CropLife Foundation
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The Importance of Soil Fumigation: Michigan Vegetables

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Introduction

With a total value of production of $175 million in 2012, Michigan was the eighth largest vegetable producing state in 2012 [1]. Michigan is among the top producers of many vegetable crops in the U.S., including carrots, celery, cucumbers, bell peppers, pumpkins, snap peas, squash and tomatoes [1]. The Total vegetable, potato and melon area harvested in 2007 was 137,887 acres [2]. Michigan's place in the nation's commercial vegetable supply is due to the diversity of crops grown and the ability of growers to supply early season markets [3].

Production Areas

Vegetable production is scattered across many regions of Michigan. Asparagus is grown primarily in the West Central region with some significant acreage also in the Southwest. Carrot production is concentrated in the West Central region. Significant cucurbit production comes from many regions, including South Central (cucumbers), West Central (squash) and Southwest (cucumbers, melons, and squash). Eggplant, pepper and tomato production is concentrated in the Southeast and Southwestern regions [14].

Cultural Practices

For fruiting crops, all fumigation practices need to completed by the first week of May to allow growers to plant early and capture the early market (July-September) [4][5][6][7]. The plant back restrictions associated with some fumigants cause growers to lose access to critical higher-priced market windows [13]. Further, high quality, early yields allow growers to provide sufficient work and wages to attract seasonal workers to their farms [18].

Major Target Pests

Phytophthora

Phytophthora capsici ranks as the most important pathogen on a number of vegetables and threatens production in Michigan [3]. *P. capsici* can survive in the soil for up to ten years and has the ability to destroy entire crops within days. The pathogen affects the root, stem and fruit of eggplants, tomatoes, peppers, snap beans, squash, melons, pumpkins and cucumber [8]. Management of disease caused by *P. capsici* is limited by the long-term survival of the pathogen in soil, wide host range, movement of the pathogen in surface water used for irrigation, the presence of fungicide-resistant pathogen populations, and a lack of commercially acceptable resistant varieties [9]. *P. capsici* is favored by rain and temperatures that occur during the Michigan growing season and has recently been found in irrigation ponds and other surface water sources [10]. It is estimated that 80,000 acres of vegetables in Michigan are susceptible to *P. capsici* [11].

In large-scale replicated field trails on commercial farms, reduced rates of fumigants under low density polyethylene (LDPE) and virtually impermeable film (VIF) were tested in pepper and squash in fields with severe Phytophthora infestation. For yellow squash, DMDS at both rates tested and methyl bromide at

the higher rate had higher yields (>136.5 lbs and 171.6 lbs, respectively) than the untreated control (26.7 lbs.) [11].

Phytophthora asparagi is one of the main soilborne pathogens of asparagus, causing crown and root rot. Infection is more likely when soils are saturated. Control of Phytophthora in asparagus extends the longevity and increases the productivity of asparagus fields [15]. Growers are now fumigating crown nurseries and production fields to limit losses caused by *P. asparagi*.

Fusarium Wilt

Midwest-grown melons are susceptible to Fusarium wilt. *Fusarium oxysporum* f. sp. *melonis*, is a long-lived fungus that can persist for many years in soil in the absence of a susceptible host. Crop losses typically range from 90-100% [3]. *Fusarium* spp. is also a soilborne pathogen of both asparagus and tomato causing crown and root rot. Infection of asparagus by *Fusarium* is more likely when plants are stressed by drought [15].

Verticillium Wilt

Midwest-grown eggplants are also susceptible to Verticillium wilt. *Verticillium albo-atrum* and *V. dahlia* are fungi that can persist in soil for 8 years as mycelium or microsclerotia. Verticillium wilt causes 60-100% yield loss when symptoms appear early in the season [3].

Nematodes

There are three key nematode pests of carrot in Michigan: Northern root-knot nematode, carrot cyst nematode and root lesion nematode. All three types cause low yields and deformed carrots of poor quality [16].

Fumigant Use

Pre-plant soil fumigation is used on acreage where the target pests infestation is high and no other control measure exists. Fumigation is used primarily in the Southwestern production areas along the St. Joseph's River, where flooding may spread target pests across fields [17]. Until recently, methyl bromide was the preferred fumigant. Table 3 shows methyl bromide use in cucurbits, eggplant, peppers and tomatoes for 2001-2006 [12]. Researchers have provided estimates of Michigan vegetable acreage fumigated in 2013 (Table 4). Asparagus and carrots are treated with metam sodium/potassium. Other crops are treated with either Telone C35 or Pic-Chlor 60 [17]. Carrots benefit from fumigation as a rotational crop grown after squash, which is fumigated prior to planting [17].

Alternatives to Fumigants

Crop Rotation

While crop rotation is a recommended practice to help manage *Phytophthora*, its efficacy is limited due to the long-term survival of oospores in the soil [9]. Crop rotation is difficult as infested acreage and urban pressure is increasing across the major growing areas of Michigan [10].

Resistant Varieties

Tolerance to Phytophthora has been identified in peppers and pumpkin, but no sources of complete resistance have been identified. Some squash, tomato and pepper varieties show complete resistance to *P. capsici*, but have unappealing horticultural characteristics [9]. Some cultivars of melons and eggplant have genetic resistance to Fusarium wilt, but it is not considered to be adequate as a stand-alone disease management tool in Michigan.

Fungicides

When environmental conditions are highly favorable for disease development, none of the currently available fungicides can completely prevent *P. capsici* disease and significant losses may be experienced [9]. Further, metalaxyl and mefanoxen insensitivity has been reported among *Phytophthora* spp. populations in several vegetable production areas. Wilts caused by species of soil-borne fungi such as *Verticillium* are endemic to many vegetable producing areas of Michigan. These fungi have an extensive plant host range, typically forming survival structures (microsclerotia) which are resistant to fungicides and periods of drought, and can overwinter in colonized plant tissue [5].

In trials of fungicides for control of Phytophthora blight of pepper, plant death was less than 10% for treatments with two currently registered fungicides, fluopicolide and mandipropamid, compared to the untreated control with 87% plant death. In addition, experimental fungicides resulted in less than 1% plant death in plots with drip application [10].

Anecdotally, a cucumber grower with Phytophthora infested fields used a fungicide program in 2013 instead of fumigation. In areas of the field with high pest pressure, yields losses of 25% were estimated [17].

Estimated Benefits of Soil Fumigants

For vegetable growers with only Phytophthora, we assume that the next best alternative to currently used fumigants is a fungicide program. For cucumber, squash and melons, the program consists of a drench treatment (Ranman) followed by 2 drip applications (Presidio) and 3 foliar applications (Presidio/Revus/Zampro) for a total cost of $165.96 [17]. For tomato and peppers, the program is the same with one additional foliar application for a total cost of $195.96 [17]. Yields for these growers are assumed to be 25% lower than with fumigation. We assume that these losses will be equally distributed across the production season.

For vegetable growers with Fusarium or Verticillium, there are no economically viable alternatives and growers would discontinue growing these crops in areas with high levels of infestation. It is estimated that 30-40% of eggplant acreage has high levels of infestation with Fusarium and 25-30% of eggplant acreage has high levels of Verticillium [17]. We assume that this is the eggplant area that is currently being fumigated.

We estimate the total benefits of soil fumigants in Michigan vegetable production to be $3.6 million (Table 4).

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Cover Photo Credits: Cucumber, Winter Squash, Beans and Tomato infected with Phytophthora from [17][19][20][21].

Table 1. Select Michigan Vegetable Production 2012

Crop	Acres Planted	Acres Harvested	Yield (cwt)	Production (1000 cwt)	Value ($1000)
Asparagus	10,300	9,100	21	191	17,274
Snap Beans for Fresh Market	2,800	2,600	47	122	6,710
Snap Beans for Processing	18,000	17,800	4.0 tons	71,200 tons	16,718
Carrots for Processing[1]	2,800	2,700	25 tons	67,500 tons	5,940
Cucumbers for Fresh Market	3,800	3,600	170	612	14,382
Cucumbers for Pickles	29,700	28,700	5.4 tons	154,980 tons	37,195
Eggplant[2]		236			
Bell Peppers	1,600	1,500	260	390	14,820
Pumpkins	6,800	6,300	150	945	13,230
Squash	6,000	5,900	240	1,416	20,249
Fresh Tomatoes	2,100	2,000	200	400	16,000
Tomatoes for Processing	3,600	3,500	35	122,500	14,210

[1] Carrot statistics for 2008.

[2] Eggplant statistics for 2007.

Sources: [1][14]

Table 2. Target Pests for Fumigants in Michigan Vegetable Production

Crop	Target Pests
Asparagus	*Phytophthora asparagi* *Fusarium* spp.
Carrots	Northern root-knot nematode (*Meloidogyne hapla*) carrot cyst nematode (*Heterodera carotae*) root lesion nematode (*Pratylenchus penetrans*)
Cucurbits	*Phytophthora capsici* *Fusarium oxysporum*
Eggplant	*Phytophthora capsici* *Verticillium* spp.
Pepper	*Phytophthora capsici*
Tomato	*Phytophthora capsici* *Fusarium oxysporum*

Sources: [4][5][6][7][15][16]

Table 3. Area Treated with Methyl Bromide in Michigan Vegetable Production

Crop	2001	2002	2003	2004	2005	2006	2008	2009	2010
Cucurbits	1400	1455	553	590	679	585	198	100	150
Eggplant	1798	1798	1598	1598	1400	751	99	50	75
Peppers	321	333	316	343	388	336	198	208	150
Tomatoes	642	667	632	687	776	669	395	201	299

Sources: [4][5][6][7]

Table 4. Estimated Benefits of Soil Fumigants in Michigan Vegetable Production

Crop	Fumigated Acreage	Value of Yield Increase Per Acre	Cost Difference Per Acre	Total
Asparagus	113	$950	$325	$70,625
Carrots	350	$375	$325	$17,500
Cucurbits	2,256			
Fresh Cucumbers	2,000	$1,451	$1,148	$606,420
Cantaloupe	125	$2,063	$1,148	$114,308
Other	331	$1,814	$1,148	$220,562
Eggplant	50	$19,818		$990,900
Peppers	45	$4,680	$1,148	$158,938
Tomatoes	400	$3,654	$1,148	$1,461,684
TOTALS	3,214			$3,640,937

Notes: Estimated fumigated acreage for asparagus is 100-125 and 300-400 for carrots [17]. Per acre revenues from [17]. Assumes fumigation with Pic-60 at 363 lbs. costs $1314/acre for cucurbits, peppers and tomatoes. Assumes eggplant will no longer be grown on area currently being fumigated. Per acre revenue for other cucurbits is average across all cucurbit crops. Assumes fumigation with Metam Sodium or Metam Potassium costs $300-350/acre for asparagus and carrots.