Ethylene
Crops

Identification

Chemical Names ethylene
Other Names: ethene, elayl, olefiant gas

CAS Numbers: 74-85-1
Other Codes: DOT #: UN 1962/UN 1938

Supplemental Information

Ethylene Use on Pineapple

Supplementary information provided to NOSB, to be added to 1999 Technical Advisory Panel review for review of use in crop production. This information was prepared by OMRI staff and did not receive additional review by the initial three TAP reviewers.

Background: At the Oct. 25-27, 1999 meeting the NOSB decided to table decision on ethylene use in crop production pending further information about formulation of materials commonly used. The initial TAP review considered the use of ethephon and calcium carbide as common ethylene generating compounds, and NOSB crops committee requested more specific information on ethephon. Subsequent to that meeting, OMRI received supplemental information to the original petition (Wielemaker, et.al. 98) that ethylene gas can be applied to crops in an aqueous solution. The crops committee agreed to re-examine ethylene applied by this method and requested that OMRI answer the following questions be answered regarding this formulation:

1. What is the source of the ethylene used in this practice and does the discussion of manufacturing ethylene and the impact of that manufacturing that was presented in the TAP review fit this material?

2. Describe in detail the practices of preparing the solution, the materials and equipment used, and the application to the crop.

3. If you think it is necessary after studying the practice, present additional information to what was already presented in the TAP review on the environmental impact of field application of this material.

Response to questions:
1. Source of ethylene, manufacturing impact

As indicated in the original TAP review, the source of commonly used ethylene gas is hydrocarbon feedstocks, such as natural gas liquids or crude oil. MSDS supplied by petitioners and communication with a manufacturer indicate this is produced in a refining process from petroleum. (Spercel, 2000) Ethanol sources of ethylene are in use for older on-site generated units in ripening houses in Florida, but are being replaced due to fire hazards and improved technology with systems using compressed gas cylinders. Active registrants of agricultural grades of ethylene are rated at 99.9999% pure in EPA registrations; others are listed at 95% and 98.5% purity. (EPA-OPP Chemical Database).

Ethylene production in the United States was 46.97 billion pounds in 1995, the fourth largest volume of chemicals produced in the US. Reporting under the Toxic Release Inventory shows that in 1996, some 35.8 million pounds were released, of this amount, 19.6 million pounds were from stack or point emissions, while 16.1 million pounds were nonpoint sources. Releases of over one pound of ethylene to air, water, and land are required to be reported (Env. Health Center, 1998).

Petroleum refining is a major source of non-point air pollution and hazardous waste generation. Ethylene is often considered a by-product in chemical engineering process manuals, and to the extent that it is captured rather than released into the environment can be seen as reducing the ambient air pollution. Ethylene reacts with ozone in the atmosphere to form water, carbon dioxide, carbon monoxide and formaldehyde, though this reaction can reduce ozone air pollution. UV light destroys ethylene in the upper atmosphere, producing hydrogen, acetylene, n-butane, and ethane. (Abeles, 92) The amount released by agricultural use is hard to judge, but can be safely assumed to be a small fraction. If all of Hawaii's 1993 acreage received ethylene at the upper rate described by petitioners, that would amount to 69,620 lbs. for one application (though the fraction of acreage that is at flower induction stage is certainly only a limited percentage of total acreage.) A ranking by industrial sector generated by Environmental Defense Fund from EPA Toxic Release Inventory data shows "food and kindred products" release of ethylene at 36,000 pounds in 1997.

2. Application methods and materials

Prof. Duane Bartholomew, University of Hawaii, has provided information from a book he is writing on pineapple production.

> "Work in Hawaii (Collins, 1960) showed that water-saturated solutions of ethylene applied with a pressurized sprayer could deliver the required quantity of gas. Green leaf tissue is required for forced induction with ethylene presumably because gases are absorbed primarily through the stomata. Forcing with ethylene is most effective at night because the stomates of pineapple typically are open from dusk to dawn, though they also may remain open on cool, cloudy days.
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> Ethylene properly applied with a pressurized sprayer late in the evening or at night to permit uptake through the stomata is considered to be the most effective forcing agent available. In Queensland, it was used as a saturated solution in 6,500 to 9,000 L ha-1. An alternative was to make two applications of 4,500 L ha-1, 24 hours apart. Activated charcoal at 20 g L-1 was added to the water to increase absorption of the ethylene in the solution. Py et al. (Py, et al. (1987) *The pineapple. Cultivation and uses*. Editions G.P. Maisonneuve, Paris) state that 800 g of ethylene is applied in 6,000 to 8,000 liters of water per hectare with 0.5% activated charcoal or 1% bentonite is added to increase retention of the gas by the water. The water should be cool if possible. I believe the original patent was based on application with a pressurized hand sprayer (Kerns, K. (1936) Method and material for forcing flowering and fruit formation in plants. US Patent No.2, 047,874.)"
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> He also reports that the engineering of sprayers has been done by the plantations and is used on one large plantation in Hawaii. The common practice is to inject ethylene at fairly high pressure into the water at the pump that moves water into the boom applicator. It has been used elsewhere, but must be applied at night so has been tried but dropped by other growers because of the added cost and difficulty in handling. Primary limitations are that the gas is combustible, is sparingly soluble in water and difficult to retain there so large volumes of water must be used to force plants. Professor Bartholomew's opinion was that environmental hazards would be small as a small amount of the gas is used, against the background of natural ethylene production by a field of plants.

A petitioner also supplied the following information:

> "The actual formulation used is pure ethylene gas which comes in a steel cylinder which is securely mounted on the spray boom vehicle and by means of a flow measuring device the gas (at 2.25 to 3.5 Kg/Ha) is injected into the boom through which abundant water (7014 L/Ha) flows with the charcoal (mixed in the tank). As the ethylene bubbles through the water it gets partially hydrolyzed and partially adsorbed by the charcoal which subsequently releases the ethylene slowly to the plants after it is applied by means of flood nozzles. Two applications are made during two consecutive nights as that is the time when the application is more effective due to the stomata opening. The concentration of ethylene is very low due to high volume of water and does not cause any phytotoxicity. The high volume of water is needed to reach the basal white tissue of the heart leaves." (Weilemaker, Dec. 1999)

Another producer who was also an original petitioner, was contacted. He was not familiar with this technique for ethylene application, but did not feel it would be prohibitive for smaller growers. He reaffirmed the position supported by other producers: that commercial production would not be possible without some type of flower induction material, and described failed efforts at providing natural sources of ethylene, including smoke, rotten bananas, and goat manure. (Johnson, 2000)

Literature review indicates that use of ethylene gas in water was successfully used an early method for flower induction (Collins, 1960). This technique many be more suited to warm, wet tropical climates (Chadha, 1998) due to slower drying and better absorption by the plant tissue. Many other plant growth regulators have been evaluated for easier application and consistent results in different locations, (Kays, 1987) and one reference considered ethylene gas "normally impractical in the field." (Lurssen, 1982.) University of Hawaii extension fact sheets refer to common use of ethylene saturated water, calcium carbide and ethephon, with most emphasis on ethephon use and rates. (Evans, 1997)

3. Additional Information on environmental impact and human health

The non-profit environmental organization, Environmental Defense, ranks ethylene as less hazardous than most chemicals, using 8 different ranking systems. (Environmental Defense, 2000). Two rankings for integrated human health and environmental effects place ethylene in the lower 50% of all chemicals ranked for hazard.

- The UTN (from University of Tennessee hazard evaluation system) considers toxicity and persistence consideration, as well as human health impact. Ranks ethylene as 0-25th percentile (a numerical score of 31/200) for relative hazards.
- IRCH (the Indiana Relative Chemical Hazard Ranking System from Purdue University) considers toxicity and exposure, and includes ecological and occupational human health impacts. The IRCH ranks ethylene as 25-50th percentile, (numerical score of 19/200) for relative hazards.

UTN uses endpoints of acute toxicity to mammals and chronic and acute toxicity to aquatic organisms as measures of environmental effects. IRCH includes a wide variety of measures relating to toxicity and physical-chemical properties such as vapor pressure, tendency to bio-accumulate, corrosivity and others.

Carcinogenicity: the National Toxicology Program Health and Safety Information Sheet, published by the National Institute of Environmental Health, states that neither the NTP, IARC, (The International Agency for Research on Cancer, part of the World Health Organization) nor OSHA lists ethylene as a carcinogen. (NTP, 2000). The only health hazard listed by Environmental Defense is based on Cal EPA data as a suspected neurotoxicant, at a relatively high level of ingestion by inhalation (20,000 ug/m^3 = 2x10^{-5} (0.00002) kg/m^3). Worker safety is thus a concern, as the density of the gas is listed at 1.169 kg/m^3. EDF identified the lack of basic testing in several categories of toxicity: chronic, reproductive, and neurotoxicity for this high volume use chemical.

Supplemental information:

4. Additional information on regulatory status:

Ethylene is registered by EPA as a pesticide used as a plant growth regulator and as a herbicide (used under a USDA control program for witchweed for numerous crops, causing premature germination). It was designated as a biorational pesticide in 1990, as EPA deemed it "naturally occurring" with a "non-toxic mode of action." (EPA, 1992). Ethylene is exempt from requirement of a tolerance (or maximum residue level) when used as a plant growth regulator on fruit or vegetable crops. (40CFR 180.1016). EPA waived all ecological testing for purposes of re-registration, stating that outdoor uses of soil injection and pineapple sprays result in only negligible exposure to aquatic and terrestrial organisms.

International status:
The European Union Standing Committee on Organic Farming decided at its December 10, 1999 meeting (EU, 1999, Imele 2000) to prohibit the use of "ethylene and calcium carbide" for all imports of organic pineapple, effective Jan. 15, 2001. The minutes state:

> "This would have the consequence that, unless the issue was reviewed on the basis of additional information, organic pineapples producers with the use of ethylene and calcium carbide would not be accepted after 15 January 2001."

Supporting or clarifying information for this decision was not available at the time of this report. A task force of European importers and brokers has been initiated to help fund research into alternative methods of flower induction. Suggested avenues of research include use of smoke under tarpaulins, use of mechanical and heat stress, and investigation of source of naturally derived calcium carbide. (Imele, pers.comm) If a more acceptable source of calcium carbide were developed, it would still require approval as a synthetic under OFPA, since its basic mode of action of reacting with water to produce acetylene and calcium hydroxide remains the same as previously discussed.

5. Discussion
The information reviewed regarding application method, manufacturing and environmental concerns do not indicate that ethylene as used in crop production would present a significant risk, although there are gaps in toxicity data. In addition, the NOSB should consider carefully if this use meets all OFPA criteria. Its use as a synthetic is not specifically listed in the exempt categories of 6517(1)(B)(i) unless it is considered a crop production aid. This term should be more carefully defined for consistent use in decision making on synthetic crop materials.

OFPA 6518(m) Criteria: Description of conformance to these criteria remains as listed in the initial TAP review (Oct. 99).

(1) The potential of such substances for detrimental chemical interactions with other materials used in organic farming systems.

(2) The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.

(3) The probability of environmental contamination during manufacture, use, misuse or disposal of such substance.
See additional information under point 2 above.

(4) The effect of the substance on human health.
Addressed under point 3 above.

(5) The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock.
Addressed in the initial review (Oct. 99.)

(6) The alternatives to using the substance in terms of practices or other available materials.
Alternatives have not been available on a commercial scale, but it appears that interest from European sources may generate research in this direction. Use of smoke may be a more natural source of ethylene, but environmental consequences of this use are potentially more damaging. According to Kader, et al., some fruits are a better source of non–synthetic ethylene than others are. Tropical fruits have the highest production rates: cherimoya, mammea, passion fruit, and sapote all are rated "very high" producers of ethylene, making over 100 μl of C_2H_2 per hour at 68°F. The highest levels found in the literature are from vanda orchids producing over 3,500 μl per hour at 68°F (Kays, 1991). Papaya is in the "high" range. Generating predictable amounts of natural ethylene in field situation at the correct time would be challenging.

Ethylene can also be derived from ethanol dehydration, though this might also be considered synthetic (ethanol is passed over heated beds of solid catalyst, typically alumina or phosphoric acid). The NOSB has considered the preparation of plant and animal derived substances by methods ordinarily used in food processing to be non-synthetic, and have also considered combustion of biologically derived materials to be non-synthetic in producing ash (NOSB, 1995). Catalytic generators have been used for introducing ethylene gas into ripening rooms, (Kays, et.al. 1987 mentions light weight mobile units powered off vehicle batteries) it is possible the technology could be adapted for field use, to produce renewable sources of ethylene.

(7) Compatibility with a system of sustainable agriculture.
The use of ethylene represents the addition of a synthetic growth regulator in order to manipulate crop production, schedule year round production, and synchronize production in order to achieve economic yields. Pineapples will produce flowers and fruit with the use of ethylene, but fewer of them in a less predictable way. These market goals are not necessarily of primary concern under OFPA, however if sustainable agriculture is considered to include the economic considerations for success of producers, then this practice might qualify as sustainable. One of the original TAP reviewers also commented that an organic system of pineapple production has a vastly better impact on the environment than conventional methods of production. Development of alternatives based on natural sources would avoid the precedent set by adding a synthetic plant growth regulator to the National List, and the subsequent petitioning for other PGRs that are synthetic analogs of natural substances or the extension of use of ethylene to other crops.

If NOSB decides to approve use of ethylene in crop production, annotations could include:
Use as a plant growth regulator only for floral induction in pineapple. All safety requirements during application and handling must be strictly followed.

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