Executive Summary

Background

Ozone is formed from the photochemical oxidation of nitrogen oxides and VOCs, such as pesticides and fumigants. This is leading to increased regulation of agricultural VOC sources. It has been estimated that 5% of the total VOC in the San Joaquin and Sacramento Valleys are from pesticides. This has led DPR to require reductions in pesticide-related VOC emissions from 1990 levels. Future regulations may require additional reductions to meet 1-hour and 8-hour SIP requirements.

Research was conducted to provide estimates of the cumulative and period-averaged emission rates for broadcast-shank fumigation for standard fumigation practices and four emission-reduction strategies: (*i*) intermittent irrigation water seal, (*ii*) addition of an organic surface amendment, (*iii*) deep injection, and (*iv*) addition of a fertilizer amendment (i.e., ammonium thiosulfate) applied as a spray (i.e., limited water).

Methods

This research was accomplished by conducting field experiments in 2005 and 2007. In each experiment, either two, or three, side-by-side emission experiments were conducted.

In the 2005 study, Telone II® was applied at a rate of 12–gal/acre and at a depth of 18 inches (46 cm) to two fields in an identical manner. One field was then subjected to intermittent water sealing in which water was sprayed onto the soil post-fumigation, and then again for the following four days. The other field had been applied with composted green waste the previous year.

In the 2007 study, Telone® C35 was applied to three fields in an identical manner at a target rate of 20 gal/acre and at a depth of either 18 inches (46 cm; control and ATS-applied fields) or 24 inches (60 cm; deep injection) One field served as a standard fumigation treatment and did not have any other agronomic operation performed that would affect emissions. For the thiosulfate treatment, ATS solution was sprayed on to the field immediately after fumigation. Since the effect of a surface water seal had already been shown to effectively reduce emissions (see 2005 field data), this test was to determine the effectiveness of thiosulfate, alone (i.e., without a water seal) in reducing emissions. For the deep injection treatment, only the depth of injection differed from the control.

Fumigant emissions were determined using two independent data sources. One set of emission estimates were obtained using aerodynamic (ADM), integrated horizontal flux (IHF) and theoretical profile shape (TPS) methods. These micrometeorological approaches require on-field measurement of the atmospheric fumigant concentration at one or more heights above the soil surface, wind speed measurements, and

temperature measurements. Another set of emission estimates were obtained using the so-called back calculation methods, where observed ambient concentrations in the atmosphere surrounding a fumigated field are used with the Industrial Source Complex Short Term (ISCST3) or the CalPuf (v.6) dispersion models to back-calculate the field-scale emission rates. These approaches utilize atmospheric fumigant concentration collected at a single height above the soil surface at numerous locations surrounding the field, along with weather data collected from a 10-m mast placed in the vicinity.

The results from this data set include: (a) period-averaged or daily emission rates, (b) total emissions, (c) atmospheric fumigant concentrations, (d) wind speed and directions, (e) air temperature and relative humidity, (f) atmospheric stability, (g) solar radiation, (h) barometric pressure information, (i) fumigant concentration in the soil pore space, (j) soil temperature, and (k) soil moisture content.

Results

Experiment #1 (2005)

The results of this study indicate that applying sprinkler irrigation water to the soil surface following soil fumigation leads to total 1,3-D (cis+trans) emissions between 10 to 15% of the applied material. Based on recent laboratory and field experiments conducted under similar soil and environmental conditions, it appears that atmospheric emissions of 1,3-D can be reduced by approximately 50% compared to conventional application methods.

The addition of composted municipal green waste material provides a means to reduce emissions of 1,3-D (cis+trans) after preplant soil fumigation. Application of green waste at a rate of 300 tons per acre the previous year and incorporated in the field soil reduced total of 1,3-D from approximately 28%-33% to approximately 5% of the applied fumigant. Based on recent laboratory and field experiments conducted under similar soil and environmental conditions, it appears that atmospheric emissions of 1,3-D can be reduced by approximately 80–85% compared to conventional application methods. This approach provides a simple, environmentally beneficial, effective and relatively low cost method to protect the environment from agricultural chemicals and to reduce VOC emissions to the atmosphere.

Experiment #2 (2007)

Very low levels of chloropicrin were lost from the three fields (i.e., < 2% total emissions). Two independent flux estimates both arrived at similar results and supported by soil gas measurements. It appears that soil-based processes were limiting chloropicrin movement to the soil surface and volatilization into the atmosphere. The most likely explanation is enhanced soil degradation in the near surface soil that rapidly degraded chloropicrin.

Due to the very low emission of chloropicrin, total emissions of Telone ® C-35 appear lower than expected. This is due to 1/3 of the Telone ® C-35 mass remaining in soil (i.e., the chloropicrin component).

Standard Fumigation Methodology. If the 1,3-D emissions are presented as a percentage of the applied 1,3-D (cis+trans); the total emission estimates from the ADM, ISCST and CalPuf methods, respectively, are 35.4%, 20.0%, and 27.2%. The average and standard deviation of the total emission from the 3 methods is, respectively, 27.5±7.7%.

Deep Injection Fumigation. The total emission estimates from the ADM, IHF, TPS, ISCST3 and CalPuf methods, respectively, are 26.7%, 18.8%, 15.1%, 15.8%, and 26.1% of the applied 1,3-D (cis+trans). The average and standard deviation of the total emission from the 5 methods is, respectively, 20.5±5.6% and for the ADM, ISCST3, and CalPuf methods is, respectively, 22.9±6.1%.

By comparing the total emission estimates for the ADM, ISCST3 and CalPuf methods, deep injection reduces emissions of Telone (cis+trans) by approximately 16.9% compared to the standard fumigation methodology.

Soil Amendment with Ammonium Thiosulfate (ATS) as a Surface Spray. The total emission estimates from the ADM, IHF, TPS, ISCST3 and CalPuf methods, respectively, are 25.0%, 12.5%, 12.5%, 14.5%, and 26.7% of the applied 1,3-D (cis+trans). The average and standard deviation of the total emission from the 5 methods is, respectively, 18.2±7.0% and for the ADM, ISCST3, and CalPuf methods is, respectively, 22.1±6.6%.

Using the total emission estimates for the ADM, ISCST3 and CalPuf methods, spraying the field with ATS reduces emissions of Telone (cis+trans) by approximately 19.9% compared to the standard fumigation methodology.

Conclusions

All methods reduced emissions of 1,3-D compared to standard fumigation practices. Emissions were reduced the most by applying composted municipal green waste to the upper 15 cm of the soil (approximately 80% emission reduction). Further research is needed to study the practicality of this method and the potential to reduce fumigant concentrations at the soil surface and compromise plant pest control.

Repeated surface irrigation appears to be a simple, relatively low cost, and effective method to reduce fumigant emissions (approximately 50% emission reduction). Incorporating this emission-reduction strategy into existing production systems should relatively easy and straightforward. Recent laboratory and field research has also demonstrated similar results providing additional support for this methodology.

Application of fertilizer amendments as a low-water spray reduced emissions by approximately 20%. This represents a relatively simple approach to reduce emissions and could be readily incorporated into typical production systems. However, further research is needed to quantify the relationship between amounts of water added relative to applied thiosulfate. Previous research has shown that increasing the total applied water also increases the effectiveness of this emission reduction strategy. Furthermore, increasing the applied thiosulfate to produce a molar ratio exceeding (2 : 1) (thiosulfate to fumigant) significantly increases effectiveness. However, this exceeds the recommendations for application as a fertilizer and has the potential to cause plant injury, in some conditions. There is also a higher cost associated with combining application of thiosulfate and applying irrigation water compared to creating an irrigation water seal alone.

Deep injection reduced emissions by about 17% in a field-soil where the shank fractures remained. In a previous study involving methyl bromide, deep injection reduced emissions by about 67% (from about 64% to 21%; Yates et al., 1997). This study did not include an investigation of the shank fractures, but indicates that lower emissions may be possible. Further research is needed to determine if improved, low disturbance, shanks would increase the effectiveness of deep injection as an emission-reduction strategy.

This research project provides information that can be used to determine if proposed methods to control VOC emissions are adequate to achieve required reductions. This information may also be useful as a starting point in the development new cost-effective methods to further reduce emissions.