Use of solarization might not be practical due to the depth of heating required to eliminate viable weed seed, nematodes, and disease organisms. The time for solarization to raise soil temperatures to the level needed to kill soil pathogens in most strawberry nursery regions is likely to also be the time when the crops themselves must complete their growth cycle. In one Southeast field trial, solarization gave poor yields in two years out of three with losses ranging from 0% to 40% (Miles et. al. 2002).	No
General IPM	IPM, the use of pest monitoring activities coupled with chemical and non-chemical management tools, has been adopted already for management of weed, diseases, and nematodes in most nurseries. General IPM is being used in strawberry nursery stock production, but it is not feasible alone to provide adequate pest control. IPM practices include field sanitation to limit inoculum buildup, crop rotation to provide non host periods, and breeding for resistance to pathogens.	No
Cover crops mulching	Cover crops/mulching is currently being used but it is not feasible as a replacement for MB; disease and nematode control required by state certification programs require several years of pest-free history prior to certification. Some cover crops that have been shown to reduce weed populations also reduced or delayed crop maturity and/or emergence, as well as yields (Burgos et al., 1996; Galloway et al., 1996). Cowpea and sun hemp have been shown to suppress nutsedge, but the effect is short lived due to the weed's capacity for rapid tuber production. Allelochemicals released by some cover crops or organic mulches can injure crops (Johnson et al., 1993; Norsworthy, 2002).	No

NAME OF ALTERNATIVE	TECHNICAL AND REGULATORY* REASONS FOR THE ALTERNATIVE NOT BEING FEASIBLE OR AVAILABLE	IS THE ALTERNATIVE CONSIDERED COST EFFECTIVE?
Crop rotation/fallow	Growers typically use this practice by growing other crops in two out of three years; this practice has not resulted in a level of disease and nematode control required by state certification programs throughout the 1 m deep root zone; no suitable nutsedge controls are available during production of the rotational crops (Culpepper, 2002). A three-year crop rotation/fallow is being used in strawberry nursery stock production in conjunction with other pest management strategies (e.g., 1,3-D). Strategies for use with other alternatives are being studied, but are not currently developed to use in a commercial nursery for the 2008 use season. Although such crop rotation and fallow procedures are generally considered useful pest management tools for weeds, diseases and nematodes, they are rarely considered standalone control measures. Significantly longer time frames may produce higher levels of control for most pests, but are generally considered impractical because of limited land availability and high costs. Johnson & Mullinix (1997) showed that uninterrupted plantings of peanut, corn, or cotton, with moderate levels of weed management suppressed yellow nutsedge in Georgia. Their data also showed an increase in nutsedge densities in fallow plots, likely due to the longevity of nutsedge tubers in soil, mild winters that prevent winter-kill of tubers, and the ability of tubers to regenerate with the long growing season in the southeastern coastal plain.	No
Soilless culture	Soilless culture is not being used, and it is not feasible for 2008, because it would require a costly transformation of the U.S. production system. According to data provided by The National Center for Food and Agricultural Policy, a greenhouse typically costs between US$12.5 million and US$20 million per hectare. Although yields obtained through greenhouse production are higher than yields of the best growers, the issue of capitalization for this and other sectors make the alternative not feasible as a near term strategy to reduce reliance on MB.	No
Substrates/plug plants grown hydroponically	Substrates/plug plants are currently being produced and sold in the southeast and to a limited extent in California, but this method alone does not provide pest control and would fail to produce a pest free product. Furthermore, this method would require extensive retooling by the nursery industry, and would be costly to change to this technology—not likely, prior to the 2008 use season.	No
COMBINATIONS OF ALTERNATIVES		

NAME OF ALTERNATIVE	TECHNICAL AND REGULATORY* REASONS FOR THE ALTERNATIVE NOT BEING FEASIBLE OR AVAILABLE	IS THE ALTERNATIVE CONSIDERED COST EFFECTIVE?
1,3-D + chloropicrin	Inconsistent efficacy on nutsedge (Locascio 1997 & 1999); level of disease and nematode control required by state certification programs might be problematic throughout the 1 m deep root zone under some conditions; may be the best alternative, especially where nutsedge is not a problem (50% of production area in Southeastern U.S.). This combination provides good nematode and disease control, but inconsistent weed control. A 30.5 meter (100 feet) 1,3-D buffer requirement, to mitigate area resident exposure, would be particularly constraining on smaller fields in predominantly urban fringe areas, which is typical for the Southeastern U.S. growers. Personal Protective Equipment (PPE) requirements also limit operations that require workers in the field, particularly given the high temperatures which occur in the southeast, which are exacerbated by high humidity. Workers wearing the required PPE become at risk for possible heat exhaustion or heat stroke. For example, PPE may require applicators to wear fully sealed suits with respirators. Such suits do not have refrigeration components, and under conditions of high heat and humidity, can become unbearable for a typical applicator. Growers believe that the requirements for buffers and PPE may make it impractical to adopt 1,3-D. The buffer requirements, especially for the small farms in the Southeastern U.S., eliminate significant growing areas around the perimeter of a field.	No

Name of Alternative	Technical and regulatory* reasons for the alternative not being feasible or available	Is the alternative considered cost effective?
1,3-D + chloropicrin + metam-sodium	For land nominated for MeBr critical use, weed, disease and nematode control are not sufficient as required by state certification programs for nursery areas nominated. Research with tarps and other combination strategies may improve efficacy (e.g., Ajwa et al., 2003), but these need to be sufficiently developed for commercial use. 1,3-D is a good nematicide and chloropicrin is a good fungicide. Metam sodium provides moderate, but in some situations, inconsistent disease, nematode, and weed control, dependent on soil conditions. Metam sodium degrades in the soil to form methylisothiocyanate, which has activity against nematodes, fungi, insects, and weeds. MeBr has a higher vapor pressure than metam sodium, therefore can penetrate and diffuse throughout the soil more effectively than metam sodium. In addition, the effectiveness of metam sodium is dependent on the organic matter and moisture content of the soil. Studies to evaluate best delivery systems for metam sodium are being conducted. Some studies have shown that soil injections and drenches are more effective than drip irrigation. Research trials show that incorporation of metam sodium with a tractor-mounted tillovator provides good results, but most growers do not have this equipment. A 3-week time interval before planting is required to avoid phytotoxic levels. This can cause delays in production schedules that could lead to missing specific market windows, thus reducing profit or causing a loss for a grower. The combination of the three chemicals would likely require a companion herbicide or hand weeding. Failure to control the full spectrum of weeds could lead to increased disease pressure over time because the weeds can be reservoirs for disease or harbors insect vectors of disease. Also, because strawberry fruit growers require pest free strawberry root stock, nursery growers who do not supply this type of product will be forced out of the market.	No

Name of Alternative	Technical and regulatory* reasons for the alternative not being feasible or available	Is the alternative considered cost effective?
1,3-D + metam-sodium	1,3-D and metam-sodium possess inconsistent control of nutsedge (Webster et. al. 2001). Research examining protocols for combination treatments have the best chance for effective pest control, but strategies must be developed so they are ready for commercial applications. The combination of 1,3-D and metam sodium is not feasible for the nominated areas because it does not consistently control pests and diseases to the level required by various state laws. 1,3-D is a good nematicide and metam sodium provides very good to poor (i.e., unpredictable) disease, nematode, and weed control, most likely due to irregular distribution through the soil. The combination of these chemicals would likely require a companion herbicide or hand weeding. Failure to control the weed seed in soil would most likely lead to increased disease pressure over time. In strawberry fruit production, there is demand for pest free strawberry root stock and nursery growers who do not supply this type of product will be forced out of the market. Personal Protective Equipment (PPE) requirements may be problematic for worker comfort in the hot or humid climates of California or the southeastern U.S. In addition, the buffer requirement of 90 meters (300 feet) would be particularly constraining on smaller fields in predominantly urban fringe areas. For small strawberry nursery operations in the southeastern U.S., the 1,3-D buffer requirements eliminate a large area around the field perimeter, which impacts the total area available for strawberry nursery production. Sequential application of each one of these chemicals requires significantly more time than using MeBr alone since growers must wait longer after fumigation to put the strawberry root stock in the ground. Growers have a greater planting delay for several weeks, which will extend their production schedule. This delay directly impacts cultivar options, Integrated Pest Management practices, timing of planting and harvest for strawberry fruit production, marketing window options, land leasing decisions, and subsequent crop rotation schedules. Since growers will require rootstock at a fixed time during the year, the nursery plants could be of lower grade and quality (smaller) causing loss to both the nursery grower and the fruit grower.	No

** Regulatory reasons include local restrictions (e.g. occupational health and safety, local environmental regulations) and lack of registration.*

SOUTHEASTERN STATES - 14. LIST AND DISCUSS WHY REGISTERED *(and Potential)* PESTICIDES AND HERBICIDES ARE CONSIDERED NOT EFFECTIVE AS TECHNICAL ALTERNATIVES TO METHYL BROMIDE

SOUTHEASTERN STATES – TABLE 14.1: TECHNICALLY INFEASIBLE ALTERNATIVES DISCUSSION

NAME OF ALTERNATIVE	DISCUSSION
Other fungicides, herbicides, or nematicides.	In addition to chemical alternatives already discussed, researchers are testing halosulfuron for control of nutsedges.

SOUTHEASTERN STATES - 15. LIST PRESENT *(and Possible Future)* REGISTRATION STATUS. OF ANY CURRENT AND POTENTIAL ALTERNATIVES

SOUTHEASTERN STATES – TABLE 15.1: PRESENT REGISTRATION STATUS OF ALTERNATIVES

NAME OF ALTERNATIVE	PRESENT REGISTRATION STATUS	REGISTRATION BEING CONSIDERED BY NATIONAL AUTHORITIES? (Y/N)	DATE OF POSSIBLE FUTURE REGISTRATION:
Iodomethane	Not registered for any crop uses in the U.S.	Yes	Unknown
Propargyl bromide	Registration in the U.S. has not been requested.	No	Unknown
Sodium azide	Registration in the U.S. has not been requested.	No	Unknown
Halosulfuron	Not registered for strawberry	No	Unknown

SOUTHEASTERN STATES - 16. STATE RELATIVE EFFECTIVENESS OF RELEVANT ALTERNATIVES COMPARED TO METHYL BROMIDE FOR THE SPECIFIC KEY TARGET PESTS AND WEEDS FOR WHICH IT IS BEING REQUESTED

The following study was conducted in the southeastern U.S. but with methyl iodide (MI) as the principal treatment comparing to 1,3-D with 35% chloropicrin (Telone C-35) and an untreated control. Based on researchers' opinions from numerous studies, MI when used as a soil fumigant generally provides yields and levels of pest control comparable to MB. Accordingly, we assumed that the results of the available study are representative of previous studies and can be relied upon for assessing the comparative value of the best available alternative (1,3-D + 35% chloropicrin).

Given the soil types present in production areas the root zone required to be protected is generally as deep as 1 m. Although several of the alternatives provided adequate levels of pest control at shallower depths, none consistently provided suitable control levels at 1 m. Failure to provide levels of pest control at the required depth will result in inadequate levels of control, which will result in rejection of the plants produced under these conditions (100% loss in affected fields). Accordingly, the maximum loss estimate is listed as 100% because the various state certification requirements, which equate to a zero tolerance for disease symptoms and nematodes.

SOUTHEASTERN STATES – TABLE 16.1: EFFECTIVENESS OF ALTERNATIVES—WEEDS

Treatment	Application Rate (kg/ha)	% MeBr Pest Control			% MeBr Yield	Comments
		Nem.	Dis.	Weeds		
Methyl Iodide (100%)	263	NQ	NQ	Assume 100%	Assume 100%	No MeBr tested
Methyl Iodide/Chloropicrin (75:25)	263/66	NQ	NQ	92%	81%	
1,3-D/Chloropicrin (Telone C-35)	254/139	NQ	NQ	87%	73%	

Source: Gilreath, J.P., E.B. Poling, J.W. Noling, 2001, unpublished study

Key to Table Abbreviations: NQ = not quantified (too low and non-uniform); Nem. = nematodes; Dis. = diseases

Methyl iodide yield was statistically higher than the combination with chloropicrin and the 1,3-D/chloropicrin treatments. There was no statistical difference between these two treatments, however, they both provided statistically higher yields than the untreated controls. The weeds were hairy galinsoga (*Galinsoga cillata*), carpetweed (*Mollugo verticillata*), and purslane (*Portulaca oleracea*). The most difficult weed to control was hairy galinsoga, with methyl iodide providing the highest levels of control of this weed, as well as the other weeds. The post treatment disease and nematode incidence data were too variable and too low in any of the plots to formulate any conclusions. The yield benefit exhibited by methyl iodide is likely to be a combination of weed control plus control of other unidentified microbial pests. The comparative weed control percentages are based solely on control of hairy galinsoga.

SOUTHEASTERN STATES – TABLE C.1: ALTERNATIVES YIELD LOSS DATA SUMMARY

ALTERNATIVE	LIST TYPE OF PEST	RANGE OF YIELD LOSS	BEST ESTIMATE OF YIELD LOSS
1,3-D/chloropicrin (Telone C-35)	Weeds (see above table)	0-27%	10%
Metam Sodium	Weeds (see above table)	0-50%	10%
OVERALL LOSS ESTIMATE FOR ALL ALTERNATIVES TO PESTS			**10%**

SOUTHEASTERN STATES - 17. ARE THERE ANY OTHER POTENTIAL ALTERNATIVES UNDER DEVELOPMENT WHICH ARE BEING CONSIDERED TO REPLACE METHYL BROMIDE

Methyl iodide (iodomethane) is in a pending registration status and is being evaluated as an alternative. It is generally considered to be as effective as MeBr for many preplant crop uses and pests. Growers might readily transition to this alternative.

Dazomet is also in a pending registration status as a nematicide on strawberries. The efficacy in the southeastern U.S. is unclear.

SOUTHEASTERN STATES - 18. ARE THERE TECHNOLOGIES BEING USED TO PRODUCE THE CROP WHICH AVOID THE NEED FOR METHYL BROMIDE

For 2008, MeBr is critical for strawberry nurseries in the southeastern U.S. because of the strict requirements of producing pest-free nursery stock. The technology changeover costs for adopting soilless culture techniques are high. Although yields reportedly obtained through greenhouse production are higher than that of the best conventional growers, capitalization for this and other sectors makes the alternative not feasible as a near term strategy to reduce reliance on MB. No information was presented on the long-term viability of this option. Conventional and organic strawberry fruit growers are dependent on MB-treated transplants to enable them to grow strawberries by starting with pest-free transplants.

SOUTHEASTERN STATES - SUMMARY OF TECHNICAL FEASIBILITY

For the area being nominated for 2008, alternatives have not been sufficiently developed to provide acceptable control of major pests in commercial strawberry nurseries in the southeastern U.S. The use of alternatives will require further study before growers can be confident that they are able to effectively control major pests, which are limiting factors in nursery production in this area. The consortium is currently developing a timeline to describe the transition from MeBr to alternatives. Research has been cited from California (e.g., Kabir et al., 2003) of the potential for MeBr replacement or reduction for this sector, but the need for MeBr for these nurseries for 2008, is critical until methods are developed for commercial strawberry nursery operations-.

Key alternatives are 1,3-D/chloropicrin, 1,3-D/chloropicrin/metam-sodium, and 1,3-D/metam-sodium. Dazomet is also a possible alternative probably in combination with chloropicrin and/or 1,3-D. These chemicals, in addition to developing strategies for use of tarps, such as virtually impermeable films, may ultimately reduce or replace MB. However, after long-term MeBr use, strategies for new treatments must be researched and transferred for commercial applications.

CALIFORNIA - PART B: CROP CHARACTERISTICS AND METHYL BROMIDE USE

CALIFORNIA - 10. KEY DISEASES AND WEEDS FOR WHICH METHYL BROMIDE IS REQUESTED AND SPECIFIC REASONS FOR THIS REQUEST

CALIFORNIA - TABLE 10.1: KEY DISEASES AND WEEDS AND REASON FOR METHYL BROMIDE REQUEST

REGION WHERE METHYL BROMIDE USE IS REQUESTED	KEY DISEASE(S) AND WEED(S) TO GENUS AND, IF KNOWN, TO SPECIES LEVEL	SPECIFIC REASONS WHY METHYL BROMIDE NEEDED
California	Diseases: Phytophthora Crown and Root Rots (*Phytophthora spp.*); Red Stele (*Phytophthora fragariae*); Verticillium Wilt (*Verticillium dahliae*); Anthracnose (*Colletotrechum acutatum*) Nematodes: Root-knot (*Meloidogyne spp.*); sting (*Belonolaimus spp.*); dagger (*Xiphinema spp.*); lesion (*Pratylenchus spp.*); foliar (*Aphelenchoides spp.*); needle (*Longidorus spp.*); stem (*Ditylenchus spp.*) Weeds: numerous weeds listed (e.g., annual bluegrass, bur clover, carpetweed, chickweed, field bindweed, goat grass, hairy nightshade, lambsquarter, malva, nutsedge, pig weed, portulaca, prostate spurge, puncture vine, purslane, vetch)	The state certification program has strict requirements for control of diseases and nematodes (CDFA, 2003). Given the growing situations encountered over the course of the 5-year transplant production cycle (a different growing location is used each year), in situations where 1,3-D is not effective, no other alternatives have been shown to provide pest control acceptable for state certification. There is research being conducted that indicates potential for acceptable alternatives in the future (e.g., Kabir et al., 2003) but, for 2008, there is a critical need for MB. Methyl iodide may prove to be an effective alternative, but it is currently not registered in the U.S.

CALIFORNIA – 11. (*i*) CHARACTERISTICS OF CROPPING SYSTEM AND CLIMATE

CALIFORNIA - TABLE 11.1: CHARACTERISTICS OF CROPPING SYSTEM

CHARACTERISTICS	CALIFORNIA
CROP TYPE: *(e.g. transplants, bulbs, trees or cuttings)*	Strawberry transplants
ANNUAL OR PERENNIAL CROP: *(# of years between replanting)*	Annual crop, only planted in the same location once every three years
TYPICAL CROP ROTATION *(if any)* **AND USE OF METHYL BROMIDE FOR OTHER CROPS IN THE ROTATION:** *(if any)*	The principal rotational crops are endive, garlic, onion, horseradish, mint, alfalfa, sugarbeets, and potatoes.
SOIL TYPES: *(Sand, loam, clay, etc.)*	80% light soils, 10% medium soils and 10% heavy soils; 70% with 2% or less organic matter
FREQUENCY OF METHYL BROMIDE FUMIGATION: *(e.g. every two years)*	Every year
OTHER RELEVANT FACTORS:	No

California (low elevation areas; years 3 & 4) -Table 11.2 Characteristics of Climate and Crop Schedule

	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb
Climatic Zone	6a, 6b, 7a, 9a, 9b											
Rainfall *(mm)*	16	72.1	17.3	0	trace	1.0	trace	0	44.7	56.9	9.9	30.5
Outside Temp. *(℃)*	14.4	14.8	20.8	25.7	30.3	27.4	25.1	18.4	13.4	9.6	10.3	10.6
Fumigation Schedule		X										
Planting Schedule			X	X								
harvest schedule											X	

*For Fresno, California.

California (high elevation areas; year 5) -Table 11.3 Characteristics of Climate and Crop Schedule

	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb
Climatic Zone	6a, 6b, 7a, 9a, 9b											
Fumigation Schedule						X	X					
Planting Schedule		X										
harvest schedule							X	X	X			

California – 11. (*ii*) Indicate if any of the above characteristics in 11. (*i*) prevent the uptake of any relevant alternatives?

Legal restrictions of some alternatives and certain soil moisture conditions can have an impact on use.

CALIFORNIA - 12. HISTORIC PATTERN OF USE OF METHYL BROMIDE, AND/OR MIXTURES CONTAINING METHYL BROMIDE, FOR WHICH AN EXEMPTION IS REQUESTED

CALIFORNIA - TABLE 12.1 HISTORIC PATTERN OF USE OF METHYL BROMIDE

FOR AS MANY YEARS AS POSSIBLE AS SHOWN SPECIFY:	1999	2000	2001	2002	2003	2004
AREA TREATED *(hectares)*	1,267	1,283	1,295	1,477	1,550	1,683
RATIO OF FLAT FUMIGATION METHYL BROMIDE USE TO STRIP/BED USE IF STRIP TREATMENT IS USED	All Flat fumigation	All Flat fumigation	All Flat fumigation	All Flat fumigation	All Flat fumigation	All Flat fumigation
AMOUNT OF METHYL BROMIDE ACTIVE INGREDIENT USED *(total kg)*	341,230	337,604	341,022	389,069	408,523	443,432
FORMULATIONS OF METHYL BROMIDE	67:33	67:33	67:33	67:33	67:33	67:33
METHOD BY WHICH METHYL BROMIDE APPLIED	Soil injection	Soil injection	Soil injection	Soil injection	Soil injection	Soil injection
APPLICATION RATE OF FORMULATIONS IN kg/ha*	404	395	395	395	395	395
APPLICATION RATE OF METHYL BROMIDE IN kg/ha*	269	263	263	263	263	263
ACTUAL DOSAGE RATE OF FORMULATIONS *(g/m^2)**	40.4	39.5	39.5	39.5	39.5	39.5
ACTUAL DOSAGE RATE OF METHYL BROMIDE *(g/m^2)**	26.9	26.3	26.3	26.3	26.3	26.3

** For Flat fumigation treatment application rate and dosage rate may be the same.*

CALIFORNIA - PART C: TECHNICAL VALIDATION

CALIFORNIA - 13. REASON FOR ALTERNATIVES NOT BEING FEASIBLE

CALIFORNIA – TABLE 13.1: REASON FOR ALTERNATIVES NOT BEING FEASIBLE

Please see the description above under the Southeastern U.S. (Southeastern U.S. Table 13.1).

CALIFORNIA - 14. LIST AND DISCUSS WHY REGISTERED *(and Potential)* PESTICIDES AND HERBICIDES ARE CONSIDERED NOT EFFECTIVE AS TECHNICAL ALTERNATIVES TO METHYL BROMIDE

CALIFORNIA – TABLE 14.1: TECHNICALLY INFEASIBLE ALTERNATIVES DISCUSSION

Please see the description in the Southeastern U.S. above (Southeastern U.S. Table 14.1).

CALIFORNIA - 15. LIST PRESENT *(and Possible Future)* REGISTRATION STATUS OF ANY CURRENT AND POTENTIAL ALTERNATIVES

CALIFORNIA – TABLE 15.1: PRESENT REGISTRATION STATUS OF ALTERNATIVES

NAME OF ALTERNATIVE	PRESENT REGISTRATION STATUS *State if registered for this crop, registered for crop but use restricted, registered for other crops but not target crop, or not registered*	REGISTRATION BEING CONSIDERED BY NATIONAL AUTHORITIES? (Y/N)	DATE OF POSSIBLE FUTURE REGISTRATION:
Iodomethane	Not registered for any crop uses in the U.S.	Yes	Unknown
Sodium Azide	Not submitted for registration.	No	Unknown
Propargyl bromide	Not submitted for registration.	No	Unknown
Muscador albus strain QST 20799	Registration package has been received.	Yes	Registered but not yet for sale in the U.S.

CALIFORNIA - 16. STATE RELATIVE EFFECTIVENESS OF RELEVANT ALTERNATIVES COMPARED TO METHYL BROMIDE FOR THE SPECIFIC KEY TARGET PESTS AND WEEDS FOR WHICH IT IS BEING REQUESTED

Numerous studies have been referenced (see section 26) in the two applications (Southeastern States [Maryland, North Carolina, Tennessee], and California). Several studies suggest that alternatives (most likely combination of alternatives) have potential as MeBr replacements, but would not be acceptable for the 2008 season. This is because protocols for alternative treatments have to go through a multi-season process of research and development before they are commercially available. This is especially true for managing pest requirements of nursery certification programs. For the 2008 season nomination, MeBr is considered critical for the strawberry nursery sector, in situations where 1,3-D cannot be used because of regulations or lack of efficacy for attaining certification. Consortia are currently developing timelines to detail their schedules for transition from MeBr to alternatives.

However, research from California (e.g., Kabir et al., 2003) (see Tables 16.5a and 16.5b, below), suggests promising alternatives to MeBr in the future. Small scale research results suggested that the use of chloropicrin followed by dazomet produced yields (during some years of the study) at least as high as MeBr treated soil. The issues of consistency and scale-up to commercial size are still outstanding, and this study did not evaluate specific pests, use of tarps, or consider California certification requirements. Therefore, there is a critical need for MeBr for the 2008 use season, until the efficacy of alternative treatments can be confirmed.

Inconsistency in performance of the alternatives results from the application methods, application rates, formulations of alternatives, soil and weather conditions, and pest species and levels present in tests. Experience with techniques in application of alternatives, and interactions of several alternatives, should improve efficacy.

The root zone to be protected is as deep as 1 m. Although several of the alternatives provide adequate levels of pest control at shallower depths, alternative chemicals do not consistently provide suitable control levels at 1 m. Failure to provide levels of pest control at the required depth will result in inadequate levels of control, which will result in rejection of the plants produced under these conditions (100% loss in affected fields).

CALIFORNIA – TABLE 16.1: EFFECTIVENESS OF ALTERNATIVES – CHEMICAL ALTERNATIVES TO METHYL BROMIDE FUMIGATION – HOW WELL DO THEY WORK?

Treatment	Application Method & Rate (kg/ha)	Pest Control (% of MB)		Yield (% of MB)	Comments
		NEM	**DIS.**		
MB/CP (67:33)	MB: 246kg/ha; CP: 121 kg/ha; chisel injection & tarped	+	+	100	
1,3-D/CP (70:30)	1,3-D: 361 kg/ha; CP: 155 kg/ha; chisel injection & tarped	+	+	96	
Chloropicrin (CP)	95-189; and 190 and higher; chisel injection & tarped	+	+	89 (< 190kg/ha); 103 (>190 kg/ha)	Evaluated both low and high dosage rates
Metam Sodium	950 kg/ha; surface drench and tarped	+	+	92	
Dazomet	340 kg/ha; broadcast, tilled into soil, and tarped	+	+	95	
Enzone (sodium tetra thiocarbonate)	2.85 kg/ha tarped	+	+	80	Not registered for use on strawberries
Untreated		+	+	70	

Source: Gubler, W.D., J.M. Duniway, and N. Welch. 1996. Chemical Alternatives to Methyl Bromide Fumigation – How Well Do They Work?

Key to Abbreviations: 1,3-D = 1,3-dichloropropene; MB = methyl bromide; CP = chloropicrin; MS = metam sodium; Nem. = nematodes; Dis. = diseases

Watsonville, CA 1993 study using large-scale plots; low levels of Phytophthora crown and root rots, Verticillium wilt, and nematodes; one-year evaluation only

CALIFORNIA – TABLE 16.2: EFFECTIVENESS OF ALTERNATIVES CHLOROPICRIN EFFECT ON WEED SEED VIABILITY.

Control Measures Evaluated	Application Method & Rate (kg/ha)	Weed Control (% of MB)	Comments
MB/CP (67:33)	MB: 225 kg/ha CP: 111 kg/ha; soil injection	100	Very good control of 3 weeds; no control of 2 weeds (mallow & filaree)
Metam Sodium (MS)	MS: 197 kg/ha; drip irrigation	Comp.	Very good control of 3 weeds; no control of 2 weeds (mallow & filaree)
MS plus CP	MS: 197kg /ha drip irrigation; CP: 83 – 220 kg/ha soil injection	Very Comp.	produced a slight increase in weed control over MS alone = best available treatment for the weed species present
Chloropicrin (CP)	CP: 83 – 220 kg/ha soil injection	Comp.	good control of 3 weeds at the higher rates; no control of 2 weeds (mallow & filaree)
Untreated		none	

Source: Haar, M.J., S.A. Fennimore, H.A. Ajwa, C.Q. Winterbottom. 2003. Chloropicrin Effect on Weed Seed Viability.

Key to Abbreviations: CP = chloropicrin; MB = methyl bromide, MS = metam sodium; 1,3-D = 1,3-dichloropropene; Comp = comparable.

The study was conducted over two years near Santa Maria, CA. Primary weed pests: *Polygonum aviculare* (knot-grass), *Portulaca oleracea* (common purslane) and *Malva parviflora* (little mallow) were introduced in both years, whereas, *Stellaria media* (chickweed) and *Erodium cicutarium* (red-stem filaree) were introduced in the second year; similar weed seed sensitivity for CP and MS; no yield data obtained.

CALIFORNIA – TABLE 16.3: EFFECTIVENESS OF ALTERNATIVES - SOIL FUMIGATION AND RUNNER PLANT PRODUCTION.

Treatment	Application Method & Rate (kg/ha)	Yield (% of MB)	Comments
Methyl bromide	Chisel	100 (4 trials)	
Chloropicrin	140-191 kg/ha , chisel	73-92 (3 trials)	
Chloropicrin	≥300 kg/ha, Chisel;	86 – 100 (4 trials)	Appeared to be the best of the alternatives evaluated
1,3-D/Chloropicrin (70:30)	Chisel;	84 (1 trial)	Did not rank very high as an alternative due to reduced plant growth and runner production
1,3-D/Chloropicrin (30:70)	Chisel	91 (1 trial)	Appeared to perform similar to the high rate of chloropicrin
Untreated	Not Applicable	38-55 (4 trials)	

Source: Larson, K.D. and D.V. Shaw, 2000, Soil Fumigation and Runner Plant Production: A Synthesis of Four Years of Strawberry Nursery Field Trials, Hort Sci. 35 (4):642-646.
Key to Abbreviations: 1,3-D = 1,3-dichloropropene.

This study was conducted on former strawberry nursery soils, however, other crops were planted in these soils prior to initiating this study; fumigants chiseled into soil at a 36 cm depth and covered with a tarp for 7 days; pest types and pressures uncertain, however, Verticillium wilt (*V. albo-atrum*) was detected in some locations and roots were examined for decay and discoloration, with the untreated plants exhibiting most of the disease symptoms; nematodes were not considered to be a problem in any of the test locations. The main focus of this study was to evaluate yield responses and that quantification of the various pest organisms was beyond the scope of this study.

CALIFORNIA – TABLE 16.4: EFFECTIVENESS OF ALTERNATIVES - EVALUATION OF ALTERNATIVES TO METHYL BROMIDE FOR SOIL FUMIGATION AT COMMERCIAL FRUIT AND NUT TREE NURSERIES

Treatment	Application Method & Rate (kg/ha)	Nematode Control (% of MB)
Methyl bromide /chloropicrin (75:25)	MB: 448 kg/ha; CP: 151 kg/ha	100
1,3-D/CP	1,3-D: 518 kg/ha; CP: 283 kg/ha	83-100
1,3-D + Metam Sodium	Sequential application; 1,3-D: 518 kg/ha; MS: (?) kg/ha.	16-100
1,3-D/dazomet	Sequential application; 396 kg/ha; 224 kg/ha DZ	28-100

Source: McKenry, M.V., 2001. Evaluation of Alternatives to Methyl Bromide for Soil Fumigation at Commercial Fruit and Nut Tree Nurseries, California Department of Pesticide Regulation (Contract # 99-0218).

Key to Abbreviations: 1,3-D = ; CP = chloropicrin ; MB = methyl bromide; DZ = dazomet; Prominent nematode pests present: lesion (*Pratylenchus* spp.), spiral (*Helicotylenchus dihystera*), dagger (*Xiphinema americanum*) and some root-knot (*Meloidogyne* spp.)

CALIFORNIA – TABLE 16.5a and 16.5b: EFFECTIVENESS OF ALTERNATIVES - EVALUATION OF ALTERNATIVES TO METHYL BROMIDE FOR THE CONTROL OF SOIL PESTS: STRAWBERRY AS A MODEL SYSTEM

Table 16.5a. **FRUIT YIELD (GRAMS PER PLANT) OF STRAWBERRY AT WATSONVILLE, CA IN 2002**. [The 'nursery' column indicates the treatment of nursery plants grown in 2001; the 'field' column indicates the fumigation treatment in the field.]

Nursery treatment (high elevation, MacDoel, CA)	Field treatment (Watsonville)	Marketable yield (g/plant)	Unmarketable yield (g/plant)	Total yield (g/plant)
control	Pic	1301.7	535.6	1837.3
MB/Pic	Pic	1235.8	550.9	1786.6
MI/Pic	Pic	1278.2	525.0	1803.3
Pic followed by dazomet	Pic	1388.4	575.1	1963.4
Telone C35 followed by dazomet	Pic	1346.4	553.3	1899.7
control	MB/Pic	1520.3	600.1	2120.4
MB/Pic	MB/Pic	1474.0	596.3	2070.3
MI/Pic	MB/Pic	1526.8	625.0	2151.8
Pic followed by dazomet	MB/Pic	1634.5	640.6	2275.1
Telone C35 followed by dazomet	MB/Pic	1434.1	634.0	2068.1
ANOVA		------------------------P values---------------------		
Nursery		0.04*	0.24	0.07
Field		<0.0001*	<0.0001*	<0.0001*
Nursery (field)		0.47	0.74	0.73
		* indicates significance		

Source: Kabir, Z., Fennimore, S., Martin, F., Ajwa, H., Duniway, J., Browne, G., Winterbottom, C., Westerdahl, B., Goodhue, R., Guerrero, L., Haar, M. 2003. Alternative[s] Fumigants for the Control of Soil Pests: Strawberry as a Model System. Methyl Bromide Alternatives Conference (2003). www.mbao.org.

Key to Abbreviations: For **nursery treatments**: **control**= no fumigation; **methyl bromide/chloropicrin (MB/Pic)** = 57:43, 450 kg/ha; **methyl iodide/chloropicrin (MI/Pic)** = 50:50, 392 kg/ha; **1,3-D/chloropicrin (Telone C35)** (300 liters/ha) followed by **dazomet (280 kg/ha)**; **chloropicrin (Pic)** (336 kg/ha) followed by **dazomet** (280 kg/ha).

For **field treatments**: **control**= no fumigation; **MB/Pic**, 67:33 (392 kg/ha); **Pic** (224 kg/ha).

Table 16.5b. FRUIT YIELD (GRAMS PER PLANT) OF STRAWBERRY AT WATSONVILLE, CA IN 2003. [The 'nursery' column indicates the treatment of nursery plants grown in 2002; the 'field' column indicates the fumigation treatment in the field.]

Nursery treatment (high elevation, MacDoel, CA)	Field treatment (Watsonville)	Marketable yield (g/plant)	Unmarketable yield (g/plant)	Total yield (g/plant)
control	Pic	1270.2	1092.5	2362.7
MB/Pic	Pic	1244.2	1070.5	2314.7
MI/Pic	Pic	1153.7	992.9	2146.6
Pic followed by dazomet	Pic	1324.6	1059.4	2384.0
Telone C35 followed by dazomet	Pic	1220.2	1069.7	2289.9
control	MB/Pic	1177.2	1216.1	2393.3
MB/Pic	MB/Pic	1132.2	1179.8	2311.9
MI/Pic	MB/Pic	1050.8	1106.2	2157.0
Pic followed by dazomet	MB/Pic	1166.9	1249.2	2416.0
Telone C35 followed by dazomet	MB/Pic	1111.0	1176.9	2287.9
ANOVA		------------------------P values----------------------		
Nursery		0.001*	0.003*	0.0001*
Field		<0.0001*	<0.0001*	0.70
Nursery (field)		0.92	0.60	0.99
		* indicates statistical significance		

Source: Kabir, Z., Fennimore, S., Martin, F., Ajwa, H., Duniway, J., Browne, G., Winterbottom, C., Westerdahl, B., Goodhue, R., Guerrero, L., Haar, M. 2003. Alternative[s] Fumigants for the Control of Soil Pests: Strawberry as a Model System. Methyl Bromide Alternatives Conference (2003). www.mbao.org.

Key to Abbreviations: For **nursery treatments**: **control**= no fumigation; **methyl bromide/chloropicrin (MB/Pic)** = 57:43, 450 kg/ha; **methyl iodide/chloropicrin (MI/Pic)** = 50:50, 392 kg/ha; **1,3-D/chloropicrin (Telone C35)** (300 liters/ha) followed by **dazomet (280 kg/ha)**; **chloropicrin (Pic)** (336 kg/ha) followed by **dazomet** (280 kg/ha).

For **field treatments**: **control**= no fumigation; **MB/Pic**, 67:33 (392 kg/ha); **Pic** (224 kg/ha).

This strawberry yield research study was conducted at three strawberry runner nurseries. Plants were grown for three years at two high elevation nurseries (HEN) or for two years at a low elevation nursery (LEN). Plants were then placed in two different field locations (Watsonville and Oxnard) for marketable yield assessments. Plants received various fumigation treatments at both nursery and field locations (results from two trials, conducted in 2002 and 2003, are presented in Tables 16.5a and 16.5b, above).

Pests were not identified and only yields were evaluated. In the 2002 test, "…fruit yield was significantly greater under the on-site MBPic treatment than in Pic treatment alone" (Table 16.5a). The fumigants used at the nursery had "…positive carryover effects on marketable fruit yield when the treatment was Pic [followed by] Basamid".

The results at the Watsonville location for the 2003 test showed "…marketable fruit yield was increased (9%) in on-site Pic treatments compared to MBPic treatments. In contrast, non-marketable fruit yield was significantly greater (4%) under MBPic than under Pic (Table 16.5b). The authors again noted that the nursery treatments had significant carryover effects on the fruit yield. They "…suggest that application of Pic fb [followed by] Basamid [dazomet] at the HEN increased runner plant production, which eventually improved fruit yield with Pic in the fruiting field. Pic could be a viable alternative to MBPic". No interaction was found between the fumigations at the nursery and field, therefore, the effects were considered additive.

CALIFORNIA – TABLE C.1: ALTERNATIVES YIELD LOSS DATA SUMMARY

ALTERNATIVE	LIST TYPE OF PEST	RANGE OF YIELD LOSS	BEST ESTIMATE OF YIELD LOSS
1,3-D/Chloropicrin	Various weeds	0-22%	10%
1,3-D + Metam Sodium	Various weeds	---	13%
OVERALL LOSS ESTIMATE FOR ALL ALTERNATIVES TO PESTS			**10-13%**

CALIFORNIA - 17. ARE THERE ANY OTHER POTENTIAL ALTERNATIVES UNDER DEVELOPMENT WHICH ARE BEING CONSIDERED TO REPLACE METHYL BROMIDE?

Iodomethane is not registered, but is reported to be a potential suitable alternative for all key pests.

Dazomet has a pending registration as a nematicide on strawberries and may be an effective alternative, especially when combined with other treatments (e.g., Kabir et al., 2003).

CALIFORNIA - 18. ARE THERE TECHNOLOGIES BEING USED TO PRODUCE THE CROP WHICH AVOID THE NEED FOR METHYL BROMIDE

Because of strict requirements for pest free nursery stock (CDFA, 2003), only certain areas can be certified as pest-free without the use of MB, or in some instances, 1,3-D. A shift to soilless cultivation would require a major shift in production and would result in a significant market disruption for the near term.

CALIFORNIA - SUMMARY OF TECHNICAL FEASIBILITY

Strict requirements for pest free nursery plants will make MeBr a critical tool for nursery growers, for the 2008 season. Protocols for effective use of the alternatives that were discussed above, have not been sufficiently developed at this time to provide sufficient control of such major pests as nematodes and root rot pathogens in commercial strawberry nurseries in California. The use of these alternatives will require further study before growers can adopt them for nursery plant production. Research from California (e.g., Kabir et al., 2003) suggests possible MeBr alternatives, but these results are preliminary, and require scale-up efforts. Timelines are being developed to outline the industry's transition to alternatives.

Key alternatives are 1,3- D/chloropicrin, 1,3-D/chloropicrin/metam-sodium, and 1,3-D/metam-sodium. Dazomet is also a possible alternative probably in combination with chloropicrin and/or 1,3-D. These chemicals, in addition to developing strategies for use of tarps, such as VIF, may ultimately reduce or replace MB. Currently, some high barrier films are in use in California and have helped to reduce the rates of MB. VIF use is restricted in California and there are concerns about acceptable off-gassing rates. Strategies for new treatments must be researched and transferred for commercial applications.

PART D: EMISSION CONTROL

19. TECHNIQUES THAT HAVE AND WILL BE USED TO MINIMIZE METHYL BROMIDE USE AND EMISSIONS IN THE PARTICULAR USE

TABLE 19.1: TECHNIQUES TO MINIMIZE METHYL BROMIDE USE AND EMISSIONS

TECHNIQUE OR STEP TAKEN	VIF OR HIGH BARRIER FILMS	METHYL BROMIDE DOSAGE REDUCTION	INCREASED % CHLOROPICRIN IN METHYL BROMIDE FORMULATION	LESS FREQUENT APPLICATION
WHAT USE/EMISSION REDUCTION METHODS ARE PRESENTLY ADOPTED?	Currently, most growers use HDPE tarps; VIF is restricted in California.	Between 1997 and 2002 the dosage rate of methyl bromide has dropped by one eighth.	All use 67:33	For certification of nursery stock, fumigation must occur prior to every planting
WHAT FURTHER USE/EMISSION REDUCTION STEPS WILL BE TAKEN FOR THE METHYL BROMIDE USED FOR CRITICAL USES?	Research is underway to develop use in commercial production systems	Possible changeover from broadcast to raised bed band treatments,	Unidentified	For certification of nursery stock, fumigation must occur prior to every planting
OTHER MEASURES *(please describe)*	Examination of promising but presently unregistered alternative fumigants with non-chemical methods.	Unidentified	Unidentified	For certification of nursery stock, fumigation must occur prior to every planting

20. IF METHYL BROMIDE EMISSION REDUCTION TECHNIQUES ARE NOT BEING USED, OR ARE NOT PLANNED FOR THE CIRCUMSTANCES OF THE NOMINATION, STATE REASONS

Tarpaulins (high density polyethylene, and mostly experimental use of virtually impermeable film) are used to minimize use and emissions of MB. In addition, practices such as deep injection are used by strawberry nursery growers to reduce the MeBr rates required for growing nursery stock.

PART E: ECONOMIC ASSESSMENT

The cost of MeBr and alternatives are given in Table 21.1. This is followed in Table 22.1 by a listing of net and gross revenues by applicant. Expected losses with use of MeBr alternatives are then estimated in Tables E1 and E2.

For this analysis, net revenue is calculated as gross revenue minus operating costs. This is a good measure of the direct losses of income that may be suffered by the users. Net revenue does not represent net income to the users. Net income, which indicates profitability of an operation of an enterprise, is gross revenue minus the sum of operating and fixed costs. Net income should be smaller than the net revenue measured in this study. Fixed costs were not included because they are often difficult to measure and verify.

21. COSTS OF ALTERNATIVES COMPARED TO METHYL BROMIDE OVER 3-YEAR PERIOD:

TABLE 21.1: OPERATING COSTS WITH ALTERNATIVES COMPARED TO METHYL BROMIDE OVER 3-YEAR PERIOD

REGION	ALTERNATIVE	YIELD*	COST IN YEAR 1 *(US$/ha)*	COST IN YEAR 2 *(US$/ha)*	COST IN YEAR 3 *(US$/ha)*
SOUTHEASTERN STATES	**Methyl Bromide**	**100**	**$ 30,245**	**$ 30,245**	**$ 30,245**
	Metam Sodium	50	$ 29,927	$ 29,927	$ 29,927
	1,3-P+Pic	90	$ 31,513	$ 31,513	$ 31,513
CALIFORNIA	**Methyl Bromide**	**100**	**$ 37,831**	**$ 37,831**	**$ 37,831**
	1,3-D+Metam Sodium	87	$ 40,157	$ 40,157	$ 40,157
	1,3-D+Pic	90	$ 37,664	$ 37,664	$ 37,664

** As percentage of typical or 3-year average yield, compared to methyl bromide*

SOUTHEASTERN STATES-22. GROSS AND NET REVENUE

SOUTHEASTERN STATES-TABLE 22.1: YEARS 1, 2, AND 3 GROSS AND NET REVENUE

ALTERNATIVES *(as shown in question 21)*	GROSS REVENUE FOR LAST REPORTED YEAR *(US$/ha)*	NET REVENUE FOR LAST REPORTED YEAR *(US$/ha)*
Methyl Bromide	**$ 42,008**	**$ 11,763**
Metam Sodium	$ 21,004	$ (8,923)
1,3-D+pic	$ 37,807	$ 6,294

CALIFORNIA-22. GROSS AND NET REVENUE

CALIFORNIA-TABLE 22.1: YEARS 1, 2, AND 3 GROSS AND NET REVENUE

ALTERNATIVES (as shown in question 21)	GROSS REVENUE FOR LAST REPORTED YEAR (US$/ha)	NET REVENUE FOR LAST REPORTED YEAR (US$/ha)
Methyl Bromide	**$ 47,741**	**$ 9,909**
1,3-D+ Metam Sodium	$ 41,773	$ 1,616
1,3-D+ Pic	$ 42,967	$ 5,303

SOUTHEASTERN STATES - TABLE E.1: ECONOMIC IMPACTS OF METHYL BROMIDE ALTERNATIVES

SOUTHEASTERN STATES	METHYL BROMIDE	ALTERNATIVE METAM	ALTERNATIVE 1,3-D+PIC
YIELD LOSS (%)	0%	50%	10%
YIELD PER HECTARE (PLANTS)	211,715	105,857	190,543
* PRICE PER UNIT (US$)	$ 0.20	$ 0.20	$ 0.20
= GROSS REVENUE PER HECTARE (US$)	$ 42,008	$ 21,004	$ 37,807
- OPERATING COSTS PER HECTARE (US$)	$ 30,245	$ 29,927	$ 31,513
= NET REVENUE PER HECTARE (US$)	$ 11,763	$ (8,923)	$ 6,294
LOSS MEASURE			
1. LOSS PER HECTARE (US$)	$0	$ 20,686	$ 5,469
2. LOSS PER KILOGRAM OF METHYL BROMIDE (US$)	$0	$ 50.15	$ 13.26
3. LOSS AS A PERCENTAGE OF GROSS REVENUE (%)	0%	49%	13%
4. LOSS AS A PERCENTAGE OF NET REVENUE (%)	0%	176%	46%

CALIFORNIA - TABLE E.2: ECONOMIC IMPACTS OF METHYL BROMIDE ALTERNATIVES

CALIFORNIA	METHYL BROMIDE	ALTERNATIVE 1,3-D METAM	ALTERNATIVE 1,3-D+PIC
YIELD LOSS (%)	0%	13%	10%
YIELD PER HECTARE (BOXES)	796	696	716
* PRICE PER UNIT (US$)	$ 60.00	$ 60.00	$ 60.00
= GROSS REVENUE PER HECTARE (US$)	$ 47,741	$ 41,773	$ 42,967
- OPERATING COSTS PER HECTARE (US$)	$ 37,831	$ 40,157	$ 37,664
= NET REVENUE PER HECTARE (US$)	$ 9,909	$ 1,616	$ 5,303
LOSS MEASURES			
1. LOSS PER HECTARE (US$)	$0	$ 8,293	$ 4,606
2. LOSS PER KILOGRAM OF METHYL BROMIDE (US$)	$0	$ 31.49	$ 17.49
3. LOSS AS A PERCENTAGE OF GROSS REVENUE (%)	0%	17%	10%
4. LOSS AS A PERCENTAGE OF NET REVENUE (%)	0%	84%	46%

SUMMARY OF ECONOMIC FEASIBILITY

The economic assessment of feasibility for pre-plant uses of MeBr included an evaluation of economic losses from three basic sources: (1) yield losses, referring to reductions in the quantity produced, (2) quality losses, which generally affect the price received for the goods, and (3) increased production costs, which may be due to the higher-cost of using an alternative, additional pest control requirements, and/or resulting shifts in other production or harvesting practices.

The economic reviewers then analyzed crop budgets for pre-plant sectors to determine the likely economic impact if methyl bromide were unavailable. Various measures were used to quantify the impacts, including the following:

(1) Losses as a percent of gross revenues. This measure has the advantage that gross revenues are usually easy to measure, at least over some unit, *e.g.*, a hectare of land or a storage operation. However, high value commodities or crops may provide high revenues but may also entail high costs. Losses of even a small percentage of gross revenues could have important impacts on the profitability of the activity.

(2) Absolute losses per hectare. For crops, this measure is closely tied to income. It is relatively easy to measure, but may be difficult to interpret in isolation.

(3) Losses per kilogram of MeBr requested. This measure indicates the value of MeBr to crop production but is also useful for structural and post-harvest uses.

(4) Losses as a percent of net revenues. We define net revenues as gross revenues minus operating costs. This is a very good indicator as to the direct losses of income that may be suffered by the owners or operators of an enterprise. However, operating costs can often be difficult to measure and verify.

These measures represent differ MeBr users, who are forest seedling producers in this case. Because producers (suppliers) represent an integral part of any definition of a market, we interpret the threshold of significant market disruption to be met if there is a significant impact on commodity suppliers using MB. The economic measures provide the basis for making that determination.

The economic analysis compared the costs of MeBr alternative control scenarios for the Southeastern Strawberry Consortium and the California Strawberry Growers Association to the baseline costs for MB. The economic estimates were first calculated in pounds and acres and then converted to kilograms and hectares. The costs for the alternatives are based on market price for the control products multiplied by the number of pounds of active ingredient that would be applied. The baseline costs were based on the average number of applications to treat strawberry plants (boxes) with MeBr per year. The loss per hectare measures the value of MeBr based on changes in operating costs and changes in yield. The loss expressed as a percentage of the gross revenue is based on the ratio of the loss to the gross revenue using MB. Likewise for the loss as a percentage of net revenue. These losses are shown in Tables E.1 and E.2.

The values to derive gross revenue and the operating costs for each alternative were derived from the baseline MeBr costs compared to the costs of changes under two fumigation scenarios in the Southeastern States: 1) metam sodium; and 2) 1,3-D + chloropicrin.

For California, the baseline MeBr costs were compared to two scenarios: 1) 1,3-D + metam sodium; and 2) 1,3-D + chloropicrin. The differences in the cost of production were primarily attributable to changes in fumigation costs.

The major production issue facing nursery growers is that customers of nursery stock require pest-free transplants. If there are incidences of disease, weeds, or insect infestation, nursery growers will not be able to market their seedlings. Fruit producers are not willing to purchase plants that have any visual symptoms of disease and may hold the nursery responsible for any disease that shows up during fruiting in the field in the first weeks after planting. A small infestation of nursery stock will be multiplied many times as plants are placed in fields for fruit production. Nearly a billion plants are produced by California strawberry nurseries each year, with world-wide distribution. There are approximately 13 seedling/runner producers in California that must manage disease incidence over the 4-year production cycle of the strawberry stock.

PART F. FUTURE PLANS

23. WHAT ACTIONS WILL BE TAKEN TO RAPIDLY DEVELOP AND DEPLOY ALTERNATIVES FOR THIS CROP?

Results of ongoing research suggest that there are treatments for strawberry nurseries that have the potential to replace MB. However, because nursery stock is so important to the strawberry fruit industry, effective alternatives will be difficult to implement. The industry supports research to identify and implement the most effective methods to treat soil, and as noted, some are promising (e.g., Kabir et al., 2003). After possibly five years of research trials, scale-up trials on a commercial level will be done to confirm the most effective treatments found in research trials. Combinations of several chemical and non-chemical controls are likely to be the most effective alternative to MB.

The amount of MeBr requested for research purposes is considered critical for the development of effective alternatives. The U.S. government estimated that strawberry nurseries research will require 454 kg per year of MeBr for 2005 and 2006. This figure will be revised for use after that time. The requested research use of MeBr is in addition to the amounts requested in the submitted CUE applications.

24. HOW DO YOU PLAN TO MINIMIZE THE USE OF METHYL BROMIDE FOR THE CRITICAL USE IN THE FUTURE?

As described in Section 23.

25. ADDITIONAL COMMENTS ON THE NOMINATION?

The MeBr critical use exemption nomination for Strawberry Nurseries for the 2008 use season has been reviewed by the U. S. Environmental Protection Agency and the U. S. Department of Agriculture and meets the guidelines of The *Montreal Protocol on Substances That Deplete the Ozone Layer*. This use is considered critical because there are conditions in some nurseries with high pest pressure where no feasible alternatives or substitutes are currently effective. While some research trials indicated treatments that could offer an alternative to MeBr under some circumstances, the high production nursery industry demands a consistent and reliable pre-plant fumigation treatment that can allow production goals to be met. Currently MeBr is the only consistent provider of this requirement. The loss of MB, therefore, would result in a significant market disruption in providing clean transplants to the industry. The effort to avoid market disruption provides the basis for nomination of this sector for critical use exemption of MB.

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APPENDIX A. 2008 Methyl Bromide Usage Newer Numerical Index (BUNNI).

2008 Methyl Bromide Usage Newer Numerical Index - BUNNI					Strawberry Nursery	
January 24, 2006	Region		CA Strawberry Nursery Assoc.	SE Strawberry Consortium	Sector Total or Average	Notes
Dichotomous Variables	Strip or Bed Treatment?		No	Strip		
	Currently Use Alternatives?		Yes	Yes		
	Tarps / Deep Injection Used?		Tarp	Tarp		
	Pest-free Cert Requirements?		Yes	Yes		
Other Issues	Frequency of Treatment (x/ yr)		1x/ year	1x/ year		*
	QPS Removed?		Yes	Yes		
Most Likely Combined Impacts (%)	Karst -1,3-D Limitation (%)		0%	0%		
	100 ft Buffer Zones (%)		0%	0%		
	Key Pest Distribution (%)		100%	100%		
	Regulatory Issues (%)		17%	0%		
	Unsuitable Terrain (%)		0%	0%		
	Cold Soil Temperature (%)		0%	0%		
	Total Combined Impacts (%)		**100%**	**100%**		
Most Likely Baseline Transition	(%) Able to Transition		0%	0%		
	Minimum # of Years Required		0	0		
	(%) Able to Transition / Year		**0%**	**0%**		
EPA Adjusted Use Rate (kg/ha)			263	350		
EPA Adjusted Strip Dosage Rate (g/m2)			26	27		
2008 Requested Usage	*Amount - Pounds*	*Pounds*	*10,340*	*77,017*	*87,357*	
	Area - Acres		*44*	*209*	*253*	
	Rate (lb/A)		*235.00*	*368.50*	*345*	
	Amount - Kilograms	Metric	**4,690**	**34,934**	**39,624**	
	Treated Area - Hectares		18	72	90	
	Rate (kg/ha)		263	484	440	
EPA Preliminary Value		**kgs**	**4,690**	**39,624**	**44,315**	
EPA Baseline Adjusted Value has been adjusted for:			MBTOC Adjustments, QPS, Double Counting, Growth, Use Rate/Strip Treatment, Miscellaneous, and Combined Impacts			
EPA Baseline Adjusted Value		kgs	4,690	3,693	8,384	
EPA Transition Amount		kgs	-	-	-	
Most Likely Impact Value (kgs)		kgs	**4,690**	**3,693**	**8,384**	
		ha	**18**	**14**	**31**	
		Rate	**263**	**271**	**267**	
Sector Research Amount (kgs)			**454**	**2008 Total US Sector Nomination**	**8,838**	

1 Pound = 0.453592 kgs   1 Acre = 0.404686 ha

Footnotes for Appendix A:

Values may not sum exactly due to rounding.

1. **Dichotomous Variables** – dichotomous variables are those which take one of two values, for example, 0 or 1, yes or no. These variables were used to categorize the uses during the preparation of the nomination.
2. **Strip Bed Treatment** – Strip bed treatment is ‘yes’ if the applicant uses such treatment, no otherwise.
3. **Currently Use Alternatives** – Currently use alternatives is ‘yes’ if the applicant uses alternatives for some portion of pesticide use on the crop for which an application to use methyl bromide is made.
4. **Tarps/ Deep Injection Used** – Because all pre-plant methyl bromide use in the US is either with tarps or by deep injection, this variable takes on the value ‘tarp’ when tarps are used and ‘deep’ when deep injection is used.
5. **Pest-free cert. Required** - This variable is a ‘yes’ when the product must be certified as ‘pest-free’ in order to be sold
6. **Other Issues**.- Other issues is a short reminder of other elements of an application that were checked

7. **Frequency of Treatment** – This indicates how often methyl bromide is applied in the sector. Frequency varies from multiple times per year to once in several decades.
8. **Quarantine and Pre-Shipment Removed?** – This indicates whether the Quarantine and pre-shipment (QPS) hectares subject to QPS treatments were removed from the nomination.
9. **Most Likely Combined Impacts (%)** – Adjustments to requested amounts were factors that reduced to total amount of methyl bromide requested by factoring in the specific situations were the applicant could use alternatives to methyl bromide. These are calculated as proportions of the total request. We have tried to make the adjustment to the requested amounts in the most appropriate category when the adjustment could fall into more than one category.
10. **(%) Karst geology** – Percent karst geology is the proportion of the land area in a nomination that is characterized by karst formations. In these areas, the groundwater can easily become contaminated by pesticides or their residues. Regulations are often in place to control the use of pesticide of concern. Dade County, Florida, has a ban on the use of 1,3D due to its karst geology.
11. **(%) 100 ft Buffer Zones** – Percentage of the acreage of a field where certain alternatives to methyl bromide cannot be used due the requirement that a 100 foot buffer be maintained between the application site and any inhabited structure.
12. **(%) Key Pest Impacts** - Percent (%) of the requested area with moderate to severe pest problems. Key pests are those that are not adequately controlled by MB alternatives. For example, the key pest in Michigan peppers, *Phytophthora* spp. infests approximately 30% of the vegetable growing area. In southern states the key pest in peppers is nutsedge.
13. **Regulatory Issues (%)** - Regulatory issues (%) is the percent (%) of the requested area where alternatives cannot be legally used (e.g., township caps) pursuant to state and local limits on their use.
14. **Unsuitable Terrain (%)** – Unsuitable terrain (%) is the percent (%) of the requested area where alternatives cannot be used due to soil type (e.g., heavy clay soils may not show adequate performance) or terrain configuration, such as hilly terrain. Where the use of alternatives poses application and coverage problems.
15. **Cold Soil Temperatures** – Cold soil temperatures is the proportion of the requested acreage where soil temperatures remain too low to enable the use of methyl bromide alternatives and still have sufficient time to produce the normal (one or two) number of crops per season or to allow harvest sufficiently early to obtain the high prices prevailing in the local market at the beginning of the season.
16. **Total Combined Impacts (%)** - Total combined impacts are the percent (%) of the requested area where alternatives cannot be used due to key pest, regulatory, soil impacts, temperature, etc. In each case the total area impacted is the conjoined area that is impacted by any individual impact. The effects were assumed to be independently distributed unless contrary evidence was available (e.g., affects are known to be mutually exclusive). For example, if 50% of the requested area had moderate to severe key pest pressure and 50% of the requested area had karst geology, then 75% of the area was assumed to require methyl bromide rather than the alternative. This was calculated as follows: 50% affected by key pests and an additional 25% (50% of 50%) affected by karst geology.
17. **Most Likely Baseline Transition** – Most Likely Baseline Transition amount was determined by the DELPHI process and was calculated by determining the maximum share of industry that can transition to existing alternatives.
18. **(%) Able to Transition** – Maximum share of industry that can transition
19. **Minimum # of Years Required** – The minimum number of years required to achieve maximum transition.
20. **(%) Able to Transition per Year** – The Percent Able to Transition per Year is the percent able to transition divided by the number of years to achieve maximum transition.
21. **EPA Adjusted Use Rate** - Use rate is the lower of requested use rate for 2008 or the historic average use rate or is determined by MBTOC recommended use rate reductions.
22. **EPA Adjusted Strip Dosage Rate** – The dosage rate is the use rate within the strips for strip / bed fumigation.
23. **2008 Amount of Request** – The 2008 amount of request is the actual amount requested by applicants given in total pounds active ingredient of methyl bromide, total acres of methyl bromide use, and application rate in pounds active ingredient of methyl bromide per acre. U.S. units of measure were used to describe the initial request and then were converted to metric units to calculate the amount of the US nomination.
24. **EPA Preliminary Value** – The EPA Preliminary Value is the lowest of the requested amount from 2005 through 2008 with MBTOC accepted adjustments (where necessary) included in the preliminary value.
25. **EPA Baseline Adjusted Value** – The EPA Baseline Adjusted Value has been adjusted for MBTOC adjustments, QPS, Double Counting, Growth, Use Rate/ Strip Treatment, Miscellaneous adjustments, MBTOC recommended Low Permeability Film Transition adjustment, and Combined Impacts.

26. **EPA Transition Amount** – The EPA Transition Amount is calculated by removing previous transition amounts since transition was introduced in 2007 and removing the amount of the percent (%) Able to Transition per Year multiplied by the EPA Baseline Adjusted Value.
27. **Most Likely Impact Value** – The qualified amount of the initial request after all adjustments have been made given in total kilograms of nomination, total hectares of nomination, and final use rate of nomination.
28. **Sector Research Amount** – The total U.S. amount of methyl bromide needed for research purposes in each sector.
29. **Total US Sector Nomination** - Total U.S. sector nomination is the most likely estimate of the amount needed in that sector.

APPENDIX B. California Strawberry Nursery Narrative

California Strawberry Nursery Narrative 2005

Introduction

The strawberry plant nursery stock produced annually in California represents one of the largest and most widely distributed nursery products in the world. Nearly a billion plants are produced by the California strawberry nursery system each year, and plants are annually distributed from California to every continent with a temperate climate suitable for strawberry fruit production. In addition, many nursery systems in other parts of the United States and throughout the world rely on California strawberry stock as a source for their propagation systems. The integrity of California strawberry nursery systems directly influences the global success of strawberry fruit as a viable crop.

Description of Strawberry Nursery Production System

Due to the complex genetic structure of the modern strawberry, plants do not replicate true to type from seed, and must be asexually propagated by rooting runners produced from source plants. The California strawberry nursery industry is responsible for providing genetically pure and clean planting material essential to the success of strawberry fruit growers and other nursery systems. Strawberry nurseries annually plant source stocks in fumigated fields, root the runners that form, and harvest these runner plants as a final product.

The strawberry nursery industry is a very complex system. A typical nursery system includes both high and low elevation nursery locations, chosen to provide a cold site for October harvest which provides fresh plants for fruit production systems, and a warmer site for December - January harvest which provides frigo plants for nursery stock and frigo plants for fruit production systems.

The high elevation nurseries are located in Northern California and Southern Oregon at elevations of 3,200 to 4,200 feet, and produce the plants used for October and November plantings for fruit production in California, throughout the United States, and internationally.

Low elevation nurseries (below 600 feet) are located in the Sacramento and northern San Joaquin valleys of California. These low elevation nurseries produce plants for both propagation and fruit plantings. The propagation stock is used by nurseries in California, throughout the United States, and internationally. The balance of the low elevation production is stored for distribution through the spring and summer months as frigo plants, and supplies fruit production systems throughout the world.

The typical strawberry nursery system is diagrammed in (Figure 1). This shows that nurseries must propagate plants in the field for multiple years before the plants are sold to customers. Guidelines established and enforced by the California Department of Food and Agriculture must be followed by all strawberry nurseries.

The nursery stock regulations include fumigation standards, as well as standards for virus, pathogen and insect control.

Figure 1. Overall California Nursery System

Year 1 Plants are grown in a screenhouse as nuclear stock. The source plants have been heat treated and meristemed in order to insure a virus and disease free stock for this first cycle of nursery production. Nurserymen may heat treatment and meristem stock in their own facilities, or may purchase meristem stock plants from the Foundation Plant Material Services located at the University of California, Davis, California.

Year 2 Meristemed stock is planted in an enclosed screenhouse structure, designed to exclude insect vectors preventing plant contamination. These plants are planted into fumigated soil or media. The plants produce about 100 daughter plants per mother plant. CDFA inspectorsexamine, and laboratory test screenhouse stocks to insure that the plants are virus and nematode free. They closely inspect for other possible insect and disease pressures. There is no tolerance for virus, nematodes, and plant diseases in screenhouse propagation. The screenhouses are generally located in low elevation nursery sites.

Year 3 Plant increases harvested from screenhouses are planted in low elevation nursery fields. The increase ratio at this level is about 50:1. These low elevation fields are called Foundation increases, and are planted outside in carefully fumigated soils. The CDFA samples these fields for nematodes and virus intrusion, and inspects carefully for full control of insect and disease levels. There is no tolerance for nematodes and virus in foundation plantings.

Year 4 Plants from the Foundation are planted into low elevation fields that have been fumigated. Fields at this level are referred to as Registered increases. The increase ratio at this level is about 50:1. These fields are inspected by the CDFA and are sampled for nematode infection. Diseases and insects are also carefully monitored at this level. There is a zero tolerance for nematodes and virus symptoms at this level. These plants are often sold worldwide as propagative stocks to nursery systems and to fruiting systems with critical needs for pathogen control.

Year 5 Plants from the Registered Fields are planted into high and low elevation fields that have been fumigated. Propagation at this level can be registered as Certified Field increases. Plants in certified fields are increased at a level of about 30:1. The CDFA inspections make sure that the fields are clean of nematode and virus infections, and evaluate insect and disease pressures for phytosanitary clearances. These plants are sold and planted for fruit production both domestically and internationally.

About 70% of the ground used for strawberry nursery production is owned by the nursery grower, and the other 30% is leased. Nurseries need sandy loam soils to allow for the deep rooting pattern produced by strawberry plants. Strawberry roots may grow three feet or more into the soil during a growing season and therefore the fumigant used for nursery production needs to be able to penetrate deeply into the soil. There are a few heavier soils used in the strawberry nursery industry which are more difficult to manage.

The total high elevation nursery acreage averages 3,200 acres per year, and the low elevation acreage averages 1,000 acres per year. The locations where strawberry nurseries are grown are dry and hot in the summer months and cold in the winter months. Rainfall averages about 20 inches per year in the high elevation locations and 30 inches per year in the low elevation locations.

Strawberry nursery fields are planted in the spring, and may be fumigated in the previous fall (August and September) on fallow ground, or may be fumigated in the spring (March and April) prior to planting. The majority of the fumigation is done in the fall (60%), but the spring fumigation is a very important option to provide the flexibility to adjust acreage based on a later projected demand. While some of the nursery growers fumigate their own fields, about 65% of the growers have contract fumigators apply the material.

Strawberry nursery culture is labor intensive. Nurseries maintain a sizeable permanent staff, and hire thousands of workers on a seasonal basis.

Nursery fields are spring planted using crews on four row mechanical transplanters. In high elevation nurseries, about 12,000 plants are placed per acre, and low elevation fields with longer growing seasons are planted with about 6,000 plants per acre. As the plants grow, runners are produced and are set by hand. Field weeds that survive fumigation are also removed by hand. This is an important part of the viral disease prevention program as some of the weeds found in nursery areas harbor virus that can be transmitted to strawberry plants. During the season, the runners produced form a solid canopy of leaf cover over the field. Before the plant canopy fills in, tractors can be used in the field to spray if necessary. Overhead sprinkler irrigation systems are used to irrigate, as well as to fertigate the fields as necessary. As the canopy fills in, tractors are no longer able to drive through the field, and chemicals are also be applied through the overhead sprinkler system when necessary. A few nurseries are now using drip irrigation instead of the standard sprinkler irrigation.

High elevation fields are harvested starting in late September when the temperatures begin to fall and the strawberry plants begin to go dormant. High elevation harvests continue through late October at which time the plants should be fully dormant. Low elevation plants are harvested in December or January after the plants are fully dormant. Several pieces of equipment are used during the harvest process. The strawberry plant leaves are removed with a mulching mower, and interconnecting runners are broken apart with a mechanical rake. The strawberry harvester is a custom designed machine that undercuts the plants, lifts the plants from the soil, and shakes remaining soil free from the root system. Plants are placed in burlap bags or bin containers on the back of the harvesters, and are loaded for transport.

During this process, about 50% of the crop biomass is left in the field. This remaining biomass consists mainly of leaf tissue, root tissue, and crowns of smaller plants. Several nurseries are now leaving the original mother plants in the field as well as the leaf tissue which further reduces the amount of biomass removed from the field. This remaining biomass is plowed back into the field before the field during the rotation cycle.

Harvested plants are removed from the field, placed in pre-cooled trucks and transported promptly from the field to the trim shed. At the trim shed, the plants are held briefly in cold storage and then trimmed and graded by large processing crews. This stage requires a large amount of skilled and qualified labor to achieve reasonable production output rates and a high quality product.

The hand-trimmed plants are graded for quality based on crown size and root development, and are packed into boxes containing 1,000 to 1,500 plants. Only plants that meet the quality grade standards are packed, and the other plants are discarded. The packed boxes are placed back into cold storage (28 - 32 degrees F) for final cooling, and are shipped on pre-cooled trucks, refrigerated ocean containers, or by fast air shipments to customers worldwide.

Nursery fields are rotated out of strawberries and into cover crops for an average of two years between strawberry planting cycles. The cover crops used are generally grains, and may be harvested, but are primarily used to increase the organic matter in the soil. Other cover crops include endive, garlic, onions, horseradish, and mint.

Fumigation and Pathogen, Nematode and Weed Control in Strawberry Nurseries

Methyl Bromide/Chloropicrin fumigation currently used at the strawberry nursery controls soil borne pathogens, nematodes, and weeds. Deep, uniform fumigation is necessary to provide the nursery with a strong base for producing clean planting stock. Methyl bromide is an ideal fumigant due to the small molecular size of the gas, which allows the fumigant to move easily through the soil and penetrate deeply into the soil profile.

The combination of Methyl Bromide and Chloropicrin thoroughly and completely sterilizes the soil from the surface to beyond the penetrable depth of the nursery crop root system. There are over 60 identified fungal diseases and seven major nematode groups that infect strawberry, and the Methyl Bromide/Chloropicrin combination is highly effective against all of them. There are many weed types common to strawberry nursery growing areas, and Methyl Bromide is by far the most effective soil treatment to eliminate them in nursery plantings. Some of the most important nematode, disease, and weed pests are listed and discussed below.

The major soil born diseases that are a problem in strawberries and are controlled by methyl bromide at the nursery level are shown in Table 1. Methyl Bromide readily kills pathogens in plant debris left in the field after harvest as well as common soil borne diseases.

Table 1. Major problem diseases in Strawberry Nursery Production

Disease	**Causal Organism**
Red Stele	*Phytophthora fragariae*
Crown Rot	*Phytophthora cactorum*
Root Rot	*Phytophthora citricola*

Anthracnose	*Colletotrichum acutatum*
Verticillium wilt	*Verticillium dahliae*
Powdery Mildew	*Sphaerotheca macularis*
Angular Leaf Spot	*Xanthomonas fragariae*
Common Leaf Spot	*Ramularia tulasneii*
Black Root Rot	*Pythium, Rhizoctonia, Cylindrocarpon*

Fumigation is also used to control nematodes (Table 2). Because fumigation is used in strawberry nurseries, nematodes have not been a problem in nurseries or production fields since the 1960's when Methyl Bromide fumigations were first used. The effectiveness of Methyl Bromide/Chloropicrin mixture in controlling nematodes contributed to the adoption of the California Nursery Stock Regulations. These regulations do not permit nursery stock infested with nematodes to be shipped from the nursery. All certified nursery plantings are sampled parasitic nematodes, and if any are found, the infected area is rejected for harvest.

Table 2. Nematodes controlled in Strawberry Nursery Production

Common Name	**Scientific Name**
Root Knot Nematode	*Meloidogyne hapla*
Sting Nematode	*Belonolaimus longicaudatus*
Dagger Nematode	*Xiphinema americanum*
Stem Nematode	*Ditylenchus dipsaci*
Root Lesion Nematode	*Pratylenchus penetrans*
Needle Nematode	*Longidorus elongatus*
Foliar Nematode	*Aphelenchoides ritzemabosi*

Fumigation is also used to control weeds (Table 3) found in California strawberry nurseries. Several of the weeds types in California strawberry nurseries areas are classified as noxious weeds by the state of California. It is important to use a fumigant that can effectively control weeds to prevent spread of seed adhering to soil particles on plants that are shipped both domestically and internationally by strawberry nursery growers. Weeds are also hosts for viruses that can be spread to strawberry plants by vectors present at the nursery.

An additional benefit is the complete control of strawberry seed from previous plantings that might germinate in a nursery field. If strawberry seed germinates in a nursery planting, variety mixes are created rendering the planting unsaleable.

Table 3. Common weeds present in Strawberry Nurseries

Common Name	**Scientific Name**
Annual bluegrass	*Poa annua*
Bur clover	*Medicago hispida*
Carpetweed	*Mollugo verticillata*
Chickweed	*Stellaria media*
Field bindweed	*Convolvulus arvensis* *
Filaree	*Erodium botrys*

Goat Grass	*Aegilops triuncialis*
Hairy Nightshade	*Solanun villosum**
Lambsquarter	*Chenopodium album*
Malva	*Malva parviflora*
Nutsedge	*Cyperus rotundus**
Pig Weed	*Amaranthus retroflexus*
Portulaca	*Oleracae*
Prostrate Spurge	*Euphorbia humistrata*
Puncture vine	*Tribulus terrestris**
Purslane	*Portulaca oleracea*
Vetch	*Vicia sativa*

*Considered noxious weeds by the California Department of Food and Agriculture.

Methyl Bromide and Strawberry Nursery Culture

The challenges in strawberry nursery production are considerable. All customers for strawberry stock depend on the nurseries to provide stock free of pests and pathogens for planting. Since the nurseries have the plants for multiple production cycles before the plants are sent to the fruit growers and nursery customers, any tiny problem or minute infection that occurs in the nursery system can be multiplied many times, and over several years before the plants are sold (Table 4).

Table 4. Amplification Schedule for Short Day and Day Neutral Cultivars

		Approx. amplification numbers	
Year	**Nursery Locations**	**Short Day Cultivars**	**Day Neutral Cultivars**
0	Low Elevation - Meristem Plant	1	1
1	Low Elevation - Screenhouse	100	100
2	Low Elevation - Foundation Field	50	35
3	Low Elevation - Registered Field	50	35
4	High Elevation - Certified Field	25	20
	Total Increase Ratio	**6,250,000**	**2,450,000**

The challenge in growing clean strawberry nursery stock is easy to visualize from Table 4. From the usual four-year process, a single plant placed in a screenhouse increase on year 1 can be increased to as many as six million plants by the end of year 4. The tiniest contamination level in years 1 and 2 can have a very broad effect on the general cleanliness status of the nursery in years three and four. Even if diseases did not spread to other plants in a field, an infection on year one could yield six million infected plants by harvest in year 4. Unfortunately, spread rates in field conditions for fungal diseases are very high, and any minute disease intrusion in propagation years 1 and 2 will lead to a general infection in production stock. Because of rapid spread rates, even minute disease intrusion into propagation in year 3 will introduce considerable disease exposure in propagation in year 4.

The challenge is even larger when the disease organisms affecting strawberry are considered. In referring to table 4, most of the fungal diseases affecting strawberry are capable of multiplying as many times per day as we might expect to multiply in plant numbers for the year. The diseases can be asymptomatic on the strawberry plants and therefore very difficult or impossible to detect until environmental conditions are conducive for disease development. Most of the nematode pests can multiple themselves weekly by what could be multiplied annually in plants numbers.

The challenge is thus defined. A strawberry nursery must increase stock in the system over a four year period, and end the process with uncontaminated stock. To do this, a strawberry nursery must do more than manage disease pressure. To be successful, the strawberry nursery must very effectively manage disease incidence. Apparent plant health and acceptable disease thresholds are not part of the language of successful strawberry nursery culture. A strawberry nursery is successful only if major plant disease incidences are controlled. The success of the nursery product provided to customers is directly related to the nursery's ability to exert this control.

As mentioned, the California strawberry nurseries produce around one billion plants annually, and production distribution is worldwide. In addition, propagation in strawberry in many countries depends on California produced nursery stocks. Canadian and Mexican nurseries use almost 80 percent California source stocks, and a high percentage (40-60%) of Spanish and South American propagation is also based on California sources. Most strawberry systems in the world are using some stocks with origin from California nurseries.

Because the strawberry plants from California are so widely distributed, any disease and insect problems that are not controlled by the California nurseries will become international control and quarantine issues.

The strawberry nursery use is possibly the most critical of the applications that will be considered in the Critical Use Exemption process. In any test evaluation that considers the spectrum of disease control important to strawberry, every chemical and every combination and every alternative scheme has proved inferior to the broad efficacy of Methyl Bromide Fumigation. There has been no data produced that would suggest alternative soil fumigation regimes provide the short and long term disease control integrity required.

Telone, Telone + Metam Sodium and Telone + Chloropicrin + Metam Sodium, Chloropicrin, Chloropicrin + Metam Sodium, and Metam Sodium (with and without VIF) for Use as an Alternative Fumigants in Strawberry Nurseries 2005

California strawberry nurseries participate in, and are regulated by the California Department of Food and Agriculture strawberry certification program. This program requires that ground be fumigated before mother plants are placed in the field (CDFA, 2003). The certification standards further require that all nursery stock be kept commercially clean of insects, pests and diseases. Nursery stock must be free of nematodes as per section 3055.1-3055.6 of the nursery stock nematode certification regulations. California strawberry varieties account for more than 50% of the world strawberry acreage and the initial stock increases of these varieties are all produced at California strawberry nurseries. California strawberry nurseries provide planting stock not only for strawberry fruit production fields throughout the world but also for other strawberry nurseries worldwide (see Strawberry Nursery Narrative) and account for 95% of the strawberry plants planted in the strawberry nurseries in Spain (De Cal, 2004, 2005). There are wide and specific destination quarantine restrictions to be met for shipping planting stock outside the United States (Martin, 2002), which include most of the identified fungal and/or viral pathogens and nematodes that can infect strawberry plants. Cultural practices used in producing strawberry runner plants result in a continuous, dense mat of plants which prevents tractors from entering the field to spray for weeds, insect pests or diseases after the initial part of the growing season. Any post emergent pest prevention used must be deliverable through the sprinkler system or by air. Thus, early weed and disease prevention via pre-plant fumigation is essential.

Studies have been conducted in California strawberry nurseries with Telone, Telone/Metam Sodium and Telone/Chloropicrin combinations and Chloropicrin alone (Larsen, 1997, 2000; Westerdahl, unpublished; Duniway, personal communication; Kabir, 2003; grower data). Studies evaluating all the above combinations have also been conducted in strawberry fruit production fields in California and several studies have also been carried out in Canadian strawberry nursery fields (Keddy, 1997), Spanish nursery fields (De Cal, 2004, 2005; Lopez-Aranda, 2004; Melgarejo, 2003) and Australian nursery fields (Mattner, 2003). One draw back for most of the studies in strawberries and other commodities is that the studies have been conducted on ground previously fumigated with MeBr (Gubler, 1996). This makes the impact of long term use of the alternatives difficult to predict, as the alternatives do not penetrate the soil as readily as Methyl Bromide (Braun, 1994) and do not deliver the deep soil control now obtained with Methyl Bromide in nursery crops (Braun, 1994; McKenry, 2001; McKenry, 1999; Schneider, 2003). Many of the studies have been conducted in areas with low pest and disease pressure (Gubler, 1996; Martinez, 2000), and it is necessary to test the alternatives under high disease pressure conditions to evaluate the true effectiveness and long term viability of each alternative regime. As an example, Canadian nursery fumigation trials are generally based on single year increases of California-provided source stocks that have been grown in soils fumigated with Methyl Bromide.

California strawberry nurseries must control all nematodes, and the complete range of pathogens to ensure that strawberry fruit growers receive stock free of pests and diseases (Gubler, 1996; Larsen, 2000; CDFA, 2003). When fruit growers receive healthy nursery stock, little is required in the form of pest control during the fruiting cycle (Gubler, 1996). Strawberries respond with increased plant vigor when fungal diseases are controlled by fumigation, plants show an increase in shoot growth, berry yield, and root development when compared to plants produced from non-fumigated soil where fungal pathogens were not controlled (Duniway, 2002).

Production Yield Factors:

In studies that have been done at the nursery, Telone fumigated soils did not produce as many runners per mother plant (Ajwa, 1999; Larsen, 2000), nor as many marketable plants per acre as soils fumigated with methyl bromide (Fennimore, 2001; Shaw, 1999). Telone/Metam Sodium combination studies have also shown reduced numbers of runner plants produced per acre in comparison to a standard Methyl Bromide/Chloropicrin fumigation (Ajwa, 2000). In the

Spanish nurseries the only fumigant that preformed consistently across nursery locations for overall yield was Methyl Bromide (De Cal, 2004). Studies conducted in the Spanish nurseries show similar results to studies in California (Melgarejo, 2003) where plots treated with methyl bromide had yields similar to plots fumigated with chloropicrin but higher yield than plots treated with Telone/Chloropicrin combinations. This reduction in yield with Telone C-35 was also seen in the strawberry nursery trials in Australia (Mattner, 2003) where the yield difference of 22% was reported to be due to fumigant induced phytotoxicity.

A complex study was undertaken by the University of California, Davis in cooperation with nursery and fruit growers to study the effect of fumigation from one production cycle to the next. Plants from various fumigation regimes at low elevation nursery fields were increased the following year in high elevation nurseries with multiple fumigation regimes. These plants were moved into fruit production fields that had been treated with various fumigation regimes. While the latest fumigations (in the fruit production field) had the largest effect on the actual fruit yield, there was still a significant benefit when Methyl Bromide fumigation was used in the low elevation nursery two years earlier vs. the use of any other alternative (Larsen, 2000).

In another study, Methyl Bromide not only gave better overall nursery runner production than stocks fumigated with Telone in the nursery, but also yielded higher fruit production when transplanted into fruiting fields, suggesting the carryover benefit of Methyl Bromide fumigation in nursery culture (Gordon, 1999). This has also been the case when Chloropicrin has been used as a nursery fumigant (Larsen, 2000).

Repeated uses of Telone in fruit production test plots resulted in declining yield each season in relation to the Methyl Bromide/Chloropicrin treated plots (Welch, 1991). In this same study, using Chloropicrin in combination with Telone did not increase yield relative to Telone used alone. Growers have also reported less consistent yield and weed control with the alternative fumigants, including Telone, as compared to Methyl Bromide (Martinez, 2000).

Spanish researchers concluded that several of the alternatives might be useful in situations with low pathogen, weed and nematode levels but because of the necessity for clean plant material from the nursery locations and to prevent possible quarantine and trade barriers from becoming problems for the Spanish strawberry nurseries, Methyl Bromide should continue to be used in the nurseries (De Cal, 2004, 2005; Lopez-Aranda, 2004).

Control of Nematodes:

Control of nematodes is essential for strawberry nursery plant production. The California nursery stock nematode certification regulations require that nursery stock be free of nematodes. In order to achieve this, nematodes must be controlled in the soil to a level of 99.9% (McKenry, 2001, McKenry, 1999). Control needs to be achieved at the level of approaching 3 feet in order to produce clean strawberry planting stock. While Telone, and Telone combinations have been effective in controlling nematodes in some cases (EPA, 2002); in an on-going strawberry nursery study, Telone did not control free living nematodes in the first 6 inches of soil, while methyl bromide controlled citrus nematode and all free living nematodes to a depth of 36 inches (Fennimore, 2001). In Spain, chloropicrin was not effective in controlling nematodes (De Cal,

2004) nor did chloropicrin control nematodes in Spanish fruit production fields (Lopez-Aranda, 2003). In a study in Greece, Methyl Bromide was superior to all other treatments (including Telone and Metam Sodium) in controlling nematodes (Giannakou, 2004). Rootknot nematodes were found on rose nursery stock in not only the untreated plots but also in plots treated with Midas, Telone C35, Chloropicrin, and Metam Sodium (Schneider, 2004). Another study concluded that the alternative fumigants could be effective in controlling nematodes but only in sites that were not infested with significant populations of nematodes (Browne, 2004). This agrees with studies conducted in Florida where in some cases alternatives were as effective as Methyl Bromide in nematode control but in other situations, Methyl bromide was more effective then the alternatives (Gilreath, 2004, 2005).

Telone in combination with Chloropicrin was less effective than methyl bromide in controlling root knot nematodes in tomatoes in Florida (Haglund, 1999). In other nursery crop studies, Telone has shown control in some cases where the soil is light and shallow (EPA, 2002), but this is not always the case (Lamberti, 2000). In perennial field nurseries, root knot nematode was controlled by methyl bromide but was not adequately controlled with untarped applications of Telone C-35 and methyl bromide control continued to be superior even when Telone C-35 was tarped during application (Schneider, 2003). Strawberry nurseries require a fumigant that can give very deep, extremely consistent control of nematodes over time. Alternative fumigants and alternative combinations in test results to date have not consistently demonstrated this level of control.

Control of Pathogens:

An equally if not more important aspect of nursery production is maintenance of pathogen free stock. Complete control of the full spectrum of pathogenic fungi is a life or death issue in strawberry nursery culture. Fruit producers are unwilling to purchase plants that have any visual symptoms of disease and hold the nursery responsible for any disease that shows up in the fruiting field after planting. Telone does not control fungi (Braun, 1994) and therefore is not of use to the strawberry nurseries as a stand-alone fumigant. Telone must be used in association with Chloropicrin (for disease control). However, even a combination of Telone and Chloropicrin is not as effective as fumigation with Methyl Bromide/Chloropicrin.

Verticillium wilt is historically one of the main pathogens affecting strawberry production in California. The sclerotia are extremely long lived in the soil and can remain viable for up to 20 years (Braun, 1994). Added to this, very low levels of infections (0.5 ms/g soil) can result in significant disease levels in fruit production fields (Duniway, 2001) and strawberry nursery fields (Shaw, 2002). Both high and low elevation nursery fields are naturally infested with Verticillium dahliae (Gordon, 2005). Control of Verticillium dahliae in the strawberry nurseries has been most effective with Methyl Bromide/Chloropicrin fumigations (Gordon, 1999, 2002). When Methyl Bromide/Chloropicrin was used to fumigate the soil, the V. dahliae innoculum was reduced to an undetectable level. The fumigation using only Chloropicrin reduced the innoculum of V. dahliae but did not eliminate the innoculum (Duniway, 2003; Gordon, 2002). While Methyl Bromide/Chloropicrin fumigations, killed all buried innoculum at 15 and 50 cm depths (at these depths Phytophthora cactorum was also completely controlled), Telone reduced the level of Verticillium dahliae but did not completely eliminate the pathogen at any depth

(Duniway, 2000; Fennimore, 2001) or only in the top few inches (Gubler, 1996). These results have been verified in other locations outside of California (Minuto, 1999) where Telone/Chloropicrin combinations did not control the soil pathogens at deeper soil depths. While VIF films improved the efficacy of Telone, Methyl Bromide/Chloropicrin fumigation was still superior in control of both Verticillium and Phytophthora (Duniway, 2002; Duniway, 2003; Minuto, 1997).

Control of Phytophthora cactorum at the nurseries and commercial fruiting field sites with either Telone or Telone/Chloropicrin combinations has been inconsistent and appears to be sensitive to rates, mulching systems and the emulsifiers used in the drip formulations (Browne, 2001). While in another study Chloropicrin used alone did not control Phytophthora cactorum but Methyl Bromide/Chloropicrin and Inline did achieve control (Duniway, 2003). Methyl Bromide/Chloropicrin typically killed all the Phytophthora at a depth of 1.5 to 2 feet, while the results with Telone mixtures were not consistently lethal (Browne, 2002) or only lethal in the top 6 of the field (Fennimore, 2001). It appears that Inline, Telone C-35 and Chloropicrin are effective in controlling Phytophthora cactorum under ideal conditions but are not equivalent to Methyl Bromide fumigations under non-optimal conditions (Browne, 2003). This is important to the strawberry nurseries as many fumigations are done under non-optimal conditions.

In other studies Methyl Bromide/chloropicrin controlled Phytophthora cactorum as deep as 36 inches, well exceeding the performance of Telone (Fennimore, 2001). Telone has also been less effective in controlling the other important pathogens, Colletotrichum acutatum (Gubler, 1996), Fusarium oxysporum, Rhizoctonia solani, Sclerotinia sclerotiorum (Minuto, 1999). Other research has shown that there is a change in the soil fungal population with the use of Methyl Bromide that is not seen with other fumigants (De Cal, 2004; Duncan, 2003) with resulting increases in Trichoderma spp. and decreases in Penicillium spp., Alternaria spp. and Mortierella spp (De Cal, 2004). This is significant, as Trichoderma spp. have been shown to be antagonistic to other fungi.

Control of Weeds:

Weeds compete with the strawberry plants in nursery and production fields. Strawberry plants do not compete well against weeds and some of the weed species found in strawberry fields harbor diseases and insects that are detrimental to the strawberry plant (Fennimore, 2003). Noxious weeds must be controlled at nursery locations to prevent unintentional shipment of weed seed adhering to plant parts to new locations. One of the more difficult noxious weeds to control is nutsedge. In multiple studies (Gilreath, 2004, 2005) demonstrated that Methyl Bromide was the most consistent fumigant for control of this weed. Weeds also act as hosts for some of the viruses which infect strawberries (Martin, personal communication). Many viruses do not show symptoms on strawberries (although the overall yield is reduced) unless multiple viruses infect the same plant (Tzanetakis, 2004). Therefore it is vital to control weed populations at nursery locations in order to help prevent the spread of viral pathogens. While Telone and Telone combinations have been effective in controlling the weed populations in the nurseries in Nova Scotia (MBTOC, 1998; Keddy, 1997), these alternatives have only been somewhat effective in controlling the spectrum of weeds found in the California strawberry nurseries

(Westerdahl, unpublished), California fruit production fields (Fennimore, 2001; Paulus, 1998) California perennial nursery fields (Schneider, 2003) and in Florida tomato fields (Haglund, 1999). Chloropicrin has been inconsistent in the control of weeds when used as a stand-alone fumigant (Haar, 2003; Fennimore, 2004). The placement of the fumigant plays a key role in the management of the weed population. Using drip applied materials, there is a difference between the level of control on the edge of the bed vs. the control at the center of the bed (Fennimore, 2003). At the nursery, tarping improved the performance of all fumigants tested (Westerdahl, unpublished). In these same studies, Metam Sodium alone did not provide effective surface weed control, but Telone alone or in combination with Metam Sodium provided good weed control if the treatments were tarped (Westerdahl, unpublished). Telone has been effective in controlling chickweed, hairy nightshade, pigweed and annual bluegrass. It was less effective then Methyl Bromide in controlling purslane and prostrate knotweed (Fennimore, 1999). Therefore, the efficacy of the fumigant is influenced by the weed population at a given location. This accounts for results that differ from location to location as to the effectiveness of alternatives (Shrestha, 2004). The addition of Metam Sodium in association with Telone did not improve weed control over the use of Telone alone (Fennimore, 2001) in all cases, although it can be effective when the fumigants are applied sequentially instead of concurrently. Neither Methyl Bromide/Chloropicrin nor Telone (alone or in combination with Chloropicrin and Metam Sodium) were effective in controlling little mallow (Fennimore, 1999). Shank applied Telone (the method of application most applicable to nursery culture), resulted in higher weeding costs in production fields (Fennimore, 2001). This has been verified by individual California nurseries growers (personal communication with growers).

Telone Township Caps:

In California township caps have been imposed by the California Department of Pesticide Regulation, limiting the amount of Telone that can be applied in any given year in a particular township due to potential chronic health concerns. These townships caps would be a problem in both high and low elevation nursery locations, since the area in which strawberry nurseries are gown is fairly restricted thus they are concentrated in particular townships that would be impacted (Carpenter, 1999, 2001; Trout, 2003; DPR, 2002). The Township cap was reached in one California township even before fall fumigation for strawberries began (Trout, 2004) and other townships were also expected to be impacted. Telone also requires a 300 buffer zone around the application area, which reduces the actual field area that can be fumigated using this product.

Movement of Fumigant through the soil:

Where Telone has been shown to have deep efficacy, the soils tend to be light and sandy (McKenry, 2001; McKenry, 1999; Minuto, 1999). Since the molecular structure of Methyl Bromide is small relative to the molecular structure of Telone, Methyl bromide can move more easily through the soil and this results in deeper penetration of the fumigant (Braun, 1994; Ajwa, 2004). In order for Telone applications to be effective, the soil moisture level should not exceed 12%. In heavy rainfall years and deeper in the soil profile, this can be difficult to achieve (McKenry, 2001, McKenry, 1999). The problem is amplified by the California requirement that moisture be added to the surface of the soil prior to fumigation with Telone. Tests show that when drip applied, Telone is not detected equally across the bed with areas around drip tape showing higher levels of the fumigant (Gilreath, 2003). In strawberry fruit production fields, extensive experimentation has been done to improve the use of drip applied fumigants (Ajwa, 2004). However results continue to be uneven and inadequate fumigation can occur. A large amount of water is necessary to move the fumigant into all areas of the soil profile and this seems to be more effective in some soil and environmental situations than in others. The large amount of water necessary has resulted in some cases in bed collapse and even with large amounts of water to carry the fumigant into the soil, poor pathogen and weed control have occurred in multiple years at the Watsonville location (Ajwa, 2004) while in Salinas drip fumigation has resulted in higher overall fruit yields (Ajwa, 2004). In addition to problems with movement throughout the soil profile, both Telone and Metam Sodium are subjected to enhanced rates of biodegradation depending on soil pH, soil type and soil calcium content. Under extreme conditions, this can result in Metam Sodium breaking down in a period of seven hours versus the normal fifteen days. This problem appears to become worse over time with a shift in the microorganisms found in the soil profile. Growers are concerned that over time with repeated use of the alternative fumigants, shifts in the soil biomass will result in higher populations of degraders that will decrease the effectiveness of the fumigant (Trout, 2004) Biodegradation does not occur with Methyl Bromide.

Other Effects of Alternative Fumigants:

Phytotoxic effects have been noted not only with higher rates of Telone (Lamberti, 2000) but also with lower rates of Telone (Mattner, 2003) and with Metam Sodium (De Cal, 2004). Phytotoxic effects have also been seen in the strawberry production fields in California (Ajwa, 2004) depending on soil type. This occurred even with extended plant back times than would interfere with the regular planting process in nursery fields. In strawberry production fields, when Metam sodium was applied at the same time as Telone there was a negative interaction (Trout, 1999; Ajwa 2004). Results have been improved with sequential application of the materials, but this increases the amount of time required to complete the fumigation cycle and doubles the amount of water necessary to move the fumigant through the profile as fumigation is basically being completed twice, once for each fumigant. Large differences in concentration of the fumigants have been found across the bed profile (Ajwa, 2004) depending on the placement and type of drip tape and the soil type. Fumigants tend to move more vertically and less horizontally in sandier soils. When the strawberry nurseries fumigate in the spring, there is a small window of opportunity to fumigate the soil and plant the nursery stock. For this fumigation, it is necessary to have a fumigant that can be applied quickly with short plant back requirements. In high elevation nurseries, it is impossible to string treat with Telone or Metam Sodium combinations due to cold soil temperatures and higher deep moisture levels in the soil during the spring fumigation window.

Use of Virtually Impermeable Films:

Studies using VIF have been conducted in both strawberry nursery and strawberry fruit production fields in California. While the use of VIF appears to improve the efficacy of Telone (Ajwa, 2002; Noling, 2002) and Chloropicrin, it does not improve the efficacy of Metam Sodium (Candole, 2004) or Methyl Bromide (Ajwa, 2002). There are several problems with the use of VIF, including the difficulty of application of the material (Noling, 2004), the expense of the material and the ability to obtain the material on a reliable basis. VIF is not embossed in a manner similar to HDPE and due to its tensile strength requires the applicator to move at a slower speed while applying this material in the field. A tractor can only move about 3 miles per hour when applying VIF which adds to the overall expense of using the material. VIF also has a tendency to zipper when applied which can result in tears in the tarp that must be repaired by individuals wearing personal protective equipment (Gilreath, 2003). VIF is relatively expensive when compared to High Density Polyethylene (HDPE) ($600 for VIF, $400 for HDPE (Noling, 2002); or $559.35 for VIF, $273.06 for HDPE (Goodhue, 2003)) and is currently produced in Europe and Israel not in the United States. This creates several problems including the ability to have material delivered on a reliable basis. The current suppliers are not set up to produce VIF in the quantities necessary to replace the HDPE currently used in California and delivery can take two to four months even when the material is available for shipment. Similar problems have been reported in Europe with the use of VIF (De Cal, 2004). While suppliers continue to work on the problems currently experienced with VIF, and suppliers predict that prices will decline with increased use of the material (Rimini, 2004), problems continue to persist including difficulty in adherence of the sheets of VIF to each other in the field. Due to the results of early studies which measured off-gassing rates from VIF-tarped fields and concerns about worker exposure when the films are removed, California currently prohibits the use of VIF for methyl bromide applications.

Use of Non-Chemical Alternatives:

The non-chemical alternatives included for consideration include: Biofumigation, Solarization, Steam Heat, BioControl, Cover crop/Mulch, Crop Rotation, Flood and Water Management, Graft Resistant Rootstocks, Organic Amendments, Physical Removal/Sanitation, Resistant Cultivars, and Soilless culture. None of these alternatives meet the requirements of the California Department of Food and Agriculture nursery stock certification program. While nurseries have spent time and money exploring the alternatives (both chemical and non-chemical), they have not found any alternatives that can provide the high level of cleanliness for nematodes, pathogens and weeds that are required for nursery culture.

About one percent of the current strawberry plants used for commercial fruit production are planted from plug plants instead of the standard bare root plant provided by most strawberry nurseries (Sances, personal communication). Plug plants are produced by obtaining runner tips from a conventionally grown high elevation strawberry nursery (fumigated with methyl bromide) and then placing these runner tips in a soil type media. The runner tips are then grown in a greenhouse environment for eight to ten weeks, conditioned by placing the plants in a cold environment and then sold to fruit producers as plug plants. During the 2003 season, plug plants were contaminated with a fungal disease that spread rapidly through the greenhouse as conditions were conducive to disease development (Sances, 2003). This stopped an expansion of this method of strawberry plant production.

Essentially all of the plug plants that are used in California are of the short day types used in the Southern growing districts, as these are the only plants that can be somewhat successfully artificially conditioned prior to planting. Currently, the cost of plug plants is 4 to 5 times higher than the cost of bare root plants. Early production of fresh market fruit can somewhat off set the cost of plug plants (grower, personal communication; Stapleton, 1999; Hochmuth, 1999) but plug plants tend to produce a hand of fruit and then have a gap in their production pattern and come back into production at the same time that the bare root plants are producing. The cost differential between bare root plants and plug plants cannot be overcome unless the plug plant can produce a very high volume of yield very early in the fruit production season when the prices are high. In a trial comparing bare root plants and plug plants in Southern California, there was no significant difference in the fresh market yield of bare root and plug plants although there was a significant different in the amount of fruit produced for the processing market in one trial (Sances, 2000). Plug plants only began production about 2 weeks earlier than standard plants in another trial (Sances, 2003). Plug plant culture is not technically feasible in the case of day neutral strawberry varieties, which are the dominant varieties in the central and northern growing regions of California. The high elevation nurseries provide natural chilling to induce dormancy in the plants before strawberry plants are shipped to fruit producers. It is not possible to artificially reproduce these conditions in a greenhouse environment for the day neutral cultivars (Shaw, 2002), and is difficult to accurately condition short day cultivars. While plug plants will continue to play a role in strawberry fruit production in California, plug plants will not be able to replace the current strawberry nursery production system. The number of plug plants utilized in California for the 2003-2004 production season was severely limited due to a disease outbreak in the greenhouses where the plug plants were being grown. This outbreak did not just occur in California but across the United States in multiple greenhouse facilities providing plug plants to the strawberry industry (Sances, 2004). If the fruit production industry was dependent on plug plants, an outbreak of this size were devastate the industry. It would simply not be possible to produce the nearly 1 billion plants currently provided by the strawberry nurseries in non-soil media since the cost associated with the necessary greenhouse space would be astronomical and the product produced would be inferior to the current product.

California strawberry nursery growers use cover crops as part of their rotation program to provide a non-host period for nematodes and pathogens and to increase the organic matter in the soil. While ongoing breeding efforts continue in California, and commercially viable strawberry cultivars used in California differ in their susceptibility to Verticillium wilt and Phytophthora induced diseases as well as in their response to viral pathogens, none of these cultivars is completely resistant. Since strawberries are octopolids, breeding for resistance while maintaining yield and fruit quality characteristics is an extremely long-term process.

Conclusions:

While Telone and Telone combinations may be viable options for some commodities, data strongly suggests this is not the case with strawberry nurseries. The uncertainly and erratic control of pathogens and nematodes currently seen with Telone and Telone mixtures render them as an unstable long term option for the strawberry nursery industry. Continuing problems with the technical aspects of applying alternative fumigants (Ajwa, 2004), problems with plant back intervals and lack of broad spectrum control of diseases, nematodes and weeds make the current alternatives economically unfeasible in California (Sydorovych, 2004; Goodhue 2004).

It is imperative that California strawberry nurseries have clean, pathogen and pest free stock to distribute not only to the California fruit producers (both conventional and organic growers) but also to fruit and nursery producers worldwide. Strawberry fruit growers are firmly in favor of the continued use of methyl bromide to produce clean stock (see grower letters, attached).

California strawberry nurseries are not attempting to suppress levels of pathogens and nematodes, but are trying to completely eliminate nematodes and pathogens from the nursery stock. The fact that successful commercial production depends on pest and disease free planting stock is a universally demonstrated fact. The necessity of utilizing methyl bromide to produce this clean planting stock has been recognized by the Methyl Bromide Technical Options Committee of the United Nations Environment Program (1998) and by many researchers (Martin, 2003;Noling, 2002; Duniway, 2002; Subbarao, 2002).

More time and research are required to find a technology that can be used to provide the same level of cleanliness from nematodes, pathogens, and weeds currently realized with the use of Methyl Bromide as a fumigant in California strawberry nurseries.

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Research into Alternatives to Methyl Bromide for California Strawberry Nurseries

The California Strawberry Commission has funded many nursery based projects from 1992-2004. They estimate that 10-15% of their overall research budget from that period of time was spent either directly on nursery projects or on projects that had a large nursery component. This research included nursery stock performance under alternative fumigant regimes, tracing nursery stock under alternative fumigant regimes from low elevation to high elevation to grower production fields to see the effect of alternative fumigants through the entire nursery cycle. Research on root pathogens and control of root pathogens by chemical and non-chemical means was also studied. The California Strawberry Commission also funds an on-going strawberry breeding program to develop superior cultivars for California production systems including evaluation and breeding for disease resistance. An unnamed amount of money is spent by private strawberry breeding programs in California on a yearly basis. These breeding programs are also working to develop disease and pest resistant varieties. Some of the research studies evaluated the root health and development, as well as weed and pathogen control in the nurseries. The California Strawberry Commission projects that they have spent between $800,000 to $1,200,000 on strawberry nursery research during this time period.

The USDA has funded projects at the California strawberry nurseries to look for alternatives to Methyl Bromide. An estimated $400,000 has been spent on these projects during the period from 1992 through 2004. These projects are ongoing. This season projects on alternatives to Methyl Bromide include evaluating chemical and non-chemical alternatives with researchers evaluating yield, pathogen populations, nematode populations and weed levels in the alternative plots. Further studies evaluating rates of fumigants, methods of application and different tarps are planned for the future.

The University of California Davis campus in cooperation with the UC Kearney Ag Research Center has ongoing nursery research project. This project includes evaluating vertical and horizontal migration of Vapam in the soil, multi layer Vapam test, C35 fumigation test, low elevation Vapam and Telone/Vapam test, High elevation Vapam, Telone and Methyl Bromide test. This is the research that generated the numbers of nematodes and weeds throughout the soil profile at the Shasta Nursery site. This is on-going research, about $100,000 has been spent on this project up to this time. Further research evaluating chemical and non-chemical alternativesis planned for the future.

Individual nurseries have also been evaluating alternatives to Methyl Bromide. Projects have included cultural changes (I.e. looking at raised beds and drip irrigation, looking a non leaking irrigation pipes, evaluating alternative planting densities with and without tractor rows), chemical alternatives (small to medium sized (1-10 acres) plots of Telone and Telone combinations as well as Chloropicrin alone, Vapam alone and Methyl iodine), and non-chemical alternatives (Steam soil sterilization, organic production). Several of these projects have been initiated in the last year and are ongoing. Limited data should be available next year. One nursery trialed several materials on a commercial basis for retail plants (not in the certification system) but due to lower crop yields, substantially higher weeding costs and visible pathogen control differences, the material is now being trialed only on an experimental scale. The estimates from the nurseries for the money they have spent to date is $250,000. All of the nurseries plan to continue to evaluate alternatives as they become available and continue to evaluate currently registered materials to attempt to improve the efficacy of the alternatives.