Alternatives to Methyl Bromide Soil Fumigation for Florida Vegetable Production [1]

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In 1991, climatic studies of historic concentrations of methyl bromide captured in polar ice showed increasing amounts of the compound over the past several decades. In subsequent studies, it was shown to catalyze the destruction of ozone, and determined to be a significant contributor to stratospheric ozone depletion, thinning, and the creation of an ozone hole over Antarctica. After being classified as a Class I ozone depleting chemical in 1993, methyl bromide was mandated by the Clean Air Act of 1990 for eventual phaseout from production and agricultural use. After a 13-year-long regulatory process with numerous shifts to the schedule for final regulatory action, the final phaseout date for methyl bromide production and importation, for use within the U.S. proceeded as scheduled on January 1, 2005. As with other ozone depleting substances regulated under the Montreal Protocol on Ozone Depleting Substances and the U. S. Clean Air Act, supplies of materials manufactured and imported prior to the scheduled phase out continue to be legal to use as approved for only specifically exempted crops.

In tomato, pepper, eggplant, and strawberry, continued post phaseout availability is now driven by a more complex process involving the use of both remaining commercial stocks of methyl bromide, as well as those from other new supplies made available only through award of a Critical Use Exemption (CUE). The CUE process is a complicated national and international regulatory driven procedure. Simplistically described, the CUE is a process of documenting the need for continued use as described by the collective research efforts of grower organizations, University of Florida - IFAS research and extension faculty, as well as many other state and federal agencies. It culminates in a final document compiled by the U. S. Government of all such petitions nationwide that is submitted for review and approval by the Parties to the Montreal Protocol. The criterion for approval is the need for continuing use of methyl bromide for crops and farming enterprises in which “no technically or economically feasible alternative to methyl bromide is shown to exist”.

Based on CUE petitions developed and submitted by the Florida Fruit & Vegetable Association (FFVA), and endorsed and supported by EPA, USDA, and the United States State Department, a critical use exemption for continuing use of methyl bromide for tomato, pepper, eggplant and strawberry has been awarded for calendar years 2005 through 2012. CUEs for these crops for 2013 are currently in the review and approval process at the international level. The reference baseline used for regulatory comparison is

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the use during the 1991 calendar year. Total Critical Use Exemptions at the national level are reported as percentages of this 1991 baseline. With each additional year of CUE submission, the amount of new methyl bromide production awarded or allowed is generally less than the amount of methyl bromide awarded the previous year and, more importantly, of the amount formally requested by the U. S. government in its Critical Use Nomination (Figure 1). Because of the diminishing level of existing commercial stocks, and significantly reduced allowances for the production of new product, shortages in methyl bromide supply are becoming increasingly more apparent, and are fully expected to become much more severe than in previous years as we progress through the 2011 - 2012 cropping seasons.

Florida growers, who have continued to rely on existing and internationally approved CUE supplies of methyl bromide, painfully recognize an increase in price, a future of diminishing supply, and the limits to which methyl bromide use rates can be reduced without loss of pesticidal efficacy and crop yield. Local competitive pressures also led to Florida growers being reluctant to transition to new integrated pest management strategies which include co-application of different fumigants and herbicides, and adoption of other alternative cultural practices to achieve pest control efficacy and crop yield response similar to that of methyl bromide.

Transition to the alternatives has also required growers to implement other significant changes to current practices, including integration of new fumigant distribution and soil injection technologies, and new tillage and irrigation practices to enhance the performance of alternatives and reduce potential fumigant emissions from treated fields. With Phase 2 labels and completion of the formal EPA fumigant reregistration process (spring 2012), all of the currently registered fumigant alternatives will have new restrictions which will further restrict or limit their use (i.e., potential needs for reduced rates and acreages treated per day and expanded buffer zones). The new regulatory criteria for fumigant use are designed to strongly encourage emission reduction strategies which include high barrier (more gas impermeable) plastic mulches to reduce overall field application rates and soil emissions of fumigant gases. Grower transition to these new IPM methods (dashed blue line Figure 1) have been largely and only recently driven by limited methyl bromide supply and formulation availability, a significantly lower cost structure for combinations of chemical alternative strategies compared to that of methyl bromide, and by many other field, pest, soil, crop, and economic considerations. The primary objective for any methyl bromide transition strategy has been to manage adoption of alternatives over time, to minimize changes to the crop production system, and define and remove performance inconsistency of alternatives.

Imperatives for Transition

As Figure 1 illustrates, with each new year the amount of methyl bromide new production approved for CUEs is generally less than the amount of methyl bromide approved the previous year. Up until 2009, it was widely believed that these reductions in new production had not significantly impacted methyl bromide availability to Florida growers because of the buffering capacity of the previously produced, existing supplies. Late in 2008 it became apparent that the distribution of those available stocks resulted in shortages of methyl bromide in the regional distribution system. As existing commercial stocks were depleted and international approval for production of new product decreases, severe shortages in methyl bromide supply were beginning to be observed in late fall 2006 and 2008 and have continued to amplify with each cropping season since. Approved CUE levels for new production and consumption for 2012 are currently projected at 3.0% of the 1991 baseline level, a significant reduction from the previous year of 7.25%. With Florida CUE vegetable acreage relatively unchanged, there are currently inadequate supplies to meet former demands and extensiveness of use. To sustain availability, methyl bromide distributors are again only currently providing formulations with increased chloropicrin content, primarily a formulation of 50% methyl bromide and 50% chloropicrin. This formulation has not been well liked by Florida growers because of its higher chloropicrin content and pest control shortcomings (particularly weeds). With limited supply and formulation availability, Florida growers are ultimately being forced to rapidly transition to alternative strategies for crops currently dependent upon methyl bromide, particularly when product pricing has finally reached the $6.75 per pound mark and lower cost alternative strategies are needed after fruit pricing volatilities in the marketplace.

Clearly the time has arrived to document and describe a process for an orderly transition and implementation of the alternatives. Many different timelines and acreage commitments to alternatives can be envisioned. A seamless transition would commit new acreage to alternatives at a rate equal to or greater than the rate that methyl bromide annually decreases in supply. Figure 1 depicts a timeline for orderly transition to alternatives as an inverse function of CUE approved levels of new methyl bromide production. This projected transition timeline would indicate a need for

Florida growers to commit as much as 40% of their acreage to alternatives by the end of calendar year 2006, and to 70% and 95% by the end of 2007 and 2010, respectively. In reality, this long term incremental approach has not occurred, and only recently have growers transitioned to broader use of the alternatives. The dashed line of Figure 1 represents what appears to be the more realistic and accurate scenario in which expedited grower transition to methyl alternatives is predominately driven by only lingering grower preference for methyl bromide, higher per pound pricing, and reduced availability of methyl bromide in a desirable formulation within the marketplace (i.e., 67/33).

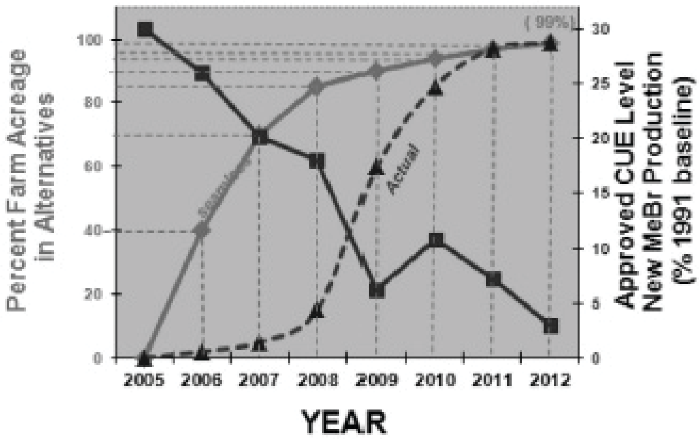

Fig. 1 Statistical projection of forced rates of adoption of alternatives based on the CUE approved amounts of "new" methyl bromide production and consumption. The projection is based on assumptions of minimal "available Stocks", 1991 use characteristics and 2005 base crop acreages.

Alternative Fumigant Chemicals

Since 1993, many different alternative soil fumigants have been evaluated in field trials to characterize pest control efficacy and crop yield response (Table 1). The results of these research trials have provided the basis for overall generalization of pesticidal activity for each of the alternative fumigant chemicals. As a standard for comparison, this research has repeatedly demonstrated methyl bromide to be very effective against a wide range of soilborne pests including nematodes, diseases, and weeds. Methyl iodide, a recent entry to registered fumigants in Florida, has shown similar broadspectrum pest control activity as that of methyl bromide. Chloropicrin has proved very effective against diseases but seldom nematodes or weeds. Telone (1, 3-dichloropropene) is an excellent nematicide but generally performs poorly against weeds and diseases. Bacterial pathogens have not been satisfactorily controlled by any of the fumigants. Metam sodium and metam potassium can provide good control of weeds when placed properly in the bed, however research to evaluate modification of rate, placement, and improved application technology have not resolved all problems of inconsistent pest control. Dimethyl disulfide (DMDS), the newest entry to registered fumigants in Florida, has demonstrated good to excellent control of nematodes, disease, and weeds when coapplied with chloropicrin.

Much of the current field research continues to focus on evaluations of chloropicrin co-applied with additional fumigants. In this co-application approach, chloropicrin has clearly been shown to be an integral, foundation component of any alternative chemical approach to replace methyl bromide. Of the chloropicrin combinations, including Pic-Clor 60, Telone C-35, a combination of 1,3-dichloropropene and 35% chloropicrin, has been the most extensively evaluated in Florida field trials since 1994. DMDS in combination with chloropicrin (21%) has also been extensively studied in west central and south Florida field trials. Over the past few years, anticipated label changes regarding personal protective equipment (PPE) and buffer zone requirements have focused Florida field research activities on evaluations of application methods which minimize grower impacts, such as drip fumigation and pre-bed shank applications. With the new fumigant labels of January 1, 2011, many new, less demanding, requirements for personal protective equipment are now in effect. For example, full face respirator must only be worn if a handler in the field complains of sensory irritation and the certified applicator decides to remain in the field and to continue fumigation. Other changes in new fumigant label language which has affected field research priority involves a new, less demanding buffer zone distance requirement to surround fumigant treated fields. As a result, field research focus has shifted back towards evaluations of in-bed shank applied fumigant treatment.

To ensure deeper placement, Telone II can be injected to flat soil prior to any soil mounding or bed forming operation (pre-bed) to a depth of at least 12 inches below the final bed top with the second fumigation pass applying the chloropicrin to the bed at 8 to 9 inches below the final bed top. In-row or pre-bed applications of Pic-Chlor 60 or Telone® C35, or more recently with drip applications of Telone Inline or Pic-Clor 60 EC continue to be field evaluated for pest control efficacy.

Research conducted in Florida and areas of the southeast appear to support the general conclusion that reasonably consistent soilborne pest and disease control can be obtained with in-row or pre-bed applications of Telone® C35 (35 gal/A) or Telone® II, applied at 12 gallons per treated acre followed by chloropicrin applied in the bed at 150 pounds per treated acre. In combination with Telone® II, Telone® C35 or Chloropicrin, use of a high barrier or virtually impermeable mulch film (VIF) will generally improve fumigant performance and reduce soil gas emissions. After EPA completion of fumigant reregistration (expected spring 2012), EPA will only recognize use of specific high barrier or true VIF mulch films where film permeabilities (mass transfer coefficients) to the different fumigant gases have been measured and meet EPA approved emission reductions to qualify for buffer zone reducing credits. With use of the more impermeable plastic SIF or VIF mulches, fumigant rates can be reduced 25% to 40% from maximum labeled application rates. Due to use restrictions for all Telone products in Dade County, either metam sodium or metam potassium at 75 and 60 gallons per acre respectively, in combination with shank injections of chloropicrin (150 pounds per treated acre) and appropriate herbicide(s) are currently defined as the best alternatives to methyl bromide. With Florida registration on May 13, 2011, use of dimethyl disulfide (Paladin), in combination with chloropicrin and metam sodium or potassium is also expected to provide a basis for statewide grower trialing of yet another effective alternative chemical approach to replace methyl bromide.

Given the general lack of herbicidal activity associated with the alternative fumigants, weed control is usually assigned the highest pest management priority for most methyl bromide alternative chemical systems. Regardless of crop, separate application of one or more herbicides is a requirement for effective weed control with any methyl bromide chemical alternative system. In general, weed control with these alternative fumigants (including Vapam® or KPam) plus herbicides is reported as good or better than that of methyl bromide. There are however numerous examples of less than ideal herbicide performance in which various grasses and broadleaf weeds were not effectively controlled. The problems incurred usually demonstrate the importance of soil conditions, incorporation method, and improper rate calibration for good weed control, as well as for inducing significant phytotoxic effects and cause for resultant yield losses.

Herbicide Partners

In addition to Telone II plus chloropicrin, Telone C35, or Pic-Clor 60, additional applications of appropriate herbicides will be necessary to provide weed control for any CUE crop (Table 2). For tomato, follow the fumigant pre-bed application of Telone C35 or Telone II and Chloropicrin with a tank mix of napropamide (2 pounds a.i.) and s-metolachlor (0.95 pounds a.i.) per treated acre applied to the top of the raised bed at plastic laying for weed control. An additional application of halosulfuron (0.024 pounds a.i.) as a post-emergent, directed spray for nutsedge control may be necessary. For strawberry, the fumigant application of Telone C35 is supplemented by a herbicide tank mix of oxyfluorfen (0.5 pounds a.i.) plus napropamide (4 pounds a.i.) per treated acre, to the raised bed surface at plastic laying. (Note: A minimum 30-day interval is required before transplanting when using oxyfluorfen.) In pepper, a herbicide tank mix of napropamide (2 pounds a.i.) and s-metolachlor (0.71 pounds a.i., 3rd party label obtained through FFVA) per treated acre is applied after the Telone II Pre-bed and Chloropicrin injection to the raised bed at plastic laying for weed control. Recent research on soil application technologies in Florida and Georgia have demonstrated improved nutsedge control with metam sodium or potassium applied through a series of minicoulters to the established plant bed just before installation of the plastic mulch. Good control of yellow and purple nutsedge has also been recently demonstrated in limited tomato trials with Eptam (S-ethyl dipropylthiocarbamate, 3rd party label obtained through FFVA), however these applications are only safe when used under LDPE (conventional) mulch.

HIGH BARRIER/VIRTUALLY IMPERMEABLE PLASTIC MULCH FILMS (VIF)

Since the early 1960's, low density polyethylene mulch film (LDPE) has been used as an integral component of the raised bed, methyl bromide soil fumigation, seep irrigated vegetable production system of Florida. In this system, the mulch is important because it confers effective nonchemical weed control and minimizes evaporative losses of water from soil and nutrient leaching due to frequent rainfall. Use of LDPE is also a federal label requirement for use of methyl bromide, where it must be installed immediately after fumigant injection into soil. Unfortunately, as much as 30% to 80% of the methyl bromide applied to soil is estimated to escape the plant bed through the LDPE mulch cover. It is obvious that the barrier properties of LDPE to fumigant gases is quite poor, particularly given the 0.7 to 1.2 mil thick films typically used in Florida agriculture. In general, the wide range in outgassing losses of methyl bromide is not just due to the permeability of the plastic mulch cover, but to the range in cultural practices and environmental conditions (hot, dry) occurring at the time of soil fumigation.

The permeability (the ability to pass through) of plastic mulch to a fumigant gas is directly related to the thickness, density, and chemical composition of the plastic sheet. Regardless of composition, thicker mulches are generally less permeable to methyl bromide than are thin mulches. In most cases, practical and cost efficiency considerations prevent the use of thicker LDPE mulches for enhanced containment of methyl bromide soil gases. There are however other, more impervious, plastic mulches commercially available which can provide a much better diffusion barrier to methyl bromide and other soil fumigants. These new low permeability films, and the classification scheme to describe them, include totally impermeable films (TIF), virtually impermeable films (VIF), and semi-impermeable films (SIF) which include the metalized films. These films, compared to standard polyethylene (PE) films, can reduce fumigant emissions to the atmosphere and via improved containment in soil and cumulative time x concentration products, improve fumigant performance even at reduced rates of fumigant application.

As indicated, significant barrier to fumigant outgassing has been achieved with VIF and TIF mulches. VIF mulches, the most widely studied, are typically manufactured as multi-layer films composed of barrier polymers such as ethylene vinyl alcohol (EVOH) or polyamide (nylon) sandwiched between other polymer layers (typically LDPE) that keep the barrier polymers from swelling. Compared to LDPE mulches, certain VIF films are over 20,000 times less permeable to methyl bromide and other fumigant compounds. The permeability of these mulches is however subject to variation induced by physical and suboptimal environmental conditions. For example, VIF has been shown to have extremely low permeability under laboratory conditions (before tarping), but its permeability can change significantly under field conditions after tarping. After laying the plastic in the field, some SIF and VIF mulch films may be as much as 2 to 3 times more permeable to a given fumigant gas than they were under laboratory conditions. This is thought to be due to a breakdown in the VIF properties under field conditions caused by the stretching and cracking of the middle, low permeability layer during tarping.

Quantitatively, the permeability of LDPE, TIF, VIF, and other SIF mulch films to a fumigant gas were formerly expressed as the amount of a fumigant (grams) passing through the mulch cover per unit time (hr) and per unit surface area. VIF mulches were first developed and mandated for use in Europe, where to be labeled VIF, film manufacturers were forced to comply with a standard testing protocol (NFT 54-105), established by the French Ministry of Agriculture. The French standard specifies that in order for a film to be classified as VIF, its permeability to methyl bromide can not exceed 0.20 g/m2/hr. Alternative standards for expressing permeability, such as the mass transfer coefficient, are now being adopted for use in defining high barrier and gas impermeable plastic mulches.

This new reference standard, the mass transfer coefficient (h) of fumigant compounds across agricultural films, is a measure of the resistance to diffusion which, unlike the French standard, is a property of the film/chemical combination and is independent of the concentration gradient across the film. The French method computes permeability based on fumigant flux or fluctuation, or grams of fumigant per unit surface area per unit time. As a measure of permeability, the French standard is thus dependent (and will necessarily change) upon the concentration gradient or concentration difference occurring on each side of the film. In the French method, the concentration difference between sides is seldom the same (not standardized), and thus cannot be compared between independent laboratory based estimates. The mass transfer coefficient method however, uses static sealed cells; a fumigant gas is introduced (spiked) to one side of the film and the concentrations on both sides of the film are then monitored until an equilibrium is reached (same on both sides). The mass transfer coefficient characterizes the equilibrium condition, and thus provides an intrinsic signature measure of the permeability of a film to a chemical which is not dependent on the chosen concentration gradient. Because the new method produces such a sensitive and reproducible measure of film permeability between laboratories, it is now being widely adopted as the new yardstick for comparing fumigant permeabilities among the high barrier plastic mulches.

During the past decade, many small plot and large scale field trials have been conducted in Florida to evaluate the use of high barrier SIF, VIF, and TIF mulch films to reduce methyl bromide field application rates, reduce soil emissions, and to compare crop yield and pest control efficacy. In general, the results of these trials have indicated no significant loss of pest control efficacy or of crop yield when application rates of methyl bromide were reduced as much as 25% to 50% and when reduced rates were accompanied by the use of a TIF, VIF, or high barrier SIF mulch. In a number of trials, attempts to further reduce use rates by more than 50% resulted in a loss of pest control efficacy and crop growth performance. Opportunities for reducing field application rates of other fumigants without compromising pest control efficacy or crop yield have also been demonstrated with methyl iodide.

More recently, field research has demonstrated that certain metalized mulches (Canslit) had significant barrier, VIF-type qualities. The thin coating of aluminum was demonstrated to retain higher methyl bromide concentrations in soil for longer periods of time, and thus provided effective weed control (e.g., nutsedge), with reduced rates of methyl bromide comparable to that of true VIF mulch film. The utility of the metalized mulch for allowing reduced fumigant application rate has also been demonstrated in other states of the southeast. The more efficient containment of gases below the barrier mulch has also resulted in cases of crop phytotoxicity. To use the high barrier mulch technology, plantings may have to be delayed to insure soil residues have dissipated and plant injury will not occur. A monitoring program using colormetric detector tubes (GasTek, Kitagawa, Sensidyne) or VOC meters to assess residual fumigant gases in soil should be considered before a commitment to planting is made.

Noteworthy problems have been encountered with some VIF mulches. In some strawberry trials, where taller yet narrower beds are used, the slick, nonembossed VIF mulches could not be installed without the need for significant hand labor. Since the VIF plastics were not embossed, they demonstrated a tendency to slip from under the rear press wheels during installation causing significant reductions in tractor speeds and frequent stoppages in the plastic laying operation. The problem with use of nonembossed does not appear to be as severe in tomato or pepper where the raised plant beds are wider and not as tall as that of strawberry. Since these VIF mulch have no stretch capability, adding 2 inches of width to the roll (if possible) has in many cases reduced, not eliminated, problems of field installation in strawberry by providing more plastic at the tuck in the row middle. With the appearance of many newly formulated VIF products, including the new embossed high barrier mulches, the previous problems of installation may be largely resolved.

From a practical standpoint, grower adoption of VIF or other high barrier films, coupled with reduced soil fumigant application rate will require continued in-field evaluations, with continued refinement of field installation application technologies and evaluations of reduced rate pest control efficacy. Increased use of TIF and VIF mulch films must also consider changes in production cost and benefits to productivity. Today, over a dozen different manufacturers or product lines can be identified which claim high barrier, VIF or TIF status. Many of these new high barriers, VIF, and TIF products are now being produced in the U.S. and Canada, while others may originate from international manufacturers. Any growers acquiring films from overseas manufacturers should be encouraged to order necessary products well in advance of the time of need in the field.

Probably the single most important reason for using a VIF or other high barrier SIF plastic mulch involves the rising cost and scarcity of methyl bromide with each new CUE approval. There are other, equally important reasons for adopting high barrier, VIF mulch technologies. After a long EPA fumigant reregistration process, new fumigant labels appeared on product containers of methyl bromide, chloropicrin, metam sodium (Vapam®) and metam potassium (Kpam) on January 1, 2011. The new fumigant labels have clearly enumerated a number of newly mandated rules, restrictions, and regulatory changes which must be satisfied prior to use of all of the alternative fumigants. For example, if a respirator is required to be worn by handlers in the application block, then OSHA approved pesticide safety training, medical certification, and respirator fit testing will be required by the new labels. The new labels will also require certified applicators to complete and archive fumigant management plans (FMP) and post application summaries for each application block in which a fumigation occurs. Effective with a second round of new labels coming sometime during spring 2012, these new label changes will include requirements for certified applicators to acquire additional product use and stewardship training every 1 to 3 years depending upon the fumigants being used in the field, as well as expanded buffer zones between agriculturally treated lands and urban residential property and or occupied structures. Buffer zone requirements, areas extending outward from the treated field where fumigants cannot be applied, will be calculated and dependent upon methods of fumigant application, the number of acres treated per day, and field application rate (the higher the field use rate, the bigger the buffer zone from residential property line or occupied structures required). Any new buffer zone and use rate restriction will surely mandate a more intensive, overall re-evaluation of alternatives and reduced rate application technologies, including use of high barrier SIF, VIF, and TIF type mulches to take advantage of buffer zone reducing credits, assure pest control efficacy and crop response consistency. As indicated previously, EPA will only recognize use of specific high barrier SIF, TIF, or true VIF mulch films where film permeabilities (mass transfer coefficients) to the different fumigant gases have been measured and meet EPA approved emission reductions to qualify for buffer zone reducing credits.

REDUCED RATE APPLICATION TECHNOLOGIES

Currently, soil injection equipment for methyl bromide is designed to dispense as much as 15 to 20 gallons of a liquid fumigant compound through armored lines from the gas cylinder, to the flow meter and rear manifold and then through each of three chisels per bed. The system is designed and calibrated to do this while moving at 3½ to 5 mph, uniformly dispensing multiple liquid streams of fumigant within 7,260 to 10,890 linear feet of row per acre. With such high rates, the flow lines are full, with liquids moving as continuous streams without in-line voids or bubbles. At reduced rates of application, such as those demanded for use with high barrier or VIF film, the situation may be vastly different.

Methyl bromide is a colorless, odorless, liquid under certain conditions of pressure and temperature. At temperatures below the boiling point of 38°F, or within the confines of a pressurized cylinder, methyl bromide exists as a liquid. At temperatures typical of field application in Florida, methyl bromides rapidly volatilizes to a gas once released from the pressurized cylinder into the ambient pressure of air or soil. With such a high vapor pressure (1420 mm Hg), methyl bromide can even exist as bubbles of gas within the distribution lines if metered flow rates are low and do exceed the total capacity of the delivery tubing and manifold system. With reduced flow and presence of bubbles within lines, a significant loss of back pressure occurs at the chisel orifices. The dramatic fall in back pressure with reduced rate prevents accurate and uniform flow of the fumigant between chisels. This occurs at the point where total internal volume (flow capacity) of 9 chisel tubes, typically ¼ inch in diameter, exceeds the flow capacity of a ¾ armored delivery hose from the flow meter. When the outflow potential is greater than inflow then you have a significant loss of pressure, and without back pressure the system becomes one of gravity flow. With the existing on-farm systems, accuracy cannot be achieved at such low volumes, and without significant back pressure. To resolve the back pressure problem, it is extremely important to reduce total line volume and/or diameter of the delivery tubes from the manifold to the chisels so as to guarantee adequate back pressure at the point of fumigant release. With a high barrier mulch, reducing the field application rate of a fumigant results in a greatly reduced rate of liquid flow. Some chisels are so reduced in flow that accuracy and uniformity of application along and between the rows was compromised along with pest control efficacy.

As indicated previously, use of VIF or high barrier plastic mulch films will be a required component of any methyl bromide transition strategy. Use of these more gas retentive mulches will however, require changes in field application and soil injection equipment to insure accurate and uniform dispensing of such low fumigant application rates (5 to 10 gallons per acre). These required changes include smaller delivery tubing size (⅛ to 1/16 inch diameter), installation of sight gauges to monitor flow uniformity among chisel streams, and installation of a low pressure gauge upstream of the flow divider to monitor overall back pressure (at least 15 psi) at the flow divider (Table 3). For additional, more comprehensive information, readers are advised to review "*Application Considerations for Successful Use of VIF and Metalized Mulches with Reduced Fumigant Rates in Tomato*". Appendix; or http://edis.ifas.ufl.edu/HS270).

TRANSITION RISKS

Transition refers to an incremental change from current status. Defined in this way, the transition from methyl bromide fumigation is the change from a 40-year-old system of being totally reliant on methyl bromide to a new multi-tactic pest control and crop production system. Clearly, the transition is not likely to be uneventful or without problems. In many cases, problems have been reduced after comprehensive review and a complete analysis of the entire production system. The transition is not likely to be easy or seamless. If the transition plans are well designed and implemented effectively, problems are likely to be few. Unavoidably however, some factors that affect the success or failure of the various tactics, such as the environment, may not be completely manageable or resolvable. For example, seasonal differences in temperature and rainfall patterns can adversely effect fumigant dissipation from soil, and herbicide efficacy and thus reduce the value of the alternative by causing treatment inconsistency. Growers can also cause significant response variability due to inappropriate land preparation or substandard application procedures. Another newly emerging concern is the risk created by the differential plant-back restrictions of some of the newly registered herbicide compounds that have to be added for weed control with the alternative fumigants. The impacts on the ability to double crop, as well as potential direct yield reduction as a result of carryover from row middle or previous crop applications, are also of concern.

Effective transition planning can only be achieved through a collaborative effort involving the grower and their field staff, commodity organization involvement, assisted by university research and extension personnel. Working together, the team should craft a realistic transition plan that addresses many of the production concerns and inconsistencies. The transition plan would also surely highlight the imperative that Florida fruit and vegetable growers actively complete the transition, to increased reliance upon the alternative fumigants as a percentage of their total farmed acreage.

Table 1. Generalized summary of maximum use rate and relative effectiveness of various soil fumigant alternatives to methyl bromide for nematode, soilborne disease, and weed control in Florida

		Relative Pesticidal Activity		
FUMIGANT CHEMICAL[1]	**Maximum Use Rate**	**Nematode**	**Disease**	**Weed**
1) Methyl bromide 50/50	350 lb	Good to Excellent	Excellent	Fair to Excellent
2) Chloropicrin[2]	300 lb	None to Poor	Excellent	Poor
3) Methyl iodide	350 lb	Good to Excellent	Good to Excellent	Good to Excellent
4) Metam sodium	75 gal	Erratic	Erratic	Erratic
5) Telone® II	18 gal	Good to Excellent	None to Poor	Poor
6) Telone® C17	26 gal	Good to Excellent	Good	Poor
7) Telone® C35	35 gal	Good to Excellent	Good to Excellent	Poor to Fair
8) Pic-Clor 60	300 lb	Good to Excellent	Good to Excellent	Poor to Fair
9) Metam potassium (Kpam)	60 gal	Erratic	Erratic	Erratic
10) Dimethyl disulfide[2]	60 gal	Good to Excellent	Good to Excellent	Poor to Excellent

[1]Currently completing Phase 2 EPA and State of Florida Fumigant Reregistration review with potential changes to maximum application rate, new fumigant training certifications, personal protective equipment, buffer zone, mandatory good application practices, and other new restrictions and requirements.

[2]Broad spectrum pest control achieved when coapplied

Table 2. Recommended alternative fumigant and herbicide treatment regime to that of methyl bromide for Florida[1] tomato, pepper, eggplant, and strawberry crops. All rates expressed per treated acre. To achieve maximum weed control an application of Metam sodium (Vapam®) at 75 gal/A or Metam potassium (KPam) at 60 gal/A should be included with all recommended products using a mini coulter applicator or through a drip application using double drip tapes

CROP	Treatment	Application Procedure	Herbicide Rate (lb a.i./A)
Tomato	Telone® C-35 35 gal/A	In-row or pre-bed[2], under LDPE, High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
	Telone® II 12 gal/A	Telone pre-bed[2], Chloropicrin In-bed under High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	Napropamide (2lb) S-metolachlor (0.95 lb)
	Chloropicrin 150 lb/A		Postemergent Halosulfuron (0.036 lb)
	Pic-Clor 60 250-300 lb/A	Pic-Clor 60 in-row or pre-bed[2] under High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
	4DMDS (79%)+ PIC (21%) 60 gal/A	In-row or pre-bed[2], under High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
	Telone® C-35 35 gal/A	In-row or pre-bed[2], under LDPE, High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
Pepper	Telone® II 12 gal/A	Telone pre-bed[2], Chloropicrin In-bed under High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
	Chloropicrin 150 lb/A		Napropamide (2 lb) S-metolachlor (0.71 lb, 3rd party label obtained through FFVA)
	Pic-Clor 60 250-300 lb/A	Pic-Clor 60 in-row or pre-bed[2] under High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
	4DMDS (79%) + PIC (21%) 60 gal/A	In-row or pre-bed[2], under High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
	Telone® C-35 35 gal/A	In-Row or pre-bed[2], under LDPE, High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
Eggplant	Telone® II 12 gal/A Chloropicrin 150 lb/A	Telone pre-bed[2], Chloropicrin In-bed under High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
	Pic-Clor 60 250-300 lb/A	Pic-Clor 60 in-row or pre-bed[2] under High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
	4DMDS (79%)+ PIC (21%) 60 gal/A	In-row or pre-bed[2], under High Barrier or VIF Mulch Film[3]; applied 3-5 weeks before transplanting	
Strawberry	Telone® C-35 35 gal/A	In-row or pre-bed[2], under LDPE, High Barrier or VIF Mulch Film[3]; applied 4-5 weeks before transplanting	Napropamide (4 lb) Oxyfluorfen (0.5 lb)

[1]Crop recommendations for Pic-Clor 60, Telone® II or Telone® C-35 do not apply to the Homestead, Dade County production region of south Florida where soil types and water tables currently prohibit product use.
[2]Inject Telone® II, Telone® C35, or Pic-Clor 60 to flat soil prior to any soil mounding or bed operation (pre-bed) to a depth of at least 12 inches below the final bed top.
[3]In combination with fumigant, use of an EPA approved high barrier or virtually impermeable (VIF) or totally impermeable (TIF) mulch film. With use of the mulch, fumigant rates can be reduced 25% to 40% from maximum pesticide labeled application rate.
[4]DMDS (dimethyl disulfide) (79%) co-formulated with 21% chloropicrin. Its use has not been broadly tested in Florida but has proved very effective against nematode and disease, and for many weeds. Provides excellent control of nutsedge but only poor to fair control of annual grasses and requires the use of a separately applied herbicide for adequate control.

Table 3. Summary of recommended fumigant injection equipment modifications required for use of high barrier / VIF mulch and reduced rate applications of soil fumigants

Replace tubing from manifold to chisels with smaller diameter poly tubing to compensate for the new reduced flow capacity requirement and to increase line back pressure needed to insure accurate, uniform flow among all chisel streams.
To the manifold - flow divider, install individual sight gauges to observe uniformity of fumigant liquid flow to each chisel outlet.
Install a low pressure gauge (0-30 psi) immediately upstream of the manifold or flow divider to insure at least 15 psi of back pressure.
Insure that the flow meter registers a minimum of 10% flow.