An economic assessment of alternatives to methyl bromide for sustainable strawberry production

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# Table of Contents

Abstract .......................................................................................................................... 3

Introduction .................................................................................................................... 4

Methyl Bromide ........................................................................................................... 4

Strawberry Production ................................................................................................. 8

Chemical alternatives ................................................................................................... 8

1,3-Dichloropropene ..................................................................................................... 8

Chloropicrin ................................................................................................................ 11

Additional Costs ........................................................................................................... 12

Non chemical alternatives ........................................................................................... 14

Solarization ................................................................................................................... 14

Steam ............................................................................................................................. 16

Crop rotation ............................................................................................................... 17

Conclusion ................................................................................................................... 19

References ................................................................................................................... 21
Abstract

Many industrial agricultural systems rely on the use of agrochemical to control pests, pathogens, and maintain high crop yields. The strawberry industry in the United States is particularly reliant on one specific chemical, methyl bromide. Due to the adverse environmental effects of excess methyl bromide, there is a global movement under the Montreal Protocol to phase out methyl bromide use completely. The phase out has created problems for strawberry producers as they struggle to find an appropriate alternative. This paper sets out to assess the economic viability of some of the current chemical and nonchemical methyl bromide alternatives specifically applied to California’s strawberry industry. The only soil treatment that has a positive net profit comparison to methyl bromide was chloropicrin. Chloropicrin is the best economic alternative but like other pesticides are confronted with public health and regulation issues.
Introduction

Methyl Bromide

Methyl bromide is a colorless, odorless, nonflammable volatile gas and was registered with the EPA in 1961 for use as a pesticide (EPA, 2008). It is a broad spectrum pesticide with application as an acaricide, fungicide, herbicide, insecticide, nematicide, and rodenticide (NPIC, 2000). Methyl bromide is manufactured and stored as a pressurized liquid and during application when the pressure decreases it converts into a gas (NPIC, 2000). Not all sources of methyl bromide are manmade, there are some natural sources of atmospheric methyl bromide. Water bodies such as, the ocean and wetlands, account for the majority of natural emissions, but it is also produced from the burning of biomass (NPIC, 2000). However anthropogenic production has greatly surpass the amount that occurs naturally and currently anthropogenic production is estimated to account for 20 – 70% of the global emission of methyl bromide (NPIC, 2000).

Figure 1: An illustration of soil fumigation (Gao et al., 2012).
The majority of the methyl bromide in the United States is used in soil fumigation but other uses include the sterilization of commodity crops and physical structures (EPA, 2008). As a soil fumigant methyl bromide is effective in controlling different weeds, pests, and soil pathogens (NPIC, 2000). In the application of soil fumigants, the chemical is either injected into the soil using tractor drawn shanks or applied through drip irrigation (EPA, 2008). Once applied the gas diffuses throughout the soil filling in the air spaces in the gaps and crevices (NPIC, 2000). The application site requires a specific concentration of the chemical to remain in the soil for a duration of time resulting in fumigate fields covered with plastic tarps or tents to confine the gas to the application site (NPIC, 2000). After the fumigation process is complete methyl bromide is allowed to dissipate from the application site.

![Image](image.jpg)

Figure 3: Tarp covered strawberry fields after fumigation (Gao et al., 2012).

The volatile nature of methyl bromide has the public concerned about both the human health and ecological effects of the fumigant that has drifted from the initial application site.
Methyl bromide is highly toxic to humans, as there have been observed deaths resulting from acute exposures (NPIC, 2000). The dose-response curve for methyl bromide is very steep, demonstrating that a small increase in the dose results in a large increase the toxicity that occurs. The main routes of entry are through inhalation and dermal absorption and the lungs, kidneys, liver, heart, and brain are the main targets (NPIC, 2000). Methyl bromide is a caustic substance and the symptom of dermal exposure include burning and irrigation of the skin and eyes. Symptoms of acute methyl bromide inhalation include headaches, nauseas, vomiting, dizziness, blurred vision and confusion (NPIC, 2000). Acute exposures have also resulted in neurotoxicity with symptoms of tremors, lack of coordination, and paralysis (EPA, 2008). The cancer risk associated with methyl bromide exposure is unclear due to lack of animal evidence. The EPA has classified methyl bromide as a group D carcinogen or a pesticide that is not classifiable as a human carcinogen (EPA, 2008).

There are also adverse ecological effects that arise due to methyl bromide drift from the site of application. Methyl bromide can persist in the environment for up to two years before breaking down (NPIC, 2000). The inhalation of methyl bromide is the main route of exposure for many ecological organisms. Researchers have found that it is moderately toxic to birds and mammals and is slightly toxic to fish (EPA, 2008). However, the main adverse ecological effect of methyl bromide is a result of its indirect effect on stratospheric ozone or the ozone layer.

Methyl bromide is very stable when located in the lower atmosphere but photodissociates when it drifts into the upper atmosphere (EPA, 2008). The breakdown of methyl bromide produces bromide free radical and a single radical can breakdown 100,000 ozone molecules, thinning the ozone layer. Stratospheric ozone shields the Earth from excessive harmful ultraviolet radiation (EPA, 2008). A decrease in the amount of stratospheric ozone associated
with the increase rates of adverse ecological effects such as skin cancer, eye disease, such as cataracts, and immunosuppression (EPA, 2008). Skin cancer or melanoma is a serious and fast growing cancer. Annually over 1,000,000 cases of melanoma are diagnosed in the US, making it the most common form of cancer. The occurrence of melanoma in the US continue to rise and has doubled in the recent two decades alone (EPA, 2008).

In 1989, response to global ecological and health concerns of the thinning ozone layer world leaders established the Montreal Protocol on Substances that Deplete the Ozone Layer (EPA, 2007). Over 190 countries have signed on the treaty and are working to reduce the manufacturing and use of chemicals that are ozone depleting substances or ODS. The US had previously been one of the largest users of ODS but has since taken a leadership role not just moving away from them but also in the development of ozone safe alternatives (EPA, 2007).

Methyl bromide has been classified as a Class I ozone depleting substance, which is the highest classification for an ODS (EPA, 2008). The standards set by the Montreal Protocol called for the complete phase out of methyl bromide in developed countries by 2005. It is currently the last Class I ODS that is still produced and used today. CFCs and halons are other Class I substances that have been completely phased out successfully (EPA, 2008). In comparison to prior Class I ODS, the US is struggling to phase out methyl bromide and meet the Montreal Protocol’s standards.

The US is able to continue their use of methyl bromide under permitted exemptions granted through the Montreal Protocol for specific circumstances. Exemptions are granted in circumstances that will have negatively impacted markets due to the lack of feasible alternatives (EPA, 2013). The EPA is increasingly limiting the number of critical use exemption allotments
with each passing year. This is to help wean the industries off of methyl bromide while alternatives are being researched and developed.

**Strawberry Production**

One agriculture industry that has found the methyl bromide ban extremely difficult is the strawberry production industry. Due to the crops susceptibility to weeds, soil pests, and diseases, farmers heavily depend on fumigation to sterilize the soil before planting the berries (Mayfield, 2012). Strawberry fields account for more than 93% of the methyl bromide critical use exemptions for 2014 (Mayfield, 2012). The ban on methyl bromide is forcing the industry towards adopting new methods of soil sterilization while maintaining consistent healthy crop yields.

The strawberry production in California accounts for 88% of the nation’s supply and is valued as a $2.3 billion industry (CSC, 2014). There are over 39,073 acres of strawberry fields in the state, with most of them located in the Central Valley or along the coast. California fields are able to produce crops year round, in the rich soil and mild climate (CSC, 2014).

Since the movement to phase out methyl bromide, strawberry producers must quickly find a sustainable alternative while keeping stable crop yields. This paper will assess the economic feasibility of chemical and nonchemical alternatives. The chemical alternatives that are evaluated are 1,3-Dichloropropene and chloropicrin. Solarization, steam, and crop rotation are the nonchemical alternatives that are reviewed.

**Chemical alternatives**

**1,3-Dichloropropene**

One potential chemical alternative to methyl bromide in strawberry production is 1,3-dichloropropene which is also known as 1,3-D or Telone, its market name. 1,3-D was first registered with the EPA in 1954 for use as a pesticide and was re-registered in 1986 (Vidrio,
1,3-D is a colorless, sweet smelling gas at room temperature and is water soluble when in the liquid state (EPA, 2000).

Most of the 1,3-D use in California is applied to strawberry fields to control nematodes and soil pathogens (Vidrio, 2012). Strawberry producers in California used 1,949,000 pounds of 1,3-D in 2010. The application rate for 1,3-D on tarp covered strawberry fields is 224.4 L/ha. The chemical fumigant is applied through shank injection up to 18 inches into the ground or through drip irrigation (Vidrio, 2012).

The economic data was derived from the average cost found in a study done on strawberry fields on the coastal plains of North Carolina and Georgia between 1996 and 2002. The data is extrapolated from the study to estimate the cost for coastal fields in California. The total cost of the application of 1,3-D fumigation on coastal strawberry fields in 2002 was $2,441/ha (Sydorovych et al., 2006). The total cost includes the cost of labor, machinery, and

Figure 2: Chemical fumigants injected into the soil using a shank drawn tractor (Gao et al., 2012).
materials. The labor rate was calculated as $8.25/hour for hired employees and $16.39/hour for operators and cost a total of $97.21/ha fumigate the field before strawberries were planted. Also include in the fumigation cost is the, $712/ha and $1,632/ha, the price of the machinery and materials needed (Sydorovych et al., 2006). The returns per hectare from fields treated with 1,3-D was $26,474. The net returns of 1,3-D suffers from a 28 percent decrease per hectares compared to fields treated with methyl bromide (Sydorovych et al., 2006).

Telone alone on strawberry fields is not as effective as methyl bromide was at controlling weeds, pests, and pathogens. Telone were only able to control nematodes and insects in the soil and was ineffective at controlling weeds and pathogens (Samtani et al., 2010). Strawberry producers had the added cost of $341/ha for weeding and had a decrease in crop yield due to loss of product to pathogens. While it was cheaper than methyl bromide to fumigate fields with 1,3-D, the high weeding cost and low crop yield reduced the profits.

1,3-D alone is not going to replace the use of methyl bromide in the production of strawberries especially with the limitation of application due to regulations and higher costs. Like many other chemical pesticides used today, 1,3-D has adverse health effects on animals and humans. 1,3-D has been discovered to be moderately acutely toxic through animal studies where acute exposure symptoms include lung irritation, chest pains, and difficulty breathing (EPA, 1998). There are also concerns of carcinogenic effects from exposure to 1,3-D since it was classified as a possible human carcinogen by the EPA (EPA, 1998).

Due to the acute toxicity of 1,3-D the use of the fumigant has been heavily regulated. The application of Telone is restricted to certified applicators who are required to wear protective respirators (EPA, 1998). There are also restrictions on where the fumigant can be applied, these fields must have a buffer zone that protects the public from exposure to the
volatile chemical. Fumigated strawberry fields that are near home, hospitals, and schools, are required buffer zone that protects the public from chemical drifts (EPA, 1998). To insure that 1,3-D doesn’t leach into ground water, the EPA requires that producers not fumigant within 100 feet of a well.

<table>
<thead>
<tr>
<th>Fumigant</th>
<th>Labor</th>
<th>Machinery</th>
<th>Material</th>
<th>Total Fumigation</th>
<th>Weeding</th>
<th>Harvesting</th>
<th>Net Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,3-D</td>
<td>$97</td>
<td>$712</td>
<td>$1,632</td>
<td>$2,441</td>
<td>$341</td>
<td>$6,543</td>
<td>$26,481</td>
</tr>
<tr>
<td>Chloropicrin</td>
<td>$97</td>
<td>$712</td>
<td>$2,094</td>
<td>$2,903</td>
<td>$553</td>
<td>$7,556</td>
<td>$40,935</td>
</tr>
<tr>
<td>Methyl bromide</td>
<td>$97</td>
<td>$712</td>
<td>$2,322</td>
<td>$3,131</td>
<td>$312</td>
<td>$7,206</td>
<td>$36,808</td>
</tr>
</tbody>
</table>

**Chloropicrin**

Chloropicrin is another broad spectrum fumigant that has been applied as an alternative for methyl bromide in the production of strawberries. The compound was first registered with the EPA in 1984 for use as a pesticide (EPA, 2008). It is a colorless gas at room temperature with a strong sharp odor (DHSS, 2005). There are also two methods for the application of chloropicrin fumigation, it can either be injected into the soil or administered by drip irrigation.

The economic data for chloropicrin application was derived from the same study that was done in the southeast coastal plains. The total cost for the application of chloropicrin on coastal fields in 2002 was higher than the cost of both methyl bromide and 1,3-dichloropropene, at $33,862/ha in 2002 (Sydorovych et al., 2006). The average return of 1,3-D application was
$40,935/ha which, reflects an 11 % increase in net profits compared to methyl bromide treated fields (Sydorovych et al., 2006).

Chloropicrin effectively controls the soil borne pathogens but does not control weeds and nematodes as well as methyl bromide fumigation (Samtani et al., 2010). The cost for weeding is higher with the use of this fumigant but there is still a higher net returns on strawberry fields treated with chloropicrin. There is also public concern with the use of chloropicrin and it is limited to sites that are in the appropriate distance of a protected buffer site. Chloropicrin is acutely toxic to humans and the two main routes of entry are through dermal contact and inhalation (EPA, 2008). Symptoms of acute chloropicrin exposure include irritation of skin, eye, mouth, throat, nausea, skin rash, and shortening of breath or difficulty breathing (DHSS, 2005). There is no known human cancer risk associated with chloropicrin exposure but there have been conflicting results from animal studies. Further studies is needed before chloropicrin can be classified as a carcinogenic agent (DHSS, 2005).

Pesticide handlers and public populations near an application site are the most at risk for acute toxic exposure to chloropicrin (EPA, 2008). To minimize the risks associated with chloropicrin, the fumigant has a mandatory buffer zone of 300 feet and notification to neighbors before the application (EPA, 2008). Since workers face a high toxicity risk, respirator mask must be worn by the applicator and site must be closed for a minimum of 48 hours before workers may return (EPA, 2008).

**Additional Costs**

There are other costs of fumigation that have not been factored into production costs. Many of these cost are due to increasing public health concerns regarding chemical fumigants use and have increased their regulation. One of the regulations that were imposed on fumigated fields was an increase in the duration of time that a field must remain covered (Carter et al.,
2002). On average the fumigation period for strawberry farmers in California has increased by up to four folds. The extended fumigation period have deceased productivity which resulted in an additional cost of $161.87/ha (Carter et al., 2002).

Another additional cost for the utilization of a chemical fumigant is the cost of providing clear notification to nearby businesses and communities before the application of the volatile chemicals. The costs associated with these notifications varies depending on specific county requirements, field size, and adjacent land types (Carter et al., 2002). The fields that had the highest cost for notifications were located near urban and developed areas. The cost for notification only accounts for the labor involved and does not include printing costs, mileage or other cost. The average cost for fields surveyed in Monterey, Santa Barbara, and Santa Cruz was $2.20/ha or about $125,000 the all the fields in the state (Carter et al., 2002).

Health care cost have also not been incorporated into the cost of chemical fumigation. Unfortunately the most at risk population segments are agricultural workers, many of whom lack sufficient health care (Reeves and Schafer, 2003). Over two thirds of surveyed agricultural workers were uninsured leaving them to pay out of pocket for medical treatment. Many simply can not afford medical care and do without it so the actual number of pesticide poisoning is heavily underestimated since many cases go unreported. The majority of reported poison cases between 1997 and 2000, are from pesticide drift, which makes up 51% of all reported cases (Reeves and Schafer, 2003). As the strawberry industry has tried to move away from methyl bromide, the usage of 1,3-dichloropropene and chloropicrin have increase rapidly in the last decades. There were 222 reported poison cases from soil fumigants and many adverse health effects are chronic conditions that require continual medication care and medication (Reeves and Schafer, 2003). Since fumigants can drift far from the fields that they were applied the public are
also at risk for pesticide drift exposure. In 1999, residents of Earlimart in Tulare County were exposed to fumigation drift from a potato field which led to 24 hospitalizations and left many residents with chronic respiratory illness (Reeves and Schafer, 2003).

**Non chemical alternatives**

**Solarization**

Solarization is one non chemical method of soil sterilization where soil borne pest and pathogens are eradicated through heating of the soil (Stapleton, 2000). The process is a passive and uses solar energy where the soil is heated during the day and cool off at night. Since solarization depends on the amount of available solar radiation, the method does optimized fields that are located warmer climates such as Mediterranean and tropical (Stapleton, 2000). Solarization uses transparent film to trap the radiation on the fields and maintain high temperatures.

Solarization does not just sterilize the soil but also has other chemical and biological effects. Through solarization ammonium and nitrates soil concentrations increase which reduce the amount of fertilizers needed (Stapleton, 2000). The soil is also altered biologically through the process of solarization where the soils are a more hospitable environment for beneficial microorganisms (Stapleton, 2000). The environment allows the microorganisms to outcompete the pest and pathogens for resources, thus increasing plant health and productivity.

For strawberries, the fields are covered with film for four to six weeks in the summer season which ranges from May to September in California (Samtani et al., 2012). Solarization is not as effective on coastal fields as it is in the Central Valley due to the lower summer temperature and moisture from the ocean. The effects of solarization also decreases with increasing soil depth and does not control all weeds and diseases.
The cost for the application of solarization on strawberry fields are low. The cost of labor in 2009 was only $130/ha and the fuel costs were only $44/ha since it mainly relies on solar energy (Samtani et al., 2012). However solarization was no effective at controlling weeds and pathogens resulting in a high labor cost of $7,497/ha for weeding and decrease in crop yield. The net profit for this method was $28,281/ha and was only a 10% decrease compared to methyl bromide fumigation (Samtani et al., 2012). This method has the benefit of very low costs but also produces lower crop yields.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Labor</th>
<th>Fuel</th>
<th>Equipment</th>
<th>Weeding</th>
<th>Harvesting</th>
<th>Total cost</th>
<th>Net Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>$130</td>
<td>$44</td>
<td>---</td>
<td>$7,497</td>
<td>$30,073</td>
<td>$37,744</td>
<td>$28,281</td>
</tr>
<tr>
<td>Steam</td>
<td>$1,276</td>
<td>$19,317</td>
<td>$4,619</td>
<td>$2,871</td>
<td>$40,552</td>
<td>$68,635</td>
<td>$20,398</td>
</tr>
<tr>
<td>MeBr+PIC</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>$47,316</td>
<td>$31,355</td>
</tr>
</tbody>
</table>

Table 2: Production costs for solar and steam alternatives in $/ha.
Steam

Steam is a non-chemical method of soil disinfestation. This method requires covering the soil with a heat resistant sheet that is sealed off at the edges (Dabbene and Tortia, 2003). Steam is injected into the sheet and percolates into the soil, killing pests and weeds in the soil. The temperature of the injected steam ranges depending on the field, but can reach a maximum of 85 degrees Celsius (Barberi et al., 2009). Application time is dependent on the temperature of the steam with the lower the temperature the longer the application duration, at maximum temperature the application duration required is three hours (Barberi et al., 2009). This method has little adverse ecological impacts as there are no chemicals used and is done in a much shorter time than solarization which requires multiple weeks.

Figure 4: Steam sterilization (Fennimore, 2013).
The drawback for this method is the high cost of the application due to the high fuel consumption (Dabbene and Tortia, 2003). The cost of fuel can account for up to 80% of the total application cost. This method requires that the steam must maintain a specific temperature, depending on the soil type and composition, during the application for it to be effective. Required application time does decrease with increasing temperatures (Samtani et al., 2012). Steam application alone fails to effectively control the weed populations. It is a method that also done in combination of another which only increases the cost (Barberi et al., 2009).

The cost of implementing steam sterilization on coastal California fields in 2009 were extremely high. Labor cost $1,276/ha, and it required $19,317 for fuel per hectare (Samtani et al., 2012). These costs are attributed to the long application time required by the method. Steam also has a high equipment cost of $4,619/ha that partially due to the cost of diesel generators. The high total of costs decreased the profit margin of strawberries cultivated on these fields so the net revenue was $20,398/ha and reflects a 35% decrease compared to the returns of strawberries under methyl bromide fumigated fields (Samtani et al., 2012).

**Crop rotation**

A third non chemical alternative to methyl bromide use is crop rotation. This method rotates plants another crop in the strawberry fields after the berries are harvested. The economic data was gathered from a study that was done from 1997 to 2000, on the fields in Watsonville and Salina California (Subbarao et al., 2007). In the study, strawberry was rotated after two rounds of either broccoli, brussels sprout, or lettuce. Each location had treatments planted in both *Verticillium dahliae* infected and non-infected sites. There was also a control treatment of fumigation with a mixture of methyl bromide and chloropicrin. Researchers found that the broccoli-strawberry rotation was the most effective rotation treatment at controlling *V. dahliae*
and had the highest crop vigor and yields, but the control fumigation treatment outperformed all of the other treatments at controlling both pathogens and maintaining high crop yields (Subbarao et al., 2007).

The production costs were calculated by factoring in the cost of labor required in preparing the fields, planting crops, irrigation, weeding, fruit harvesting, and fumigation which was $3,952/ha (Subbarao et al., 2007). The average value for a tray of strawberries and a carton of broccoli was $7.13/tray and $6.50/carton. The study found that the most economically feasible rotation treatment was the alternation of broccoli and strawberry. The average production cost between the two locations was high, at $81,350/ha but the average net profit was $7,290/ha (Subbarao et al., 2007). The fumigation fields had a production cost of $80,979/ha and a net profit of $10,535/ha. The fumigated fields also had a higher crop yield of 12,844 trays/ha while the broccoli rotated sites only produced 8,350 trays/ha of strawberry and 2,100 cartons/ha of broccoli (Subbarao et al., 2007). The broccoli rotated fields had a 30% decrease in net profits compared to the fumigated sites since the production costs for each method is similar. The fields that did not use any fumigation or crop rotation treatments had the lowest crop yields and a production cost that exceeded the profits (Subbarao et al., 2007).

Crop rotation did not surpass the vigor or crop yield of methyl bromide fumigated fields but was still profitable and successful in controlling V. dahlia fungal pathogens (Subbarao et al., 2007). Crop rotation may be a viable method for some of the strawberry producers that are willing to skip a year of strawberry cultivation and move away from year round strawberry production (Subbarao et al., 2007). This is not a solution for everybody and those with larger fields may be burden by the labor required and high production costs.
Table 3: Production cost and net profits per hectare for broccoli-strawberry crop rotation and fumigation treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Production Cost</th>
<th>Net Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop Rotation with broccoli</td>
<td>$81,350</td>
<td>$7,290</td>
</tr>
<tr>
<td>Fumigation</td>
<td>$80,979</td>
<td>$10,535</td>
</tr>
</tbody>
</table>

Conclusion

The strawberry industry has yet to completely phase out methyl bromide fumigation to disinfect the soil before planting the crops. The two chemical alternatives, 1,3-D and chloropicrin, do not control all the pest, pathogens, and weeds that plague strawberry farmers. The use of chemical fumigants have also created public concern about the adverse effects of nonspecific pesticides. Chemical alternatives also have many additional costs that have not been factored into the production cost. Taking into account these additional costs, public concern, and increasing regulation, chemical alternatives face many challenges.

The nonchemical alternative, solarization, steam, and crop rotation, also do not completely control soil pests and pathogens. The main benefit from these soil treatments is the lack of adverse health and ecological effects. Of the three treatments, solarization had the highest net return, but it still reflect a decrease in profit compared to the methyl bromide treated sites.

The only alternative that had a greater return than methyl bromide was chloropicrin, as shown in Table 4. The profits from chloropicrin fields was 11% higher than methyl bromide treated fields. Almost all of the production costs associated with chloropicrin application were lower than methyl bromide. The only cost that exceeded the methyl bromide treatment was the labor cost for weeding, which demonstrates chloropicrin’s inferior weed control abilities. Even with this increase in cost, chloropicrin treatment had a higher harvest. Based on the economic
data, chloropicrin is the best methyl bromide alternative for strawberry grower. All of the other soil treatments had negative comparative net returns, which was an indication of the treatment higher production cost, and or lower crop yields.

The solution for methyl bromide alternatives in the strawberry industry may be a combination of two or more soil treatments. Alternatives may also become more economically feasible as the critical use exemptions decrease, pushing up the cost of methyl bromide fumigants. Whatever the results, the United States needs to move toward completely phasing out methyl bromide and stop producing strawberries that are grown at the external cost to the environment.

<table>
<thead>
<tr>
<th>Soil Treatment</th>
<th>Net Return</th>
<th>Δ net return compared to fumigant control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,3-D</td>
<td>$26,481</td>
<td>-25%</td>
</tr>
<tr>
<td>Chloropicrin</td>
<td>$40,935</td>
<td>11%</td>
</tr>
<tr>
<td>Solar</td>
<td>$28,281</td>
<td>-10%</td>
</tr>
<tr>
<td>Steam</td>
<td>$20,398</td>
<td>-35%</td>
</tr>
<tr>
<td>Broccoli crop rotation</td>
<td>$7,290</td>
<td>-31%</td>
</tr>
</tbody>
</table>

Table 4: A comparison of the net returns of all the treatments as compared to the corresponding methyl bromide fumigation control.
References


Vidrio, E., 2012, 1, 3-Dichloropropene risk characterization document, California Environmental Protection Agency, Department of Pesticide Regulation.