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Maximizing the Efficacy of Soil Fumigant Applications for Raised-Bed Plasticulture Systems of Florida [1]

Andrew MacRae, Joseph Noling, and Crystal Snodgrass[2]

As Florida farmers transition into the post-methyl-bromide era of soil fumigation, a number of crop production and soil fumigation costs and practices could change. These changes will include:

1. An increase in the cost of fumigation if certain fumigant products are used. Alternative fumigant products may cost more than methyl bromide. Costs may also increase because of the added expense of having to use a high-barrier, gas-impermeable plastic mulch.

2. An increase in the cost of fumigation application due to new EPA regulations. Some new costs will accrue in the form of added labor costs to complete and implement the newly required fumigant management plan (FMP). New requirements for worker personal protection equipment and training will also add significant costs to fumigant application, particularly if respirators and new filters are required for each day's use, and if workers must be medically certified and respirator fit tested prior to use.

3. Changes in effectiveness. None of the currently proposed fumigant alternatives are quite as effective as methyl bromide in sustaining high yields and controlling soilborne pests and diseases. While alternative fumigants may achieve close to that level of effectiveness, most will not be quite as effective as 350–400 lb of methyl bromide 98:2, as it was typically applied a decade ago.

With the potential for these increased costs and a small drop in efficacy for current methyl bromide alternatives, growers must receive all of the benefit of these products to maximize yield potential and pest control. A single-season approach to fumigant application can no longer be biologically and economically justified. Instead, growers will need to develop a sustainable program for each field in which they farm. Sustainability will become the key concept motivating programmatic change. It will no longer be possible to correct pest problems in one season when flawed and imperfect programs were used in previous seasons. Pest control will have to become an integrated, programmatic effort to maintain pest populations at their lowest levels and to extend the productive life of methyl bromide alternative programs.

In the coming post-methyl-bromide era, successful fumigation programs will also rely less on

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2. Andrew W. MacRae, assistant professor, UF/IFAS GCREC; Joseph Noling, professor, UF/IFAS CREC; and Crystal Snodgrass, vegetable agent, UF/IFAS Manatee County Extension

fumigant selection and more on field preparation, new technologies for fumigant application, and other good agricultural crop production practices (GAPs). With methyl bromide, variations in soil tilth, temperature, or moisture seldom played a prominent role in defining or lowering overall performance. However, in order to achieve maximum efficacy with a methyl bromide alternative program, it will be necessary to pay attention to every detail involved in field preparation, application, and environmental condition. Simply stated, methyl bromide was forgiving, the alternatives are not. The alternatives currently being trialed by growers may actually fail in their control of soilborne pests if used in the same manner as methyl bromide.

Fallow Weed, Nematode, and Disease Program

Using a methyl bromide alternative program for managing soilborne pests requires a continuous and sustained programmatic effort. Multicropping (growing two or more crops in succession on the same piece of plastic) requires consideration of pest management opportunities that exist in between cropping cycles. Using a single cropping system in which the plastic mulch is removed and the raised bed is destroyed provides for an expanded list of pest management tactics that could be used to reduce pest pressures in between production cycles. In a multicrop system, sufficient time should be allotted for cleaning up the field in between cycles and allowing for adequate decomposition of crop and weed residues. Early crop destruction is a key founding principle of integrated pest management (IPM). In a true multicropping system in which plastic-covered beds are maintained, crop termination using drip-applied fumigants has proven to be extremely important as a means of crop destruction and food elimination, as well as a pest management tool to control those soil pests currently active in the raised bed. Under fallow conditions between crops, additional cultivation can help prevent establishment of weed species. Adding herbicide such as glyphosate (Roundup® and similar products) is often an economical alternative to disking for control of weeds. Planting of a cover crop can also help to keep weed populations low and manage other soil pathogens.

Soil Moisture

Soil moisture affects both shank and drip fumigant applications. With shank applications, if the soil is too dry, then fumigant gases may not be retained in the bed long enough to satisfactorily or adequately control soilborne pests. If the soil is too wet when fumigants are shank applied, the fumigant will not volatilize from a liquid to a gas or adequately diffuse through soil where pore spaces are water saturated and impede radial movement. This will result in poor pest control and may also increase the plant-back window for the desired crop.

In drip applications, applying to dry soil will also lead to a narrow band of pest control since the water containing the fumigant will move rapidly and near vertically in soil with only limited lateral movement. Too much soil moisture for drip applications will cause poor distribution of the fumigant in the bed. Water containing the fumigant will move deep in the soil or into the row middles where it will provide little pest control in the top 4 in. of the bed.

Fumigants containing 1,3-Dicloropropene (an active ingredient in several products, including Telone® II, Telone® C-35, and PicClor 60®) can have a long plant-back interval if the soil remains wet after application. To maximize pest control and reduce crop injury, growers should manage fields based on soil type and moisture tendencies.

Bed Compression

Bed compression (soil compaction) has been demonstrated to significantly impact the performance of soil-applied fumigant compounds. Soil compaction is a measure of how firmly soil particles are pressed together. In a compact soil, open air pore space between particles is significantly reduced and impedes gas phase movement of fumigants. When in their gaseous phases, fumigants move through soil via the path of least resistance.

To maximize the efficacy of alternative soil fumigants, soil moisture and bed compression must be considered, particularly during the time of soil application and bed construction. The objective should be to uniformly compress the soil across the entire width of the bed. Soil moisture is important in this regard since it is not possible to increase soil compaction with too little or too much water in the bed. If the soil is dry, it is not possible to exert enough pressure to form a bed; if the bed is wet, it will rebound after compression because of the hydrologic pressure in the soil caused by the excess water. If the edges (shoulders) of the bed are loose, the path of least resistance for mass flow of the fumigant will track to the greater air space and channels on the outside portion of the bed to escape. Under these conditions, soilborne pests and diseases contained within the bed are subjected to different fumigant concentrations and durations of exposure. To maximize soil retention of fumigant gases uniformly across the bed, growers should strive to construct a tight, firm bed along the length of the rows and across the full width of the bed. From practical experience, this may be as simple as moving the top link of the bed press out 0.5–1 in., or around 4–8 turns. Other equipment options are to adjust the disk hiller, if using one, to throw the soil wider instead of taller. If the soil is thrown tall, it will lead to greater compaction in the bed center and looser compaction at the bed shoulders. If using a prebedder, some modifications can be made to improve soil distribution prior to pressing the bed. Opening up the channel on the soil-accumulating blades will allow more soil to be pulled to the edges of the beds instead of to the center. With the new fumigants, growers will need to experiment with fumigant application equipment and bed-forming operations to determine the best way to create consistent bed firmness.

Soil Type and Field Location

While some areas of Florida have karst features preventing the use of certain fumigants, most of the fields in southern peninsular Florida are generally defined as fine sands. Much of the difference that occurs between fields on any given farm relates more to soil drainage than soil type. Wet fields can confer either an advantage or disadvantage as it relates to pest suppression or the gas phase movement and timetables for soil aeration of applied fumigants. For example, if the field is wet during the off-season, nematode numbers may be lower, but weed and disease incidence numbers may be higher. In addition, fumigants containing 1,3-Dicloropropene (an active ingredient in several products, including Telone® II, Telone® C-35, and PicClor 60®) can have a long plant-back interval if the soil remains wet after application, trapping the fumigant and preventing its volatilization and escape from the soil. In this regard, some fields will require a higher degree of management (application timing, drainage, etc.) to maximize pest control while reducing crop injury.

Soil Temperature, Weather Conditions, and Fumigation Season

Soil temperature is an important environmental parameter that affects biological activity and fumigant performance. The general rule is to ensure that soil will be at least 50°F for at least two weeks after application to ensure proper pest control and gassing off. Failure to comply with this basic requirement can result in decreased treatment effectiveness and increased risk of crop injury. If freezing weather is anticipated, soil treatments should be delayed until soil temperatures return to levels that do not impede volatilization and diffusion. Fumigant retention times are greater in the spring under cooler soil temperatures than the summer. When cooler soil temperatures prevail, fumigant residuals (gases) in the soil should be monitored and the plant-back schedule adjusted to account for the longer aeration period. Use of a highly retentive film, such as a metalized or high-barrier virtually impermeable film (VIF), is recommended whenever possible and should be used in the summer to maximize soil retention of fumigant gases and pest control efficacy. Growers must read the fumigant label to determine if the use of a VIF or metalized plastic mulch is mandatory.

Fumigation Equipment

A number of the methyl bromide alternative systems will require changes to fumigant application rigs to account for different fumigant application rates (in gallons per acre). Growers should consult a fumigant supplier to ensure application equipment and metering and delivery systems are properly designed and accurately calibrated to effectively and uniformly apply the fumigant within the bed and across rows within the field. Do not make the discovery that some delivery lines should have been changed, lengthened, or shortened after the fumigant is applied within the field. System checks and calibration are probably the most important components of fumigant application. Growers should not skip or minimize the importance of this step prior to taking the rig to the field, particularly when postplant corrective measures may not be possible for many crop and pest species combinations.

Fumigant Placement for Shank Applications

With widely varying differences in vapor pressures, proper fumigant placement is another critical element that must be considered prior to use of a methyl bromide alternative fumigant. In some instances, application depth and placement varies by the formulation of the fumigant product, giving the grower the opportunity to choose a fumigant that does not have as restrictive label requirements for costly personal protective equipment.

For the 3-Way systems approach to methyl bromide replacement, there are essentially three different locations to consider for fumigant placement. Placement of prebed applications of Telone® II are made to the flat to a soil depth that places the fumigant 12–15 in. from the top of the bed or nearest soil interface. If fumigants are placed at this depth and used in conjunction with a seepage irrigation system, growers should ensure that the soil is not wet at this depth. Otherwise, poor nematode control and longer aeration times and crop plant-back intervals may be observed. Metam sodium (Vapam®) or metam potassium (K-PAM™) should be applied 4 in. from the top of the bed and 4 in. apart using multiple coulters or shanks. After application, the bed must be recompressed and mulched immediately to prevent rapid escape of volatilizing gases. The primary objective for such shallow placement is to achieve the maximum control of weeds. Most other fumigants can be placed 8–9 in. deep with shanks no further than 9–12 in. apart.

While methyl bromide will rapidly diffuse as a gas across a bed, many of the currently proposed alternatives lack the vapor pressure or chemical properties to move as fast and effectively throughout the bed. Their movement in the bed is clearly limited and must be accounted for in fumigant placement practices. For example, if the shanks are not close enough together for some fumigants, an overlap in the area between shanks may not occur, leaving streaks of pests down the length of the bed. Many products are formulated for shank or drip applications. To maximize efficacy via drip application, proper placement of the fumigant generally mandates two drip tapes per bed to improve bed coverage.

Fumigant Selection

The most important factor in fumigant selection is matching the pest control efficacy of the fumigant to the pest complex present in the field. Currently, there are five EPA-registered and commercially available fumigant active ingredients identified as possible alternatives to methyl bromide: chloropicrin, 1,3-dichloropropene, metam sodium, metam potassium, and methyl iodide. Dimethyl disulfide, a sixth fumigant active ingredient that is currently not registered, is also expected to become available for use in mid-2010.

In general, methyl bromide has been shown to be very effective against a wide range of soilborne pests, including nematodes, diseases, and weeds. When applied alone, chloropicrin has proven very effective against diseases, while 1,3-dichloropropene (Telone® II) is generally considered to be an excellent nematicide. Methyl iodide (Midas®), like methyl bromide, can provide control of a broad range of soilborne pests and diseases. Metam sodium (Vapam®) and metam potassium (K-PAM™) are considered semi-broad spectrum in pesticidal activity, but are not as consistent in achieving pest control. Combining chloropicrin with any of the other soil fumigants generally broadens the spectrum of activity and improves the level of pest control beyond what either fumigant would have achieved if applied alone (synergy). Given their broad diversity and seasonality of growth habit, weeds are often the most difficult to manage with any of the new alternative fumigants. Bacterial pathogens have not been consistently controlled by any fumigant, including methyl bromide.

In general, fumigant selection is based on the match between pest control activity and the predominant pests present in the field. Field research has demonstrated that there will be no stand-alone single fumigant replacements for methyl bromide. The alternative system will typically involve or require as many as two to three fumigants being coformulated or coapplied to provide an equivalent level of soilborne pest and disease control as that of methyl bromide. When selecting fumigants, it is important for growers to consider any specialized fumigant application technologies that may be required to ensure accurate and uniform delivery of the fumigant in the field. Growers must therefore recognize the capabilities and limitations of their own equipment (i.e., metering and delivery systems). Other important considerations of the fumigant selection process include the production system involved, the number and type of crops grown, the season of fumigation, and the amount of soil moisture present in the field. Growers would be wise to delay any inclinations to reduce either the number or rate of fumigants used before testing the approach for several years in the same location. In the first few years following long-term use of methyl bromide, most fumigant systems and programs can look good. With time and reestablishment of primary pests, however, changes to the system may be required. Growers are encouraged to use test blocks on the farm to repeat specific programs for several years before deciding to adopt the fumigant system farmwide. By taking all of these factors into consideration, finding a suitable fumigant alternative program is possible.